Determinants of pubertal development in an urban South African cohort

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Abstract

Age at the initiation of puberty and at menarche are key maturational indicators. They reflect health both within and between populations; in that a declining average age is associated with improving health, nutrition, and socio-economic conditions. Knowledge of the timing of pubertal development and menarche is important as earlier development within a population, in particular, has been linked with an increased risk of negative sequelae including overweight and obesity, development of risk factors for non-communicable diseases such as hypertension and insulin resistance, and engagement in risk behaviours such as early sexual debut and substance abuse.

The main aims of this study were to investigate the timing of, and the early life factors (such as body composition and growth velocities) associated with pubertal development and age at menarche in Black and White urban South African adolescents. Mixed-longitudinal data (n = 401) from the Birth to Twenty (Bt20) birth-cohort study, initiated in 1990 and set in Soweto-Johannesburg, South Africa were used. Median age at the initation of puberty and at menarche was derived by fitting logistic curves to cumulative frequency plots. Logistic regression models were constructed to examine the early life predictors of the timing of puberty and menarche. Data were also collected from adolescents and Bt20 staff (n = 72) using focus groups to explore views on the pubertal development questionnaire used in the Bt20 study.

Median age at the initiation of genitalia development was 10.4 years (95% CI = 8.4, 12.4) for Black boys and 9.8 years (95% CI = 9.4, 10.2) for White boys. Median age for the initiation of pubic hair development for Black males was 10.8 years (95% CI = 9.6, 12.0) compared to White males, which was 10.2 years (95% CI = 8.4, 12.0). Median age at the initiation of breast development in Black females was 10.1 years (95% CI = 9.3, 10.9) compared to White females which was 10.2 years (95% CI = 8.2, 12.2). Median age for the initiation of pubic hair was 10.3 years (95% CI = 9.3, 11.3) and 10.5 years (95% CI = 8.7, 12.3) for Black and White girls respectively. Results from logistic regression showed that a greater weight and height velocity in late childhood significantly increased the odds of achieving early breast/ genitalia development. Furthermore, a low socio-economic status (SES) index at 9/10 years significantly reduced the odds of achieving early breast/genitalia development. A greater

weight, height, body mass index (BMI), and growth rate during infancy and childhood significantly increased the odds of achieving early pubic hair development.

Median age at menarche for Black females was 12.4 years (95% CI = 12.2, 12.6) and 12.5 years (95% CI = 11.7, 13.3) for White females. Average menarcheal age for Black girls has declined by 0.56 years per decade and 0.32 years for White girls in South Africa, when comparing the current study findings with those from previous studies. Results from logistic regression showed that being taller, fatter and heavier in late childhood significantly increased the odds of achieving earlier menarche.

The focus groups provided a range of opinions relating to the Bt20 pubertal development questionnaire and procedure. The majority of views were positive and included the ease of understanding and completion of the tool. Negative views revolved around the language used and privacy issues. These qualitative results provided a unique insight into the way in which pubertal development data are assessed and how these methods can potentially be improved to enhance the reliability and accuracy of pubertal development data collection.

The results from this study provide the most recent estimates of age at the initiation of puberty and age at menarche for urban Black and White South African adolescents. This is particularly important given the social, nutritional, and economic transition currently occurring in this country as these key maturity indicators reflect population health. This study has also added to our knowledge of the factors that are associated with pubertal development, showing that proximate rather than distal factors are the most sensitive indicators in this urban transitioning environment. In addition, the results from the focus groups provided a unique insight into how pubertal development data are assessed and how these methods could be improved. The negative health outcomes which have been associated with earlier pubertal development and age at menarche are major public health concerns, particularly in the South African context given the HIV/AIDS epidemic and rising levels of obesity. This study highlights the need for renewed research and resources for intervention strategies and policy programmes which target appropriate sex and obesity education in urban South African children.

Key words: menarche, pubertal development, sexual maturation, body composition, secular trend, South Africa

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"You must keep on going when the odds are against you. No matter what doubts lie within, the darkness of the night has to reach its conclusion, before a new day can begin. Face up to the challenge and show that you're worthy, repeat that you can and will. Life has a tariff on every ambition, and effort comes high on the bill...faith is a candle that glows in the darkness, lighting the road to relief. All it requires is a burning ambition and a touch of flame from belief" (David Prowse)

"It's not the size of the fight that counts, it's the size of the fight in the man...in other words...far better it is to dare mighty things; to win glorious triumphs even though chequered by failure, than to take rank with those poor spirits who neither enjoy much nor suffer much because they live in the grey twilight that knows no victory nor defeat" (Anon)

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"I love you because you are amazing, and yes you are a kindred spirit, but most of all I love you because you are willing to share your world with me"

"May you love as long as you live and live as long as you love"
(Robert A. Heinlein)

Publications Arising

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- "Age at menarche and the evidence for a secular trend in urban South Africa" Laura L. Jones, Paula L. Griffiths, Shane A. Norris and Noël Cameron (paper). European Anthropological Association (EAA) 16th annual congress - Denmark 28th to 31st August 2008.
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- "At an increased risk for the metabolic syndrome? Secular trends in age at menarche in urban South African females" Laura L. Jones, Paula L. Griffiths, Shane A. Norris and Noël Cameron (paper). Developmental Origins of Health and Disease (DOHaD) Conference – Perth, Western Australia 6-10th November 2007
- "Secular trends in age at menarche in urban South African females" Laura L. Jones, Paula L. Griffiths, Shane A. Norris and Noël Cameron (paper). British Society for Population Studies (BSPS) – St. Andrews, Scotland 11-13th September 2007
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Abbreviations

95% CI	95% Confidence Interval
ABW	Average Birth Weight
AGA	Appropriate for Gestational Age
AIDS	Acquired Immunodeficiency Syndrome.
AGS	Adolescent Growth Spurt
ANC	African National Congress
AS	Adolescent Scale
B1-B5	Breast stage 1 to Breast stage 5
BH	Bone Health
BHSFGF	Bone Health Staff Focus Group Female
BHSFGM	Bone Health Staff Focus Group Male
BMI	Body Mass Index
BSFGF	Bara Staff Focus Group Female
BSFGM	Bara Staff Focus Group Male
Bt20	Birth to Twenty
DHS	Demographic and Health Survey
DXA	Dual-energy X-ray Absorptiometry
EDCs	Endocrine Disrupting Chemicals
EPFFG	Early Puberty Female Focus Group
EPMFG	Early Puberty Male Focus Group
FG	Focus Group
FPFG	Female Pilot Focus Group
FSH	Follicle Stimulating Hormone
G1-G5	Genitalia Stage 1 to Genitalia Stage 5
GH	Growth Hormone
GH/IGF-1	Growth Hormone/Insulin like Growth Factor-1
GHRH	Growth Hormone Releasing Hormone
GnRH	Gonadotrophic-Releasing Hormone
HBW	High Birth Weight
HDI	Human Development Index
HIV	Human Immunodeficiency Virus
HPA	Hypothalamic-Pituitary-Adrenal
HPG	Hypothalamic-Pituitary-Gonadal
IGF	Insulin-like Growth Factor
IMR	Infant Mortality Rate
LBW	Low Birth Weight
LH	Luteinising Hormone
LPFFG	Late Puberty Female Focus Group
LPMFG	Late Puberty Male Focus Group
MPFG	Male Pilot Focus Group
NCD	Non-Communicable Disease
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
NP	National Party
OR	Odds Ratio
PCA	Principal Component Analysis
PDS	Pubertal Development Scale

PH1-PH5	Pubic Hair Stage 1 to Pubic Hair Stage 5
PHV	Peak Height Velocity
PROS	Pediatric Research in Office Settings
QCP	Quality Checking Procedure
SD	Standard Deviation
SEE	Standard Error of the Estimate
SES	Socio-Economic Status
SGA	Small for Gestational Age
STI	Sexually Transmitted Infection
TFR	Total Fertility Rate
TH	Thyroid Hormone
U5MR	Under-five Mortality Rate
UK	United Kingdom
UN	United Nations
USA	United States of America
WHO	World Health Organisation

1 Introduction

1.1 Investigating pubertal development in urban South Africa

The timing of pubertal development (the start of breast/genitalia and/or pubic hair development) and age at menarche (first menstrual period) are key maturational indicators. They reflect health both within and between populations; in that a declining average age is associated with improving health, nutrition, and socio-economic conditions, typically seen in transitioning economies such as South Africa. Knowledge of the timing of pubertal development and menarche are important as early development within a population, in particular, has been linked with an increased risk of negative sequelae including overweight and obesity (Garn, LaVelle & Pilkington 1983, Adair & Gordon-Larsen 2001, Anderson, Kaplowitz et al. 2001, Dallal & Must 2003), development of risk factors for later non-communicable diseases such as hypertension and insulin resistance (Siervogel et al. 2003), and engagement in risk behaviours such as early sexual debut (Golub et al. 2008) and substance abuse (Mendel et al. 2007).

There have been a number of South African studies of pubertal development and age at menarche, particularly in Black girls (Oettle & Higginson 1961, Frere 1971, Richardson & Pieters 1977, Richardson et al. 1983, Chaning-Pearce & Solomon 1987, Cameron & Wright 1990, Cameron et al. 1993, Norris & Richter 2005). There are however, fewer studies of boys (Cameron et al. 1993, Norris & Richter 2005) and of White adolescents (Chaning-Pearce & Solomon 1987). There are a lack of recent estimates for the timing of pubertal development and age at menarche in South Africa and, in addition, there are no studies that examine the factors associated with these maturational events. Knowledge about the timing of, and factors associated with pubertal development and age at menarche are particularly important given the transitioning nature of South Africa.

Since the deregulation of Apartheid legislation in 1994, South Africa has undergone rapid political, social, and economic transition. The most significant characteristic of this transition has been the rate of urbanisation. The World Bank (1998) reports a current rate of urbanisation of 54% which is projected to rise to 73% by 2010. Urbanisation is said to create opportunities for improvements in the social, economic, and health status of a population (Yach 1988); however, the impact of such rapid urbanisation places additional stress on the

already poor urban support systems including health care, sanitation and housing provision (Cameron et al. 1998). The residual impact of this rapid urbanisation on population health is not well understood. As pubertal development and age at menarche are sensitive indicators of population health, estimating average ages and examining how they change over time may help to gauge changes in health and well-being in South Africa. In addition, knowledge of the timing of, and factors associated with pubertal development and age at menarche provide an opportunity to enhance knowledge for intervention strategies and policy makers to help reduce the prevalence of potential negative health outcomes associated with the timing of pubertal development.

Whilst it is important to determine age at the initiation of puberty and menarche, the methods used to assess these maturational events must provide reliable and accurate estimates, in order for appropriate conclusions to be drawn from the results. There are variations on the exact tool used, but typically pubertal development and age at menarche are assessed either by a physician (physician-rated) or by the adolescent (self-rated). Few authors have engaged the user's perspective on the design of such self-rating tools. By gauging the user's perspective through such techniques as using focus group discussions, there is potential to improve the reliability and accuracy of self-rated pubertal development questionnaires.

Therefore, the aims of the current study are four-fold and involve both quantitative and qualitative research methods. Samples of Black and White adolescents from the Birth to Twenty (Bt20) longitudinal birth cohort study, set in Soweto-Johannesburg, South Africa will be used. Firstly, the study aims to determine median age at the initiation of puberty and at menarche. Secondly, to examine the evidence for a secular trend in pubertal development and menarcheal age using data from the current study and from previous South African studies between 1961 and 2005. Thirdly, to investigate which peri-natal, infant and childhood factors (such as socio-economic status (SES), birth weight, body composition) are associated with the timing of pubertal development and age at menarche. The fourth and final aim is to use focus group methods to help inform the current Bt20 pubertal development data collection procedures by exploring the views and opinions of study participants and staff.

1.2 Thesis chapter outlines

This thesis consists of seven chapters. Chapter two presents an overview of South Africa and provides the context in which the Bt20 study is set. This is followed by a critical review of the literature relating to pubertal development and age at menarche in both developing and developed countries. Chapter three provides a summary of the methods used in the current study, for both the quantitative and qualitative research strands. The results are split into two chapters, with chapter four presenting quantitative results and chapter five presenting qualitative results. Chapter six synthesises the results from the current study and those of previous studies to provide a critical discussion of the findings. In addition, the limitations and policy implications of the current study and future research ideas are discussed. A summary of the conclusions from the current study are presented in chapter seven.

2 Background

This chapter initially introduces South Africa, the Gauteng Province, and Johannesburg-Soweto, the area within which this study was conducted and discusses the legacy of apartheid. It then briefly highlights the uniqueness and richness of the Birth to Twenty (Bt20) longitudinal birth cohort study data. This is followed by a critical review of the literature relating to pubertal development and age at menarche, the timing of these maturational events and a review of the evidence for a secular trend in developing and developed countries. In addition, the factors that have been shown to be associated with pubertal development and menarche are highlighted.

The studies presented in this chapter were identified through regular searches of the following computerised databases: Medline (pubmed), Zetoc and Web of Science. In addition, an examination of published paper reference lists was undertaken and papers were also found on recommendation from colleagues. Key words used in searches included: (menarche or puberty or pubertal development or adolescence or breast development or genitalia development or pubic hair development) and (South Africa or developing countries or developed countries). As this section covers a number of review questions, other more specific terms were used to review the literature on topics such as secular trends (secular trend or secular change AND the puberty key words above), the endocrinology of puberty (endocrine or hormones or sex steroids or androgens or growth hormone or testosterone or oestrogens or leptin AND the puberty key words above) and the factors associated with the timing of pubertal development (genetics or psychosocial stress or delinquency or body composition or obesity or nutrition or ethnic group or small for gestational age or birth weight or rapid growth or intrauterine growth retardation or childhood growth or endocrine disrupting chemicals or urbanisation or socio-economic status).

2.1 South Africa

South Africa is located on the southern tip of Africa and made up of a total of nine provinces (Figure 2.1). Desmond Tutu and in turn Nelson Mandela referred to South Africa as the "Rainbow Nation" due to the multicultural diversity of the population. Mid year estimates for 2007 projected the population of South Africa to be greater than 47.9 million (51% female),

split into four ethnic groups†: African (79.7%), White (9.1%), Coloured (8.8%) and Indian/Asian (2.4%) (Statistics South Africa 2007). Life expectancy at birth was estimated at 52 years for females and 49 years for males; total fertility rate (TFR) was 2.69 children per woman, and the infant mortality rate (IMR) was estimated at 45.2 per 1000 births (Statistics South Africa 2007). According to the 2007/08 United Nations Human Development Report, South Africa is a medium human development country (United Nations 2007); however, according to the UN State of World Population Report (UNFPA 2007), life expectancy (female 52; male 49) in South Africa is similar or lower than that of the least developed countries (female 53.2; male 51.4), mostly as a result of increasing prevalence of HIV/AIDS.

Figure 2.1 Provincial map of South Africa

Source: (Martins 2006)

† "The Apartheid regime created a system of so-called race classification which legally differentiated between Whites (of European origin), Indians (a collection of different people from the South East Asian region, mainly from India), Coloureds (people of mixed ancestry), and Blacks (people of African descent). Participation in society was differentiated in freedom and quality on a continuum from Whites to Indians to Coloureds to Black people. The terminology is retained in this thesis because it carries the legacy of decades of oppression and discrimination, the effects of which are still evident" (Richter et al. 2007).

2.1.1 The study area

2.1.1.1 The Gauteng Province

Gauteng, meaning "house of gold" in Sesotho, is the smallest province within South Africa, covering 1.4% (17010km^2) of the total land area, but it is the second most populous province, with 20.2% (8.8 million people) of the population residing in this area. Gauteng had the highest population growth of all the provinces, growing at a rate of 20.3% between 1996 and 2001 (Statistics South Africa 2007). Estimated life expectancy at birth for males (2001-2006) was 54 years and 58 years for females. Projected life expectancy at birth for males (2006-2011) is 52 years and 55 years for females. Total fertility rates for this area (2001-2006) were the lowest in the country at 2.2 children per woman and are projected to decline to 2.1 children per woman in the 2006-2011 period (Statistics South Africa 2007).

The population density within this province in 2001 was 519.5/km^2, the household density was 155.9km^{2,} and the average number of persons per household was 3.3. The population was split into four ethnic groups: Black (73.8%), White (19.9%), Coloured (3.8%) and Indian/Asian (2.5%) (Statistics South Africa 2001). The population age structure in 2001 was: 23.6% under 15 years of age, 19.6% between the ages of 15 and 24 years, 37.9% between the ages of 25 and 44 years, 15.0% between the ages of 45 and 64 years, and 4.0% who were 65 years of age or older (Statistics South Africa 2001). The main languages spoken at home were Afrikaans (14.4%), English (12.5%), IsiZulu (21.5%), Sesotho (13.1%), Sepedi (10.7%) and Xitsonga (5.7%) plus a number of other local vernaculars.

Table 2.1 shows the level of education achieved by Gauteng adults over the age of 20 years in 2001. In total, 40.6% of adults completed high school (Statistics South Africa 2001). Table 2.2 shows the employment/unemployment levels of Gauteng adults of working age, split by ethnic group (15 to 65 years of age) in 2001. In total 25.8% of this working population were unemployed and there was a clear gradation in the percentage that were unemployed by ethnic group. Whites (4.6%) were the least likely group to be unemployed, followed by Indian/Asians (8.1%), Coloureds (23.6%), and Blacks (32.3%) (Statistics South Africa 2001).

Table 2.1 Gauteng province educational levels for adults over 20 years of age in 2001

Educational Achievement (adults aged 20+ years)	Percentage
No schooling	8.4
Some primary school	11.2
Completed primary school	5.5
Some high school	34.3
Completed high school	28.0
Greater than high school	12.6

Source: (Statistics South Africa 2001)

Table 2.2 Gauteng province unemployment levels split by ethnic group for working adults 15 to 65 years in 2001

Ethnic Group	Unemployed (%)
Black	32.3
Coloured	23.6
Indian/Asian	8.1
White	4.6

Source: (Statistics South Africa 2001)

The average annual income for employed adults (15 to 65 years of age) was R23539 (£1960); split by gender, males earned on average R24977 (£2080) compared to females who earned on average R20838 (£1740) in 2001. There was clear division in average annual incomes between ethnic groups, on average Whites earned the most at (R73438/£6120), followed by Indian/Asians (R57036/£4750), Coloureds (R33448/£2790) and Blacks (R15399/£1280) (Statistics South Africa 2001). Table 2.3 shows the Gauteng province annual income distribution for 2001 and highlights the large income inequalities that exist.

Table 2.3 Gauteng province annual income distribution

Income bands	Percentage
No income	2.0
R12-R4800 (£1-£400)	6.4
R4812-R9600 (£401-£800)	13.0
R9612-R19200 (£801-£1600)	24.0
R19212-R38400 (£1601-£3200)	20.4
R38412-R76800 (£3201-£6400)	15.8
R76812-R153600 (£6401-£12800)	10.4
R153612-R307200 (£12801-£25600)	5.0
R307212-R614400 (£25601-£51200)	1.8
R614412+ (£51201+)	1.1

Source: (Statistics South Africa 2001) (Note: Exchange rate used £1 = R12)

2.1.1.2 Johannesburg-Soweto

The city of Johannesburg is the most populous (3.2 million) and largest (1.644km^2) within South Africa and is the provincial capital of Gauteng (City of Johannesburg 2007). Figure 2.2 shows the location of Johannesburg within the Gauteng province. In 2001, the population of Johannesburg was over 3.2 million and topped over seven million people when the East Rand and Suburban areas were included in the total. Of these people, 74% were Black, 16% White, 6% Coloured and 4% were Asian. Some 42% of the population were 24 years of age or younger and just six percent were over 60 years of age. Of the potential working population (15 to 65 years) 37% were unemployed and of these 91% were of Black ethnic origin. There are four main languages spoken at home within this area including: Nguni (34%), Sotho (26%), English (19%), and Afrikaans (8%). Approximately 7% of adults (older than 20 years) were illiterate, 15% have primary education, 29% high school education, and 14% attended technical school and/or university (Statistics South Africa 2001).

Figure 2.2 Location of Johannesburg within the Gauteng province

Source: (City of Johannesburg 2007)

Figure 2.3 shows the 11 administrative regions of Johannesburg. Each administrative region is responsible for the provision of health, social welfare, and leisure services to approximately 300 000 residents. These administrative regions juxtapose neighbourhoods at both ends of

the socio-economic continuum e.g. from the informal settlements of Alexandra to the prosperous suburbs of Sandton. Soweto (SOuth WEstern TOwnships) is located approximately 15km to the south-west of central Johannesburg (Figure 2.3, regions 6 and 10) and comprises some 32 townships (City of Johannesburg 2007), although others estimate upwards of 87 if each zone/extension is counted individually. Originally there were only temporary living quarters for the mine workers, before Soweto was declared a ghetto for the Black population of Johannesburg under the "Urban Areas Act" in 1923. Population estimates are difficult for this area, due the high population growth rate and the lack of detailed recording of births and deaths. Nearly all of the inhabitants of Soweto are of Black ethnic origin and the 2001 South African Census estimated the population of Soweto to be nearly 1 million people, or one third of the city's total population (Statistics South Africa 2001).

Figure 2.3 Administrative areas of Johannesburg

Region 1: Diepsloot, Kya Sand
Region 2: Midrand, Ivory Park
Region 3: Bryanston, Douglasdale, Fourways, Randburg, Sandton, Strijdompark, Sunninghill, Woodmead
Region 4: Emmarentia, Greenside, Melville, Northcliff, Rosebank, Parktown, Parktown North
Region 5: Roodepoort, Constantia Kloof, Northgate
Region 6: Doornkop, Soweto, Dobsonville, Protea Glen
Region 7: Alexandra, Wynberg, Bruma
Region 8: Inner City
Region 9: Johannesburg South, City Deep, Aeroton, Southgate
Region 10: Meadowlands, Diepkloof
Region 11: Orange Farm, Ennerdale, Lenasia

Source: (City of Johannesburg 2007)

Within South Africa's borders there is clear economic disparity and the country is ranked second only to Brazil for income inequality globally (May 2000). In 2001, approximately 57% of South Africa's population lived below the poverty line (Schwabe 2004). These income inequalities have been, in part, driven by the South Africa's political and economic history,

which resulted in a skewed distribution of wealth, employment, and earning potential for the Black population (Barbarin & Richter 2001).

2.1.1.3 South Africa's political history & the legacy of apartheid

South Africa is a developing nation that has undergone rapid urbanisation and social and economic transition in the past two decades, yet it is still engaged in a complex process of economic and social change, a legacy of Apartheid. Apartheid, the racial segregation between the White minority and the Black majority was formally instituted in 1948 by the National party (NP). Racial segregation was informal for some 300 years prior to its law enforced introduction in 1948 (Lapping 1989). One law that was established prior to the enforcement of Apartheid was the 1913 Land Act which forbade Blacks from owning land or practicing share-cropping (Roberts 2001). Ultimately, this law split South Africa into Black and White areas with Blacks being allocated only 13% of the total land, with most of this land, known as the "homelands" being the poorest and least productive (Seidman 1980). A number of other laws were passed between 1948 and 1956 to ensure citizens abided by the racial segregation policies, or faced prosecution should they break them (see Figure 2.4 for a brief summary).

These "pillars of apartheid" resulted in intense opposition from the non-White population and in 1955 the African National Congress (ANC) adopted the Freedom Charter which called for equal political rights for all racial groups. The South African government responded violently to both national and international opposition and in 1960, following the Sharpeville massacre (confrontation between police and large numbers of Black protestors, which lead to the death of 69 people and injury to hundreds of other) banned all opposition groups. In 1961, the government left the commonwealth and declared South Africa a Republic as a result of opposition and criticism from other commonwealth member states. Following suspension, South Africa left the United Nations (UN) in 1963. In 1964, the leader of the ANC, Nelson Mandela, was sentenced to life imprisonment after been found guilty of sabotage and trying to overthrow the government (Mandela 1994).

Figure 2.4 A brief summary of the Apartheid laws passed by the National Government between 1948 and 1956

The prohibition of Mixed Marriages Act (1949) made it illegal for people from different population groups to marry.

The Population Registration Act (1950) forced South African's into a particular population group (Black, White, Coloured, or Indian/Asian) by registering their population group with the government.

The Group Areas Act (1950) allowed the government to segregate the land into Black and White communities, forcing Blacks to move out of the White areas.

The Suppression of Communism Act (1950) led to the ban of communism and any political party that aimed to bring about political change through disturbances and disorder.

The Negative Laws Amendment Act (1952) allowed the government to control the movement of Blacks into and out of towns and cities.

The Abolition of Passes Act (1952) forced all Blacks to carry passbooks that contained personal information including their population group. It was illegal for Blacks to live and work in White areas without a passbook.

The Separate Amenities Act (1953) led to the segregation of public services (such as buses, post offices, park benches, and beaches) for Whites and non-Whites.

The Bantu Education Act (1953) established complete governmental control over Black education. Black schools had to teach a distorted curriculum, in their native tongue (i.e. not English), with poor training, overcrowded classrooms, and limited resources.

The Separate Representation of Voters Act (1956) prevented Coloureds from voting in elections with Whites.

Source: (Roberts 2001)

Violent demonstrations, riots, and strikes intensified in the two decades following the imprisonment of Mandela and in 1986 a national state of emergency was declared. National and international pressure on the National Party continued to grow and by the end of the 1980s the government acknowledged that the laws of apartheid were no longer feasible to maintain stability of the state (Glaser 2001) and so repealed the pass laws of 1952. Having been elected president in 1989, FW de Klerk over a two year period repealed the Separate Amenities Act (1953), the Land Act (1913), the Group Areas Act (1950), the Population Registration Act (1950), and unbanned all opposition parties. The repealing of these acts saw the breakdown of Apartheid legislation and the initiation of negotiations that ultimately led to South Africa's first democratic elections in 1994. Following his release from prison in

1990, Nelson Mandela was elected President in May 1994. The abolishment of 46 years of formal racial segregation led to a society based on majority rule that aimed to reduce poverty, hunger, and disease. However, the Apartheid legacy was still reflected in the morbidity and mortality patterns and in the growth and maturation of the South African population, particularly in children (Cameron 2003). The Birth to Twenty (Bt20) longitudinal birth cohort study, provides a unique opportunity to investigate how the legacy of apartheid has influenced the growth and maturation of adolescents born in the weeks following Nelson Mandela's release from prison in 1990. These adolescents are the first generation of South African's to live in a democratic society.

2.2 The Birth to Twenty (Bt20) Study

Birth to Twenty (originally Birth to Ten) is one of very few longitudinal birth cohort studies within the developing world, and is the largest and longest running study of child and adolescent health and development within Africa. The Bt20 cohort was established over a seven week period between April 23rd and June 8th 1990. A total of 3273 mother-infant dyads that were resident and continued to be resident in the metropolitan area of Soweto-Johannesburg, South Africa were enrolled into the study. Bt20 was established to track the growth, health, well-being, and educational achievements of a group of urban South African children who were born at the start of this transitioning economy (Richter et al. 2007). To date, data have been collected at 17 time points through questionnaires (self-complete and interviewer administered) and physical examinations. Key themes of data collection include growth, nutritional status, pubertal development, physical activity, and health; demographic and household socio-economic status. Detailed pubertal development and body composition data are available annually from 9 years of age (see Methods, section 3.1.1.1 for a more detailed description of the Bt20 sample). These longitudinal data therefore provide a unique opportunity to investigate the determinants of pubertal development across diverse socio-economic milieu.

2.3 Pubertal development

Puberty refers to the process of reproductive maturation which results in the functional ability to procreate. Although not directly measured in the current study, it is important to understand the hormonal regulation of puberty to help facilitate our understanding of the

morphological factors that are associated with the timing of pubertal development in this cohort.

2.3.1 Endocrine control of puberty

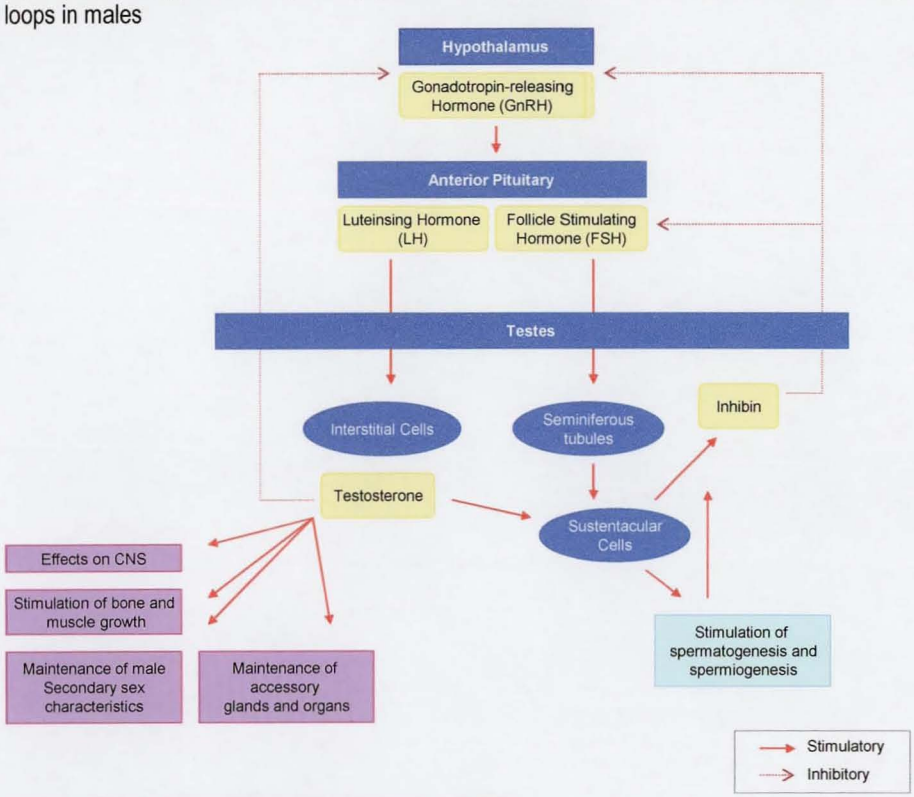
Puberty occurs primarily as a result of the reactivation of the hypothalamic-pituitary-gonadal (HPG) axis (Dorn & Rotenstein 2004). Gonadarche refers to the reactivation of the gonadotrophic-releasing hormone (GnRH) pulse generator in the hypothalamus, and is the viewed as the start of pubertal development (Knobil 1988, Medhamurthy, Gay & Plant 1990, Plant 2002). The HPG axis is the main reproductive endocrine axis and is composed of the hypothalamus, pituitary gland, and the gonads. It controls an individual's reproductive function by regulating the production and maturation of gametes and other reproductive tract activities that are necessary for reproduction (Ellison 2002). The regulatory peptide of the HPG axis is GnRH which is secreted from the hypothalamus. GnRH stimulates the production and secretion of two gonadotrophins: follicle stimulating hormone (FSH) and luteinising hormone (LH) from the anterior pituitary gland. The release of GnRH is pulsatile or episodic (Brook 1999, Plant 2002) and this secretory pattern governs the release of FSH and LH, although the release of FSH and LH does not directly reflect the pattern of GnRH secretion (Ellison 2002). For example, the level of circulating steroid hormones modifies gonadotrophin pulse frequency and amplitude in females (Knobil 1981, Veldhuis et al. 1984).

In males, LH stimulates the secretion of testosterone by the interstitial cells of the testes. FSH targets the sustentacular cells of the seminferous tubules in the testes. In the presence of FSH and testosterone, sustentacular cells promote spermatogenesis and spermiogenesis. Spermatogenesis is regulated by a negative feedback system involving GnRH, FSH, inhibin, and testosterone. As the rate of spermatogenesis increases under stimulation from FSH, the rate of inhibin secretion from the sustentacular cells increases. Inhibin suppresses the release of FSH by the anterior pituitary and GnRH by the hypothalamus. Testosterone suppresses the release of GnRH by the hypothalamus. A summary of the male HPG axis is shown in Figure 2.5.

In females, LH stimulates the production of oestrogens and inhibin by the granulosa cells in the developing follicles of the ovary. As oestrogen and inhibin levels rise, they suppress both hypothalamic GnRH secretion and anterior pituitary FSH production and secretion.

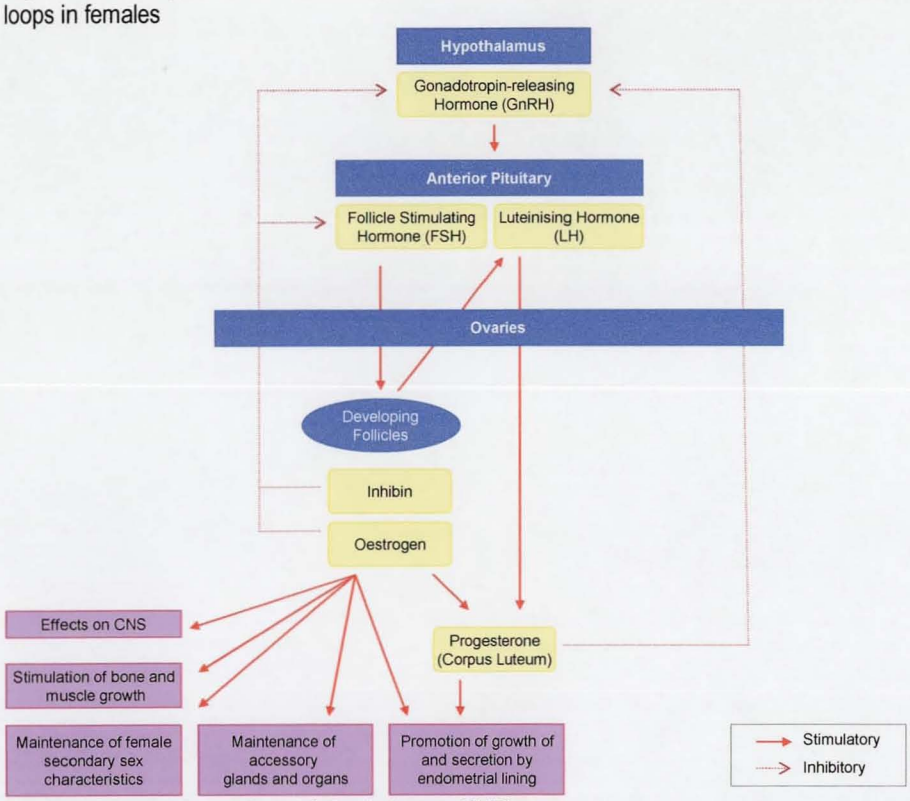
Oestrogen also has an influence on the rate of LH secretion. Whilst GnRH promotes the synthesis of LH, the rate of secretion is dependent on the circulating levels of oestrogens. Thus, as the level of oestrogens rise due to stimulation by FSH, there is a concurrent rise in LH levels. After ovulation, LH stimulates to formation of the corpus luteum which in turn secretes progesterone. Progesterone has an inhibitory effect on GnRH secretion. A summary of the female HPG axis is shown in Figure 2.6. Due to the nature of the feedback systems within the HPG axis, gamete production is self-sustaining in both males and females (Ellison 2002).

Figure 2.5 The hypothalamic-pituitary-gonadal axis, its principal hormones, their main effects, and feedback loops in males



Source: Adapted from (Martini & Bartholomew 2000)

Figure 2.6 The hypothalamic-pituitary-gonadal axis, its principal hormones, their main effects, and feedback loops in females



Source: Adapted from (Martini & Bartholomew 2000)

2.3.1.1 Maturation & reactivation of the HPG axis

The HPG axis and its associated feedback mechanisms have been shown to mature during foetal life and to be fully functional at birth (Jakacki et al. 1982, Ellison 2002); however, over the first five years of life it becomes progressively quiescent (Winter et al. 1975, Kaplan, Grumbach & Aubert 1976, Bridges et al. 1994, Brook 1999, Dorn & Rotenstein 2004). This period of suppression is followed by a reactivation in late childhood which leads to the initiation of pubertal development (Jakacki et al. 1982). The mechanism through which the HPG axis is inhibited or suppressed during childhood is not well understood. One suggestion is that the secretion of hypothalamic GnRH is inhibited via the negative feedback action of the sex steroids (Kaplan, Grumbach & Shepard 1969). In addition, Winter et al. (1975) and Kaplan et al. (1976) have suggested that during the post-natal period, the sensitivity of the HPG axis increases, which results in a decrease in gonadotrophin secretion. Very low levels of pulsatile gonadotrophin release are detectable in pre-pubertal children (Plant 1988) and it is clear that gonadotrophin levels are important in the suppression mechanism, as agonadal children exhibit higher levels of sex steroids when compared to normal children prior to puberty (Conte, Grumbach & Kaplan 1975, Ropelato et al. 1997).

There is also limited knowledge about the factors or signals that trigger the reactivation of the HPG axis in later childhood. Two theories have been postulated that describe the maturational changes in the HPG axis at puberty, although these hypotheses are somewhat contradictory and the proximate cause of the HPG axis reactivation remains unknown. The first theory has been termed the *gonadostat hypothesis* and suggests that, at puberty, the hypothalamus becomes less sensitive to the negative feedback effect of sex steroids leading to increasing levels of circulating gonadotrophins and sex steroids (Kulin, Grumbach & Kaplan 1969). In contrast, Plant (1988) argued that the *gonadostat hypothesis* implies that the castration of an individual prior to puberty would lead to a sharp rises in gonadotrophins, a phenomenon that does not occur (Ellison 2002). Plant suggested that instead of the HPG axis being regulated by sensitivity to sex steroids, rather it is regulated by positive stimulation and puberty occurs due to positive hypophysiotropic drive. The neuro-endocrine mechanisms that mediate the reactivation of the HPG axis in humans remain an area of active research.

Although the trigger for puberty is unknown, the mechanism through which the somatic characteristics of puberty develop is understood. One of the first signs of HPG maturation is the emergence of sleep-related increased LH and FSH pulse amplitude and frequency (Rogol, Roemmich & Clark 2002). The night time secretions of LH result in higher post sleep gonadotrophin levels, which decrease as the day progresses. As the maturation of the HPG axis progresses, pulsatile release of LH occurs more frequently during waking hours resulting in more stable sex steroid release over a 24 hour period. This increase in circulating levels of gonadotrophins promotes gonadal maturation and the subsequent increase in sex steroids promotes the development of secondary sexual characteristics. In combination with other endocrine axes and hormones (see Background, section 2.3.1.3 for further discussion), there is accelerated linear growth, body composition changes and redistribution of body fat (Rogol 2002, Rogol, Roemmich & Clark 2002).

So far, this discussion has focussed on the maturation of the HPG axis; however, from an endocrine perspective, puberty or the process of pubertal maturation consists of two independently regulated, but overlapping processes: adrenarche and gonadarche (Sklar, Kaplan & Grumbach 1980, Ibáñez et al. 2000a, Dorn & Rotenstein 2004, Biro, Huang & Lucky 2006,). On average, adrenarche or the activation of the hypothalamic-pituitary-adrenal (HPA) axis occurs some two years prior to gonadarche, at around five to eight years of age in

girls (Sizonenko 1978, Grumbach & Styne 1992, 2003). The maturation of the HPA axis leads to an increased production of adrenal androgens which stimulates the development of pubic and axillary hair (termed pubarche) (Ibáñez et al. 2000a, Dorn & Rotenstein 2004). In addition, adrenal androgens have been associated with body odour and acne (Dorn & Rotenstein 2004).

Currently, the regulatory mechanisms for adrenarche and gonadarche are unknown. However, clinical examples support evidence for adrenarche and gonadarche being independently regulated (Sklar, Kaplan & Grumbach 1980, Ibáñez et al. 2000a). Adrenarche occurs prior to gonadarche and at a time when pulsatile GnRH release is at its lowest, during mid childhood. Girls with Turner Syndrome do not undergo gonadarche due to ovarian dysgenesis but do experience adrenarche (Saenger 1996). In addition, puberty occurs at a normal time in males who gain treatment for primary adrenal insufficiency (Urban et al. 1980). It is important to recognise that the hormonal regulators of adrenarche and gonadarche are independently controlled as the current study aims to investigate the factors that are associated with the timing of the development of secondary sexual characteristics (breasts in females, genitalia in males, and pubic hair in both sexes). Therefore, separate analyses should be undertaken for the predictors of breasts/genitalia and for the predictors of pubic hair development. Having said this, one must consider if the appearance of pubic hair in the absence of breasts/genitalia development represents pubertal maturation, or is simply a manifestation of adrenarche. Biro and colleagues (2006) have elegantly answered this question by examining the height velocity and pubertal development of a sample of 1155 girls over a ten year period. Girls were classified as having "gonadarche" if they had breast development without pubic hair development and as having "pubarche" if pubic hair was present in the absence of breast development. The results from the study showed that puberty attained via either pathway was associated with pubertal growth velocities (accelerated) rather than pre-pubertal velocities. Therefore, the appearance of pubic hair in the absence of breasts/genitalia development can be taken as a true sign of the initiation of pubertal development.

2.3.1.2 The potential role of leptin

Leptin has been proposed as a regulator of menarche in humans (Bray 1996) and more recently as a mediator between adipose tissue and the maturation of the hypothalamic-

pituitary-gonadal (HPG) axis (Carlsson et al. 1997). Leptin is only produced in adipose tissue and is encoded by the Obesity (*ob*) gene (Zhang et al. 1994). In mouse models, leptin has been shown to influence appetite, energy expenditure and the neuro-endocrine axis (Maffei et al. 1995, Stephens et al. 1995, Vaisse et al. 1996). In addition, mice who became anovulatory due to food-restriction regained reproductive capacity when given leptin treatment (Ahima et al. 1996). In human models, mutations in the leptin receptor gene and congenital leptin deficiency result in early-onset clinical obesity and pituitary dysfunction (Montague et al. 1997, Clément et al. 1998, Strobel et al. 1998). The results from these studies suggest that leptin may be an important regulator between adipose tissue and the hypothalamus, by signalling to the CNS that there are sufficient energy stores for successful reproduction. This would fit with the "critical body mass theory" proposed by Frisch and McArthur (1970), suggesting that a critical level of fat mass was required for menstruation to occur. Although, Ellison (1981, 1990) has since shown that Frisch's hypotheses were empirically and theoretically flawed. There is evidence in the literature to show that girls who are overweight and/or obese experience menarche at a younger age in comparison to their leaner peers (Garn, LaVelle & Pilkington 1983, Adair & Gordon-Larsen 2001, Kaplowitz et al. 2001, Anderson, Dallal & Must 2003). This may be mediated through the interaction between leptin and the HPG axis as obese girls, in the same stage of pubertal development have been shown to present with higher leptin concentrations when compared to their non-obese peers (Klein et al. 1998).

A number of studies have reported a progressive increase in leptin levels at puberty (Blum et al. 1997, Falorni et al. 1997, Garcia-Mayor et al. 1997, Demerath et al. 1999). This rise runs in parallel with increases in fat mass seen during puberty, but not prior to puberty and therefore leptin cannot be the trigger for the maturation of the HPG axis (Ahmed et al. 1999, Grumbach & Styne 2003). In males, leptin levels rise in early puberty and then decline as androgen levels increase and suppress leptin production. In contrast, oestrogens promote leptin synthesis and so levels continue to rise in girls as puberty progresses, serum levels of oestrogen rise and fat mass increases (Blum et al. 1997). In addition, pubertal development has been shown to occur within a wide range of circulating leptin levels (Mann & Plant 2002) indicating that leptin is permissive rather than causal. Overall, these findings show that leptin plays an important, but permissive role in the initation of pubertal development and of continuing reproductive function.

2.3.1.3 The endocrinology of physical growth

Postnatal growth (height and weight) consists of three distinct phases: infancy, childhood, and puberty, with each of these phases being regulated by different aspects of the endocrine system (Hindmarsh 2002). Little is known about the endocrinology of growth in the first year of life, perhaps due to a lack of access to human foetal tissue and so the majority of studies are based on animal models. These models suggest that early post-natal growth is largely growth hormone (GH) independent. Nutrition appears to have a key role and has been closely linked to the action of insulin-like growth factors (IGF's) (Wang & Chard 1992, Hindmarsh 2002). The childhood or GH dependent phase of growth is initiated at around six months of age with the appearance of GH receptors in the growth plate. Prior to puberty, the GH/ IGF-1 axis and thyroid hormone (TH) regulate linear growth (Rogol, Roemmich & Clark 2002). Growth hormone is released from the anterior pituitary gland under stimulation from growth hormone releasing hormone (GHRH) and has effects of the liver, skeletal muscle (mediated through IGF's), adipose tissue, and epithelial and connective tissues (see Figure 2.7). Thyroid hormone has a permissive effect with GH to promote cartilage and bone formation as well as being essential for the normal growth and development of the central nervous system (CNS) (see Figure 2.8). The original somatomedin hypothesis (Daughaday et al. 1972) suggested that GH had an indirect effect on linear growth by stimulating the liver to produce IGF-1, which then promoted the expansion and growth plates. It has now been shown that GH has a direct effect on linear growth by stimulating the local production of IGF-1 and chondrocytes in the growth plate itself (Ohlsson et al. 1992).

Figure 2.7 Schematic representation of the growth hormone releasing hormone - growth hormone - insulin-like-growth factor endocrine axis

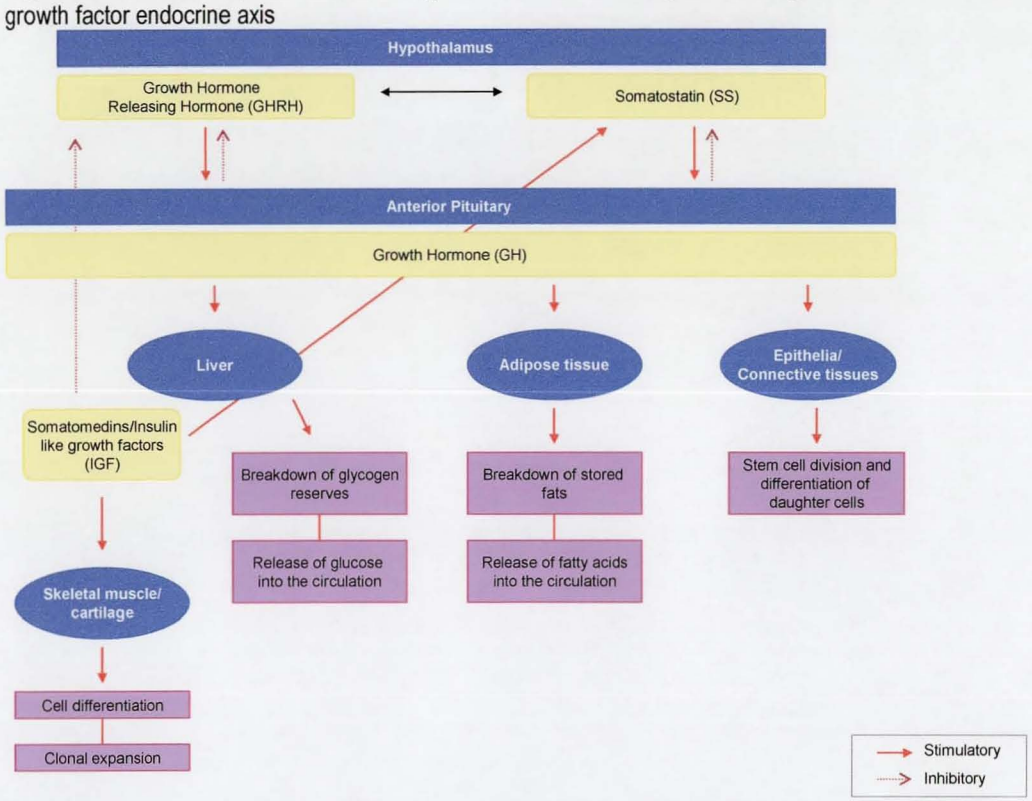
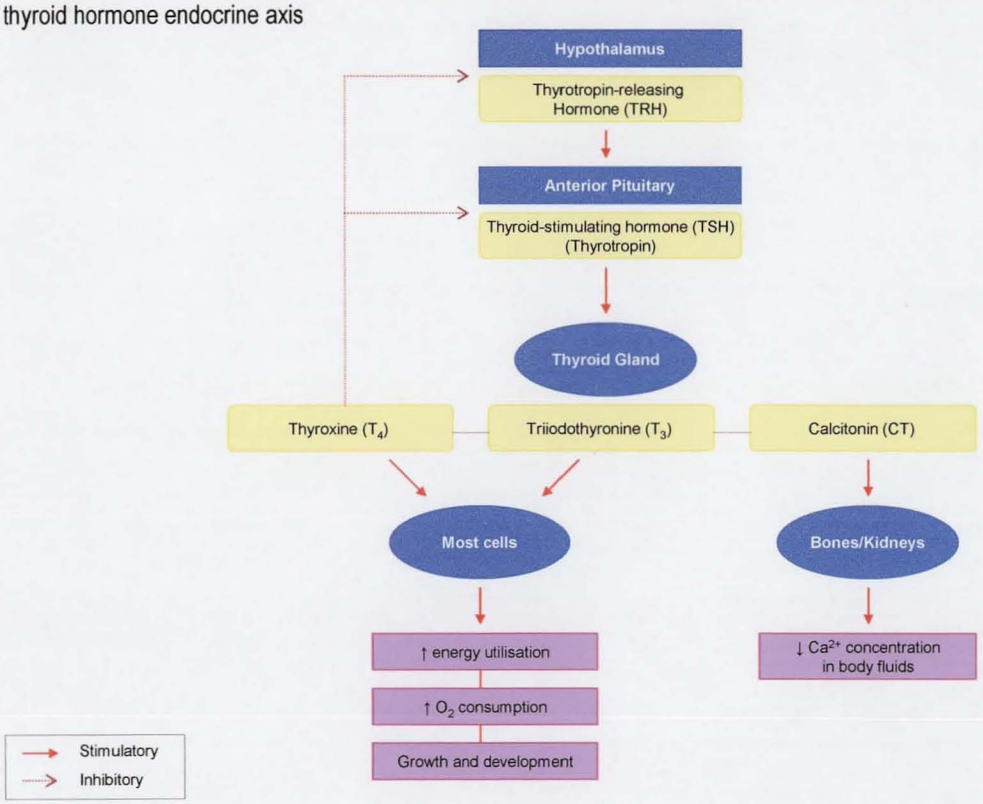


Figure 2.8 Schematic representation of the thyrotropin releasing hormone - thyroid stimulating hormone - thyroid hormone endocrine axis



Whilst GH/ IGF-1 and TH are essential for linear growth during childhood, it is the interaction between GH and gonadal and adrenal hormones that becomes essential for the adolescent growth spurt (AGS) and sexual maturation (Rogol, Roemmich & Clark 2002). During puberty, the maturation of the HPG axis leads to increasing levels of sex steroids (testosterone and oestrodiol). This increase is associated with a subsequent increase in the amplitude of GH pulses (but not the frequency) (Ho et al. 1987, Maurus et al. 1987, Blizzard et al. 1989), followed by an increase in circulating levels of IGF-1 (Rosenfield, Furlanetto & Bock 1983, Harris et al. 1985, Mansfield et al. 1988). Sex steroids and GH each contribute approximately 50% of the total height gained during the AGS (Hindmarsh 2002, Rogol, Roemmich & Clark 2002). Traditionally, it was thought that the increased GH production and subsequent increase in height velocity in adolescence was attributable to testicular androgen secretion in boys, and to oestrogen and adrenal androgen secretion in girls. However, more recent research has shown that the principal hormone for the stimulation of the GH/IGF-1 axis is oestrogen in both sexes (with testosterone aromatisation into oestradiol in males) (Juul 2001). Thus, it appears that sex steroids have a stimulatory effect on the GH/IGF-1 axis as oestrodiol amplifies the pulsatile release of GH by the anterior pituitary gland (Caufriez 1997). Oestrogens exert two different effects on growth and maturation, depending on circulating levels. Low levels of oestrogen stimulate bone formation at the growth plate via the GH/IGF-1 axis but do not promote the development of secondary sexual characteristics. Higher levels of circulating oestrogens stimulate the development of secondary sexual characteristics and have a growth-suppressive role by stimulating the fusion of epiphyses (Juul 2001).

During puberty, there are marked sexually dimorphic changes in body composition, with girls accruing substantial amounts of fat but relatively little lean mass compared to boys who accrue greater lean mass and lose peripheral fat mass (Guo et al. 1997, Maynard et al. 2001, Rogol, Roemmich & Clark 2002, Siervogel et al. 2003, Wells 2007). These changes in body composition are sex steroid driven. The pubertal increase in circulating sex steroids and adrenal androgens promotes the accumulation, metabolism, and distribution of adipose tissue (Wells 2007). For example, the sexually dimorphic regional distribution of fat, gluteo-femoral in females and abdominal in males is facilitated by oestrogen and testosterone respectively (Norgan 1997). Testosterone has also been shown to be important for male lean mass accrual during puberty (Schoenau 2006).

2.3.1.4 Summary of the endocrinology of puberty

In summary, puberty results from the maturation of the HPG axis. Two independently regulated, but overlapping processes: adrenarche and gonadarche promote the development of secondary sexual characteristics (pubic hair and breasts/genitalia). In combination with the GH/IGF-1 axis, sex steroids promote the adolescent growth spurt and changes in body composition such a fat mass distribution. The trigger or signal that causes the maturation of the HPA and HPG axes is currently unknown and is an area of active research. It has been speculated that leptin may play a key role; however, evidence suggests that whilst important, leptin is permissive for pubertal development. Whilst we do not know what triggers puberty, knowledge of the factors that are associated with pubertal development may highlight areas for future endocrine research.

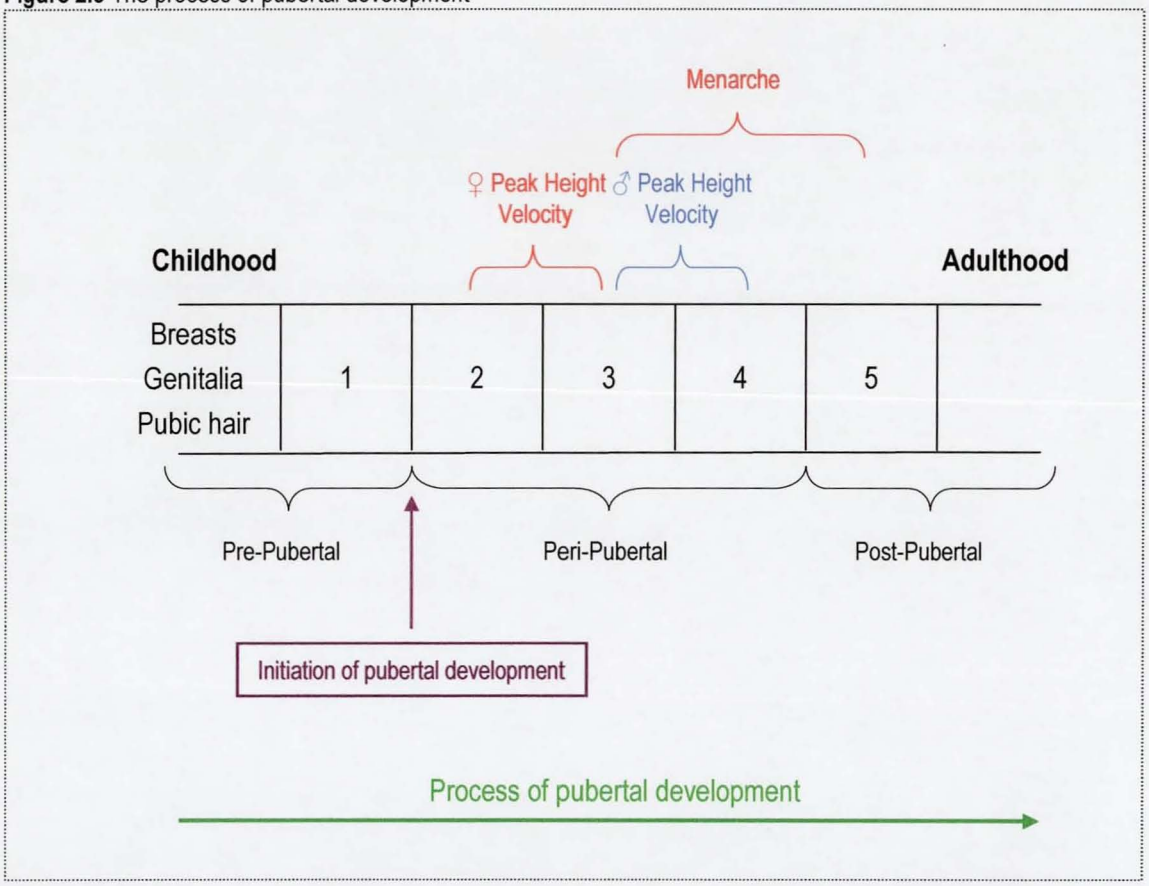
2.4 Assessing pubertal development & age at menarche

Secondary sexual development (breasts in females, genitalia in males and pubic hair in both sexes) is characteristically assessed using developmental scales. Several methods including clinical examination, parental assessment and self-reporting are used to assess which developmental stage an individual is in at any particular point in time (Coleman & Coleman 2002). There are three different development scales reported in the literature: (1) The Tanner Staging Technique (Tanner 1962), (2) Pubertal Development Scale (PDS) (Petersen et al. 1988), and (3) Adolescence Scale (AS) (Kaiser & Gruzelier 1999).

The majority of studies investigating secondary sexual development use the Tanner Staging Technique (Tanner 1962). The pioneering work by Reynolds and Wines (1948) and Nicholson and Harley (1952) provided a basis on which Tanner and colleagues devised this scale. The processes of breast development in girls, genitalia development in boys and pubic hair development in both sexes are split into five stages (B1-B5, G1-G5, and PH1-PH5) (see Appendix I for graphical representations of each of these scales). The typical sequence of progression through these stages and other development milestones is shown in Figure 2.9. Stage 1 is pre-pubertal, stages 2-4 peri-pubertal and stage 5 post-pubertal. The initation of puberty occurs when an adolescent progresses from stage 1 to stage 2 and adulthood is reached when an adolescent progresses from stage 4 to stage 5. Peak height velocity (PHV) occurs relatively early in the process of pubertal development in girls, typically in B3/PH3 and girls gain on average 25cm in height during puberty (Marshall & Tanner

1969). In boys, PHV occurs later in the process of pubertal development, on average in G4/PH4 and they gain approximately 28cm in height in total (Marshall & Tanner 1970). The shorter duration of pre-pubertal growth and the smaller magnitude of PHV in girls results in an average final height difference of 13cm between adult males and females (Tanner 1989). Menarche is a maturational event that occurs late in the process of pubertal development, on average in B4/PH4 and post PHV (Marshall & Tanner 1969). Whilst both of these maturational events (PHV and menarche) occur on average in specific stages of development, there is actually a Gaussian distribution around a specific stage and so some adolescents will achieve menarche in B2/PH2 and others in B4/PH4. Menarche is the most commonly used indicator of pubertal development and this perhaps, reflects the relative ease of assessment. Three different methods are used to collect menarche data: (1) *status quo*, (2) prospective, and (3) retrospective (Tanner 1989, Cameron 2002). In studies that use the *status quo* method, girls are asked if they have periods (menstruate) and the data collected are used to plot a sigmoid curve from which median age at menarche and other parameter estimates can be derived. The prospective method can only be used in longitudinal research and clinic settings, where girls are seen on a regular basis. At each visit the girl is asked if she has started her periods, if the girl is seen regularly enough her age at menarche can be calculated with confidence. This is the most accurate method of assessing age at menarche; however, it is difficult to follow a large and representative sample of girls in order to obtain a reliable population estimate. The retrospective method involves asking each participant at what age they began to menstruate. As menarche is considered a significant life event, most adolescent and young adult females can remember how old they were to within a month. Care must however be taken when retrospective techniques are used with older women as there is a negative association between the age of the woman being asked and the age at which she reports achieving menarche, thus a resulting population estimate may be downwardly biased for older women (Cameron 2002).

Figure 2.9 The process of pubertal development



Having found it difficult to gain ethical approval to use the Tanner staging technique in school settings, Petersen and colleagues (1988) developed a verbal method of assessing pubertal development in the context of an interview. Although, the use of verbal self ratings overcame the problem of gaining ethical approval, the authors do not appear to take into account the subjective nature of a verbal interview technique and the potential errors of reporting and social desirability effects i.e. the need to appear like one's peers. A total of 253 (gender split not provided in the paper) sixth grade students were enrolled into the three year longitudinal study. The participants were asked to rate characteristics such as growth in height, pubic hair, skin changes, and foot growth in both sexes, facial hair and voice changes in boys, breast development, and menarche in girls on a four point scale (1-4). The score from each response was summed and then the total divided by five to give an overall development score between one and four. The authors reported a median Cronbach's alpha‡ of 0.77 for internal consistency. Whilst this appears to be a moderate reliability value, in reality all it

‡ Cronbach's alpha (Cronbach 1951) is a measure of the reliability of a psychometric instrument. Cronbach's alpha tends to increase when the correlations between the items increase. For this reason the coefficient is also called the internal consistency or the internal consistency reliability of the test.

shows is that adolescents are consistent in their reports of pubertal change across characteristics, yet the authors conclude that "the PDS is reliable and valid" (Petersen et al. 1988). However, the questionnaire has not been validated within the current study and there are no comparisons with physician ratings that would infer reliability. The PDS is subjective, lacks sensitivity to identify the onset of pubertal development, and provides only a rough indication of whether a child is pre-, peri- or post-pubertal, therefore it is inadequate to use in a clinical setting or in studies where there is an interest in examining the initation of pubertal development and the factors associated with it. The PDS may only be appropriate for school based settings, in which more direct measures of puberty may not be possible.

The AS consists of four questions and an example can be seen in Figure 2.10. It was developed on the basis of work by Sanders and Soares (1986) and Gilger and Ho (1989) and is defined as "a tool for the retrospective assessment of puberty milestones". This raises the first question about the validity and reliability of the AS, as it was used on 318 adults (166 females) with a mean age of 20.7 years (range = 18 to 36 years). Evidence suggests that determining age at menarche using recall is reliable, particularly if the girls involved are still in adolescence or early adulthood; however, there is little or no evidence to suggest that adults can reliably recall the age at which they "most increased in height" or for adult males "how old they were when they experienced their first nocturnal emission".

Figure 2.10 The Adolescent Scale (AS) questionnaire

1. Compared with others of the same sex, did you reach sexual maturity?

Much earlier	Earlier	Same time	Later	Much later
-2	-1	0	1	2

2. How old were you when you increased most in height?

3. For females:
   a. How old were you when you began to menstruate? (years/months)

4. For males:
   a. How old were you when your voice started to break? (years/months)
   b. How old were you when you began to shave regularly? (years/months)
   c. How old were you when you had your first nocturnal emission? (years/months)

Source: (Kaiser & Gruzelier 1999)

Cronbach alpha values of 0.82 were reported for both males and females, again showing that there is a high level of internal consistency between characteristics assessed in the questionnaire. Although it was not possible to determine pubertal development by physician assessment because of the recall nature of this questionnaire, the single measure of internal

consistency was not appropriate to allow the authors to conclude that "the AS was a reliable instrument for the measurement of pubertal development" (Kaiser & Gruzelier 1999). As with the PDS, the AS has not been appropriately validated in the field and is not a sensitive measure of pubertal development due to potential recall biases.

Given the problems with the PDS and AS described above, the Tanner Scaling Technique, even though it has limitations, remains the most appropriate method to assess pubertal development. The most valid and reliable method for assessing pubertal development is longitudinally via clinical examination by a trained health care professional (Brooks-Gunn & Warren 1985, Finkelstein et al. 1999, Taylor et al. 2001). This is however often impractical, expensive and time consuming. In addition, and perhaps the root cause of problems such as selection bias, is that the assessment of pubertal status invades the privacy of adolescents and so subjects may be reluctant to participate in or drop out of studies if a clinical examination is required.

The development of the self-complete questionnaire based on Tanner scales has provided researchers with a non-invasive and indirect measure of secondary sexual development (Duke, Litt & Gross 1980, Morris & Udry 1980). Numerous studies have investigated the validity of self-reporting in comparison to other methods of assessment such as physician rating. The results produced show variability in the validity of using self-report techniques in comparison to clinical assessment; for example Morris and Udry (1980) reported a kappa value of 0.29 compared to Duke et al. (1980) who reported a kappa value of 0.81 for breast assessment. Using a multi-ethnic sample, Hergenroeder et al. (1999) evaluated inter-observer reliability of physician assessment and the validity of self-assessment in comparison to physician assessment for breast and pubic hair maturation. The authors concluded that both breast and pubic hair self-assessment were not reliable in their cohort, in addition physician inter-observer agreement for breast development was low ($\kappa^{\S} = 0.5$). This suggests that physicians also have difficulty using this scale and may not be reliable as a comparative "gold standard". Very few studies report inter-observer reliability statistics thus, the accuracy of data may be questionable in studies where more than one physician makes assessments.

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§ Kappa (Cohen 1960) is the proportion of observer agreement for categorical data. Landis and Koch (1977) proposed a scale of concordance: "fair" 0.21-0.40, "moderate" 0.41-0.60, "substantial" 0.61-0.80 and "almost perfect" 0.81-1.00.

Self-assessment involves the use of the Tanner scale depicted as photographs and/or line drawings accompanied by a written description. A potential problem with line drawings is that they require abstract thinking and the ability to read and understand the description given, in comparison to a photograph which is self illustrative (Hergenroeder et al. 1999). Hergenroader (1999) has also suggested that coloured photographs and/or line drawings specific to the ethnic group being studied should be used to help standardise the self-assessment method. Further research is required to validate the use of coloured photographs/line drawings and to investigate the need for ethnic group specific self-assessment tools.

The use of a modified self-assessment questionnaire has been validated in a sample (n = 182; age range 10 to 18 years) of urban Black South African adolescents (Norris & Richter 2005). The authors created a questionnaire using the line drawings of Morris and Udry (1980) with modified Tanner descriptions to help improve clarity and understanding. Changes to the pubic hair descriptions included the differentiation between texture, density, and distribution of hair between the five stages. For breast development in girls, the wording was changed to allow clear differentiation of the development of the breast, areola, and the nipple between the five stages. For genitalia development in boys, the wording was changed to allow clear differentiation of the development of the scrotum, testes and penis between the five stages. There was significant concordance ($P < 0.0005$) between the adolescent's self rated score and that of the physician for breast ($\kappa = 0.76$) and pubic hair ($\kappa = 0.71$) development for females and for genitalia ($\kappa = 0.60$) and pubic hair ($\kappa = 0.63$) development for males. Therefore, the authors concluded that this modified questionnaire is a valid tool for the self-assessment of secondary sexual development in urban Black South African adolescents. Another potential problem with the use of this questionnaire in urban South African populations is that the authors did not take into account the potential confounding influence of body composition. This is particularly important given the increasing numbers of overweight/obese adolescents within South Africa (Armstrong et al. 2006). Body mass index was reported in the Norris and Richter paper and the sample average was 19.1kg/m^2, although it was not reported whether these BMI's were calculated using international age and gender specific cut offs. On average, the adolescents within this sample had normal BMI's and therefore, BMI may not have influenced the validity of the study, but this is something that should be taken into account in future studies of pubertal development in South Africa. Having acknowledged the inherent limitations of the questionnaire proposed by Norris and

Richter (2005), and taken into account the other tools within the literature, it is apparent that this questionnaire is the best tool that is currently available for the study of self-assessed pubertal development in urban South Africa.

Like the Norris and Richter study (2005), the majority of the literature discusses the use of self-assessment in 'healthy, normal' children, but few studies have investigated whether self-reporting is accurate for overweight and obese children. Bonat et al. (2002) studied 244 children aged 6 to 12 years, 41% of whom were obese (BMI ≥ 95th percentile for age and gender). Pubertal development was self-assessed using line drawings accompanied by explanatory text; this was followed by a blinded rating by a physician. In non-obese females, 25% overestimated and 27% underestimated breast development compared to 38% who overestimated and 12% who underestimated in obese females. Non-obese and obese females did not significantly over or underestimate pubic hair development. Boys however, significantly overestimated their maturity level irrespective of BMI. The authors concluded that in boys and obese girls, self-assessment is not a reliable alternative to clinical examination by a trained practitioner.

2.4.1 The potential for the use of qualitative methods to improve the reliability of self-assessment questionnaires

Given the inherent difficulties of assessing pubertal development as previously discussed, it is surprising to find that researchers have not engaged the users (i.e. adolescents) in the design of such tools. The use of focus group methods could provide insight into the acceptability of self-assessment and may help to develop questionnaires that provide more accurate and reliable pubertal development data. For example, changes to the wording of the descriptions may help to enhance understanding and thus allow adolescents to rate themselves more accurately. As far as the author is aware, there are no published qualitative data relating to the self-assessment of pubertal development. However, focus groups have been shown to be an important and useful vehicle to help gain adolescent perspectives on health and well-being (Peterson-Sweeney 2005), particularly for sensitive issues (Morgan 1997) such as discussions relating to, eating behaviours, teenage pregnancy, sex and sexuality, substance abuse, HIV-related risk behaviours and living with chronic disease (see for example Brown et al. 1998, Hinds et al. 1999, Neurman-Sztainer et al. 1999, Aquilino & Bragadottir 2000, Weinger, O'Donnell & Ritholz 2001). In addition,

Morgan (1997) has argued that focus groups can assist researchers to develop surveys or to clarify survey findings.

2.4.2 Summary of assessing pubertal development

There are a number of different methods to assess the process of pubertal development. Although there are some limitations, the most valid and reliable of these measures is the Tanner staging technique which uses pictures/line drawings with an appropriate description to depict the development of breasts in females, genitalia in males and pubic hair development in both sexes. Physician based assessments of pubertal status invades the privacy of adolescents and so, subjects may be reluctant to participate in or drop out of studies if a clinical examination is required. The development of a self-complete questionnaire based on the Tanner scales has provided researchers with a non-invasive and indirect measure of secondary sexual development. If the self-rated questionnaire is administered appropriately then it has been shown to be reliable when compared to physician assessed data. In addition, the use of the self-rated questionnaire has been validated for use with urban South African adolescents. There are however, some problems with the self-rating technique, with a reduced reliability in males compared to females and in overweight/obese individuals. The latter is potentially a problem given the rising levels of obesity in South African adolescents and needs to be taken into account in future studies of pubertal development. Given the inherent difficulties in collecting pubertal development data, the engagement of users in the design of future questionnaires may help to improve accuracy and reliability.

2.5 South African studies of pubertal development & age at menarche

The development of Tanner staging (Tanner 1962) provided a unique opportunity to investigate the timing, duration, and pattern of secondary sexual development both within and between populations. A mean or median declining age at initiation of puberty has been associated with improving health, social and economic environmental conditions (Eveleth & Tanner 1990). To utilise the benefits of the Tanner scale a longitudinal study design is required so that a cohort of individuals can be followed through the progression of pubertal stages. The requirements for a longitudinal study are seldom met in the South African literature and at present, longitudinal pubertal development data have been used in only two

South African studies of Cape Coloured adolescents (Cameron et al. 1988, 1990). Relatively more cross-sectional data have been used in studies of rural and urban Black, Indian, Coloured, and White South African females, as well as rural and urban South African Black males (Richardson & Pieters 1977, Chaning-Pearce & Solomon 1987, Richardson et al. 1983, Cameron & Wright 1990, Cameron et al. 1993). The most commonly used indicator of pubertal development within the literature is age at menarche and this perhaps, reflects the relative ease of assessment. A number of studies have examined menarcheal age in both urban and rural South African females between 1943 and 2005 (Kark 1943, Burrell, Healy & Tanner 1961, Oettle & Higginson 1961, Frere 1971, Richardson & Pieters 1977, Richardson et al. 1983, Chaning-Pearce & Solomon 1987, Cameron et al. 1988, Cameron & Wright 1990, Cameron, Kgamphe & Levin 1991, Cameron et al. 1993, Henneberg & Louw 1995, Cameron & Nagdee 1996, Norris & Richter 2005). Table 2.4 provides a descriptive summary of each of the South African pubertal development and age at menarche studies published between 1943 and 2005. Ninety-five percent confidence limits were calculated from median and standard error values or from mean, standard deviation, and sample size values provided in these studies.

Before critically reviewing the timing of pubertal development in South African adolescents, it is important to acknowledge that there are intrinsic difficulties when attempting to make comparisons between studies, particularly as ethnic groups, SES, sample sizes, and methodologies vary. Whilst is it possible to control for ethnic group and SES within analyses, the methodological differences pose the biggest problem when making comparisons. The assignment of a child's development into a discrete stage has proved to be problematic as some clinicians and adolescents have problems distinguishing between the Tanner stages. To try and overcome these problems, several authors have created their own pubertal development assessment scales. For example, Chaning-Pearce and Solomon (1987) reduced the five Tanner stages into three stages: pre-adolescence (Tanner stage 1), adolescence (Tanner stages 2-4) and maturity (Tanner stage 5). Du Toit (1987) (data not shown in Table 2.4 as mean/median values were not reported) asked, via questionnaire, if the girls had noticed 'slight', 'moderate', or 'large/pronounced' changes in breast size and pubic hair growth. This combining and/or simplifying of the Tanner stages significantly reduces the sensitivity of pubertal assessment, influences the efficacy of the results, and makes comparisons between studies difficult. In addition to the above methodological issues, whilst numerical differences may be evident, no study to date has considered the

variance between studies in order to test the statistical significance of these differences. Therefore, it has not been possible to distinguish if average age at the initation of puberty and age at menarche are statistically significantly different between studies based on the previously published literature.

Studies from rural populations are included in Table 2.4, although the sample that will be used in the current analysis is urban. For breast development, irrespective of author reported SES, rural Black girls were on average delayed compared to their urban Black peers. For example, in a study comparing urban (n = 148) and rural (n = 121) Black girls, Cameron et al. (1990) reported a mean age at the initation of breast development for urban girls of 10.4 years (95% CI = 10.3, 10.5), compared to 11.7 years (no 95% CI reported), this would suggest a delay of 1.3 years on average. This difference was similar for mean age at menarche, with urban girls (13.2 years [95% CI = 13.0, 13.4]) achieving menarche on average 1.4 years prior to rural girls (14.6 years [no 95% CI reported]). As the authors did not report a measure of variance for the rural sample, it was not possible to determine if this delay was statistically significant. The finding that rural girls were delayed compared to their urban peers is supportive of evidence from other studies and this finding has been shown consistently over time (See for example Graham et al. 1980, Cumming & Aherne 1987, Garnier et al. 2003, Gillett-Netting, Meloy & Campbell 2004, Kirkwood, Campbell, Gillett-Netting & Meloy 2004, Facchini et al. 2008). The advancement of urban children is thought to be a result of higher SES and access to better sanitation, health care, education, welfare, and recreational services (Eveleth & Tanner 1990). There have been two other South African studies that have examined both urban and rural samples within the same analysis (thus excluding the potential confounding influence of a positive secular trend) (Richardson & Pieters 1977, Richardson et al. 1983). In a study of urban (n = 415) vs. rural (n = 405) Black low SES girls, Richardson and Pieters (1977) reported that urban and rural girls achieved breast development at approximately the same time (11.1 vs. 11.0 years respectively); however, menarche was achieved earlier in urban girls (13.0 years) compared to rural girls (14.1 years). In a follow up study, Richardson et al. (1983) reported an average age for breast development of 11.4 years and 13.6 years for age at menarche for urban Black low/mid SES girls (n = 1092). In contrast, rural Black low SES girls (n = 1067) were reported to achieve breast development at 11.7 years and menarche at 14.6 years. However, care must be taken when interpreting these results as these studies have been heavily criticised within the literature (e.g. Cameron & Wright 1990). Neither of the Richardson studies

detailed the statistical techniques used to calculate the mean or median age at initiation of breast development and/or menarche. The majority of studies use probit analysis (Finney 1971) which provides the age at which 50% of the cross sectional sample have attained a particular developmental milestone, for example, menarche. Due to a lack of knowledge about the appropriateness and robustness of the statistical techniques used, both the 1977 and 1983 studies by Richardson et al. have been removed from any further analysis within this thesis.

Given the lack of information about the statistics used, the averages reported for the onset of breast development in Indians (10.4 years) and Coloured girls (10.6 years) by Richardson et al. (1983) may be erroneous and so the estimate of 11.3 years (95% CI = 11.1, 11.5) reported by Cameron et al. (1988) for Coloured girls may be more representative. The results from this study (Cameron et al. 1988) were based on longitudinal data; however, the sample size was relatively small (n = 88) and the data were collected between the ages of 10 and 15 years, thus some girls may have already been pubertal before enrolling into the study and some may not have completed puberty by the time that the study ended. It is possible that for breast development, the mean age at attainment of B2 was overestimated and the mean age at menarche may have been underestimated.

If one discounts the data of Richardson et al. (1983) there has been only one study of pubertal development in urban White South African females (Chaning-Pearce & Solomon 1987) and no studies of pubertal development in urban White South African males (with the exception of one study examining testicular volume, but no correlates of pubertal development were reported [Cameron et al. 1993]) (See table 2.4). The cross-sectional study of Chaning-Pearce and Solomon (1987) examined the sexual maturation of 362 Black and 355 White girls (age range 3.5 to 18.5 years) living in Johannesburg in 1976/77. Mean age at breast development was 11.5 years (95% CI = 11.4, 11.6) for both Black and White girls. Pubic hair development was significantly advanced for White girls (11.3 years [95% CI = 11.2, 11.4) vs. 12.1 years [95% CI = 12.0, 12.2]), as was age at menarche (13.1 years [95% CI = 13.0, 13.2] vs. 13.9 years [95% CI = 13.8, 14.0]) compared to Black girls. However, while the menarcheal data analysis (probit analysis using retrospective recall data) was methodologically robust, care should be taken when interpreting the results for breast and pubic hair development as a simplified Tanner scale was used. As previously discussed, this may have significantly reduced the sensitivity of the study to accurately detect the

development of secondary sexual characteristics. There are clearly a lack of data, particularly in recent years on the timing of pubertal development in urban White South African adolescents. In addition, the problems with the methods used to collect puberty data in the Chaning-Pearce study (1987) indicate that there is a need for more robust methods to be used in order that appropriate comparisons can be made between studies.

A total of six studies (see Table 2.4) have investigated some aspect of pubertal development (secondary sexual characteristics and/or menarche) in urban Black South African adolescents between 1961 and 2005 (Oettle & Higginson 1961, Frere 1971, Chaning-Pearce & Solomon 1987, Cameron & Wright 1990, Cameron et al. 1993, Norris & Richter 2005). All studies, with the exception of Norris and Richter (2005) used cross-sectional status quo techniques and probit analysis to determine mean age at menarche, breast development, and/or pubic hair development. The Norris and Richter (2005) study was cross-sectional in nature and used status quo techniques to ascertain menarcheal status; however, the authors did not use probit analysis, rather the decimal age at menarche for the subgroup of females who reported being menarcheal (69%) within the sample was calculated and then the mean age derived. One has to question the reliability of this estimate given that 31% of the 56 females used in the menarcheal analysis were still pre-menarcheal, which suggests that 13.0 years is a significant underestimate of current age at menarche for urban Black South African girls. In addition, Norris and Richter (2005) determined mean age at entry into stage 2 for breast (11.2 years; 95% CI = 11.0, 11.4) genitalia (12.6 years; 95% CI = 12.2, 13.0) and pubic hair (girls = 11.5 years; 95% CI = 11.3, 11.7, boys = 12.4 years; 95% CI = 12.2, 12.6) development for urban Black males (n = 92) and females (n = 90) aged between 10.0 and 18.0 years (average n per year group, split by sex = 10). Such small sample sizes raise concerns about the reliability of the estimate for age at pubertal initiation. In addition, Cameron et al. (1993) had reported a mean age at the initation of breast and pubic hair development of 10.1 years (95% CI = 10.0, 10.2) and 10.5 years (10.3, 10.7) for genitalia development in boys prior to the work conducted by Norris and Richter (2005). This suggests that the mean ages reported in the Norris and Richter paper (2005) paper may be overestimated, as a proportion of children in stage 2 would have been excluded due to the age range criteria.

Mean age at menarche for the other five papers which used status quo and probit analysis were between 14.9 years (95% CI = 14.8, 15.0) in 1961 (Oettle & Higginson 1961), 13.9

years (95% CI 13.8, 14.0) in 1987 (Chaning-Pearce & Solomon 1987), and 13.2 years (95% CI = 13.0, 13.4) in 1990 (Cameron & Wright 1990) and 1993 (Cameron et al. 1993). The other studies that examined the development of secondary sexual characteristics in urban Black adolescents used Tanner scales (Cameron & Wright 1990, Cameron et al. 1993) or a derivative of this scale (Chaning-Pearce & Solomon 1987). As previously discussed, the results from the Chaning-Pearce study should be interpreted with care. Physician assessed Tanner scales were used in both of the papers by Cameron and colleagues (1990, 1993). These data are therefore, perhaps the most reliable estimates of breasts/genitalia and pubic hair development for urban Black South African adolescents. From a study of 148 females (age range 6.0 to 19.0 years) conducted in 1998, Cameron and Wright (1990) reported a mean age at breast development of 10.4 years (95% CI = 10.3, 10.5). A further study of 148 females and 152 males reported a mean age at breast development and pubic hair development of 10.1 years (95% CI = 10.1, 10.2). For males, mean age for genitalia development was 10.5 years (95% CI = 10.3, 10.7) and 12.4 years (95% CI 12.3, 12.6) for pubic hair development. The only potential issue with these estimates is that the authors characterised the sample as being from a high SES background as the majority of the adolescents were attending private fee paying schools in Soweto-Johannesburg. Therefore, these estimates may be slightly biased towards a younger age at initation.

Of the other urban Black studies the majority reported some measure of SES (Frere 1971, Norris & Richter 2005). Frere (1971) used nutritional status as a proxy for SES. Females who were of "average nutritional status" were classified as having a middle level of SES and those with poor nutritional status were classified as having a low SES. There is evidence in the literature to suggest that SES acts indirectly on pubertal timing through a body composition pathway (Onat & Ertem 2005, Hernández et al. 2007, Kirchengast & Bauer 2007) (see Background, section 2.8.3 for a more detailed discussion). Therefore, this may have been a reasonable proxy measure for SES at this time; however, it does not allow one to disentangle the influence of body composition and SES on the timing of pubertal development. Like Cameron et al. (1990, 1993), Norris and Richter (2005) used type of school (public non fee paying vs. private fee paying) as a proxy measure for SES and reported that their sample were from low/mid SES backgrounds. Using school as a proxy for SES makes the assumption that if caregivers have sufficient funds that they will automatically send their child to a fee paying school, which may not be true. The choice of school is clearly affected by a number of other factors not considered in these papers. The results from these

studies highlight that SES plays an important role in the timing of pubertal development and suggests that there is a need for studies of pubertal development in urban Black South African adolescents that use more objective measures of SES such as those used regularly in Demographic and Health Surveys (DHS) (DHS 2008) e.g. measures of maternal education and consumer durable ownership.

The majority of research examines pubertal development in females, thus there are less data available on pubertal maturation in males. This may be because of the lack of a clearly discernable event in the process of male pubertal maturation. Two studies have looked at secondary sexual development in boys using Tanner scales (Cameron et al. 1990, 1993). Like females, rural Black boys were significantly delayed in the initiation of pubertal development with G2 being attained on average, at 13.4 years (95% CI = 13.1, 13.7) compared to 10.3 years (95% CI = 10.3, 10.7) in urban Black boys (Cameron et al. 1993). Within this study, the rural group were a low to middle SES group rather than a low SES group as they attended a farm school which was run by a paediatrician, who provided health care to the local community which may not have been a true reflection of rural living. Thus, the reported delay in the attainment of G2 between rural and urban Black boys may have been underestimated. In comparison to Black boys, Cape Coloured boys attained G2 on average at 13.1 years, (95% CI = 12.9, 13.3) which was slightly advanced compared to rural Black boys, but significantly delayed compared to urban Black boys (Cameron et al. 1990). However, Cameron et al. (1990) did not provide an indication of the SES of the Cape Coloured sample; therefore, these differences may actually reflect differences in SES between samples.

Two studies have looked at sexual maturation in South African boys using measures other than a form of the Tanner scales (see Table 2.4). Cameron and colleagues (1993) investigated testicular volume (Prader 1966) in 115 urban boys. Pubertal onset is associated with a testicular volume of greater than or equal to 4ml (Tanner & Whitehouse 1976). In this comparison between Black and White boys, Cameron et al. (1993) found that Black boys, within each genitalia stage, had smaller testicular volumes compared to White boys. However, the Black boys were advanced in age compared to the White boys in entry into each genitalia stage. One potential problem with using testicular volumes is that boys may present with asymmetrical volumes and as convention is to assess one testicle only, a boy could potentially be classified as pre-pubertal when he is actually pubertal. Bornman et al.

(1990) investigated spermaturia (presence of spermatozoa in the urine) as a proxy for the onset of pubertal development in 226 10-16 year old Tswana schoolboys. The authors reported that the onset of puberty, calculated by the presence of spermaturia occurred between 14.1 and 15.8 years. There are a small number of studies that have investigated the reliability of using spermaturia as a proxy of the initation of pubertal development (Nielsen et al. 1986a, Nielsen et al. 1986b, Schaefer et al. 1990, Jørgensen, Keiding & Skakkebaek 1991, Pedersen et al. 1993, Nysom et al. 1994,). Mol et al. (2002) found significant associations between Tanner stages, testicular volume, and spermaturia. However, the authors reported that there was large variation in spermaturia between and within boys in the same Tanner stage for genitalia/pubic hair development and that a substantial rate of false negatives influence any estimate of average age at spermaturia. The presence of spermatozoa in urine does not occur consistently during the process of pubertal development; it is more likely to be present in early/mid puberty rather than in late puberty. The main problem that prevents the use of spermaturia as an indicator of pubertal onset is the regular occurrence of sperm-negative urine samples. Rockett et al. (2004) have suggested that there is a need for a number of large, nationally representative studies of spermaturia and pubertal development to assess the reliability of using spermaturia as a method for determining age at the onset of puberty. Because of these limitations when using spermaturia as a marker of the timing of pubertal development, it is appropriate to conclude that the results from the Bornman et al. (1990) study may have overestimated age at onset. This is further confirmed by comparing these data with those presented by Cameron et al. (1993) who reported that even the rural boys group attained G2 on average by 13.4 years (95% CI = 13.1, 13.7).

Table 2.4 Descriptive summary of each South African pubertal development and age at menarche study published between 1943 and 2005

Reference	Year	(n)	Age (Yrs)	Urban/Rural Status	Geographical Area	SES	Ethnic Group	Average age (†denotes median) (95% confidence interval)					
								Boys			Girls		
								Sperm-aturia	Genitalia	Pubic Hair	Breasts	Pubic Hair	Menarche
Kark****	1943	1038		Rural			Black						15.7 (15.5, 15.8)
Burrell, Healy and Tanner	1961	47420		Rural	Transkei Reserve	Low	Black						15.4 (95% CI not reported)
				Rural		Mid/High							15.0 (95% CI not reported)
Oettle and Higginson	1961	1002		Urban			Black						14.9 (14.8, 15.0)
Frere	1971	3150		Urban		Middle	Black (Bantu)						14.8† (14.7, 14.9)
		1688		Urban		Low	Black (Bantu)						14.8† (14.7, 14.9)
Richardson and Pieters	1977	415		Urban	Soweto-Johannesburg	Low	Black				11.1 (95% CI not reported)		13.0 (95% CI not reported)
		405		Rural	Rustenburg	Low	Black				11.0 (95% CI not reported)		14.1 (95% CI not reported)

**** These data were reanalysed by Cameron and Wright (1990) using probit analysis to determine mean age and standard deviation

Table 2.4 cont. Descriptive summary of each South African pubertal development and age at menarche study published between 1943 and 2005

Reference	Year	(n)	Age (Yrs)	Urban/ Rural Status	Geographical Area	SES	Ethnic Group	Average age (†denotes median) (95% confidence interval)					
								Boys			Girls		
								Sperm-aturia	Genitalia	Pubic Hair	Breasts	Pubic Hair	Menarche
Richardson, Laing, Rantsho and Swinel	1983	1092	6-17	Urban	Soweto-Johannesburg	Low/Mid	Black				11.4 (95% CI not reported)		13.6 (95% CI not reported)
		1067		Rural	NW Transvaal	Low	Black				11.7 (95% CI not reported)		14.6 (95% CI not reported)
		695			Lenasia	Middle	Indian				10.4 (95% CI not reported)		12.4 (95% CI not reported)
		760		Urban	Johannesburg	Middle	Coloured				10.6 (95% CI not reported)		12.9 (95% CI not reported)
		776			Johannesburg	Middle	White				10.6 (95% CI not reported)		12.4 (95% CI not reported)
Chaning-Pearce and Solomon	1987	355	3.5-18.5	Urban	Johannesburg		Black				11.5 (11.4, 11.6)	12.1 (12.0, 12.2)	13.9 (13.8, 14.0)
		362			Johannesburg		White				11.5 (11.4, 11.6)	11.3 (11.2, 11.4)	13.1 (13.0, 13.2)
Cameron, Mitchell, Meyer, Moodie, Bowie, Mann and Hansen	1988	88	10-15		Cape Town		Cape Coloured				11.3 (11.1, 11.5)	12.43 (12.1, 12.7)	
		85											14.2 (14.0, 14.4)

Table 2.4 cont. Descriptive summary of each South African pubertal development and age at menarche study published between 1943 and 2005

Reference	Year	(n)	Age (Yrs)	Urban/Rural Status	Geographical Area	SES	Ethnic Group	Mean/Median age (95% confidence interval)					
								Boys			Girls		
								Sperm-aturia	Genitalia	Pubic Hair	Breasts	Pubic Hair	Menarche
Cameron and Wright	1990	148	6.0-19.0	Urban	Soweto-Johannesburg	High	Black				10.4 (10.3, 10.5)		13.2 (13.0, 13.4)
		121	7.2-15.0	Rural	NW Transvaal	Low/Mid	Black				11.69 (No 95% CI reported)		
		75	12.2-16.9										14.63 (No 95% CI reported)
Cameron, Mitchell, Meyer, Moodie, Bowie, Mann and Hansen	1990	131	10.0-15.0		Cape Town		Cape Coloured		13.1 (12.9, 13.3)	14.2 (14.0, 14.4)			
Bornman, Ramasodi, Schulenburg, Boomker and Reif	1990	151	10.0-16.0		Tswana		Black	14.10-15.80					
Cameron, Kgamphe and Levin	1991	230	11.0-17.0	Rural	N KwaZulu	Low	Black						14.03 (13.8, 14.2)

Table 2.4 cont. Descriptive summary of each South African pubertal development and age at menarche study published between 1943 and 2005

Reference	Year	(n)	Age (Yrs)	Urban/Rural Status	Geographical Area	SES	Ethnic Group	Mean/Median age (95% confidence interval)					
								Boys			Girls		
								Sperm-aturia	Genitalia	Pubic Hair	Breasts	Pubic Hair	Menarche
Cameron, Grieve, Kruger and Leschner	1993	152	6.0-19.0	Urban	Soweto-Johannesburg	High	Black		10.5 (10.3, 10.7)	12.4 (12.3, 12.6)			
		148									10.1 (10.0, 10.2)	10.1 (10.0, 10.2)	13.2 (13.0, 13.4)
		178	6.5-18.2	Rural	NW Transvaal	Low/Mid	Black		13.4 (13.1, 13.7)	13.8 (13.5, 14.1)			
		175	6.3-18.7								11.6 (11.3, 11.9)	12.1 (11.9, 12.3)	14.6 (14.4, 14.8)
Henneberg and Louw	1995	857		Urban		High	Cape Coloured						12.6 (12.5, 12.6)
Cameron and Nagdee	1996	146 (Mothers) 84 (Daughters)	6-14	Urban	Lenasia	Mid/High	Indian						13.20 (12.9, 13.5) 12.5 (12.2, 12.8)
Norris and Richter	2005	182	10-18	Urban	Soweto-Johannesburg	Low/Mid	Black		12.6 (12.2, 13.0)	12.4 (12.2, 12.6)	11.2 (11.0, 11.4)	11.5 (11.3, 11.7)	
		56	11-16										13.0 (12.7, 13.3)

2.5.1 Summary of the timing of pubertal development & age at menarche in South Africa

In Summary, rural adolescents were significantly delayed in all aspects of pubertal development in comparison to their urban peers. There have been a number of studies using urban Black samples to determine mean age at the initation of secondary sexual characteristics and age at menarche, but only one of urban White adolescents. However, there were a number of issues that made it difficult to make comparisons and draw definitive conclusions between the study findings including, inappropriate methods and statistical analyses, different sample sizes, and cohorts from a range of socio-economic milieu. There are a clear lack of recent data, both cross-sectionally and longitudinally that provide robust assessments of pubertal development and age at menarche in South African populations. Pubertal development and age at menarche are sensitive indicators of population health, estimating average ages and examining how they change over time may help to gauge changes in health and well-being in South Africa. This is particularly important given the current transitioning environment in South Africa.

2.6 The timing of puberty in developing & developed countries

2.6.1 Sub-Saharan Africa, Europe, & America

There are relatively few data on the development of secondary sexual characteristics and age at menarche in other sub-Saharan Africa countries, although more are available for Europe and the USA. Figures 2.11 to 2.13 provide average ages at menarche, breast development in females, and genitalia development in males from different populations split by ethnic group.

If one compares the most reliable estimates of age at menarche in urban Black South African females (13.2 years [95% CI = 13.0, 13.4]) (Cameron et al. 1993) with contemporaneous urban Black values from other sub-Saharan African countries, it is apparent that South African females are significantly ($P < 0.05$) in advance of their peers in Ghana (14.0 years [95% CI = 13.9, 14.1) (Adadevoh et al. 1989), but are not in advance of those from Cameroon (13.2 years [95% CI = 13.0, 13.4) (Pasquet et al. 1999). In a cross-sectional status quo study of middle and low SES (based on parental occupation) Nigerian girls (n = 900; age range = 8 to 18 years; born 1989 to 1999), Ofuya (2007) reported a mean age at

menarche of 12.2 years (95% CI = 12.1, 12.3) for middle SES girls and 13.0 years (95% CI = 12.9, 13.1) for low SES girls. When compared to data from South Africa, Nigerian low SES girls experienced menarche at a similar time; however, middle SES Nigerian girls were significantly ($P < 0.05$) advanced. Given that Nigeria is a low human development[††] country in comparison to South Africa which is a middle index country (United Nations 2007), it is surprising that middle class Nigerian girls were significantly in advance of high SES Black South African girls. The sampling and statistical methods used in the Nigerian paper appear to be robust; however, 32.4% of the middle SES sample were still pre-menarcheal by 15 years of age, indicating that 12.2 years may be an underestimate of average age at menarche. In addition, it has been shown that parental occupation may not be a good proxy measure of SES, particularly if self-reported by an adolescent (Wardle, Robb & Johnson 2002), which was the method used in the Ofuya (2007) paper. Therefore, the allocation of SES groups may have been inaccurate, resulting in poor estimates of menarcheal age in relation to SES.

Data for menarcheal age in White females are available for a number of European countries including the UK (Whincup et al. 2001), the Netherlands (Mul et al. 2001), and Sweden (Edgardh 2000) amongst others and in the USA (Herman-Giddens, Wang & Koch 2001, Wu, Mendola & Buck 2002, Chumlea et al. 2003,). It is however, difficult to make direct comparisons with the South African data for White girls as the estimate of Chaning-Pearce and Solomon (1987) may not be contemporaneous given that the girls in this sample were born between 1957 and 1972. Figure 2.11 highlights that the 95% confidence intervals for South Africa, Europe, and the USA overlap and thus there are no statistically significant differences in the timing of menarche between these countries. On average, menarche occurred between 12.6 and 13.2 years for urban White girls for South Africa, Europe, and the USA between 1987 and 2002 (study publication dates). The pattern is somewhat different for Black girls, when comparing South African data with that from the USA. American girls achieve menarche around 12.1 to 12.2 years (Herman-Giddens, Wang & Koch 2001, Wu, Mendola & Buck 2002, Chumlea et al. 2003). This is significantly ($P < 0.05$) earlier than

[††] The HDI utilises three dimensions of human development: living a long and healthy life (measured by life expectancy), being educated (measured by adult literacy and enrolment at the primary, secondary and tertiary level) and having a decent standard of living (measured by purchasing power parity, PPP, income) to create a composite index score (United Nations 2007). The higher the HDI score (range 0 to 1), the higher the social and economic development of the country, thus South Africa has a higher HDI in comparison to the other countries.

South African girls who achieve menarche on average, at 13.2 years (Cameron et al. 1993). Having said this, it is important to critically review the American studies, particularly the Pediatric Research in Office Settings (PROS) study published by Herman-Giddens et al. (1997) as this study has been criticised within the literature (See for example Parent et al. 2003). This study examined 17 000 girls and reported a mean age at menarche of 12.2 years (SD = 1.2) for Black girls and 12.9 years (SD = 1.2) for White girls. The results from this study must be interpreted with care as the sample was not representative of the American population; 15% of the sample was excluded as they had not achieved menarche at 13 years, thus the ages reported may be underestimated. In addition, these girls were seen in private clinics and so the sample may be socio-economically biased. However, more recent, nationally representative American studies reported mean ages of 12.1 years (Chumlea et al. 2003) and 12.2 years (Wu, Mendola & Buck 2002) for urban African-American girls, suggesting that perhaps the estimate reported in the Herman-Giddens study (1997) for this ethnic group was not particularly biased.

Whilst the menarcheal age estimates from the Herman-Giddens (1997) study may not have been biased, the estimates for mean age at breast development have caused some controversy. The authors reported a mean age at breast development of 8.9 years (95% CI = 8.8, 9.0) for African American girls and 10.0 years (95% CI = 8.7, 8.9) for White girls. These ages were significantly younger than any previous study of American adolescents (Slyper 2006). As the girls within the Herman-Giddens (1997) sample were seen in paediatric clinics, it has been suggested the early onset of breasts and/or pubic hair may have been the reason for visiting the clinic, and thus the sample would not have been random (Sun et al. 2002). In addition, breast palpation techniques were not employed for 63% of the sample, which raises further questions about the accuracy of the results (Herman-Giddens et al. 1997, Sun et al. 2002, Slyper 2006). Following the publication of the PROS study, a number of more nationally representative studies have been published (Herman-Giddens, Wang & Koch 2001, Wu, Mendola & Buck 2002, Chumlea et al. 2003) that have some of the limitations of the PROS study, for example a lack of breast palpation but used a wider age range of participants to include later maturers and so are in general more methodologically robust. Therefore, it may be more appropriate to use the estimates from these studies when making comparisons with South African data.

Figure 2.12 shows the average age at breast development from different populations for both Black and White females. Black South African females are significantly ($P < 0.05$) delayed for breast development compared to African-American females (10.1 years [95% CI = 9.9, 10.3] vs. 9.4 years [95% CI = 9.1, 9.7]). This is also true of South African White females if one uses the data from the Chaning-Pearce and Solomon study (1987). White girls from Europe (Lindgren 1996, Fredriks et al. 2000, Juul et al. 2006) and America (Herman-Giddens et al. 1997, Sun et al. 2002) are achieving breast stage 2 at similar times although it was not possible to determine if these differences were statistically significant as a number of authors did not report measures of variance.

Figure 2.13 shows the average age at genitalia development from different populations for both Black and White males. Black South African males are significantly ($P < 0.05$) delayed for genitalia development compared to African-American males (10.5 years [95% CI = 10.2, 10.8] vs. 9.2 years [95% CI = 8.8, 9.6]). There are no South African data for White males for the attainment of G2. When comparing data from Europe (Lindgren 1996, Fredriks et al. 2000, et al. 2006b) and America (Herman-Giddens, Wang & Koch 2001, Sun et al. 2002), it appears that European boys are delayed in comparison to the their American peers; however, it was not possible to determine if these differences were statistically significant as a number of authors did not report measures of variance.

2.6.2 Summary of the timing of pubertal development in developing and developed countries

In summary, there have been numerous studies of pubertal development and age at menarche globally. African-American children are significantly advanced in their development when compared to their Black and White peers globally. White South African, European, and American adolescents are achieving menarche at similar times. These similarities were also found for White European and American adolescents for breast/genitalia development. The above review of the literature has further highlighted that there are limited robust data on the timing of pubertal development in South African adolescents. Even though each of the studies reviewed has limitations, the lack of data prevents any form of global comparison between South Africa and other countries. Because age at the initation of pubertal development and menarche are sensitive indicators of population health and well-being, a lack of data makes it impossible to investigate how recent

political and socio-economic changes within South Africa have influenced these development indicators.

2.7 The evidence for a secular trend in pubertal development

Over the last two decades, there have been numerous papers that have provided evidence for a secular trend in the timing of sexual maturation in different populations worldwide. For example in the USA (Wattigney et al. 1999, Freedman et al. 2002, Sun et al. 2002, Anderson, Dallal & Must 2003, Herman-Giddens 2006), the UK (Kaplowitz & Oberfield 1999), the Netherlands (Fredriks et al. 2000), Brazil (Kac, Auxiliadora de Santa Cruz & Velasquez-Melendez 2000, Silva & Padez 2006), Italy (Danubio et al. 2004), Egypt (Hosny et al. 2005), South Korea (Hwang et al. 2003), Thailand (Mahachoklertwattana et al. 2002), Cameroon (Pasquet et al. 1999), and South Africa (Cameron, Kgamphe & Levin 1991) In contrast, other studies have suggested that in recent decades there has been a slowing down or a plateau in the secular trend towards earlier puberty in several populations including the USA (Viner 2002, Slyper 2006), the UK (Whincup et al. 2001), Denmark (Juul et al. 2006), the Netherlands (Muinck Keizer-Schrama & Mul 2001) Belgium (Hauspie, Vercauteren & Susanne 1996), and Norway (Hauspie, Vercauteren & Susanne 1996). In addition, both Cole (Cole 2000) and Ong et al. (Ong, Ahmed & Dunger 2006) have summarised that the secular trend in pubertal timing has slowed or stopped in a number of Western European countries, although they did not provide details on specific countries.

So why are the results from these different studies somewhat contradictory? Firstly, making comparisons between studies is difficult due to a number of confounding influences including SES, ethnic group, the temporal context of the study, and the assessment and statistical methods employed. Secondly, the evidence for a secular trend is often based on the assumption that the relationship is linear; however, the relationship may well be curvilinear with a lower "genetic or physiological ceiling" for age at sexual maturation being attained if there are no environmental constraints such as poor nutrition. The idea that the relationship is in fact curvilinear is supported if one examines the findings from developing and developed countries separately.

Figure 2.11 Average age at menarche and 95% confidence intervals for different populations split by ethnic group

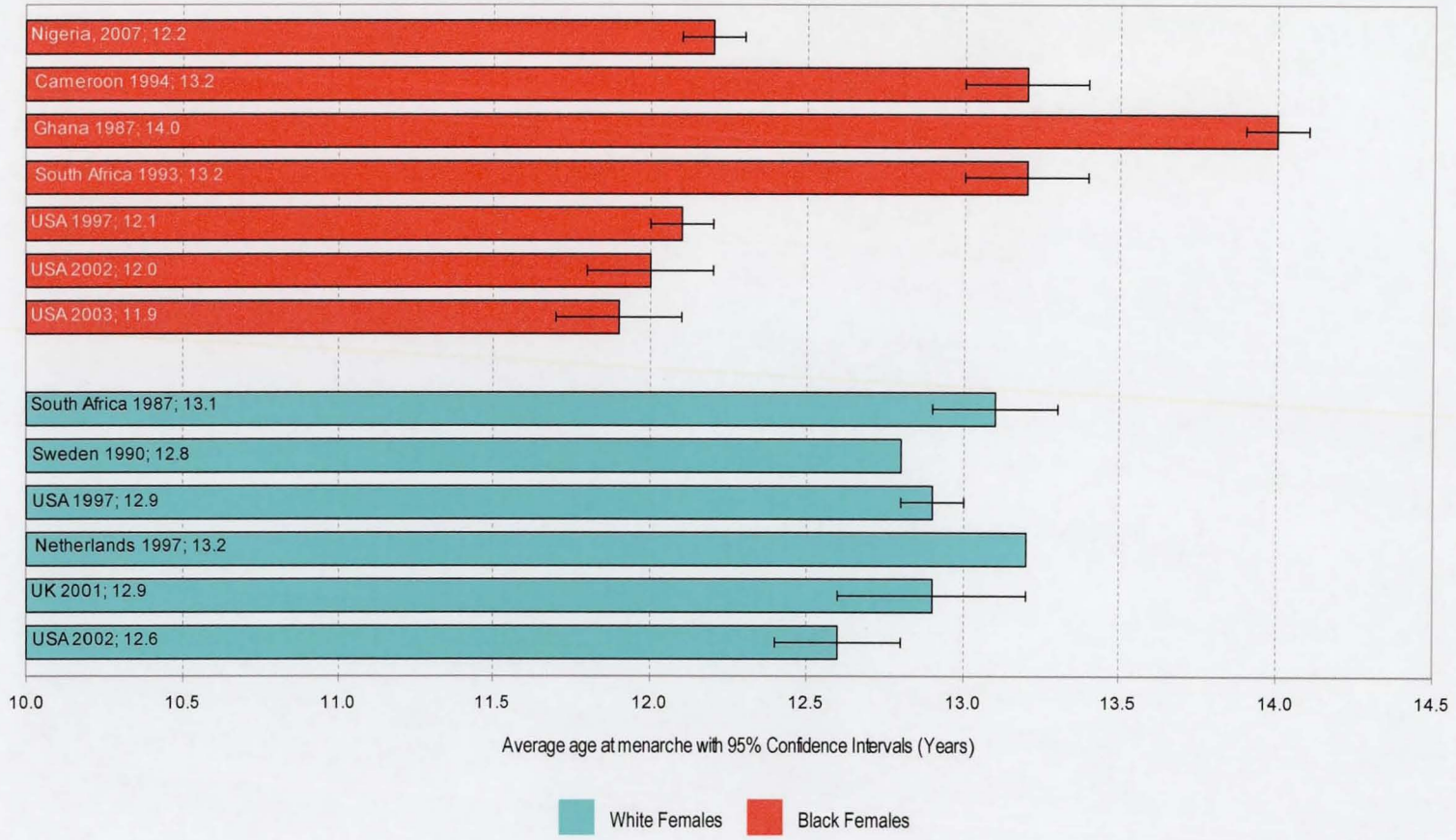


Figure 2.12 Average age at breast development for females and 95% confidence intervals for different populations split by ethnic group

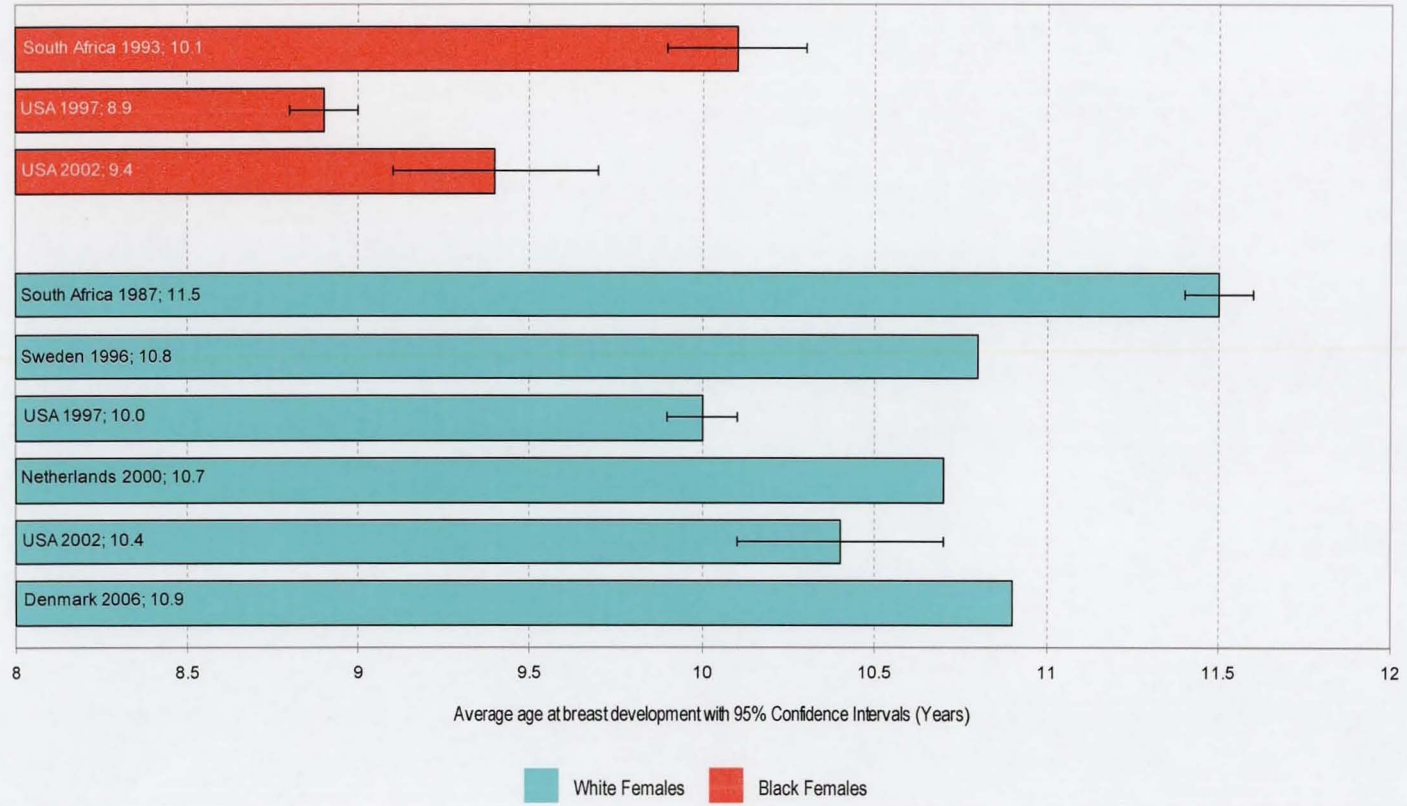
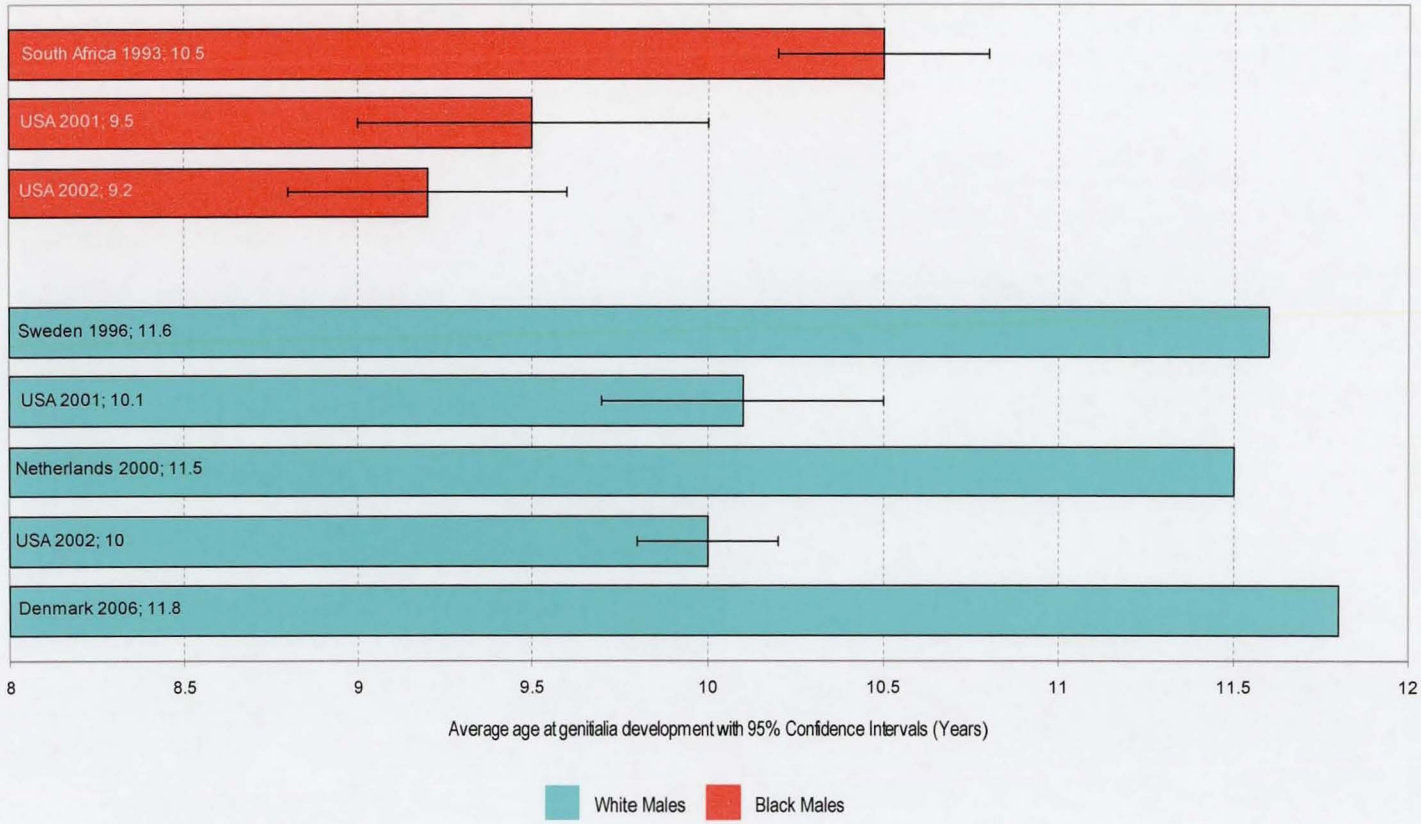


Figure 2.13 Average age at genitalia development for males and 95% confidence intervals for different populations split by ethnic group



From the data that are available it is clear that in developing countries, particularly those undergoing transition, there is a continuing secular change towards earlier pubertal development i.e. they have not yet reached a plateau as environmental conditions continue to constrain the genetic predisposition for pubertal timing. In a study in urban Cameroon, Pasquet (1999) reported a mean age at menarche of 13.2 years and demonstrated a secular trend of approximately 0.25 years per decade between 1946 and 1986. In a study of urban Black South African females, Cameron et al. (1991) reported a decline of 0.73 years per decade for menarcheal age between 1960 and 1990. In contrast, to these developing country data, there is robust evidence to suggest that in developed countries, there has been a plateau in the age at sexual maturation over recent decades (Whincup et al. 2001, Viner 2002, Chumlea et al. 2003). This theory of a lower genetic or physiological limit has been further supported by the fact that a number of European countries are still experiencing secular increases in height in parallel to a plateau in age at menarche (Cole 2000).

In contrast to the majority of the developed country literature, Ong and colleagues (2006) have opposed the finding of a plateau in menarcheal age and have stated that they believe that it is unhelpful to say that downward trends have stopped, particularly in Europe, and that there is no lower limit to the age at which puberty and menarche can occur. They support this statement by suggesting that countries who have experienced the removal of nutritional and socio-economic constraints are still exhibiting a reduction in age at menarche and that there is just a wide normal distribution in age at menarche. However, the authors do not discuss this in relation to time. A secular trend refers to the process of change in size or maturation over at least one biological generation (approximately 20-25 years), therefore populations who have experienced the removal of environmental constraints (e.g. the ending of apartheid in South Africa) may still exhibit a declining age at menarche for a significant period of time following the removal of the constraint. In addition, Ong et al. (2006) do not appear to have considered any other factors that may influence population estimates for the timing of pubertal development such as SES and the life history strategy of the species.

With regards to SES, Ong et al. (2006) did not consider the fact that a population average does not allow for the potential differences in SES within a population. For example, a decline in average age at menarche for high SES groups may have initially driven a decline in population average. Following the removal constraining factors, the population average may then be driven by a decreasing age at menarche in lower SES groups. This would lead

to a further reduction in the population average, but the higher SES group age may have remained the same i.e. the variation within a population may be reduced over this period of time that constraining factors were removed. This differing pattern of decline in age at sexual maturation across SES groups has been shown in a small number of studies in Italy (Veronesi, Gueresi 1994), Croatia (Prebeg 1998), and Brazil (Junqueira Do Lago et al. 2003). In a study of Brazilian women (n = 2053) mean age at menarche was determined using historical recall questionnaires for women born between 1931 and 1977 (Junqueira Do Lago et al. 2003). (The results from these recalled data should be considered with care because of the negative association between chronological age at recall and the age at which a woman believes that she became menarcheal (Cameron 2002)). Paternal education (less than 8 years of formal schooling vs. greater than 8 years of formal schooling) was used as a proxy measure to establish high and low SES groups. The rate of decline in age at menarche was three-fold greater in those from lower SES backgrounds compared to those women from higher SES backgrounds (3.6 vs. 1.2 months per decade). Overall, the authors of three papers that have examined the temporal context of pubertal development in relation to SES group have shown that when SES constraints were removed from a population age at sexual maturation declined more rapidly in the previously poorer groups. This finding suggests that improvements in SES provide greater benefit for the poor as opposed to those who were relatively better off during constraint.

Ong et al. (2006) do not make any reference to the evolutionary or life history perspectives which suggest that there has to be a lower age limit at which pubertal development and menarche can be reached in order to successfully procreate. Puberty results in the attainment of reproductive capacity, with the appearance of secondary sexual characteristics not only being reflective of hormonal changes, but also providing an external indication of reproductive readiness (Gluckman & Hanson 2006a). The timing of puberty or reproductive competence is central to the life history theory or strategy of the species by allowing maximal reproductive capacity within the environment in which the species resides (Gluckman & Hanson 2006a, Gluckman & Hanson 2006b). Stearns (1992) suggested that the life history traits relative to reproductive strategy include the pattern of growth, growth phase timing, and longevity, achievement of optimal body size, fecundity, and age at reproduction, length of gestation, birth intervals, and parental investment. Typically, reproductive competence is a trade-off between a number of the above traits. *Homo sapiens* have evolved with several characteristics that make them distinct from their predecessors. These characteristics

include the adoption of an upright posture, which led to a distortion in the shape of pelvic canal and a large brain size at maturity (Bogin & Smith 1996). Unlike some primates, who are precocial (well developed/mature) at birth human infants are altricial (immature), in that they are completely dependent on their caregiver and experience the majority of brain and central nervous system development in the postnatal period (Gluckman & Hanson 2006a, Gluckman & Hanson 2006b). Even after weaning, there is a significant period of human development that is caregiver dependent. This extended period of development, or 'childhood', is a unique human characteristic (Bogin & Smith 1996). This extended period of dependency is said to be advantageous to humans because it provides *"(1) an extended period for brain development, (2) time for the acquisition of technical skills e.g. tool making and food processing, and (3) time for socialisation, play and the development of complex social roles and cultural behaviour"* (Bogin 1999). In addition, Bogin (1999) argues that while the above three advantages are "textbook", there are at least five other advantages for the evolution of childhood. These mainly involve reproductive and feeding adaptations for the parents, strategies to ensure parental care following infancy and to minimise the risk of child starvation, reducing the strain on parents by shifting care to other kin such as grandparents and siblings and as a means to allow tracking of ecological conditions. Ultimately, the evolution of childhood provides a reproductive advantage to the mother and her off-spring.

Humans, but not other primates, also experience a distinct pubertal growth spurt following a juvenile period (Bogin 1994). This peak in growth occurs during adolescence. According to Bogin, adolescence refers to a stage of human life cycle that involves somatic growth, socio-sexual maturation, and interest and practice in adult social, economic, and sexual activities (Bogin 1999). All of which are fundamental to successful reproduction. Peak height velocity occurs relatively early in puberty for females, which means that they approximate final height before they reach reproductive competence. In addition, in approximately half of women, the first two years of menstrual cycles are typically anovulatory (Ellison 1994). This reduces the risk of becoming pregnant before physical maturation occurs and so increases the mother's reproductive chance of carrying an infant to term and of being able to deliver successfully. It is well known that young mothers experience a higher level of poor perinatal outcomes compared to older mothers (Fraser, Brockert & Ward 1995, Olausson, Cnattingius & Haglund 1999, Smith & Pell 2001). The pattern of adolescent development is somewhat different for males as they achieve fertility prior to secondary sexual maturation and the completion of somatic growth. This is advantageous in terms of evolution as these males, whilst fertile still

present with childlike features and thus are not viewed by prospective mothers (or her family) as economically, biologically or socially viable partners or fathers (Bogin 1999).

Thus adolescence provides both males and females with a period of time in which they can learn and practice adult skills relating to social, economic, and sexual behaviours. Given the evolutionary evidence that the human "childhood" and "adolescence" provides a reproductive advantage to the mother and that younger mothers experience poorer peri-natal outcomes, it seems that there must be a lower limit to which menarche and pubertal development occur. A very young age at puberty would not be selectively advantageous to the species as a decline in the rate of successful procreation may result.

2.7.1 Summary of the evidence for a secular trend in pubertal development

A lack of longitudinal studies of growth and pubertal development, which use a small number of expert observers, reliable assessment methods, and robust statistics techniques, has prevented clinicians and researchers from reliably determining if changes in the timing of puberty are occurring at the population level. There is evidence to suggest that the average age at sexual maturation is continuing to decline in developing countries such as South Africa, but a lower limit or genetic "ceiling" may have been reached in developed countries such as the UK and America where environmental constraints do not impact the genetic predisposition for the timing of puberty. Evolutionary theory suggests that it is selectively disadvantageous for the species for puberty to occur at a young age as it results in a reduced capacity to successfully procreate. Therefore it is appropriate to conclude that there is a lower age limit at which puberty can occur.

2.8 Factors associated with the timing of pubertal development

A range of factors including, genetics, demographic, biological, and environmental influences have been associated with the timing of pubertal development and age at menarche (Figure 2.14).

2.8.1 Genetic variability

The genetic component or heritability of age at menarche is said to account for a large proportion of the variation in the individual timing of menarche (van den Berg & Boomsma 2007). As the timing of menarche and breast development are regulated by similar genetic effects, the heritability of menarche can be used as a proxy for the heritability of pubertal development (Pickles et al. 1998, van den Berg et al. 2006). Depending on the definition of heritability and the research design, heritability coefficients range from 0.5 to 0.8 (Meyer et al. 1991, Palmert & Hirschhorn 2003, Towne et al. 2005, van den Berg & Boomsma 2007). The findings from these studies indicate that as much as 50% of the variation in the timing of pubertal development is due to the interaction between genetics and the environment.

2.8.2 Demographic factors

Demographic factors that influence the timing of puberty include gender and ethnic group. Girls are consistently in advance of males in maturation and this is evident as early as 20 weeks of gestation. At this point, the female skeleton is advanced by some 3 weeks compared to males (Tanner 1989). At birth, this difference is four to six weeks (Tanner 1989), and it has been reported that by the start of puberty it can be upwards of six to 12 months (Eveleth & Tanner 1990). There is some evidence of girls being advanced in relation to boys for the initation of puberty; however, these differences are not statistically significant indicating that in reality males and females from the same ethnic group are entering puberty at a similar time. For example, in a study of 300 (152 boys) urban Black South African children, Cameron et al. (1993) reported median age at entry into B2 for girls as 10.1 years (95% CI = 9.9, 10.3) and G2 for boys as 10.5 years (95% CI = 10.2, 10.8). By only looking at the median ages, it would be assumed that girls, on average, were advanced of boys; however, by examining if these ages were statistically significantly different it is apparent that urban Black South African adolescents are entering puberty at similar times. This relationship also holds true for physician assessed Black and White American adolescents, although boys appeared to be in advance of girls. Using NHANES III data (total n = 1335), Sun et al. (2002) reported median age at entry into B2 for Black girls as 9.5 years (95% CI = 9.1, 9.7) and G2 for Black boys as 9.2 years (95% CI = 8.6, 9.6). For White girls median entry into B2 was 10.4 years (95% CI = 10.1, 10.7) and into G2 for White boys was 10.0 years (95% CI = 9.6, 10.4). By examining the 95% confidence limits, it can be seen that there was no statistically significant difference in age at the initation of puberty between US

males and females from the same ethnic group. The results from the above studies highlight the need for caution when using median or mean values to examine trends in data between genders and different ethnic groups as the conclusions drawn may be different to those drawn from examining the spread of data around the median/mean.

Differences in the timing of pubertal development have also been reported between ethnic groups. Reports from developed countries have shown that Black girls are advanced compared to White girls for age at the initation of puberty and at menarche (Herman-Giddens et al. 1997, Kaplowitz et al. 2001, Freedman et al. 2002, Sun et al. 2002, Wu, Mendola & Buck 2002, Anderson, Dallal & Must 2003, Chumlea et al. 2003,). The advancement of Black girls has been shown consistently between different countries, time periods and between different study designs. It has been reported that this ethnic difference is independent of relative weight, with several studies showing that ethnic group is an independent predictor of the timing of menarche, having controlled for socio-economic status, body composition, and age (Wattigney et al. 1999, Kimm et al. 2001, Anderson & Must 2005). Controlling for body composition is an important factor in this type of analysis as greater fat mass has been associated with earlier puberty (Garn, LaVelle & Pilkington 1983, Adair & Gordon-Larsen 2001, Kaplowitz et al. 2001, Anderson, Dallal & Must 2003). In addition, levels of overweight/obesity have been shown to be higher in Black adolescents compared to their White peers in both developed and developing countries such as South Africa (Shear et al. 1988, Kuczmarski et al. 1994, Troiano et al. 1995, Walker 1995, Lewis et al. 1997, Ogden et al. 1997, Kimm et al. 2001, Labadarios et al. 2005, Strauss & Pollack 2001, Armstrong et al. 2006, van der Merwe & Pepper 2006). Even when considering these findings and the conclusions from the above papers, it appears that the aetiology of these ethnic differences remains speculative.

2.8.3 Biological factors

Several biological factors have also been associated with the timing and magnitude of pubertal development. It has been shown that the intrauterine milieu may influence physiological and pathological events in later life, for example low birth weight (LBW) has been associated with an increase risk of cardiovascular disease and type II diabetes in adulthood (Barker 1990, Barker et al. 1993, Barker 1994a, Barker 1994b). With respect to pubertal development, girls who were born with a LBW exhibited earlier initiation of breast

development and menarche, in contrast to LBW boys who have been shown to mature later than their average birth weight peers (Delemarre-van de Waal, van Coeverden & Engelbregt 2002). Persson et al. (1999) investigated the influence of perinatal factors such as size and weight at birth on the timing of pubertal development in Swedish children (n = 1238). The authors found that girls born small for gestational age (SGA) entered puberty on average 0.4 years earlier ($P < 0.05$) than their non-SGA counterparts. Although the result for SGA vs. non-SGA girls was statistically significant, this may not be a true difference in the onset of puberty as the sample were seen at two yearly intervals and so the potential for error in the estimate of pubertal timing may be greater than the difference reported. This was further confirmed when childhood growth factors such as height and weight were added into the model as the difference in pubertal timing became insignificant. This suggests that differences in pubertal timing in this cohort were explained by differences in childhood growth patterns rather than by peri-natal factors such as SGA. However, it is important to acknowledge that these childhood growth patterns may well have been influenced by size at birth. There was no association between peri-natal factors and the timing of pubertal development in boys from this Swedish sample.

A number of other studies, with more robust measures of pubertal development (such as Tanner scaling) have reported that being born LBW or SGA was associated with an earlier age at the initation of puberty and menarche for girls (Bhargava et al. 1995, 2006, Ibáñez et al. 2000b, Ghirri et al. 2001). One important consideration is whether SGA girls experience the same sequence and tempo of pubertal events given the altered timing of puberty. Bhargava and colleagues (1995) examined the growth of 428 (252 LBW, 45 SGA) urban Indian children from birth to 14 years of age. The results from this study showed that whilst LBW and SGA babies entered puberty earlier, they experienced the same sequence and tempo of pubertal development compared to their non LBW/SGA peers. However, one must also take into account that Indian babies are the smallest in the world (Yajnik 2004) and more than half of LBW babies born globally are born in Southeast Asia (UNICEF 2008). Therefore, the babies in the Bhargava study (1995), may have been small but not at greater risk for later negative health outcomes.

In a more recent study of 2738 Swedish children, being born short and thin was associated with earlier onset of puberty and reduced height gain during adolescence (Luo et al. 2003). However, the timing of puberty was measured by PHV which is not a sensitive measure of

age at the initation of pubertal development and therefore these results must be interpreted with care. Whilst this paper cannot report the factors associated with age at the initiation of puberty (transition from Tanner stage one to Tanner stage two) it did show that faster linear growth during infancy was associated with an earlier PHV. In addition, it showed that those children with a greater BMI during infancy and childhood gained less height between the ages of eight and 18 years.

Therefore, it appears that those children who are born small, but grow rapidly during infancy and childhood are more likely to enter puberty early and have a shorter final adult stature (Ibáñez et al. 2000b, 2006). This reduction in final adult stature has been attributed to suboptimal growth during infancy and childhood, as opposed to during puberty (Bhargava et al. 1995, Persson et al. 1999, Ghirri et al. 2001). The mechanism that links SGA and rapid growth in infancy with altered pubertal timing is currently unknown. It has been reported that SGA babies present lower levels of neonatal and childhood serum leptin, IGF-1 and insulin-like growth factor 3 binding protein (Boguszewski et al. 1996, Boguszewski et al. 1997a, Boguszewski et al. 1997b, Harigaya et al. 1997, Cance-Rouzaud et al. 1998, Luo et al. 2003), suggesting that this altered infantile hormone profile may programme the HPG axis to mature earlier (Luo et al. 2003). A number of other reports have suggested that in addition to programming of the HPG axis, intrauterine growth restriction may lead to altered target organ responsiveness to hormonal stimulation by, for example, FSH, inhibin and GH (Achermann et al. 1998, Cacciari et al. 1999, Ibanez et al. 1999, Ibanez, Potau & de Zegher 2000, Ibáñez et al. 2000, Ibáñez et al. 2000b).

2.8.4 Environmental factors

The environmental factors that have been shown to be associated with the timing of pubertal development and age at menarche include: nutrition, socio-economic status, urbanisation, disease burden, psychosocial stress, and endocrine disrupting chemicals (EDCs). Nutrition is perhaps the most complex of these factors, due to its interaction with urbanisation, socio-economic status, and disease burden (Parent et al. 2003). Nutrition is an important regulator of the tempo of growth and pubertal development (Dunger, Ahmed & Ong 2005, 2006). Chronic illness and malnutrition in childhood has been shown to reduce growth tempo and cause a delay in the onset of puberty (see for example Pozo & Argente 2002). Disease and malnutrition are closely linked as the interaction is typically cyclic particularly in lower SES

households i.e. an episode of diarrhoea may lead to malnutrition which depresses the immune system leading to an increased likelihood of further diarrhoeal episodes (Nandy et al. 2005).

In contrast to under nutrition, over nutrition or obesity has been linked with rapid growth in infancy and earlier pubertal development (Dunger, Ahmed & Ong 2005). There have been a number of studies that have examined the association between weight status and the timing of pubertal development and age at menarche, because adiposity has been suggested as a causal factor for earlier puberty in girls (Frisch & McArthur 1974). As previously discussed, there is evidence that suggests that girls who are overweight and/or obese experience pubertal development at a younger age compared to their leaner peers (Garn, LaVelle & Pilkington 1983, Adair & Gordon-Larsen 2001, Kaplowitz et al. 2001, Anderson, Dallal & Must 2003). In a longitudinal study of 180 White girls, Davison et al. (2003) showed that a higher BMI at five years of age and a greater increase in BMI between five and nine years were associated with earlier puberty. He and Karlsberg (2001) have also shown that children who have the greatest gain in BMI during childhood (two to eight years) entered puberty at an earlier age compared to their leaner peers. In a more recent study of 354 American girls, Lee et al. (2007) reported that higher BMI z scores at three years of age and a greater increase in BMI z score between three and five years of age was significantly associated with earlier puberty, independent of ethnic group, maternal education and maternal age at menarche. Whilst there is clear evidence from both cross-sectional and longitudinal studies showing that greater adiposity is linked with earlier puberty, it is somewhat difficult to explain the mechanism through which increased adiposity is associated with the timing of pubertal development as a significant correlation may indicate a direct link that can be causal or consequential i.e. does increased adiposity lead to earlier puberty or does earlier puberty lead to increased adiposity. This association is further confounded, as the pubertal period is associated with significant changes in body composition, including increases in total body and fat mass (Rogol, Roemmich & Clark 2002). It appears that there are conflicting views within the literature about the causal or consequential nature of adiposity and the timing of pubertal development; therefore, there is a need for further longitudinal research which examines the association between body composition and the timing of pubertal development.

The roles of SES, body composition and the timing of pubertal development are intricately linked. It is difficult to isolate the specific factors that are responsible for the observed

differences in pubertal timing between those from higher and lower socio-economic groups as studies use different measures of SES to represent different factors such as maternal education, access to health care, consumer durable ownership, family size, parental martial status, calorie intake, and energy expenditure amongst others (Ellis 2004). In societies that experience inequalities in health and nutritional status (e.g. Sudan, Mozambique, Iran, Morocco, Philippines, and China) adolescents from higher socio-economic groups experience earlier pubertal development in relation to their lower socio-economic peers (Abioye-Kuteyi et al. 1997, Montero et al. 1999, Adair 2001, Ayatollahi, Dowlatabadi & Ayatollahi 2002, Wang, Murphy 2002, Padez 2003, Ku et al. 2006). What a number of these studies fail to recognise is that there appears to be an interaction between body composition and SES. A small number of more recent studies have shown that whilst SES was an independent predictor of the timing of pubertal development, once body composition was controlled for in the analysis, SES was no longer an independent predictor (Onat & Ertem 2005, Hernández et al. 2007, Kirchengast & Bauer 2007). For example, in a study of 1302 Chilean females aged seven to 19 years, Hernandez et al. (2007) found that type of school (public vs. private), a proxy for SES in Chile influenced age at menarche due to differences in body composition. These results suggest that socio-economic status differences are mediated through body composition. In a recent paper, Griffiths et al. (2008) have shown the need to control for pubertal development when examining the SES predictors of body composition in a sample of South African adolescents. Given the results from the Griffiths (2008) study, it may be appropriate to suggest that if one needs to control for pubertal development when examining the influence of SES on body composition, then one needs to consider the role of body composition when looking at the association between SES and pubertal development.

A number of studies have examined the relationship between physical activity prior to adolescence and the timing of pubertal development; the results from these studies are however somewhat contradictory. It has been shown that intensive training in childhood is associated with delayed age at menarche compared to non-elite age matched controls, particularly in elite female athletes such as gymnasts, track and field athletes, swimmers, and ballet dancers (Constantini & Warren 1995, Pigeon et al. 1997, Dusek 2001, Klentrou & Plyley 2003, Torstveit & Sundgot-Borgen 2005). This finding has not been replicated in male gymnasts (Gurd & Klentrou 2003). Several studies have argued that a delay in pubertal development is not associated with training *per se*, but rather with genetic factors that

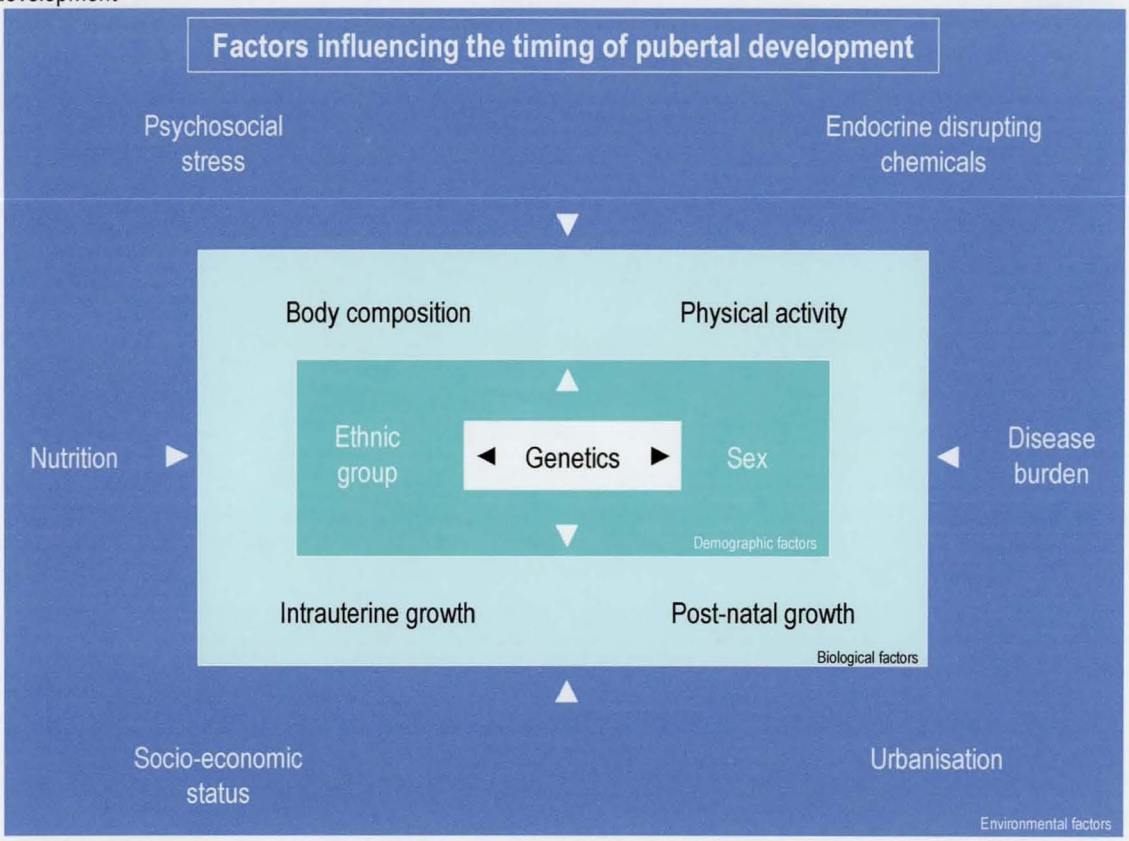
predispose an individual to be successful in a particular sport and/or dietary factors such as calorie intake that is inadequate to meet the energetic demands of training and growth and development (Ledoux, Brisson & Peronnet 1983, Ersoy 1991, Klentrou 2006).

A further environmental factor that interacts with nutrition, SES, and physical activity to influence the timing of pubertal development is urbanisation. Urbanisation is an economic change that facilitates the nutrition transition in developing countries. The nutrition transition refers to a shift from a diet low in fat and refined carbohydrates to a diet high in fat and low in fibre, with consequential increases in obesity and non-communicable diseases (Popkin & Gordon-Larsen 2004). In addition, the economic changes such as urbanisation that drive the nutrition transition result in the globalisation of food production, increased media and marketing, increased sedentary behaviours and changes to working patterns and hours (Lang 2002). Living in urban areas and improving socio-economic conditions have been shown to be associated with greater food availability, less seasonal fluctuations, increased access to and consumption of fast foods (Popkin & Bisgrove 1988, Popkin et al. 1995). Each of these factors increased overweight/obesity, improving SES and reduced physical activity, driven by urbanisation, have been associated with a decreasing age at pubertal development and age at menarche. Knowledge of the impact of urbanisation on pubertal timing is particularly important given the South African context of the current study where the rate of urbanisation is projected to rise to 73% by 2010 (World Bank 1998).

Other environmental factors associated with the timing of pubertal development include; organic pollutants such as phthalates that are regularly found in cosmetics, toys and plastic food containers (Colón et al. 2000), and psychosocial stress such as parental divorce and conflict (Wierson, Long & Forehand 1993). A number of studies have highlighted that exposure to pollutants and other endocrine-disrupting chemicals may contribute to earlier achievement of female pubertal development and menarche by influencing physiological pathways (Colburn, Dumanoski D & Myers 1996, Blanck et al. 2000, Schell et al. 2006). Humans that have been exposed to the effect of polychlorinated biphenyls (PCBs), a persistent organic pollutant that is stored in fat tissue, have been shown to present with a smaller size at birth, advanced sexual maturation and altered hormone profiles for thyroid regulation (Denham et al. 2005, Schell et al. 2006). However, whilst there is some evidence in the literature to suggest that exposure to environmental pollutants influences the underlying mechanisms that control growth and development, human populations are

simultaneously exposed to a number of pollutants at any one time, making it very difficult to isolate the individual effect of one specific pollutant (Parent et al. 2003, Schell et al. 2006).

Figure 2.14 The genetic, demographic, biological, and environmental factors influencing the timing of pubertal development



2.8.5 Summary of the factors influencing the timing of pubertal development

The timing of pubertal development and age at menarche are driven by genetics, and the interaction between genetics and the environment. The genetic component accounts for some 50 to 80% of the variation in the timing of pubertal development. Thus, some 20 to 50% of the variation is attributable to the interaction with the environment. The factors associated with the timing of puberty can be broadly split into three categories: (1) demographic, such as gender and ethnic group, (2) biological, such as intrauterine growth and childhood body composition, and (3) environmental, such as SES and nutrition. As a number of these factors may be present or occur simultaneously such as low SES and poor nutrition, it can be difficult to examine the influence of one particular factor on the timing of pubertal development.

2.9 The potential consequences of pubertal timing

Whilst there is global interest in the timing of pubertal development and whether there is evidence for a positive secular trend, one must also consider the potential consequences, both proximate to the initation of puberty and distally to later life events of pubertal timing. Two hypotheses have been suggested that provide a framework in which the timing of pubertal development is associated with negative adolescent outcomes such as behaviour and adjustment (Dorn, Susman & Ponirakis 2003). The *maturational deviance hypothesis* suggests that a higher level of stress is experienced by adolescents who achieve puberty early or late with respect to their peers (Petersen & Taylor 1980, Brooks-Gunn, Petersen & Eichorn 1985, Caspi & Moffitt 1991, Tschann et al. 1994, Williams & Dunlop 1999, Dorn, Susman & Ponirakis 2003). An early or late maturing adolescent is thought to be placed in a socially deviant group of individuals in comparison to their average counterparts and experience a mismatch between their developmental status and the demands of society and the social context (Williams & Dunlop 1999). In addition, the usual resources and social support available to average maturers are inappropriately timed due to the early or late nature of the individual's pubertal development (Dorn, Susman & Ponirakis 2003). The second hypothesis, the *early-maturation hypothesis* (Petersen & Taylor 1980, Brooks-Gunn, Petersen & Eichorn 1985, Caspi & Moffitt 1991, Dorn, Susman & Ponirakis 2003, Tschann et al. 1994, Williams & Dunlop 1999) suggests that early maturers, particularly early maturing females are at a disadvantage to their average and later maturing peers. The reasons for this relate to the attainment of biological, but not psychosocial maturity. Early maturers may face increased societal pressure as they exhibit physical signs of maturity, thus society expects more adult cognitive and social behaviours (Brooks-Gunn, Petersen & Eichorn 1985).

Although results are not always consistent, males who achieve puberty later than average for their peer group, have been shown to be at an increased risk for delinquency, criminal activity, and substance abuse in a bid to raise self-esteem, gain popularity amongst their peers and to achieve autonomy (Williams& Dunlop 1999, Graber et al. 2004, Michaud, Suris & Deppen 2006). There are relatively more studies of the negative consequences of pubertal timing for females, and this perhaps reflects the easier assessment of pubertal status in females through the use of age at menarche data. Females who enter puberty earlier than their peers have been shown to initiate sexual exploration (kissing etc) and intercourse

earlier (Wyatt et al. 1999, Lam et al. 2002) than their later maturing peers. In turn, by the age of 18 years, early maturing girls were twice as likely to have become pregnant, given birth, or had an abortion (Edgardh 2000, Morgan, Chapar & Fisher 1995). The mechanism through which early maturing females engage in more risk behaviours is thought to act via an increased interaction with older, more dominant males (Marín et al. 2000). Early maturing girls, exhibit physical characteristics that are attractive to older males and as a consequence are more likely to become romantically and sexually involved with an older partner (Gowen, Feldman & Diaz 2004, Marín et al. 2000, 2006). Other, more recent research has also shown that earlier menarche and age at first intercourse was linked with increased levels of self-reported partner violence, sexual, and emotional abuse (Watson, Taft & Lee 2007). This is particularly important given the South African context of the current study, as domestic violence has also been shown to be linked with an increased risk for HIV/AIDS (Dunkle et al. 2004). In 2005, UNICEF reported that 16.9% of females and 4.4% of males aged 15-24 years were infected with HIV/AIDS (UNICEF 2005), a number set to continue to increase. These studies therefore suggest that early maturation is linked with an increased engagement in risky sexual behaviour, an increased interaction with older, more dominant partners, who in turn, were more likely to be physically, emotionally, and sexually abusive, and thus ultimately these women were at an increased risk of becoming infected with HIV/AIDS.

In addition to increased sexual risk behaviour, early maturing females have been shown to be at a greater risk of being overweight and/or obese, both in childhood and in adulthood (Garn, LaVelle & Pilkington 1983, van Lenthe, Kemper & van Mechelen 1996, Biro et al. 2001). Intrauterine growth, the period of adiposity rebound, childhood, and adolescence have all been identified as critical windows for the development of obesity (Dietz 1994, Cameron & Demerath 2002). In addition, rapid weight velocity in infancy and childhood has been found to be associated with an increased risk of childhood and adolescent obesity (Ong et al. 2000, Stettler et al. 2002, 2003, Cameron et al. 2003, Dennison et al. 2006). These studies suggest that later risk of obesity is programmed in *utero* and/or during post-natal life, although it is not clear which critical period is of the most importance. However, whilst these studies were methodologically robust, one must consider the argument presented by Wells and colleagues (2005) who suggest that whilst early growth has been linked with later adiposity as categorised by BMI, there is a paucity of data relating to the development of body composition. It has been suggested that BMI is a poor measure of fatness as it is

correlated with both fat and lean mass (Wells 2000), and so may be an ambiguous outcome in obesity research (Wells 2001). In addition, there have been only a small number of studies (Stettler et al. 2002, Monteiro et al. 2003, Wells et al. 2005) that have examined the development of obesity in transitioning economies that exhibit a high prevalence of malnutrition (such as low birth weight) in parallel with energy-dense food consumption in childhood (Bavdekar et al. 1999). In a recent paper, Wells et al. (2005) examined the relationship between birth weight, infant, and childhood weight gain and late childhood body composition (BMI, fat mass [FM] and lean mass [LM]) in 172 Brazilian boys aged nine years. The authors found that size at birth and infant growth velocities were associated with late childhood BMI, height and lean mass index (LMI, lean mass adjusted for size), but not with total fat, fat mass index (FMI), or with a FM:LM ratio. In addition, the authors showed that whilst foetal and infant weight gains were not associated with later fatness, they were associated with late childhood BMI. This suggests that early life rapid weight gain is associated with late childhood BMI through an association with LM rather than FM for boys. Wells et al. (2005) concluded that early programming may occur for *physique* rather than *fatness* per se. However, the authors do not comment on the fact that these relationships may be sexually dimorphic. In adolescence, boys on average have higher LM and girls have greater FM, thus it is plausible that early *physique* programming may occur in boys resulting in a greater accrual of LM in adolescence. Similar research is required using a female sample to establish if these relationships between early life growth and later LM hold true or if programming is potentially gender specific, in that programming for later fatness occurs for girls, but less so for boys. Even though the reliability of using BMI as a measure of risk for later obesity has been questioned, the ease of assessment and availability of BMI data in growth studies as opposed to more complex and expensive measures such as DXA to assess fat and lean tissues warrants the use of BMI as long as authors are aware of the limitations and take these into account when interpreting findings.

Irrespective of the body composition measure used, a large number of studies have shown that obesity acquired during childhood and adolescence is detrimental to health and well-being (Cameron & Demerath 2001, Loke 2002, Reilly et al. 2003, Reilly 2005, Swallen et al. 2005, Weiss & Caprio 2005, Sabin & Shield 2008). This is a major public health concern, not only for developed countries, but also for developing countries such as South Africa. Several papers have reported a progressive increase in the prevalence of obesity within the South African population in recent decades (van der Merwe & Pepper 2006), particularly among

adolescent females (Walker 1995, Labadarios et al. 2005). In systematic reviews of the consequences of childhood and adolescent obesity, Reilly et al. (2003, 2006) have shown that the principal consequences of paediatric obesity in childhood and adolescence include: psychological ill health, cardiovascular risk factors, asthma, chronic inflammation, diabetes (potentially type I and type II), orthopaedic abnormalities, and premature mortality. The long term or adulthood consequences of paediatric obesity include: the persistence of obesity, cardiovascular risk factors, adverse socio-economic outcomes (particularly in women), and premature mortality.

The results from studies that examine the association between childhood BMI and later cardiovascular risk have not been consistent (Unal, Critchley & Capewell 2004). However, it has been shown that obesity in childhood is associated with a number of negative cardiovascular sequelae, including reduced arterial distensibility, impaired endothelial function, adverse changes in intimamedia thickness, and a greater risk of atherosclerosis in early adulthood (Reilly et al. 2003, Klein et al. 2004, Whincup & Deanfield 2005). In a study of 5 to 10 year old American children, Freedman et al. (1999) reported that overweight children (Quetelet index, > 95th percentile) were significantly more likely (relative to non-overweight 5 to 10 year olds) to have raised systolic (odds ratio [OR] 4.5) and diastolic blood pressure (OR 2.4), raised LDL (OR 3.0) and low HDL (OR 3.4) cholesterol, raised triglycerides (OR 7.1), and high fasting insulin concentration (OR 12.1). Each of these adverse outcomes is a marker of cardiovascular risk. Freedman et al. (1999) also reported that 58% of the 5-10 year old sample presented with at least one of these risk factors and 25% had two or more. These results provide evidence for clustering of risk factors for cardiovascular disease in children who are overweight and/or obese, which are similar to that shown in overweight and/or obese adults. These ideas have also been supported by a number of studies which have shown that the lifestyle factors and biological mechanisms that link obesity with the promotion of cardiovascular risk are similar in both children and adults (Dietz 1998, Williams et al. 2002, Reilly et al. 2003).

There are two areas to consider when examining the psychosocial impact of pubertal timing. The first refers to the psychosocial consequences of being an early or late developer in relation to ones peers. A recent review of the literature by Mendel et al. (2007) reported that, in comparison to their later maturing peers, early maturers were at an increased risk of becoming depressed in adolescence and adulthood, were more likely to engage in excessive

dieting that may result in an eating disorder, exhibit poor academic performance in high school, and engage in earlier initiation of smoking, drinking, and sexual activity. The second area to consider is the indirect psychosocial pathway that links early puberty with an increased risk of overweight/obese which in itself is associated with negative psychosocial outcomes. Whilst there is evidence in the literature to suggest that obese adolescents have been shown to face stigmatisation, discrimination, and negative stereotyping (Dietz 1992, Hill, Draper & Stack 1994), it is assumed that these factors result in low psychosocial well-being. In a systematic review, Wardle and Cooke (2005) argued that obese children experienced only moderate levels of body dissatisfaction and very few were depressed or had low self-esteem. The authors highlighted the importance of distinguishing between those individuals who were sub-clinically obese and those who were clinically obese when examining the psychological impact of obesity, as clinical obesity was associated with a higher level of psychological trauma (Wardle & Cooke 2005).

2.9.1 Summary of the potential consequences of pubertal timing

A number of negative outcomes have been shown to be associated with the timing of pubertal development. Individuals who mature earlier or later in relation to their peers have been shown to be at an increased risk of being and remaining overweight and/or obese, which in itself is linked with increased clustering of risk factors for cardiovascular disease. Other factors include an increased risk of early sexual activity, depression, substance abuse, eating disorders and low academic achievement. Whilst the list is relatively long for potential detrimental outcomes of early puberty in females and later puberty in males, it should be stated that not all these early or late developers exhibit negative sequelae and that the timing of puberty in itself may not be the causal mechanism, but a by product of the environment in which the adolescents were exposed during infancy and childhood. However, in general the findings of the above studies highlight and substantiate the need for longitudinal studies of growth and development prior to, and during puberty in order that early and late maturers can be identified and appropriate interventions targeted.

3 Methods

This chapter is split into two main sections quantitative research and qualitative research. The quantitative section firstly describes the Birth to Twenty (Bt20) study and the Bone Health (BH) sub-study. This is followed with a description of the sample and then the measures used in the analysis. The data cleaning and preparation procedures are then discussed, followed by a description of the statistical analysis. The qualitative section includes the rationale for using focus group (FG) methods, FG organisation, recruitment and moderator training, and analysis methods. A detailed description of the author's role and contribution to data collection, organisation, management, and analysis can be found in Appendix II.

3.1 Quantitative research

3.1.1 Sample

3.1.1.1 Birth to Twenty sample

Birth to Twenty (originally Birth to Ten) is one of very few longitudinal birth cohort studies within the developing world, and is the largest and longest running study of child and adolescent health and development within Africa. The Bt20 cohort was established over a seven week period between April 23rd and June 8th 1990. A total of 3273 mother-infant dyads that were resident and continued to be resident in the metropolitan area of Soweto-Johannesburg, South Africa were enrolled into the study. There were a total of 5449 births within this geographic region; however, a number of these infants were born to rural mothers who came into Johannesburg to deliver and then returned home. At this time, South Africa was undergoing rapid social, political, and economic change as the regime of Apartheid began to fall and a new democratic South Africa emerged. Bt20 was established to track the growth, health, well-being, and educational achievements of a group of urban South African children who were born at the start of this transitioning economy (Richter et al. 2007). To date, data have been collected at 17 time points through questionnaires (self-complete and interviewer administered) and physical examinations. Key themes of data collection include growth, nutritional status, pubertal development, physical activity and health; demographic and household socio-economic status; risk behaviours; cognitive ability and school achievements; and social and psychological adjustment.

3.1.1.2 Bone Health sub-sample

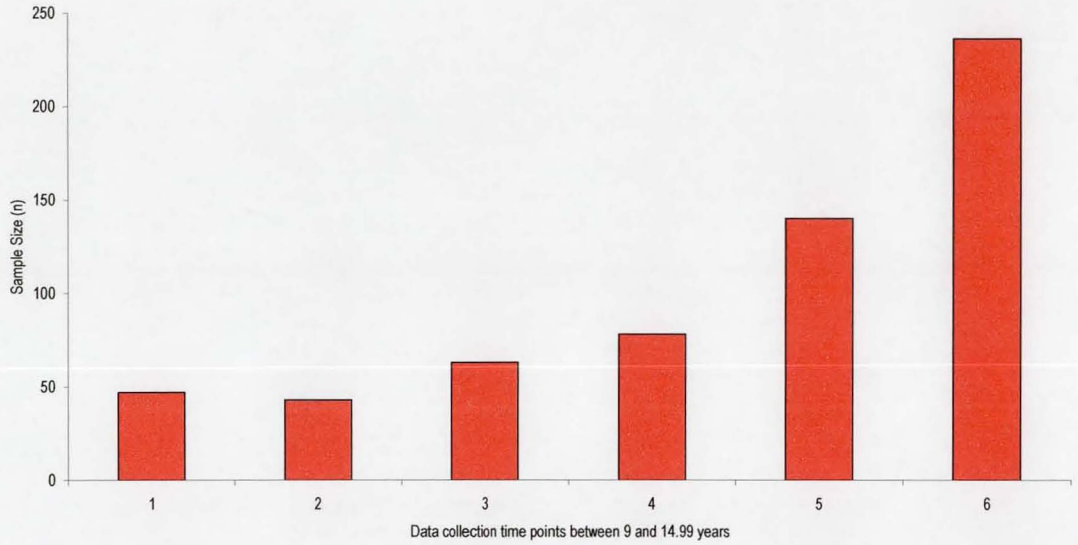
Towards the end of the 1990's Bt20 severely lacked resources and a decision was taken to raise funds for two hypothesis-driven longitudinal research strands which would incorporate and utilise Bt20 data from the first 10 years (Richter et al. 2007). One research strand examines sexual risk and the second bone health. The Bone Health (BH) sub-study was established in 1999 with the main aim of collecting detailed data to answer specific questions relating to adolescent growth and development. It was not financially feasible to recruit the whole Bt20 cohort because of the cost of the measures required to do this study. Therefore, only 523 Bt20 children from the original sample of 3273 were recruited and enrolled into the BH sub-study. This sample size was calculated using a power analysis based on hypotheses relating to bone health outcomes. These cases were purposively selected as they had complete data at critical time points in the Bt20 study including birth, two, and five years of age. This maximised data availability in order to investigate the relationship between historical and contemporary factors relating to adolescent growth and development. In addition, risk factors for future physical, reproductive, and sexual health could be identified. This purposive selection of cases lead to an under representation of the White sample within the BH cohort and thus this initial BH sample was not socio-economically or demographically representative of the original Bt20 cohort, or of children living in the Johannesburg-Soweto area. The main reason for this under-representation of whites is two fold; firstly they were largely under represented within the original Bt20 cohort as it was not possible to recruit infants through private health clinics, which is where White mothers typically deliver. Secondly, a higher proportion of Whites were lost through attrition (Richter LM, Norris SA & De Wet 2004). In order to address this, 151 White children from the Johannesburg area, born at a similar time to the Bt20 children were newly recruited into the sample between 2000 and 2001, through Bt20 school surveys. Nine Black children were also recruited as the families captured in the school surveys had marked "White" on the questionnaire. However, when they attended these families were Black, and a decision was made to keep these adolescents in the sample. A total of 683 (50.1% males, 38.8% White) adolescents formed the BH sample from Year 11. Detailed data were collected bi-annually and included interview administered questionnaires for adolescents and caregivers, an adolescent risk behaviour questionnaire (smoking, alcohol use, sexual activity etc), pubertal development ratings, anthropometric measurements, and blood and urine profiles. Data on socio-

economic status (SES) were collected through questionnaires administered to the primary caregiver.

3.1.1.3 Analysis samples

There were two separate analysis strands within this thesis, the first examined the determinants of the initiation of pubertal development, and the second examined the determinants of the initiation of menarche. Pubertal development, anthropometric and socio-economic status (SES) data from the BH sample were utilised within both of these analyses. Data for six time points were available: 9-9.99 years, 10-10.99 years, 11-11.99 years, 12-12.99 years, 13-13.99 years, and 14-14.99 years. Figure 3.1 shows the total number of times (from one to six) a case was seen across the six data collection waves between the ages of 9 and 14.99 years. Two hundred and thirty-six cases (36.9%) were seen at all data collection waves. In addition to these data collection points, "early life" data were utilised from birth to eight years where available. Of the original 683 adolescents enrolled into the BH study, 76 cases were removed from the dataset as they were enrolled, but not seen at any time point. A total sample size of 607 (51.4% male, 33.9% White) adolescents were available for analysis of the initiation of pubertal development, each of whom had been seen at one or more time points. Figure 3.2 shows the gender and ethnic breakdown of the Bt20, BH and initiation of pubertal development analysis samples. Figure 3.3 shows the breakdown of the Bt20, BH and the menarche analysis samples. A total of 287 females (65.5% Black) were available for this analysis.

Figure 3.1 Total number of times a case was seen across the six data collection waves



3.1.1.4 Power, sample, and effect size

Calculating sample sizes required for a logistic regression analysis requires prior knowledge from existing studies on both predictor and outcome variables. It was therefore difficult to undertake a power calculation prior to analysis for the current study as there were no reliable data on which to base these calculations as few, if any studies have analysed the factors associated with pubertal development and age at menarche using a dichotomous outcome variable (i.e. early vs. late development). Given that the sample size for the current analysis was fixed, as these data were drawn from an established cohort, it was possible to do a retrospective power calculation once the logistic regression models had been constructed. Using Power and Precision software (v 3.2, Englewood, NJ), power could be estimated for the menarche outcome by inputting the odd's ratio and sample size for any given statistically significant explanatory variable (it was not possible to estimate power for a model with more than one predictor or explanatory variable as the software to do this seems to be problematic and makes interpretation particularly difficult. The author in not aware of any other software that has the ability to estimate power for logistic regression models with more than two explanatory variables). Two individual statistically significant predictors of the timing of menarche were selected to be entered into the power estimations, one that explained the least amount of variance (Year 4 BMI) in the model (Cox & Snell $R^2 = 0.04$) and one that explained the most amount of variance (Year 8 weight) in the model (Cox & Snell $R^2 = 0.08$). Selecting the two variables at the upper and lower ends of the total variance explained allowed a range of power to be estimated. By entering the variable mean, standard

deviation, event rate at mean (e.g. number of girls who had achieved menarche at the mean value of the explanatory variable), sample size, and odd's ratio (from the logistic regression model) power was estimated at 27% for the year 8 weight model and at 42% for the year 4 BMI model. These power estimates show that between 27 and 42% of studies one would expect to yield a significant effect and thus appropriately rejecting the null hypothesis. These estimates were significantly lower than the 80% power value commonly used in sample size estimations and indicates that the models within the current analysis were under powered. It is possible to hypothesise that models with an increased number of explanatory variables are likely to yield even less power and thus the puberty models, whilst having a greater sample size, had more explanatory variables and so it is expected that they would have similar or lower levels of power to the menarche models. As the models within this thesis may be under powered the results must be considered within the context of this limitation.

Figure 3.2 Birth to Twenty Cohort - Bone Health sample – pubertal development analysis sample breakdown by ethnicity and gender

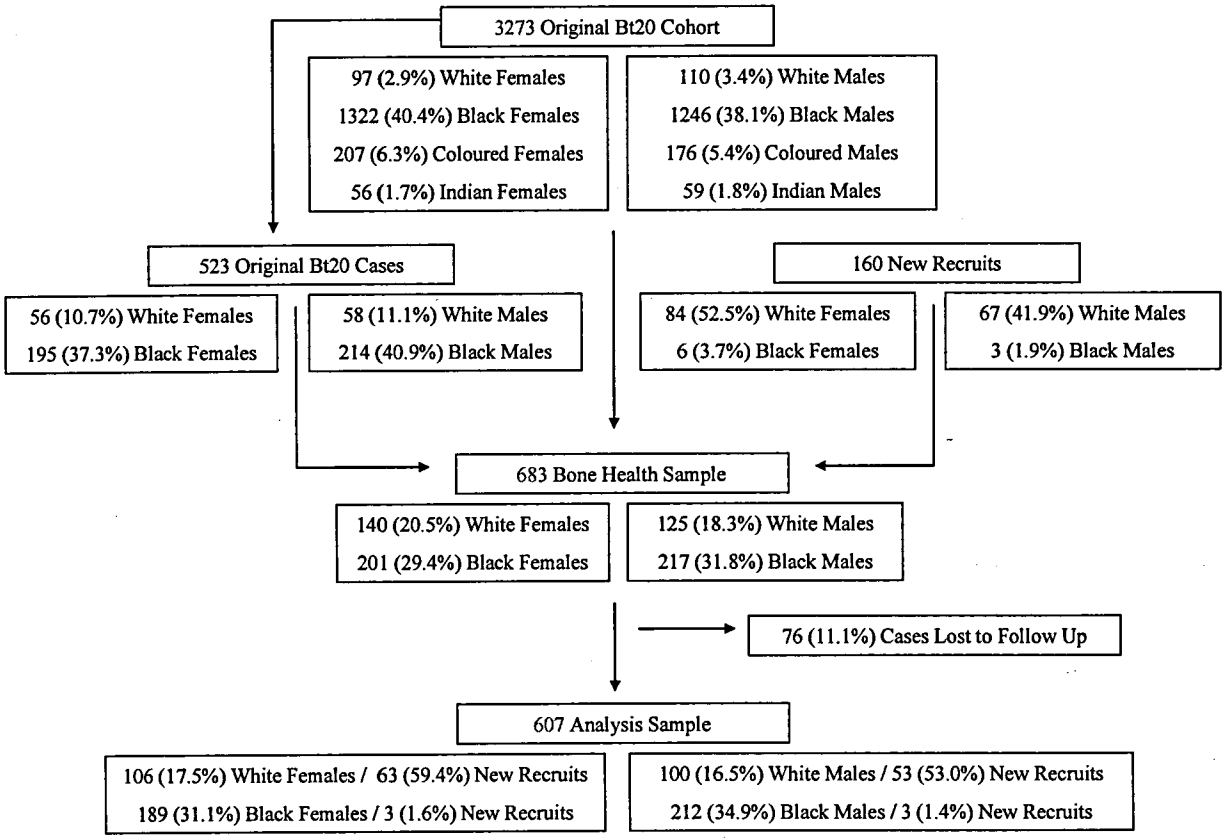
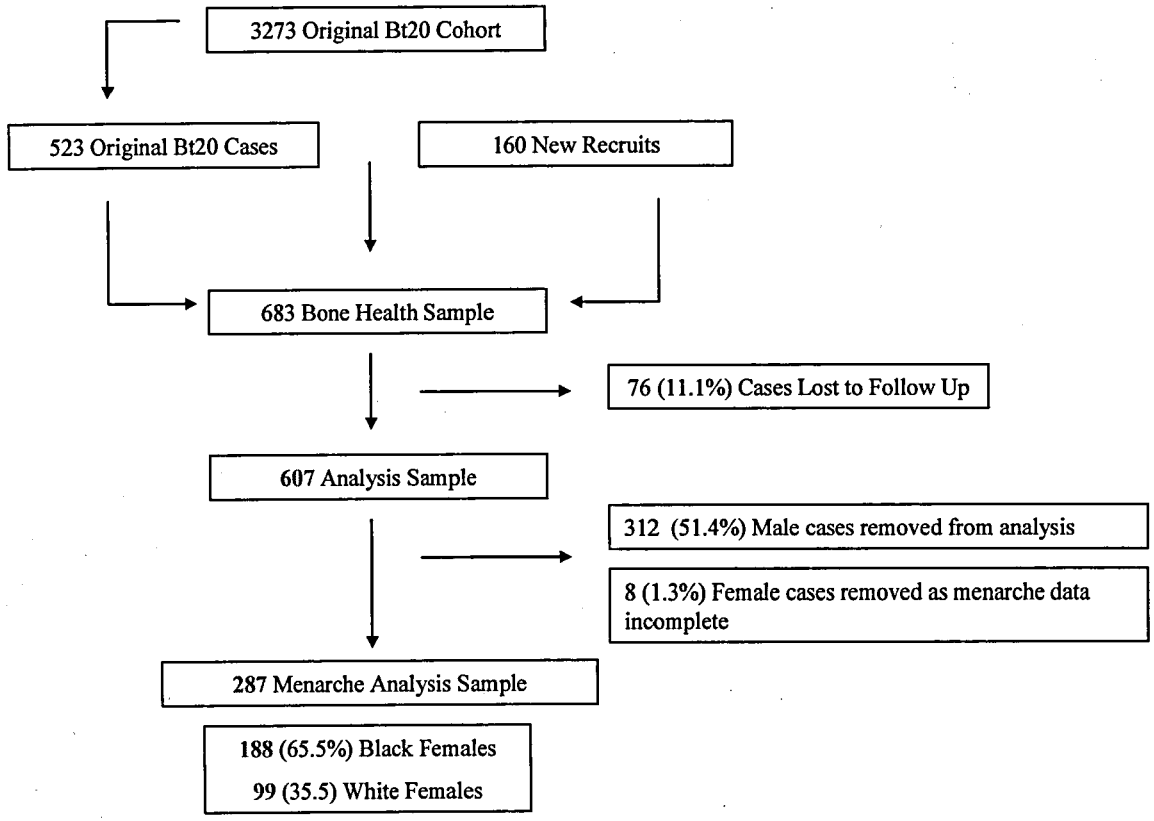


Figure 3.3 Birth to Twenty Cohort - Bone Health sample – menarche analysis sample split by ethnicity



3.1.2 Measures

3.1.2.1 Anthropometrics and body composition

Over 20 anthropometric variables were measured on each participant at each time point between the ages of 9.00 and 14.99 years. All measurements were recorded on anthropometric charts that formed part of the child/adolescent questionnaire (for an example of the adolescent questionnaire see Appendix III). Participants wore light clothing and were barefoot. For each dimension two measurements were taken, with the exception of skinfolds where three measurements were taken and weight, and height where only one measurement was taken. For those measurements with more than one repetition an average was derived once the raw data had been inputted into the database. Each assessment was made following standard procedures (Cameron 1984) and the techniques for measuring the key anthropometric variables are briefly described below.

3.1.2.1.1 Height

Height was measured using a Holtain wall-mounted stadiometer (Holtain Ltd., UK) graduated to the nearest 0.1 cm. Participants were asked to stand upright with their feet together and with their shoulders, buttocks and heels (if possible) touching the backboard. Arms and hands were held in a relaxed position by the participant's sides, with the palms facing medially. The observer then placed the head in the "Frankfurt Plane" and the headboard was lowered until it rested on the vertex of the skull, ensuring that the participant's hair was compressed. The participant was then asked to inhale deeply and then exhale, the measurement of height was then taken at the maximum point and to the last completed unit.

3.1.2.1.2 Weight

Weight was measured to the nearest 0.1 kg using digital electronic scales (Dismed, USA). The participant was asked to stand in a relaxed position on the scales, ensuring both feet were completely on the base unit and to look straight ahead. Weight was recorded once the digital reading had been displayed for more than two seconds without fluctuating.

3.1.2.1.3 BMI

Body mass index (BMI) was calculated (weight (kg)/height $(m)^2$). BMI status (normal/at risk of overweight/obese) was calculated using the Cole/International Obesity Task Force (IOTF) cut-offs (Cole et al. 2000). These percentiles were used as they allow for international comparison of the prevalence of childhood overweight and obesity using BMI-for-age specific cut-offs. The following are the IOTF international cut-off points:

Underweight	BMI-for-age < 5th percentile
Normal weight	BMI-for-age 5th to 90th percentile
At risk of overweight	BMI-for-age 90th to 97th percentile
Overweight	BMI-for-age > 97th percentile

3.1.2.1.4 Waist circumference

Waist circumference was measured at the narrowest point between the lowest rib and the iliac crest using a tape measure graduated to the nearest 0.1 cm. The participant was asked to stand upright in front of the observer and to raise their shirt to above their navel, the tape was then passed around the body at the narrowest point of the torso, ensuring that the tape was horizontal and lying flat against the skin, without compressing the soft tissue (Lohman, Roche & Martorell 1988).

3.1.2.1.5 Hip circumference

Hip circumference was measured at the point of maximum extension of the buttocks using a tape measure graduated to the nearest 0.1 cm. Wearing thin clothing, the participant was asked to stand sideways on to the observer with the their feet together and their arms folded, the tape was then passed around the maximum point of the buttocks, ensuring that the tape was horizontal and lying flat against the clothing, without compressing the soft tissue (Lohman, Roche & Martorell 1988).

3.1.2.1.6 Skinfolds

Using appropriate anatomical landmarks, the sites for each of the five skinfold measurements were marked and taken on the left hand side of the body using Holtain callipers (Holtain Ltd.,

UK) following standard procedures (Cameron 1984). Each skinfold was read once the callipers had achieved a steady state and were recorded to the last completed 0.2 cm.

Triceps: the skinfold was taken at the midpoint of the posterior vertical axis between the acromion and olecranon and at the midpoint between the medial and lateral surfaces of the upper arm. The observer stood behind and to the left of the participant, the participant was asked to flex their arm and the skinfold was picked up approximately 1 cm above the marked point, the participant then extended and relaxed their arm and the measurement was taken.

Biceps: the skinfold was taken at the midpoint of the anterior vertical axis between the acromion and olecranon and at the midpoint between the medial and lateral surfaces of the upper arm. The measurement was taken as for the triceps skinfold.

Subscapular: the participant was asked to stand upright with the shoulders relaxed allowing the skinfold site to be located and marked 1 cm below the inferior angle of the scapula. The angle of the sweep of the skinfold was lateral and downward and the callipers were placed below the fingers.

Suprailiac: this vertical skinfold was marked and taken 1 cm above and 2 cm medially from the anterior superior iliac spine. The calliper was placed and the measurement taken below the sweep of the skinfold.

Medial Calf: the participant was seated with their knees at a right angle. This vertical skinfold was marked and taken on the medial aspect of the calf at the point of maximal circumference.

3.1.2.1.7 Body composition

A fan-beam densitometer (model QDR 4500A; Hologic Inc, Bedford, MA) was used to obtain dual-energy X-ray absorptiometry (DXA) readings of body-composition. Body composition [fat mass (kg), and lean tissue mass (kg)], was assessed using software version 8.21 (Hologic Inc) under standardized patient positioning and scan analysis. A trained technician for DXA performed all scans, and intra-observer variation was below 1%.

3.1.2.2 Perinatal factors

Data on pre- and peri-natal factors were collected through interview administered questionnaires to the mother of the Bt20 child at both antenatal clinic appointments and at delivery interviews for the 485 Bt20 infants who remained in the BH sample and who are in

the current analysis sample. Birth weight was initially measured by birth attendants and then by trained Bt20 observers once the birth had been reported. Infants were classified as low birth weight (LBW) if their birth weight was less than 2.5 kg, average birth weight (ABW) if their birth weight was between 2.51 and 4.00 kg and as high birth weight (HBW) if their birth weight was greater than 4.01 kg. Gestational age was calculated based on maternal report of last menstrual period. Infants who had a birth weight below the 10th percentile of sex and gestational-age specific references (Williams et al. 1982) were classified as small for gestational age (SGA). Data were also collected on infant gender, ethnicity, gravidity, parity, and maternal age.

For the newly recruited White adolescents (n = 116), historical birth and delivery data were collected through a historical recall questionnaire. The current primary caregiver was contacted either by telephone or through a home visit by trained observers in spring 2006. Missing data were collected retrospectively on birth weight, gestational age, gravidity, parity, maternal age, marital status, and educational level at the time of the infant's birth, place of birth and the type of hospital the baby was delivered in (public/private).

3.1.2.3 Post-natal factors & early childhood growth

Anthropometric measurements were collected at five different time points during infancy and childhood. Table 3.1 indicates which variables were collected/derived and available for analysis at each time point. BMI and the categorisation of normal, overweight and obese were calculated using the methods previously described in section 3.1.2.1.3. Height and weight measurements were compared to the NCHS/World Health Organisation (WHO) reference population in order to calculate z-scores using ANTHRO software (v 1.02, 1999) for infants from birth to 8 years of age. Z scores were created using the WHO Anthro 2005 software for infants up to 5 years of age; however, these are growth standards, rather than references, and so it was deemed inappropriate to use them within the current analysis. The distinction between a reference and a standard is that a growth reference is descriptive and reflects "normal" growth, whereas a growth standard is prescriptive and reflects "desirable" growth as the reference population is restricted to "healthy" participants only. There are disadvantages to using standards including the need to define "healthy", typically the criteria to include and exclude participants is arbitrary, for example should one exclude all children who have asthma, as in some, but not all cases asthma can restrict growth. In addition, if the

reference is restricted to healthy children only, how is one supposed to assess the growth of those children excluded, as the chart by definition is not appropriate for them? (Cole 2002) Cole (2002) recommends that it is simpler and easier to use a growth reference rather than a growth standard, so that all children, irrespective of health status are included. Stunted children were identified using a definition of a height-for-age z-score of less than two standard deviations below the median for the reference population for the appropriate gender and age. Height velocity (cm/yr^{-1}) was calculated by dividing change in height by time [$(Ht_2 - Ht_1)/(Age_2 - Age_1)$] and weight velocity ($kg/yr^{-1}$) by dividing change in weight by time [$(Wt_2 - Wt_1)/(Age_2 - Age_1)$] (Tanner, Whitehouse & Takaishi 1966). Infants were categorised as having experienced either "normal" growth, catch up, or catch down growth during the first two years of life. This was calculated by subtracting their birth weight-for-age z score from their second year weight-for-age z score. If this value fell between -0.67 and 0.67 they were categorised as "normal" growth. If this value was greater than 0.67 they were categorised as having experienced catch up growth‡‡ and if the value was greater than -0.67 they were categorised as having experienced catch down growth (Ong et al. 2000, Cameron & Demerath 2002). No post-natal or early childhood growth data were available for the 116 new recruits and so they were excluded from analysis that used these data.

Table 3.1 Anthropometric data available for analysis from infancy and childhood

Variable	Time Point				
	1 Year	2 Years	4 Years	5 Years	8 Years
Height	x	x	x	x	x
Weight	x	x	x	x	x
BMI*	x	x	x	x	x
Normal/overweight/obese*		x	x	x	x
Height-for-age z score*	x	x	x	x	x
Weight-for-age z score*	x	x	x	x	x
Weight-for-height z score*	x	x	x	x	x
Stunting*	x	x	x	x	x
Height velocity*	x	x	x	x	x
Weight velocity*	x	x	x	x	x
Rapid growth*		x			

* Variable derived using anthropometric data

‡‡ Catch up growth in this thesis refers to rapid growth in infancy which is not regression to the mean but achievement of growth percentiles that are greater than the mean and that pre-determined genetically, based on parental size.

3.1.2.4 Pubertal development data

3.1.2.4.1 Years 9 and 10

In the year 9 and year 10 data collection waves, secondary sexual development was assessed in a private cubicle by one of two trained physicians (one male and one female). Both physicians had been trained in the use of the Tanner Staging Technique (Tanner 1962). Breast development in females, genitalia development in males, and pubic hair development in both sexes was assessed and recorded. Females were also asked if they had achieved menarche and if yes, on what date did menarche occur (dd/mm/yyyy). This provided a baseline physician assessment of secondary sexual development within the cohort.

3.1.2.4.2 Year 11

At year 11 a self-assessment questionnaire was administered to each adolescent. An example of the questionnaire used to self-assess female breast development can be seen in Figure 3.4. The original English Tanner pictures and descriptions were used and were translated into isiZulu, Afrikaans and seSotho, which are three of the most commonly spoken languages in South Africa. This was to help the adolescents to differentiate each stage of development and thus help to improve the reliability of the self-assessment tool. A set procedure was followed for each adolescent when they came in to be assessed. A short tutorial was given to the adolescent by a trained observer, which explained the purpose of the questionnaire; that it was confidential and that if required they could have access to a private cubicle in which they could examine themselves. In front of the observer, the adolescent was asked to select the photograph and description that best reflected their stage of development by marking the relevant picture on the questionnaire. Data on the menarcheal status of females were obtained by a trained observer at the same time as the anthropometric measurements were taken. Questions included the day of the week and the date (dd/mm/yyyy) of their first menstrual period. No further questions with regards to pubertal development were asked of the males at this time point.

Figure 3.4 Year 11 self-assessment questionnaire: female breast development

birth to ten

TANNER STAGES: FEMALE BREAST DEVELOPMENT

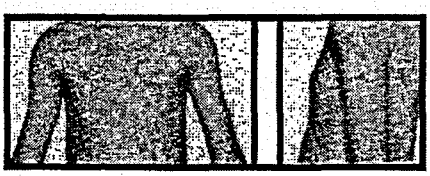
birth to ten

The pictures on this page show different stages of development of the breasts. A female passes through each of the five stages shown by these sets of pictures. Please look at each set of pictures and read the sentences next to the picture. Then choose the set of pictures closest to your stage of breast development and mark an "A" on the picture. Then choose the picture that is the next closest and mark a "B" on the picture.

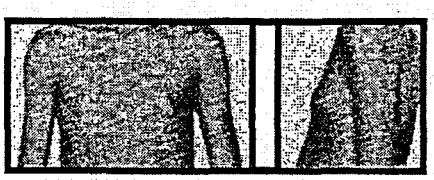
Die fotos op hierdie bladsy beeld die verskillende ontwikkelingstadiums van die borste uit. 'n Meisie gaan deur elk van die vyf stadiums wat hier geïllustreer word. Kyk asseblief na elke stel fotos en lees ook die beskrywing langs die foto. Kies dan die stel fotos wat jy dink die meeste na jou stadium van borsontwikkeling lyk en merk dit "A" op die foto. Kies dan die stel fotos wat tweede meeste daarna lyk, en merk dit "B" op die foto.

Ditshwantsho tse di mo tsebeng e di bontsha dikgato tse di farologaneng tsa go tlhaga le go gola ga matswele. Motho wa mosadi o itemogela dikgato di le tlhano tseo di bontshiwang ke ditshwantsho tse. Leba setshwantsho sengwe le sengwe tsweetswee o be o buise mela e e latelang ka fa thoko ga ditshwantsho tseo. Morago tlhopha setshwantsho se se gaufi thata le kgolo ya matswele a gago "A". Tlhopa gape setshwantsho se le latelang ka bo gaufi, kgolo ya matswele a gago mme o se tshwaye "B".

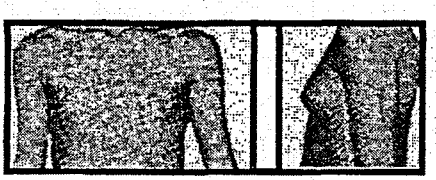
Izithombe ezikuleli khasi zikhombisa izigaba ezehlukene zokuvela nokukhula kwamabele. Umuntu wesifazane udlula kwesinye nesinye isigaba salezo ezinhlanu ezikhonjiswe yilezizithombe ezihamba ngazimbili. Ake ubheke lezizimbe ufunde imisho eseceleni kwazo. Khetha izithombe ezihamba ngazimbili ezicishe zifane nesigaba sokukhula kwamabele wena okuso, bese ubhala u-"A" kuzo. Khetha izithombe ezilandelayo nezicishe zifane nesigaba wena okuso ubhale u-"B" kuso.



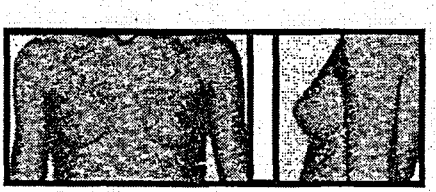
Stage 1
The nipple is raised a little in this stage. The rest of the breast is still flat.
Tlhoko ya letswele e kwa godingwana mo kgatong e, fela letswele lotlhe ga le ise le bonale.
In hierdie stadium is die tepel 'n bietjie opgelig. Die res van die bors is steeds plat.
Ingono iphakeme kancane kulesi sigaba. Yonke enye ingxenye yamabele iseyisicaba ayikazibonakalisi.



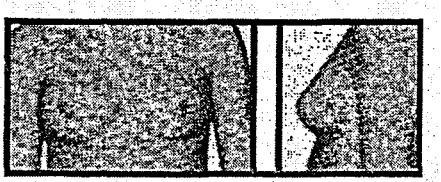
Stage 2
This is the breast bud stage. In this stage the nipple is a little more raised. The breast is a small mound. The areola (the darker, coloured middle part) is larger.
E ke kgato ya diolamelora. Mo kgatong e, tlhoko ya letswele e kwa godingwana go gaisa. Letswele le lebega e kete thothobolonyana. Areola karolo e ntshonyana eemo bogareng kgolwane go gaisa.
Hierdie stadium word die borsknopstadium genoem. Die tepel is meer opgelig as in die eerste stadium. Die bors lyk soos 'n klein heuweltjie. Die areola is groter as wat dit in stadium 1 was.
Lesi yisigaba sezimpumamlotha. Ingono ithe uku phakama kancane. Amabele ayizimpumamlotha. I-ariyola (indawo emaphakathi emnyama) ikhulakhulile.



Stage 3
The areola and the breast are both larger than in stage 2, but the areola does not stick out above the breast.
Bobedi areola le letswele di kgolwane go gaisa mo kgatong ya 2, mme areola ga e dire motsu go tswa mo letsweleng.
Die areola en die bors is altwee groter as wat hulle in stadium 2 was. Die areola steek nie weg van die bors uit nie.
Kokubili i-ariyola namabele kukhulile kunasesigabeni 2. I-ariyola ayiphumanga yagqama ngaphezu kwamabele.



Stage 4
The areola and the nipple make up a mound that sticks up above the shape of the breast. (Note: this stage may not happen at all for some girls. Some girls develop from stage 3 to stage 5, with no stage 4).
Areola le tlhoko ya letswele di dira thothobolonyana e e dirang motsunyana mo godimo ga popego ya letswele. (Go a kgonagala gore kgato e, e se diragale gotlhelele mo basetsaneng bangwe. Basetsana bangwe ba gola go tswa mo kgatong ya 3 go ya go ya 5, mme go se kgato ya 4.)
Die areola en die bors vorm saam 'n heuweltjie wat bó die vorm van die bors uitsteek. (Let wel: nie alle meisies gaan deur hierdie stadium nie. Party meisies ontwikkel van stadium 3 tot stadium 5 sonder om deur stadium 4 te gaan).
I-ariyola kanye nengono zenza iqhuzwana elithe thwi phezu kwesakhiwo samabele. (Qaphela: Lesi sigaba sinokungenzeki nhlobo kwamanye amantombazane. Amanye amantombazane wona aqala ukuba nezimpumamlotha/namabele esigabeni 3 aye esigabeni 5, engadlulanga esigabeni 4).



Stage 5
This is the mature adult stage. The breasts are fully developed. Only the nipple stands out in this stage. The areola has flattened into the general shape of the breast.
E ke kgato ya bofelo ya mogolo. Matswele a godile ka botlalo. Mo kgatong e, ke tlhoko ya letswele fela e dirileng motsunyana. Areola e boetse kwa morago kwa popegong ya letswele ka kakaretso.
Dit is die volwasse stadium. Die borste is volledig ontwikkel en slegs die tepel steek nou bó die bors uit. Die areola het nou teruggeskuif en vorm deel van die bors se vorm.
Yisigaba somuntu omdala osephelele lesi. Amabele asekhule ngokuphelele. Yizingono kuphela ezime thwi kulesi sigaba. I-ariyola seyibuyele phansi yaba isicaba esakhiweni esijwayelekile samabele.

3.1.2.4.3 Year 12 onwards

From the year 12 data collection wave onwards, "assessment of physical development in adolescence" questionnaires were administered to the adolescents. These questionnaires were gender specific and included three sections. Section A included questions on somatic development, for example:

For both sexes:
- Have you grown taller in last 6 months?
  - (No/yes, a little/yes, some/yes, a lot/don't know)
- Have you started puberty (i.e. do you have any pubic hair)?
  - (No/yes)
- Has your skin started to change (pimples)?
  - (No/yes, a little /yes, some/yes, a lot/don't know)
- Do you have any hair underneath your arms or in the pubic region?
  - (No/yes, a little/yes, some/yes, a lot/don't know)

For males only:
- Do you have to shave your face because you have facial hair?
  - (No/yes, a little/yes, some/yes, everyday/don't know)
- Has your voice started breaking (do you speak in a deeper voice)?
  - (No/yes)
- If YES, have you been speaking in a deeper voice for more than two years?
  - (No/yes)
- If YES, how old were you when your voice broke?
  - (? Years)

For females only:
- Have your breasts started to develop (grow) yet?
  - (No/yes, a little/yes, some/yes, a lot/don't know)
- Have you begun to menstruate (have your period)?
  - (No/yes)
- If YES, at what age did you begin to menstruate?
  - (? Years)
- If YES, do you have regular menstrual cycles (periods)?
  - (No/yes)
- If YES, have you been having periods for more than two years?
  - (No/yes)

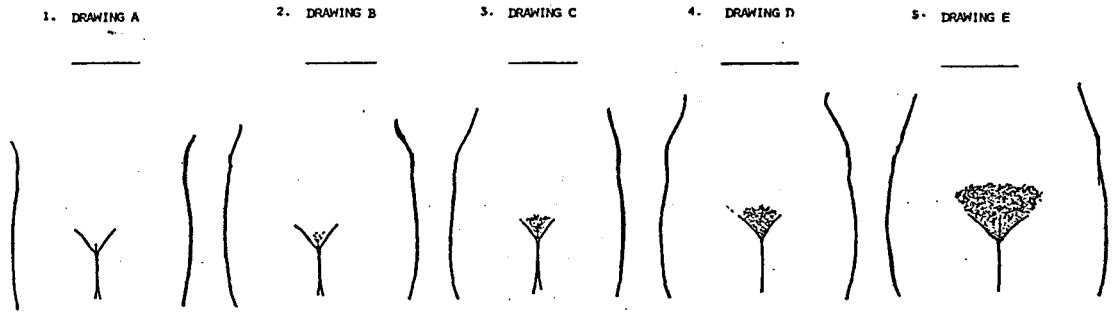
Only data on menarcheal status (highlighted in red) from section A have been used in the current analysis. This was due to data availability and time restrictions for cleaning and analysis for this study.

Examples of section B and C, which were used to assess secondary sexual development, can be seen in Figures 3.5 and 3.6 for females and in Figures 3.7 and 3.8 for males. Instead of using the photographs proposed by Tanner, the line drawings of Morris and Udry (1980) were computerised and graphically enhanced, this was to aid the mass reproduction that is required for this type of study. Tanner's descriptions were also reworded to help improve clarity and understanding. Changes to the pubic hair descriptions included the differentiation between texture, density, and distribution of hair between the five stages. For breast development in girls, the wording was changed to allow clear differentiation of the development of the breast, areola, and the nipple between the five stages. For genitalia development in boys, the wording was changed to allow clear differentiation of the development of the scrotum, testes and penis between the five stages. A validation study was undertaken to examine the validity and reliability of this questionnaire when used in an urban South African setting. Norris & Richter (2005) concluded that this questionnaire was a valid tool for the self-assessment of secondary sexual development in urban Black South African adolescents (female κ coefficients[§§] of 0.71 for pubic hair and 0.76 for breast development, $p < 0.0005$ and male κ coefficients of 0.63 for pubic hair and 0.60 for genitalia development; $p < 0.0005$). The assessment of pubertal development from year 12 onwards was completely self-rated, with no interviewer presence.

[§§] A Kappa coefficient measures the agreement between two observers. The value is always less than or equal to 1, with 1 representing perfect agreement.

Figure 3.5 Assessment of physical development questionnaire: section b female pubic hair development

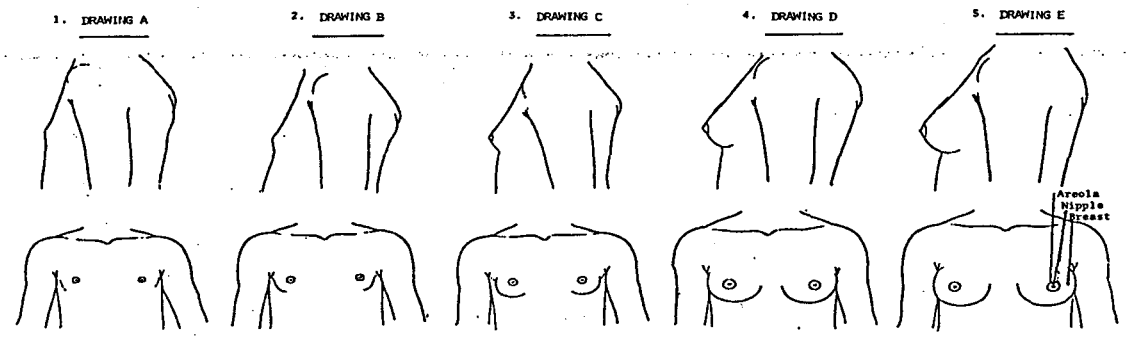
The drawings below show different amounts of pubic hair. A teenager passes through each of the five stages shown by these drawings. Please look at each drawing and read the sentences under the drawings. Then choose the drawing closest to your stage of hair development and mark it.



1. DRAWING A	2. DRAWING B	3. DRAWING C	4. DRAWING D	5. DRAWING E
There is no pubic hair	**Texture** of the hair is soft. **Density** of the hair is little. **Distribution** of the hair is along the mid-line. Pubic hair may be straight or curly	**Texture** of the hair is coarser. **Density** of the hair is a little more. **Distribution** of the hair has spread out thinly, up the mid-line, and covers a somewhat larger area.	**Texture** of the hair is coarse. **Density** of the hair is much more. **Distribution** of the hair covers a large area in a triangular shape, but has not spread to the thighs. The hair is a darker colour.	**Texture** of the hair is coarse. **Density** of the hair is that of an adult. **Distribution** of the hair has spread to the thighs and moved up the mid-line.

Figure 3.6 Assessment of physical development questionnaire: section c female breast development

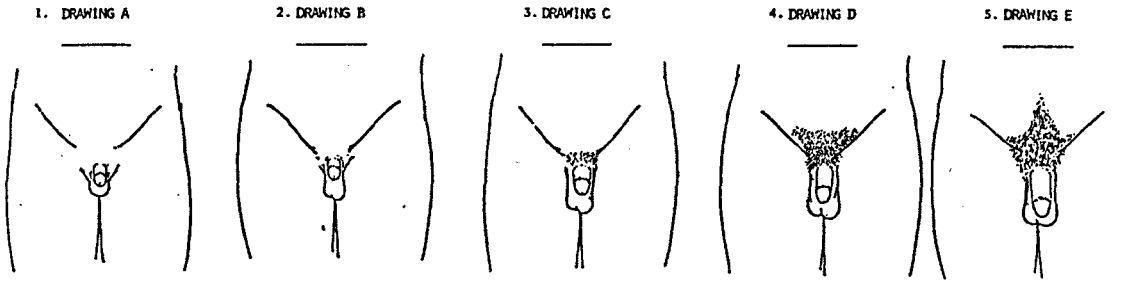
The drawings below show the different stages of development of breasts. A teenager passes through each of the five stages shown by these sets of drawings. Please look at each set of drawings and read the sentences under the drawing. Then choose the set of drawings closest to your stage of breast development and mark it.



1. DRAWING A	2. DRAWING B	3. DRAWING C	4. DRAWING D	5. DRAWING E
The breast is flat.	The breast is a small mound. The **areola** (circle around the nipple) is larger. The nipple is slightly raised.	The **areola** circle has gotten bigger, and the **breast** has increased in size and more cone-shaped	The **areola** and the **nipple** make up a mound that sticks up above the shape of the breast. Small bumps may be developing on the areola. The breast may have gotten bigger and rounder.	The **breasts** are fully developed and extend to the arm pit, there are small bumps on the areola around the nipple; and only the **nipple** sticks out in this stage.

Figure 3.7 Assessment of physical development questionnaire: section b male pubic hair development

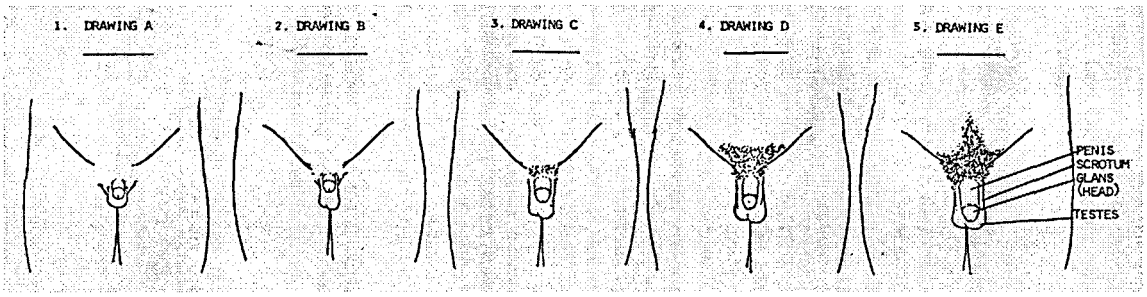
The drawings below show different amounts of **pubic hair.** A teenager passes through each of the five stages shown by these drawings. Please look at each drawing and read the sentences under the drawings. Then choose the drawing closest to your stage of hair development and mark it.



1. DRAWING A	2. DRAWING B	3. DRAWING C	4. DRAWING D	5. DRAWING E
There is no pubic hair	**Texture** of the hair is soft. **Density** of the hair is little. **Distribution** of the hair is at the base of the penis, especially on the sides. Pubic hair may be straight or curly	**Texture** of the hair is coarser. **Density** of the hair is a little more. **Distribution** of the hair has spread out thinly and covers a somewhat larger area around the base of the penis.	**Texture** of the hair is coarse. **Density** of the hair is much more. **Distribution** of the hair covers a large area but has not spread to the thighs. The hair is a darker colour.	**Texture** of the hair is coarse. **Density** of the hair is that of an adult. **Distribution** of the hair has spread to the thighs and moved up the mid-line.

Figure 3.8 Assessment of physical development questionnaire: section c male genitalia development

The drawings below show the different stages of development of genitals. A teenager passes through each of the five stages shown by these sets of drawings. Please look at each set of drawings and read the sentences under the drawing. Then choose the set of drawings closest to your stage of genital development and mark it.



1. DRAWING A	2. DRAWING B	3. DRAWING C	4. DRAWING D	5. DRAWING E
There has been no change in the **testes** (balls), **scrotum** (sack holding the balls), and **penis.**	The **scrotum** has lowered a bit, and the skin of the scrotum has changed (smoother). The **testes, scrotum** and **penis** have gotten a little larger.	The **scrotum** has dropped lower than in stage 2. The **testes, scrotum** and **penis** have grown more.	The **scrotum** is bigger because the **testes** have gotten bigger. The **penis** has grown even larger and wider. The head of the **penis** is bigger	There have been no further size changes in the **penis, scrotum,** and **testes.**

3.1.2.5 Socio-economic status data

Household socio-economic status was measured using questionnaires administered to the mother or the primary caregiver of each child, which assessed a range of proxies of SES at the time of the birth of the infant and in late childhood (9/10 year data collection waves). The socio-economic variables that were available for analysis are shown in Table 3.2. The majority of the variables were common to both the questionnaire administered at birth and that administered at 9/10 years. New consumer durable ownership variables were added at year 9/10 including: the ownership of a video player and the ownership of a microwave. Video players and microwaves had limited commercial availability in 1990 and so these questions were not asked at the time of the birth of the Bt20 child. There were some discrepancies in the data for caregiver education and marital status between birth and 9/10 years. This was because the questions were administered to the biological mother at birth; however, at 9/10 years the questions were administered to the primary caregiver, who may or may not be biologically related to the adolescent.

Table 3.2 Household socio-economic variables available for analysis at birth and at 9/10 years

Socio-Economic Variables	Birth Index	9/10 Years Index
Caregiver education (< high school/> high school)	x	x
Caregiver marital status (other/married or cohabiting)	x	x
TV ownership (no/yes)	x	x
Fridge ownership (no/yes)	x	x
Car ownership (no/yes)	x	x
Telephone ownership (no/yes)	x	x
Water facility type (outside & other/inside)	x	x
Toilet facility type (outside & other/inside flush)	x	x
Video player ownership (no/yes)		x
Microwave ownership (no/yes)		x

3.1.3 Data cleaning procedures

Systematic cross-sectional and longitudinal cleaning methods were employed to search, identify, and clean erroneous data within the dataset. A complete list of all cleaning alterations to the database can be found in Appendix IV.

3.1.3.1 Cross-sectional cleaning

Data for each year group were initially cleaned cross-sectionally. This involved cleaning each variable individually. Firstly, all cases that were coded as "missing" were checked against the raw paper files. The dataset was then populated with any case that was found to not be missing in the paper files. Secondly, frequencies were run to check that all data values fell within the expected range, for example between 1 to 5 for all Tanner staging variables. If the value for any case fell outside of this range the paper file was cross-checked.

Once these initial data cleaning tasks were completed, cross-referencing with the bone health inventory was undertaken. For each year group an inventory is created during or at the end of the data collection wave when capturing commences. A database separate to that of the BH file is created that uses binary coding. Each questionnaire or measurement (e.g. DXA scan) that should have been completed in that data collection wave was recorded in the inventory under separate variables. For example, if an adolescent was seen at year 13 and completed the adolescent, anthropometric, and physical development in adolescence questionnaires, but did not complete the DXA scan they would be coded as 1 (complete) for the questionnaires and 0 (incomplete) for the DXA scan.

Creating this type of inventory allows cross-referencing once the raw data have been captured, to ensure that data have not been missed and other data not erroneously captured when the adolescent was seen but did not complete specific questionnaires. Cross-referencing was undertaken for each year group individually and identified a number of potential areas that required further investigation. Cases were flagged where data were found in the inventory file but were missing in the database and where data were found in the database but were missing in the inventory file. The raw data file was pulled for each case and erroneous data corrected and recaptured into the appropriate database or removed from the database if applicable. For year 13, no inventory had been created and this created the problem of not being able to cross-reference. A decision was therefore taken to check every case for year 13 against the paper file to ensure that no data were missed and also to create an inventory to help with future BH cleaning projects and data analysis.

Following on from the cross-reference cleaning, a 5% random sample for each year was extracted from the dataset and each variable checked against the raw paper files. A one

percent error limit was set; if this limit was exceeded data were cleaned as appropriate or populated and recaptured into the dataset. A further 5% random sample was then extracted and the process repeated. For years 9 and 10 three consecutive 5% random samples exceeded the 1% error limit within the datasets and so a decision was taken to pull and check every case for these time points to ensure that the physician assessed baseline measurements were accurate and reliable. Data were therefore completely re-entered for years 9 and 10.

3.1.3.2 Longitudinal cleaning

Once the cross-sectional cleaning had been completed, a single database containing all variables from each of the five time points was created, thus permitting longitudinal cleaning. The first step in the longitudinal cleaning process was to create flag variables. For example, to clean longitudinally between years 10 and 11 for Tanner breast ratings, the breast score from year 10 was subtracted from the breast score from year 11. All cases that were flagged as negative, so the child had effectively gone backwards in their development, were checked against the paper file. If the database was found to be correct, then the case would be cleaned using the baseline assessment of year 10 (physician assessed) as the correct rating as opposed to the year 11 (self-rated) rating. A systematic cleaning procedure was followed and all cases that were found to have gone backwards since the physician assessments (year 9 and/or year 10) were cleaned and the physician ratings taken to be correct (for example see Table 3.3, BoneID 123). Once a physician or adolescent had rated a score of 2 it was taken that there was evidence of pubic hair/genitalia or breast development and so subsequent ratings of 1 were increased to 2 (for example see Table 3.3, BoneID 688). For cases that had gone backwards between other years, the decision was taken to clean conservatively. Previous and future ratings were taken into account and if an adolescent had two prior or two post ratings that were the same, the erroneous rating was increased or decreased to the same score as the two consecutive ratings (for example see Table 3.3, BoneID's 660 and 552).

Table 3.3 Longitudinal cleaning examples for Tanner ratings

Bone ID	Yr 9 Tanner Rating		Yr 10 Tanner Rating		Yr 11 Tanner Rating		Yr 12 Tanner Rating		Yr 13 Tanner Rating	
	O	C	O	C	O	C	O	C	O	C
123	2		99		1	2	2		3	
688	99		1		2		2		1	2
660	1		3		3		2	3	3	
552	1		2		4	3	3		3	

O = original data, C = cleaned data, 99 = missing data

Recoding of the year 9, 10, and 11 menarcheal status questions occurred before they were cleaned longitudinally. At these three time points a specific date at menarche was obtained from the females (dd/mm/yyyy), from year 12 onwards the age in years at which menarche occurred was obtained. This provided an inconsistency when cleaning longitudinally. Therefore, age at menarche was calculated using the participant's date of birth and date of menarche for these three earlier data collection waves. Longitudinal cleaning for the menarche variables followed a similar procedure to that of the Tanner ratings. Flagged variables were created to highlight the females that had stated that they were menarcheal and then at a subsequent time point reported being pre-menarcheal. In addition, flag variables were created to highlight cases where females had reported different ages for their menarcheal initiation. Once a female had reported that she was menarcheal all subsequent reports of being non menarcheal were recoded to indicate that she was menarcheal. The earliest reported age at menarcheal initiation was taken to be correct in all cases.

Once the cross-sectional and longitudinal cleaning procedures had been completed a final 5% random sample check was run. Each case file was pulled and each variable at each time point checked against the raw paper file for these 5% of cases. The percentage of erroneous cases did not exceed the pre-determined error limit of 1% and so no further cleaning was required at any time point.

3.1.4 Quantitative analysis

3.1.4.1 Logistic curve fitting

Data analyses were undertaken using SPSS Version 14 (Chicago, IL). Logistic curves were fitted to cumulative percentage data to determine median age at pubertal initiation and median age at menarche. A logistic curve was selected as the most appropriate curve

shape, as the data were s-shaped in nature i.e. showed a dose-response curve. Equation 3.1 shows the equation used to fit the models and equation 3.2 shows the equation used to derive achievement percentiles.

$$y = 1/(1/u + (b0*(b1^t))) \quad (3.1)$$

$$t = \ln((1/y-1/u)/b0)/\ln b1 \quad (3.2)$$

Where y = % achieved, u = upper boundary (100%), b0 = b coefficient, b1 = constant and t = age (years)

3.1.4.2 Secular trend analysis

Data from several previous studies were used in order to investigate the evidence for a secular trend in age at menarche and age at pubertal initiation within urban South Africa. Tables 3.4 and 3.5 provide an overview of each of the studies included in the secular trend analysis. Ninety-five percent confidence limits were calculated from median and standard error or mean and standard deviation measures provided in previous studies. A linear regression was used to determine the rate of decline in age at menarche for Black girls. The gradient of the regression line represented the change per year and this was multiplied by ten to give a rate of change per decade. For the White girls, the difference in age between the two studies was divided by the number of years and the multiplied by ten to provide an estimate of change per decade. Whilst there are some differences in SES between the studies, perhaps reflective of the different methods used to assess SES, generally all of the studies were conducted within the urban Soweto-Johannesburg area and involved either Black and/or White adolescents (for a more detailed review of each of these studies please see Background: Section 2.5).

Table 3.4 A summary of the studies used within the secular trend analysis for age at menarche within urban South Africa

Reference	Year	(n)	Age of participants (Yrs)	Rural/Urban Status	Geographical Area	SES	Ethnic Group	Average age (†denotes median) at menarche (95% confidence interval)
Oettle and Higginson	1961	1002		Urban	Soweto-Johannesburg		Black	14.9 (14.8, 15.0)
Frere	1971	3150		Urban	Soweto-Johannesburg	Middle	Black	14.8† (14.7, 14.9)
Chaning-Pearce and Solomon	1987	355	3.5-18.5	Urban	Johannesburg		Black	13.9 (13.8, 14.0)
		362			Johannesburg		White	13.1 (13.0, 13.2)
Cameron and Wright	1988	148	6.0-19.0	Urban	Soweto-Johannesburg	High	Black	13.2 (13.0, 13.4)
Cameron, Grieve, Kruger and Leschner	1993	152	6.0-19.0	Urban	Soweto-Johannesburg	High	Black	13.2 (13.0, 13.4)
Norris and Richter	2005	69	11.0-16.0	Urban	Soweto-Johannesburg	Low/Mid	Black	13.0 (12.7, 13.3)
Current Study	1999-2005	188	9.0-15.0	Urban	Soweto-Johannesburg	Low/Mid	Black	12.4† (12.2, 12.6)
		99				High	White	12.5† (11.7, 13.3)

Table 3.5 A summary of the studies used within the secular trend analysis for age at pubertal initiation within urban South Africa

Reference	Year	(n)	Age of participants (Yrs)	Rural/Urban Status	Geographical Area	SES	Ethnic Group	Secondary Sexual Development			
								Boys		Girls	
								Genitalia	Pubic Hair	Breasts	Pubic Hair
								Average age (†denotes median) (95% confidence interval)			
Chaning-Pearce and Solomon	1987	355	3.5-18.5	Urban	Johannesburg		Black			11.5 (11.4, 11.6)	12.1 (12.0, 12.2)
		362			Johannesburg		White			11.5 (11.4, 11.6)	11.3 (11.2, 11.4)
Cameron and Wright	1988	148	6.0-12.0	Urban	Soweto-Johannesburg	High	Black			10.4 (10.3, 10.5)	
Cameron, Grieve, Kruger and Leschner	1993	152	6.0-19.0	Urban	Soweto-Johannesburg	High	Black	10.5 (10.3, 10.7)	12.4 (12.3, 12.6)		
		148								10.1 (10.0, 10.2)	10.1 (10.0, 10.2)
Norris and Richter	2005	182	10.0-18.0	Urban	Soweto-Johannesburg		Black	12.6 (12.2, 13.0)	12.4 (12.2, 12.6)	11.2 (11.0, 11.4)	11.5 (11.3, 11.7)
Current study	2007	607	9.0-14.0	Urban	Soweto-Johannesburg	Low/Mid	Black	10.4† (8.4, 12.4)	10.8† (09.6, 12.0)	10.1† (9.3, 10.9)	10.3† (9.3, 11.3)
						High	White	9.8† (9.4, 10.2)	10.2† (8.4, 12.0)	10.2† (8.2, 12.2)	10.5† (8.7, 12.3)

3.1.4.3 Bivariate analysis

Early (≤ median) and late (> median) achievement groups for menarche and pubertal initiation were created. Bivariate tests; independent t tests for continuous variables and Pearson's Chi^2 tests for categorical variables were undertaken to examine potential differences ($P < 0.05$ was used to assess statistical significance) between the two groups for the predictor variables of interest (i.e. birth weight, measures of body composition [see Appendix V for a complete list], and SES).

3.1.4.4 Principal component analysis

Principal component analysis (PCA) was used to create a birth and an end of childhood socio-economic index (9/10 years). Maternal education (completed high school vs. not completed high school) and maternal marital status (married or cohabiting vs. other) were kept as separate predictors as they have been shown to have significant independent effects on body composition at the end of childhood within this cohort (Griffiths et al. 2008). PCA is a data reduction technique which has been shown to be a valid and reliable method for the construction of socio-economic indices (Filmer & Pritchett 2001). Initially indices were constructed using both Black and White children; this was later changed to include only Black children due to a lack of SES data for White children, particularly at birth. There were a lack of SES data at birth for Whites, because the majority of these adolescents were newly recruited into the BH sample at 9/10 years and so it was inappropriate to collect retrospective data on household SES at the time of the infant's birth, due to poor recall reliability. Separate indices were constructed for the menarche and the pubertal initiation databases for Black adolescents only. Tables 3.6 and 3.7 show the scoring factors and the summary statistics for the SES variables in the first principal component for the menarche and pubertal initiation databases respectively. For the menarche database, 43.7% of the variance was explained by the birth SES index and the eigenvalue was 2.6. For the 9/10 year SES index, 47.7% of the variance was explained and the eigenvalue was 3.8. For the pubertal initiation database, 42.5% of the variance was explained by the birth SES index and the eigenvalue was 3.0. For the 9/10 year SES index, 46.8% of the variance was explained and the eigenvalue was 4.3. The values for the variance explained in the current study are higher than those in other papers which advocate the use of PCA such as Filmer and Pritchett (2001) who reported a value of 26%.

Table 3.6 Scoring factors and summary statistics for the SES variables in the first principal component in the menarche database at birth and at 9/10 years (for Black adolescents only)

Variable	Birth Index			9/10 Year Index		
	Scoring Factor	Mean	*SD*	Scoring Factor	Mean	*SD*
Water type (outside & other/inside)	0.66	0.57	0.50	0.74	0.69	0.47
Toilet type (outside & other inside flush)	0.61	0.34	0.47	0.72	0.56	0.50
Own TV (no/yes)	0.59	0.82	0.39	0.56	0.92	0.27
Own car (no/yes)	0.69	0.37	0.48	0.76	0.53	0.50
Own refrigerator (no/yes)	0.68	0.78	0.42	0.50	0.93	0.25
Own landline phone (no/yes)	0.73	0.66	0.47	0.62	0.74	0.43
Own video (no/yes)	N/A			0.78	0.59	0.49
Own microwave (no/yes)				0.79	0.49	0.50

Table 3.7 Scoring factors and summary statistics for the SES variables in the first principal component in the pubertal initiation database at birth and at 9/10 years (for Black adolescents only)

Variable	Birth Index			9/10 Year Index		
	Scoring Factor	Mean	*SD*	Scoring Factor	Mean	*SD*
Water type (outside & other/inside)	0.71	0.55	0.50	0.74	0.67	0.47
Toilet type (outside & other inside flush)	0.70	0.33	0.47	0.74	0.58	0.49
Own TV (no/yes)	0.57	0.80	0.40	0.43	0.94	0.23
Own car (no/yes)	0.70	0.36	0.48	0.78	0.50	0.50
Own refrigerator (no/yes)	0.60	0.78	0.41	0.43	0.93	0.25
Own landline phone (no/yes)	0.61	0.63	0.48	0.59	0.74	0.44
Own video (no/yes)	N/A			0.77	0.58	0.49
Own microwave (no/yes)				0.77	0.47	0.50

3.1.4.5 Logistic regression model building strategy and potential confounders

Following on from the bivariate analysis, logistic regression ($P < 0.05$ was used to assess statistical significance) was used to examine the associations between early life predictors (see Appendix V for a complete list) and age at menarche, age at breasts/genitalia initiation and age at pubic hair initiation. To examine the differences between the user-built models (i.e. using enter methods to include covariates into the analysis using a theoretically driven model building process) and statistically built models (i.e. stepwise methods where parameters are retained based on the strength of their statistical association with the outcome) several models were created. The final models were different, for forced stepwise entry when it was run forward and when it was run backward. This may be attributable to the fact that stepwise techniques are biased by random variation within the data and that it is difficult to replicate results of the same model within the sample (Field 2000). Therefore, the decision was taken to use previous theoretical knowledge from the literature to build user-constructed models by hand (enter method) rather than relying on statistical probability to

build models. Studenmund & Cassidy (1987) argue that for theory based models, the enter method is the only appropriate technique.

The logistic regression model building used in this thesis was theory driven. A detailed review of the literature highlighted a large number of factors that have been shown to be associated with the timing of pubertal development and age at menarche (see Background section 2.8 for a review of the literature). Each of factors highlighted in the literature was cross-referenced with the variables available for analysis in the BH database. An analysis database was then constructed containing each variable of interest. The initial analysis strategy looked at the association between each of the individual variables of interest against each of the outcome variables (menarche or breasts/genitalia or pubic hair). Those variables that were significantly ($P < 0.05$) associated with the outcome variables were retained in the analysis. As the multiple predictor models would include pre-, peri-, and post-natal variables a decision was taken to build the models in the order of which the variable was collected i.e. in chronological order so the birth variables were added into the model first, followed by the infancy variables and then the childhood variables.

Before the multiple predictor models were constructed a number of potential confounding influences needed to be taken into account. Whilst weight and height were significant independent predictors of age at menarche and the initiation of puberty, once combined they became insignificant, due to co-linearity within the two variables. A decision was taken to include weight and height in the analysis by keeping them in separate models, because previous literature has shown that both variables may be important for the timing of menarche/pubertal development. There was a similar problem with consecutive weight and height measurements due to a lack of independence between the measures, for example year 5 and year 8 weight were both individual significant predictors; however, once combined in the same model they became insignificant. Weight has been shown to track through infancy into childhood with this cohort (Cameron et al. 2007) i.e. a child who is heavy at 5 years is more likely to be heavy at 8 years or age. Therefore, weight and height at each time were kept in separate models. In each of the models that included a velocity variable i.e. weight velocity 5 to 8 years, a decision was taken to control for the starting body composition, so in this example weight at 5 years, to try and reduce the impact of initial body composition variability within the sample on velocity. Sex, a potential confounding variable, was entered into each of the models constructed for breasts/genitalia and pubic hair initiation. Sex was

not controlled for in the menarche models as the sample was female. As birth SES was not significantly associated with any of the outcome variables, it was not included in the multiple predictor models. Only year eight body composition data (height, weight, and BMI) were modelled with the year 9/10 SES index as it was deemed inappropriate to combine a measure of end of childhood SES with early life variables (i.e. year 5 height and weight etc) due to the transitioning economy within South Africa.

3.1.4.5.1 Logistic regression analysis – age at menarche

The binary outcome was early (≤ median) vs. late (> median) achievement of menarche. Each of the 50 predictor variables from birth through to 9/10 years was entered into individual logistic regression models (see Appendix V for a complete list). A total of 13 of these variables were significant ($P < 0.05$) individual predictors of age at menarche (BMI at years 1, 2, 4, 5 and 8; weight at years 2, 4, 5 and 8; height at years 4 and 8; weight velocity between 5 and 8 years and SES index at 9/10 years). As there were no confounding variables that needed to be controlled for in the menarche models and the fact that height and weight could not be put into the same model, the significant early life measures (i.e. BMI at 1, 2, and 4 years and weight at 2 and 4 years) were not included in the multiple predictor analysis, but rather left as individual predictors. A total of four models were constructed (A-D) for age at menarche; model A = year 5 weight + weight velocity 5 to 8 years, model B = year 8 weight + year 9/10 SES index, model C = year 8 height + year 9/10 SES index, model D = year 8 BMI + year 9/10 SES index.

3.1.4.5.2 Logistic regression analysis – initiation of puberty

The binary outcomes were early (≤ median) vs. late (> median) achievement of breasts/genitalia development and early (≤ median) vs. late (> median) achievement of pubic hair development. Each of the 50 potential predictor variables was added separately into logistic regression models for the two outcomes (see Appendix V for a complete list of variables). A total of four variables (weight and height velocities from 5 to 8 years, SES index at 9/10 years and the primary caregiver's marital status at 9/10 years) were individually significantly ($P < 0.05$) associated with early breasts/genitalia initiation, these were then used to build multiple predictor models. A total of seven models were constructed (A-F) for age at breasts/genitalia initiation: model A = sex + year 5 weight + weight velocity 5 to 8 years,

model B = sex + yr 5 height + height velocity 5 to 8 years, model C = sex + year 5 weight + weight velocity 5 to 8 years + Year 9/10 SES index, model D = sex + year 5 height + height velocity 5 to 8 years + Year 9/10 SES index, model E = sex + caregiver marital status Year 9/10 + Yr 9/10 SES index, model F = sex + year 5 weight + weight velocity 5 to 8 years + caregiver marital status Year 9/10 and model G = sex + year 5 height + height velocity 5 to 8 years + caregiver marital status Yr 9/10. A total of 12 variables (weight velocities from 0 to 12 months, 1 to 2 years, 2 to 4 years and 5 to 8 years; weight at years 1, 2, 4 5 and 8; height at years 4, 5 and 8; and BMI at year 8) were significantly ($P < 0.05$) associated with age at pubic hair initiation. From this a total of nine multi-predictor models were constructed: model A = sex + birth weight + weight velocity 0 to 12 months, model B = sex + year 1 weight + weight velocity 1 to 2 years, model C = sex + year 2 weight + weight velocity 2 to 4 years, model D = sex + year 4 weight, model E = sex + year 4 height, model F = sex + year 5 weight + weight velocity 5 to 8 years, model G = Sex + year 8 weight, model H = sex + year 8 height and model I = sex + year 8 BMI.

3.2 Qualitative research

3.2.1 The use of focus groups with adolescents

Focus groups have been shown to be an important and useful vehicle to help gain adolescent perspectives on health and well-being (Peterson-Sweeney 2005), particularly for sensitive issues (Morgan 1997) such as discussions relating to pubertal development. There are numerous studies within the literature that have examined sensitive topics with adolescents using focus group techniques, these typically relate to amongst others, eating behaviours, teenage pregnancy, sex and sexuality, substance abuse, HIV-related risk behaviours and living with chronic disease (see for example Brown et al. 1998, Hinds et al. 1999, Neurman-Sztainer et al. 1999, Aquilino & Bragadottir 2000, Weinger, O'Donnell & Ritholz 2001).

There are several important considerations that should be taken into account when conducting focus groups with adolescents, in particular, communication skills of the participants, the sensitivity of the topic, peer influence on group dynamics, group composition, and the interview structure (Horner 2000, Peterson-Sweeney 2005). This is to try and help to enhance participation and data quality. In order to participate in a focus

group, the participants must have basic communication skills. The level of communication skills need to be considered when planning the interview structure, particularly when interviewing adolescents as they may not have the same cognitive competence as adults (Graue & Walsh 1998, Dixon, Stein 2000). Adolescents are used to articulating responses to questions in the classroom setting; however, open ended interview questions can prove difficult and so responses are typically monosyllabic (Dixon & Stein 2000). In contrast, when asked to describe specific experiences, adolescents often give complete, descriptive responses (Horner 2000). Given this, the interview or question route for adolescent focus groups should be semi-structured and should avoid open ended questions.

Peers have a pervasive influence on group dynamics in focus groups because adolescents are particularly sensitive to the reactions and opinions of others (Bagwell, Newcomb & Bukpwski 1998, Richards et al. 1998). As adolescence progresses, peers become primary role models (Richards et al. 1998) and so peer approval becomes a major concern (Conrad & Horner 1997). This has the potential to influence focus groups as adolescents with differing views from their peers may withhold or be more open with comments in a bid to conform to "socially accepted norms" or to appear more like their peers (Horner 2000). Therefore, the composition of focus groups must be carefully considered prior to recruitment. For example, groups should be gender specific as they experience different maturational events during puberty (Warren 1988) and so may be uncomfortable discussing sensitive topics with members of the opposite sex (Balmer et al. 1997). In addition, it may be advantageous to split the participants according to their maturational status as late developers may feel inhibited by earlier developers, who may have already experienced certain maturation events such as menarche.

There are some disadvantages to using focus groups with adolescents, which typically relate to group composition and topic. Some topics may not be suitable to discuss in a group setting such as sexuality, sexual initiation, and substance misuse (Morgan 1996). In addition, peer status can cause polarisation of groups where dominant, higher status individuals try to dominant and lead the discussion (Morgan 1996). It is important that moderators are trained in how to deal with dominant participants to ensure that this type of problem does not influence the quality of the data collected from focus groups. Although there are some disadvantages, it appears that the data that emerge from well designed focus

groups have the potential to provide unique insights into the collection of pubertal development data.

3.2.2 Aim of the qualitative work

Focus groups were conducted to help inform the current Bt20 pubertal development data collection procedures, to highlight potential areas for improvement and to increase awareness of the knowledge and understanding of the terms "adolescent" and "pubertal development" in urban South African Black adolescents, as well as Bt20 and BH staff who administer the current "physical development in adolescence" questionnaire.

3.2.3 Objectives of qualitative work

There were three main objectives of the qualitative work:

(a) To elicit a range of views and opinions on pubertal/adolescent development and the current assessment questionnaire and procedures from urban Black South African male and female adolescents at varying stages of maturity and from a range of socio-economic backgrounds.

(b) To elicit a range of views on pubertal/adolescent development and the current assessment questionnaire and procedures from Bt20 and BH staff.

(c) To inform the current questionnaire and procedure for assessing pubertal development in urban, South Africa.

3.2.4 Rationale for conducting community, adolescent, and staff focus groups

It was considered important to collect data from community adolescents, Bt20 adolescents, and Bt20/BH staff as they may have different views on the current Bt20 pubertal development questionnaire and procedure. Community adolescents were friends of current Bt20 adolescents who attended the same school, lived in the same area, and were of a similar age. These adolescents were recruited to participate in focus groups as they provided a unique insight into urban South African adolescents' knowledge and understanding of pubertal development. They were considered different to Bt20 adolescents, as they had not been previously exposed to the current Bt20 pubertal development questionnaire or procedure. By comparison Bt20 adolescents, may have seen these

questionnaires upwards of six times, thus these adolescents may elicit different responses regarding knowledge of pubertal development and regarding the current questionnaire. The overall aim of recruiting both types of adolescents was to elicit a range of responses from adolescents who had seen the questionnaire on previous occasions and from those who had only completed it just prior to the focus group. Staff were recruited as they use the questionnaire differently to the adolescents, as they administer it, rather than complete it. In addition staff see the questionnaire on a daily basis with a large number of different adolescents from the cohort, compared to Bt20 adolescents who see it annually. They offered a unique viewpoint about potential issues with the questionnaire and procedure, in addition to potentially being able to offer solutions.

3.2.5 Focus group organisation

The focus groups were lead by the main researcher and a group of five staff. Focus groups were lead by same sex moderators and with same sex note-takers (with the exception of the staff focus groups which were mixed). Participants were seated around a central table and were audio-recorded with informed consent. The moderators of the pilot and adolescent focus groups inter-changed between English and other local vernaculars and the participants were free to respond in whichever language they felt articulated their point most clearly. The staff focus groups were conducted solely in English as all staff participants spoke fluent English. The length of the focus groups was limited to 90 minutes.

3.2.6 Interviewer and note-taker training

A total of five fieldworkers (three female) were employed in addition to the main researcher as the adolescent focus groups were not conducted entirely in English. This was to try and foster an environment in which the adolescents felt most comfortable expressing themselves in their native tongue. Two fieldworkers (one female) were employed to moderate the focus groups, as they had experience in conducting interviews prior to the current study and the other three fieldworkers (two female) were employed as note-takers. Training took place with the main researcher prior to all focus groups and topics included: how to conduct focus groups, the role of the moderator and note taker, and how to deal with difficult or quiet participants. All fieldworkers were multilingual speaking English, Zulu, and Sotho amongst other local vernaculars and had good speaking, listening and handwriting skills.

3.2.7 Recruitment

Sampling of the adolescents was purposive and was undertaken by the main researcher and a team of four staff who spoke English and a range of other local vernaculars. All Black Bt20 adolescents that had been seen in the Year 15 data collection wave and had completed the physical development in adolescence questionnaire were identified (n = 1403). Using the physical address***** data within the bone health address database, the suburb of residence for each adolescent was identified and categorised into low or mid/high socio-economic status. Those adolescents who resided in richer Soweto neighbourhoods or in the suburbs were classified as mid/high SES and those who lived in shacks or matchbox housing were classified as low SES. These categories were established by the recruitment team using their contextual knowledge of the local area. The categorisation by SES was to ensure that adolescents from a range of socio-economic backgrounds were present in each focus group.

3.2.8 Community adolescent focus groups

3.2.8.1 Recruitment

A total of 50 adolescents (15 mid/high SES females, 15 mid/high SES males, 10 low SES females and 10 low SES males) were randomly selected from the database and contacted telephonically. The adolescents were asked if they had a friend or relative that may be interested in participating in a discussion group about adolescence and puberty at the Baragwanath Hospital, Soweto. There were several criteria that had to be met for the "community" adolescents: they had to be between the ages of 14 and 16 years, of Black African ethnic origin and of the same sex and live within the same area as the randomly selected Bt20 adolescent. If the Bt20 adolescent had a friend or sibling who was interested and met the selection criteria, the recruitment team then contacted the "community" adolescent telephonically. The recruitment staff continued to contact Bt20 and "community" adolescents until at least 12 females (5 low SES and 7 mid/high SES) and 12 males (5 low SES and 7 mid/high SES) had been successfully recruited. The over recruitment of mid/high SES was suggested by the recruitment team who had experience of recruiting similar groups for previous focus groups and had found that these were the individuals who were less likely

***** Physical address refers to the place of residence where the individual spends the majority of their time and where they sleep most regularly.

to present on the day. Thus the overall aim was to have approximately equal numbers of low and mid/high SES adolescents within each focus group.

3.2.8.2 Question route development

Four main themes were developed within the adolescent focus groups (for a copy of the question route see Appendix VI):

(1) Ascertaining a definition of puberty and adolescence
(2) Investigating how the adolescents feel about puberty and growing up
(3) Views on the current pubertal/adolescent development questionnaire and Bt20 procedures and potential areas for change
(4) Examining where the adolescents learned about puberty and with whom they discuss emotional/physical changes

3.2.8.3 Focus groups

The two community adolescent focus groups (one male n = 6 and one female n = 9) were run as "pilots" using the adolescent focus group question route to establish its acceptability to this age group in this setting. In addition it was used to see if alterations needed to be made to the wording, questions, probes, and/or question order. They also provided the moderators and note-takers with an opportunity to practice their skills and to ensure that they understood the intent and meaning of the questions. The main researcher was present during the female community focus group.

3.2.9 Bt20 adolescent focus groups

3.2.9.1 Recruitment

Recruitment took place in May 2006. All Bt20 adolescents who had been contacted as part of the community focus group recruitment were excluded from selection for the adolescent focus groups. This was to try and reduce potential response bias through communication between the "community" adolescent and the Bt20 adolescent. Further selection criteria were included when identifying potential participants for the adolescent focus groups. The adolescents were split according to their Year 15 Tanner rating (these data were collected between September 2005 and March 2006) for breast development in females and genitalia

development in males. Those adolescents who were in Tanner stages 1 to 3 were classified as "in early puberty" and those that were in Tanner stages 4 and 5 were classified as "in late puberty". This allowed homogenous recruitment of early and late pubertal groups. A total of 160 adolescents were randomly selected from the database in the following eight groups:

(A) 20 females, early puberty, low SES
(B) 20 females, early puberty, mid/high SES
(C) 20 females, late puberty, low SES
(D) 20 females, late puberty, mid/high SES
(E) 20 males, early puberty, low SES
(F) 20 males, early puberty, mid/high SES
(G) 20 males, late puberty, low SES
(H) 20 males, late puberty, mid/high SES

The recruitment staff contacted adolescents telephonically until at least: 12 early puberty females (5 low SES and 7 mid/high SES), 12 late puberty females (5 low SES and 7 mid/high SES), 12 early puberty males (5 low SES and 7 mid/high SES) and 12 late puberty males (5 low SES and 7 mid/high SES) had been successfully recruited

3.2.9.2 Question route development

The same question route was used for both the community and Bt20 adolescent focus groups. See section 3.2.8.2 for a summary of the main topics.

3.2.9.3 Focus groups

A total of four adolescent focus groups were conducted:

(1) Early puberty (Tanner stages 1-3) female (4 low/8 mid-high SES) (n = 12)
(2) Late puberty (Tanner stages 4-5) female (5 low/ 5 mid-high SES/ 1 missing) (n = 13)
(3) Early puberty (Tanner stages 1-3) males (7 low/ 6 mid-high SES) (n = 13)
(4) Late puberty (Tanner stages 4-5) males (7 low/ 6 mid-high SES) (n = 13)

Background questionnaires on contact information, socio-economic status, and physical development in adolescence were completed before the commencement of the focus group (See Appendix VII).

3.2.10 Staff focus groups

3.2.10.1 Recruitment

Through discussions between the main researcher and a Bt20 senior researcher, staff who were regularly involved in pubertal development data collection were identified. A total of eight staff (five female) were contacted and all agreed to participate.

3.2.10.2 Question route development

Four main themes were developed within the staff focus groups (for a complete copy of the question route see Appendix VI):

(1) Investigating the key concepts about puberty and adolescence
(2) Ascertaining views on the current (and past) Birth to Twenty procedures for the collection of pubertal development data
(3) Identification of issues/problems with the current procedures for collecting pubertal development data
(4) Identification of a potential for change in the procedures for collecting pubertal development data

3.2.10.3 Focus groups

Within Bt20 there are two different sites where the adolescents and their caregivers attend for data collection, (Baragwanath hospital (Bara), Soweto and the University of the Witwatersrand Medical School, Johannesburg). Typically, Bt20 adolescents attend the Baragwanath hospital and BH adolescents attend the Medical School site. Due to this split, two separate staff focus groups were conducted, one with Bara staff and one with medical school staff (BH staff). This was to establish if there were differences in opinions between the two groups. The Bara staff focus group consisted of four participants (two female). The BH staff focus group also consisted of four participants (three female). The main researcher moderated the staff focus groups with a female note taker and they were undertaken prior to

the pilot and adolescent focus groups, so as not to bias the moderation of the staff focus groups. This was because the majority of the staff participants were involved in conducting the adolescent focus groups.

3.2.11 Qualitative analysis

The South African female note taker transcribed the adolescent focus groups verbatim and then translated them into English. Where the interaction was in English the transcripts were cross-checked by the main researcher for transcription errors. The staff focus groups were transcribed in the UK and were cross-checked by the main researcher. Due to time restrictions for completion of this thesis, only the methodology section of the focus groups was analysed. An interpretive descriptive approach was used for analysis. Through repetitive reading of the transcripts, main and sub themes were identified and tree-nodes (diagrammatic hierarchies) were established to allowing coding of these data (see Appendix VIII for a copy of the full codebook). In order to provide some validation of the codebook, double coding was employed, discrepancies discussed and changes were made where appropriate (see Appendix IX for a full copy of this discussion and subsequent codebook changes).

3.3 Ethics

Birth to Twenty (originally Birth to Ten) acquired ethical approval before the initiation of data collection through a human subject's clearance issued by the University of the Witwatersrand, South Africa. The Bone Health study gained approval by the Committee for Research on Human Subjects of the University of the Witwatersrand, South Africa (protocol number: M980810). The current analysis has been approved by the ethical committee of the Department of Human Sciences at Loughborough University, United Kingdom. Informed consent was obtained from both the caregiver and the adolescent for each part of the assessment procedure at each time point for the quantitative analysis. For the qualitative analysis informed consent was obtained from the caregiver telephonically and from the adolescent prior to the focus group.

4 Quantitative Results

4.1 Menarche Results

This section provides quantitative results including: age at menarche, evidence for a secular trend in age at menarche and demographic, socio-economic, and early growth characteristics as predictors of age at menarche of Black females within the Birth to Twenty (Bt20) Bone Health (BH) sub-sample.

4.1.1 Menarche Sample

The sample sizes and cumulative percentage of those who had achieved menarche by age are presented for Black and White females and the entire sample in Table 4.1. No females, of either ethnic group reported having achieved menarche before 10.99 years. There was a clear degree of similarity in the proportion of Black and White girls who had achieved menarche at each time point from 11 years onwards. There were no statistically significant differences in the proportion of females who had achieved menarche between ethnic groups at any time point.

Table 4.1 Total sample size and cumulative percentage of those who had achieved menarche for Black, White and the combined sample of girls from 9 to 14 years of age

Age (years)	Black		White		Whole Sample	
	Total n	% Achieved Menarche	Total n	% Achieved Menarche	Total n	% Achieved Menarche
9	118	0.0	24	0.0	142	0.0
10	164	0.0	66	0.0	230	0.0
11	118	10.2	33	6.2	151	8.9
12	159	36.4	70	38.5	229	37.0
13	165	68.8	67	75.3	232	70.8
14	170	92.0	76	89.7	246	91.3

4.1.2 Deriving age at menarche

Figure 4.1 shows the logistic curves that were fitted to cumulative percentage data for age at menarche for Black (Figure 4.1a) and White girls (Figure 4.1b) respectively. Median age at menarche derived from these curves was 12.4 years (SEE = 0.1; 95% CI = 12.2, 12.6) for Black girls and 12.5 years (SEE = 0.4; 95% CI = 11.7, 13.3) for White girls. There was no statistically or biologically significant difference in age at menarche between Black and White girls within this urban South African cohort.

Figure 4.1 Logistic curves fitted to cumulative percentage data for age at menarche for Black and White girls

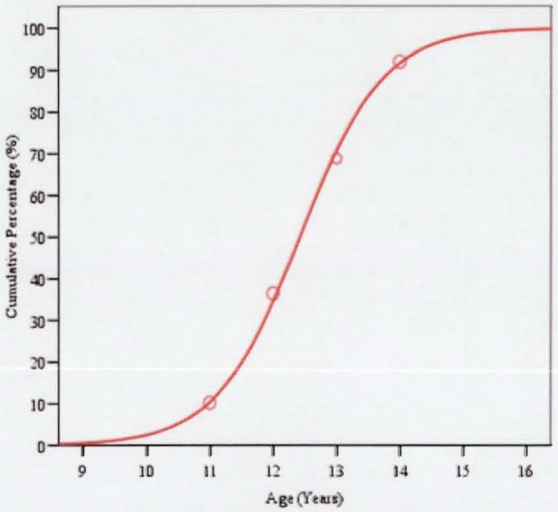


Figure 4.1a (Blacks)

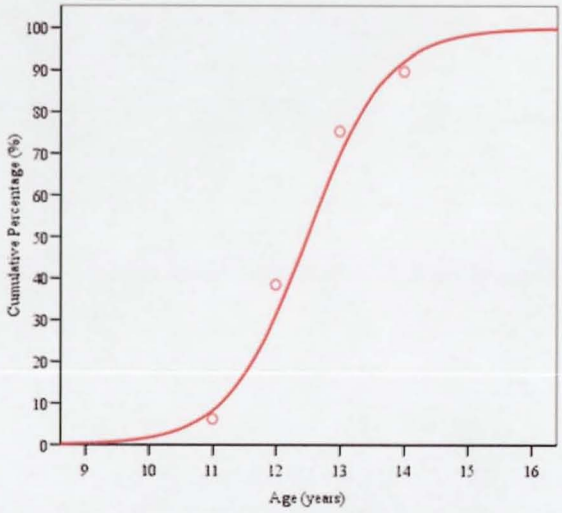


Figure 4.1b (Whites)

Table 4.2 shows the derived percentiles for age at which menarche was achieved for Black and White females. Fifty percent of Black girls achieved menarche between 11.7 and 13.2 years, a range of 1.5 years; compared to 11.8 and 13.2 years, a range of 1.4 years for White girls.

Table 4.2 Percentile estimations for age at menarche for Black and White females

Menarche Percentiles	Black Girls (Years)	White Girls (Years)
10	11.0	11.1
25	**11.7**	**11.8**
33	12.0	12.0
50	**12.4**	**12.5**
66	12.9	12.9
75	**13.2**	**13.2**
90	13.9	13.8

4.1.3 Demographic, socio-economic and growth characteristics of the menarche analysis sample, split by ethnicity

Within this sample, there was no statistically significant difference in age at menarche between Black and White. Table 4.3 shows the key demographic, socio-economic and growth characteristics of the menarche sample split by ethnic group. There were several differences between Black and White girls, with White girls experiencing a significantly longer gestation (39.4 vs. 38.0 weeks) compared to Black girls. White girls were also significantly taller at nine years (136.3 vs. 133.0 cm), ten years (145.0 vs. 142.8 cm), 11 years (148.3 vs.

145.0 cm), 12 years (155.4 vs. 150.9 cm), 13 years (160.2 vs. 155.0 cm), and 14 years (163.0 vs. 156.9 cm). This represents an average height difference of 3-5 cm through the early years of adolescence; however, there were no differences in weight or BMI between the two Ethnic groups. Socio-economic status (SES) was also significantly higher for White girls compared to Black girls when assessed using proxy measures such as maternal education, maternal marital status and an SES index (see Methods section 3.1.2.5 for notes on how this index was created) at 9/10 years. At birth and 9/10 years, White girls mothers were significantly more likely to be married or cohabiting (Birth: 87.8 vs. 20.2%; 9/10 years: 80.7 vs. 40.3%) and significantly more likely to have completed high school (Birth: 93.7 vs. 42.2%; 9/10 years: 86.4 vs. 55.0%†††). White girls were also significantly more likely to be in the high SES index category at 9/10 years (97.7 vs. 25.8%) for Black girls.

4.1.4 Secular trends in age at menarche

Figure 4.2 shows average menarcheal age of Black and White urban South African females from the Soweto-Johannesburg area between 1961 and 2007. Data from six previous studies of age at menarche of girls born in the Soweto-Johannesburg area were used in combination with data from the current study (for further information on these studies please see Background 2.5) (Oettle & Higginson 1961, Frere 1971, Cameron & Wright 1990, Cameron et al. 1993, Norris & Richter 2005). Fitting a linear regression to these data provides evidence for a statistically significant positive secular trend towards earlier menarche in Black, but not for White females. Average menarcheal age for Black females has decreased from 14.9 years (95% CI = 14.8, 15.0) in 1961, to 13.9 years (95% CI = 13.8, 14.0) in 1987, to 12.4 years in the current study. This represents an average decline (the slope of the regression line) of 0.56 years per decade. There were relatively less data available for White girls, but average age at menarche has decreased from 13.1 years (95% CI = 13.0, 13.2) in 1987 to 12.5 years in the current study, an average decline of 0.32 years per decade. There appears to be a diminishing difference in age at menarche between Black and White females within urban South Africa.

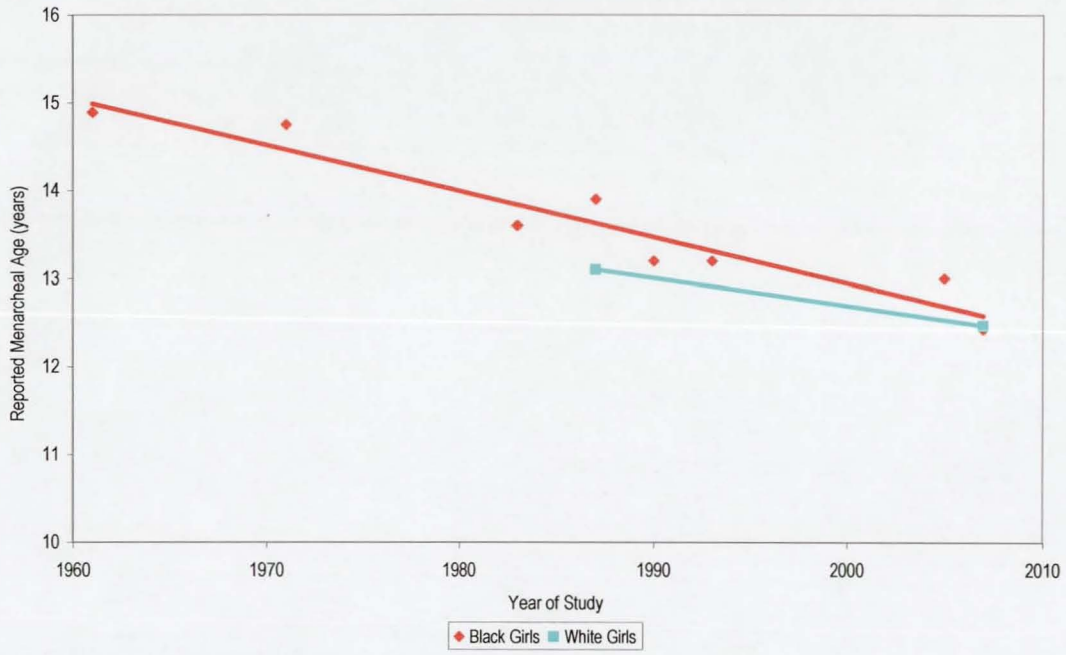
††† Please note that maternal education at 9/10 years is lower than that reported at birth for White girls as this question was asked specifically of the mother at birth and of the primary caregiver at 9/10 years. Therefore, the primary caregiver at year 9/10 may not necessarily be the biological mother of the child.

Table 4.3 Key peri-natal and post-natal growth characteristics of the menarche sample split by ethnic group

Variable	n	Black Grils	n	White Girls
Birth Weight (g) (Mean [SD])	186	3022.7 (495.8)	89	3136.8 (444.6)
Low Birth Weight (% [95% CI])		13.4 (8.5,18.3)		9.0 (3.0,14.9)
Gestational Age (Weeks) (Mean [SD])	188	38.0 (1.8)	88	39.4 (1.7)***
Pre-term (<36 Weeks) (% [95% CI])		16.0 (10.7,21.2)		9.1 (3.1,15.1)
Term (37,41 Weeks) (% [95% CI])		83.5 (78.2,88.8)		85.2 (77.8,92.6)
Small For Gstational Age (% [95% CI])	183	10.9 (6.4,15.4)	55	12.7 (3.9,21.5)
Parity				
Primaparous (% [95% CI])	187	46.5 (39.4,53.7)	91	47.3 (37.0,57.5)
Non,primaparous (% [95% CI])		53.5 (46.3,60.6)		52.7 (42.5,63.0)
Weight at 9 Years (kg) (Mean [SD])	143	29.9 (6.6)	37	30.4 (6.7)
Height at 9 Years (cm) (Mean [SD])		133.0 (5.8)		136.3 (6.9)**
BMI at 9 Years (kg/m2) (Mean [SD])		16.8 (2.9)		16.2 (2.2)
Weight at 10 Years (kg) (Mean [SD])	158	34.8 (8.3)	59	35.9 (8.2)
Height at 10 Years (cm) (Mean [SD])		139.2 (6.3)		142.8 (7.9)**
BMI at 10 Years (kg/m2) (Mean [SD])		17.8 (3.4)		17.4 (2.5)
Weight at 11 Years (kg) (Mean [SD])	172	39.1 (9.5)	68	41.2 (11.6)
Height at 11 Years (cm) (Mean [SD])		145.0 (6.8)		148.3 (8.0)**
BMI at 11 Years (kg/m2) (Mean [SD])		18.5 (3.7)		18.1 (2.8)
Weight at 12 Years (kg) (Mean [SD])	165	44.6 (10.4)	77	46.8 (11.0)
Height at 12 Years (cm) (Mean [SD])		150.9 (7.4)		155.4 (7.8)***
BMI at 12 Years (kg/m2) (Mean [SD])		19.5 (3.9)		19.3 (3.4)
Weight at 13 Years (kg) (Mean [SD])	160	49.7 (10.8)	66	51.9 (10.7)
Height at 13 Years (cm) (Mean [SD])		155.0 (5.9)		160.2 (6.8)***
BMI at 13 Years (kg/m2) (Mean [SD])		20.6 (4.0)		20.1 (3.3)
Weight at 14 Years (kg) (Mean [SD])	168	53.7 (11.2)	74	55.1 (10.6)
Height at 14 Years (cm) (Mean [SD])		156.9 (5.6)		163.0 (6.7)***
BMI at 14 Years (kg/m2) (Mean [SD])		21.8 (4.2)		20.8 (3.4)
Maternal Age at Birth (Years) (Mean [SD])	188	25.1 (6.0)	92	29.4 (4.7)***
Maternal Education at Birth				
< Grade 10/ High School (% [95% CI])	185	57.8 (50.7,65.0)	79	6.3 (1.0,11.7)***
> Grade 10/ High School (% [95% CI])		42.2 (35.0,49.3)		93.7 (88.3,99.0)***
Maternal Marital Status at Birth				
Married/ Cohabiting (% [95% CI])	188	20.2 (14.5,26.0)	90	87.8 (81.0,94.5)***
Not married/ Cohabiting (% [95% CI])		79.8 (74.0,85.5)		12.2 (5.5,19.0)***
Maternal Education at 9/ 10 Years				
< Grade 10/ High School (% [95% CI])	180	45.0 (37.7,52.3)	88	13.6 (6.5,20.8)**
> Grade 10/ High School (% [95% CI])		55.0 (47.7,62.3)		86.4 (79.2,93.5)**
Maternal Marital Status at 9/ 10 Years				
Married/ Cohabiting (% [95% CI])	181	40.3 (33.2,47.5)	88	80.7 (72.4,88.9)***
Not married/ Cohabiting (% [95% CI])		59.7 (52.5,66.8)		19.3 (11.1,27.6)***
SES Index at 9/ 10 Years				
Low (% [95% CI])	182	74.2 (67.8,80.5)	88	2.3 (0.0,5.4)***
High (% [95% CI])		25.8 (19.5, 32.2)		97.7 (94.6,100.0)

* P < 0.05, ** P < 0.01, *** P < 0.001

Figure 4.2 Menarcheal age of urban Black and White South African females from the Soweto-Johannesburg area between 1961 and 2007



Data Sources: Oettle and Higginson 1961; Frere 1971; Chaning-Pearce & Solomon 1987; Cameron & Wright 1990; Cameron, Grieve, Kruger & Leschner 1993; Norris & Richter 2005, and the current study

4.1.5 Associations between demographic, socio-economic and growth characteristics and age at menarche

Table 4.4 shows the key peri-natal and post-natal growth characteristics of Black females, grouped by early (≤12.43 years) and late (≥12.44 years) achievement of menarche. There were several statistically significant differences between the early and late groups. BMI at one year of age was significantly higher (18.1 vs. 17.2kg/m^2) for early maturing girls compared to late maturing girls. Early maturing girls being significantly heavier (11.9 vs. 11.2kg) and had a greater BMI (17.4 vs. 16.5kg/m^2) at two years of age and this trend continued at four years with early maturing girls being significantly heavier (16.0 vs. 14.9kg) taller (100.0 vs. 97.7cm) and having a greater BMI (15.9 vs. 15.4 kg/m^2) than late maturing girls. Late maturing girls were significantly more likely to be stunted at four years of age (11.7 vs. 1.8%). By five years of age early maturing girls remained significantly heavier (19.0 vs. 17.8kg) and had a greater BMI. At eight years of age early maturing girls were also significantly heavier (26.2 vs. 23.8kg), taller (125.7 vs. 123.0cm) and had a greater BMI (16.5 vs. 15.7kg/m^2) compared to later maturing girls. Weight velocity‡‡‡ from five to eight years

‡‡‡ weight velocity (kg/yr^{-1}) = $(Wt_2 - Wt_1)/(Age_2 - Age_1)$

was also significantly greater (2.3 vs. 2.0 kg/yr^{-1}) for early maturing girls. There were several other trends within these data, although they were not statistically significant. These trends are reported within this thesis as there is evidence of consistent differences between the groups across time, suggesting that whilst there is no statistical difference, there may be biological differences. Early maturing girls were more likely to be born LBW (15.6 vs. 11.6%), SGA (11.3 vs. 9.9%) and to experience catch up growth in the first two years of life (34.2 vs. 19.5%) compared to late maturing girls. Weight velocity was greater between birth and 1 year (6.4 vs. 6.0kg/yr^{-1}), six to 12 months (3.5 vs. 3.1kg/yr^{-1}), birth to two years (4.3 vs. 4.0 kg/yr^{-1}), one to two years (2.2 vs. 2.0 kg/yr^{-1}), two to four years (2.1 vs. 2.0 kg/yr^{-1}), four to five years (2.6 vs. 2.5 kg/yr^{-1}) and five to eight years (2.4 vs. 2.0 kg/yr^{-1}). This trend was also true for height velocity[§§§], with the exception of six to 12 months where late maturers had a greater growth rate (13.6 vs. 18.7 cm/yr^{-1}) and four to five years (7.5vs. 7.6 cm/yr^{-1}). Early maturers had a greater velocity one to two years (9.5 vs. 9.3 cm/yr^{-1}), two to four years (8.9 vs. 8.3 cm/yr^{-1}) and five to eight years (5.6 vs. 5.3 cm/yr^{-1}). Early maturers were also more likely to be classified as overweight and/or obese in childhood (two years 31.8 vs. 18.9%; four years 12.3 vs. 4.9%; five years 14.6 vs. 10.5%), this trend reverses by eight years of age (3.8 vs. 7.1%). Early maturing girls had on average, a higher BMI compared to late maturing girls throughout infancy and childhood within this cohort.

Table 4.5 shows the key socio-economic characteristics of Black girls, grouped by early and late achievement of menarche. Whilst there were no statistically significant differences, the primary caregiver of early maturing girls were less likely to be married/cohabiting at the time of their daughter's birth (15.4 vs. 21.2%); however, by 9/10 years they were more likely to be married/cohabiting (48.4 vs. 34.9%) compared to later maturing girls. In addition, primary caregivers of early maturing girls were more likely to have completed high school at both the time of their daughter's birth (56.3 vs. 41.4%) and when they were 9/10 years of age (54.8 vs. 53.7%) compared to later maturing girls. At year 9/10, early maturing girls were more likely to have a higher level of SES as measured by an index of SES variables (59.7 vs. 42.7%) compared to late maturing girls.

[§§§] Height velocity (cm/yr^{-1}) = $(Ht_2 - Ht_1)/(Age_2 - Age_1)$

Table 4.4 Key peri-natal and post-natal growth characteristics of Black females grouped by early and late achievement of menarche

Variable	n	Early Menarche	n	Late Menarche
Birth Weight (g) (Mean [SD])		3.0 (0.4)		3.0 (0.5)
Low Birth Weight (% [95% CI])	64	15.6 (6.7, 24.5)	112	11.6 (5.7, 17.5)
Average Birth Weight (% [95% CI])		84.4 (75.5, 93.3)		86.6 (80.3, 92.9)
High Birth Weight (% [95% CI])		0.0 (0.0, 0.0)		1.8 (0.0, 4.2)
Gestational Age (Weeks) (Mean [SD])		37.8 (1.7)		38.0 (2.0)
Pre-term (<36 Weeks) (% [95% CI])	65	15.4 (6.6, 24.2)	111	16.8 (9.9, 23.7)
Term (37-41 Weeks) (% [95% CI])		84.6 (75.8, 93.4)		82.3 (75.3, 89.3)
Post-term (>42 weeks) (% [95% CI])		0.0 (0.0-0.0)		0.9 (0.0, 2.6)
Size For Gestation				
Appropriate for Gestational Age (% [95% CI])	62	88.7 (80.8, 96.6)	111	90.1 (84.5, 95.6)
Small For Gestational Age (% [95% CI])		11.3 (3.4, 19.2)		9.9 (4.4, 15.5)
Parity				
Primaparous (% [95% CI])	65	47.7 (35.5, 59.8)	112	59.8 (50.7, 68.9)
Non-primaparous (% [95% CI])		52.3 (40.2, 64.5)		40.2 (31.1, 49.3)
Weight at 1 Year (kg) (Mean [SD])		9.6 (1.7)		9.1 (1.4)
Height at 1 Year (cm) (Mean [SD])	41	72.6 (3.2)	78	72.5 (3.2)
BMI at 1 Year (kg/m2) (Mean [SD])		18.1 (2.2)		17.2 (1.8)*
Height for Age at 1 Year				
Stunted at 1 Year (% [95% CI])	41	4.9 (0.0, 11.5)	78	11.5 (4.4, 18.6)
Not Stunted at 1 Year (% [95% CI])		95.1 (88.5, 100.0)		88.5 (81.4, 95.6)
Weight Velocity 0 to 12 Months (kg/yr^{-1}) (Mean [SD])	41	6.4 (1.3)	78	6.0 (1.2)
Weight Velocity 6 to 12 Months (kg/yr^{-1}) (Mean [SD])	5	3.5 (1.2)	19	3.1 (1.4)
Height Velocity 6 to 12 Months (cm/yr^{-1}) (Mean [SD])		13.6 (4.6)		18.7 (7.8)
Weight Velocity 0 to 2 Years (kg/yr^{-1}) (Mean [SD])	38	4.3 (0.8)	77	4.0 (0.7)
Weight at 2 Years (kg) (Mean [SD])		11.9 (1.7)		11.2 (1.4)*
Height at 2 Years (cm) (Mean [SD])	38	82.6 (3.7)	77	82.2 (3.8)
BMI at 2 Years (kg/m2) (Mean [SD])		17.4 (2.2)		16.5 (1.9)*
Height for Age at 2 Year				
Stunted at 2 Year (% [95% CI])	38	10.5 (0.8-20.3)	77	22.1 (12.8, 31.3)
Not Stunted at 2 Year (% [95% CI])		89.5 (79.7-99.2)		77.9 (68.7, 87.2)
Year 2 Normal/Overweight/Obese				
Under/Normal Weight (% [95% CI])	22	68.2 (48.7, 87.6)	53	81.1 (70.6, 91.7)
Overweight/Obese (% [95% CI])		31.8 (12.4, 51.3)		18.9 (8.3, 29.4)
Weight Velocity 1 to 2 Years (kg/yr^{-1}) (Mean [SD])	27	2.2 (1.1)	57	2.0 (1.0)
Height Velocity 1 to 2 Years (cm/yr^{-1}) (Mean [SD])		9.5 (3.2)		9.3 (2.9)
Growth rate (0-2 years)				
Catch up Growth (% [95% CI])		34.2 (19.1, 49.3)		19.5 (10.6, 28.3)
Same Growth Trajectory (% [95% CI])	38	34.2 (19.1, 49.3)	77	44.2 (33.1, 55.2)
Catch Down Growth (% [95% CI])		31.6 (16.8, 46.4)		36.4 (25.6, 47.1)
Weight at 4 Years (kg) (Mean [SD])		16.0 (2.6)		14.8 (1.7)***
Height at 4 Years (cm) (Mean [SD])	57	100.0 (4.3)	103	97.7 (3.7)**
BMI at 4 Years (kg/m2) (Mean [SD])		15.9 (1.6)		15.4 (1.3)*

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 4.4 continued Key peri-natal and post-natal growth characteristics of Black females grouped by early and late achievement of menarche

Variable	n	Early Menarche	n	Late Menarche
Height for Age at 4 Years				
Stunted at 4 Years (% [95% CI])	57	1.8 (0.0, 5.2)	103	11.7 (5.5, 17.8)*
Not Stunted at 4 Years (% [95% CI])		98.2 (94.8, 100.0)		88.3 (82.2, 94.5)*
Year 4 Normal/Overweight/Obese				
Under/Normal Weight (% [95% CI])	57	87.7 (79.2, 96.2)	103	95.1 (91.0, 99.3)
Overweight/Obese (% [95% CI])		12.3 (3.8, 20.8)		4.9 (0.7, 9.0)
Weight Velocity 2 to 4 Years (kg/yr^{-1}) (Mean [SD])	27	2.1 (0.8)	73	2.0 (0.7)
Height Velocity 2 to 4 Years (cm/yr^{-1}) (Mean [SD])		8.9 (1.4)		8.3 (1.6)
Weight at 5 years (kg) (Mean [SD])	48	19.0 (2.3)	86	17.8 (2.2)**
Height at 5 Years (cm) (Mean [SD])		108.9 (4.6)		107.4 (4.2)
BMI at 5 Years (kg/m2) (Mean [SD])		15.9 (1.1)		15.4 (1.3)*
Height for Age at 5 Years				
Stunted at 5 Years (% [95% CI])	48	4.2 (0.0-9.8)	86	5.8 (0.9, 10.8)
Not Stunted at 5 Years (% [95% CI])		95.8 (90.2-100.0)		94.2 (89.2, 99.1)
Year 5 Normal/Overweight/Obese				
Under/Normal Weight (% [95% CI])	48	85.4 (75.4, 95.4)	86	89.5 (83.1, 96.0)
Overweight/Obese (% [95% CI])		14.6 (4.6, 24.6)		10.5 (4.0, 16.9)
Weight Velocity 4 to 5 Years (kg/yr^{-1}) (Mean [SD])	45	2.6 (0.8)	83	2.5 (1.0)
Height Velocity 4 to 5 Years (cm/yr^{-1}) (Mean [SD])		7.5 (1.8)		7.6 (1.7)
Weight at 8 Years (kg) (Mean [SD])	52	26.2 (4.5)	98	23.8 (3.5)***
Height at 8 Years (cm) (Mean [SD])		125.7 (5.20		123.0 (4.6)**
BMI at 8 Years (kg/m2) (Mean [SD])		16.5 (2.0)		15.7 (1.7)**
Height for Age at 8 Years				
Stunted at 8 Years (% [95% CI])	52	3.8 (0.0, 9.1)	98	5.1 (0.7, 9.5)
Not Stunted at 8 Years (% [95% CI])		96.2 (90.9, 100.0)		94.9 (90.5, 99.3)
Year 8 Normal/Overweight/Obese				
Under/Normal Weight (% [95% CI])	52	96.2 (90.9, 100.0)	98	92.9 (87.8, 98.0)
Overweight/Obese (% [95% CI])		3.8 (0.0, 9.1)		7.1 (2.0, 12.2)
Weight Velocity 5 to 8 Years (kg/yr^{-1}) (Mean [SD])	40	2.4 (0.8)	76	2.0 (0.7)*
Height Velocity 5 to 8 Years (cm/yr^{-1}) (Mean [SD])		5.6 (0.9)		5.3 (1.0)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.5 Key socio-economic characteristics of Black females grouped by early and late achievement of menarche

Variable	n	Early Menarche	n	Late Menarche
Maternal Age at Birth (Years) (Mean [SD])	65	25.3 (6.7)	113	24.82 (5.64)
Maternal Education at Birth				
< Grade 10/High School (% [95% CI])	64	59.4 (47.3, 71.4)	111	58.6 (49.4, 67.7)
> Grade 10/High School (% [95% CI])		56.3 (44.1, 68.4)		41.4 (32.3, 50.6)
Maternal Marital Status at Birth				
Married/Cohabiting (% [95% CI])	65	15.4 (6.6, 24.2)	113	21.2 (13.7, 28.8)
Not married/Cohabiting (% [95% CI])		84.6 (75.8, 93.4)		78.8 (71.2, 86.3)
1° Caregiver Education at 9/10 Years				
< Grade 10/High School (% [95% CI])	62	45.2 (32.8, 57.5)	108	46.3 (36.9, 55.7)
> Grade 10/High School (% [95% CI])		54.8 (42.5, 67.2)		53.7 (44.3, 63.1)
1° Caregiver Marital Status at 9/10 Years				
Married/Cohabiting (% [95% CI])	62	48.4 (35.9, 60.8)	109	34.9 (25.9, 43.8)
Not married/Cohabiting (% [95% CI])		51.6 (39.2, 64.1)		65.1 (56.2, 74.1)
SES Index at birth				
Low (% [95% CI])	60	55.0 (42.4, 67.6)	108	59.3 (50.0, 68.5)
High (% [95% CI])		45.0 (32.4, 57.6)		40.7 (31.5, 50.0)
SES Index at 9/10 Years				
Low (% [95% CI])	62	40.3 (28.1, 52.5)	110	57.3 (48.0, 66.5)
High (% [95% CI])		59.7 (47.5, 71.9)		42.7 (33.5, 52.0)

* P < 0.05, ** P < 0.01, *** P < 0.001

4.1.6 Logistic regression analysis – predictors of age at menarche

Each of the variables shown in Tables 4.4 and 4.5 were entered into individual logistic regression models (see Methods, section 3.1.4.5 for a detailed description of the model building strategy). The binary outcome variable was early vs. late menarche achievement. In total there were 13 variables that were individual significant predictors of age at menarche in Black females. Table 4.6 shows the unadjusted odds ratios (OR) and 95% confidence intervals (95% CI) for these statistically significant predictors. A greater body mass, height, and BMI through infancy and childhood consistently predicted early achievement of menarche, as did greater weight velocity in childhood and a high SES at 9/10 years.

A total of five models (Models A-E) were constructed to examine the predictors of age at menarche for Black girls. Table 4.7 shows the adjusted odds ratios (OR) and 95% confidence intervals (95%) for each of these models. Weight and height were kept in the models separately as once combined each variable became non-significant, this method was applied to all three logistic regression analyses included within this thesis (a. menarche, b. breasts/genitalia development, and c. pubic hair development). As there were no other variables that needed to be controlled for (i.e. gender) and it was not possible to combine

height and weight or weight, height and BMI in a single model, the significant early life predictors were left as individual predictors and so not used to build models with more than one predictor. Whilst weight at 5 years and weight velocity between five and eight years were individual significant predictors, once combined in Model A they both become non-significant. Models B to D combine year 8 anthropometrics and SES at year 9/10. Only year eight data were modelled with year 9/10 SES as it was deemed inappropriate to combine this variable with early life measures due to the transitioning economy within South Africa. Whilst SES becomes non-significant, a greater weight (OR = 1.16; 95% CI = 1.06, 1.28; $P < 0.01$), height (OR = 1.12; 95% CI = 1.04, 1.20; $P < 0.01$) and BMI (OR = 1.27; 95% CI = 1.04, 1.57; $P < 0.05$) at eight years significantly increased the odds of achieving early menarche in Black girls.

Table 4.6 Unadjusted odds ratios (OR) and 95% confidence intervals (95% CI) for predictors of early vs. late menarche for Black females

Variable	Categories	n	Unadjusted OR (95% CI)	Cox & Snell R^2	Nagelkerke R^2	Wald Statistic
Year 1 BMI (kg/m^2)		119	1.26* (1.03, 1.54)	0.04	0.06	4.91
Year 2 Weight (kg)		115	1.35* (1.03, 1.77)	0.04	0.06	4.85
Year 2 BMI (kg/m^2)		115	1.24* (1.01, 1.51)	0.04	0.05	4.14
Year 4 Weight (kg)		160	1.33** (1.12, 1.58)	0.08	0.10	10.69
Year 4 Height (cm)		155	1.16** (1.06, 1.27)	0.07	0.10	10.49
Year 4 BMI (kg/m^2)		160	1.28* (1.01, 1.62)	0.03	0.04	4.07
Year 5 Weight (kg)		134	1.24** (1.06, 1.46)	0.06	0.08	7.01
Year 5 BMI (kg/m^2)		134	1.39* (1.04, 1.86)	0.04	0.05	4.98
Weight Velocity 5 to 8 Years (kg/yr^{-1})		116	1.89* (1.09, 3.26)	0.05	0.07	5.17
Year 8 Weight (kg)		150	1.17** (1.07, 1.29)	0.08	0.11	10.67
Year 8 Height (cm)		150	1.12** (1.04, 1.21)	0.07	0.09	9.49
Year 8 BMI (kg/m^2)		150	1.29* (1.06, 1.56)	0.05	0.06	6.16
SES Index (9/10 Years)	Low	88	0.50* (0.27, 0.95)	0.03	0.04	4.50
	High (r)	84	-			

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category

Table 4.7 Adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for the predictors of early vs. late achievement of menarche for Black girls

Variable	Categories	Model A Cox & Snell R^2 = 0.06 Nagelkerke R^2 = 0.09			Model B Cox & Snell R^2 = 0.08 Nagelkerke R^2 = 0.11			Model C Cox & Snell R^2 = 0.07 Nagelkerke R^2 = 0.10			Model D Cox & Snell R^2 = 0.05 Nagelkerke R^2 = 0.07		
		n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald
Year 5 Weight (kg)		116	1.16 (0.95, 1.41)	2.10		-			-			-	
Weight Velocity 5 to 8 Years (kg/yr^{-1})		116	1.48 (0.79, 2.79)	1.47		-			-			-	
Year 8 Weight (kg)			-		146	1.16** (1.06, 1.28)	9.27		-			-	
Year 8 Height (cm)			-			-		146	1.12** (1.04, 1.20)	8.33		-	
Year 8 BMI (kg/m^2)			-			-					146	1.27* (1.04, 1.57)	5.27
Year 9/10 SES Index	Low		-		78	0.71 (0.35, 1.45)	0.91	78	0.60 (0.30, 1.23)	1.95	78	0.73 (0.37, 1.48)	0.76
	High (r)		-		68	-		68	-		68	-	

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category
Model A = Yr 5 weight + weight velocity 5 to 8 yrs
Model B = Yr 8 weight + Yr 9/10 SES index
Model C = Yr 8 height + Yr 9/10 SES index
Model D = Yr 8 BMI + Yr 9/10 SES index

4.2 Pubertal Initiation Results

This section provides quantitative results including age at initiation of puberty (breasts/genitalia and pubic hair development), evidence for a secular trend in age at initiation; demographic, socio-economic and early growth characteristics of the sample and predictors of the timing of puberty initiation within the Birth to Twenty (Bt20) Bone Health sub-sample.

4.2.1 Pubertal initiation sample

Table 4.8 shows the total number of adolescents who have complete Tanner staging data at each time point, grouped by gender and gender/ethnic group. Sample sizes range from 360 (year 9) to 497 (year 14) for males and females combined. Sample sizes were greater for Black adolescents compared to White adolescents. Table 4.9 shows the cumulative percentages of Tanner stage 2 achievement (pubertal initiation) for breasts/genitalia and pubic hair achievement grouped by gender and gender/ethnic group. A higher percentage of White boys had achieved Tanner stage 2 for both genitalia and pubic hair development at each time point. Up to 11 years a higher proportion of Black girls had achieved Tanner stage 2 compared to White girls. From 11 years approximately the same number of Black and White girls had achieved Tanner stage 2 for both breast and pubic hair development.

Table 4.8 Total number of adolescents with complete Tanner Staging data at each time point

Age (Years)	Total Tanner staging sample (n)	Total female Tanner staging sample (n)	Black Females	White Females	Total male Tanner staging sample (n)	Black Males	White Males
			Tanner Staging (n)	Tanner Staging (n)		Tanner Staging (n)	Tanner Staging (n)
9	360	173	141	32	187	150	37
10	460	225	161	64	235	174	61
11	482	228	162	66	254	185	69
12	480	229	158	71	251	185	66
13	471	233	166	67	238	179	59
14	497	246	168	78	251	188	63

Table 4.9 Cumulative percentage of adolescents who are peri-pubertal at each time point grouped by gender and ethnic group

Age (Years)	Black Boys		White boys		Black girls		White girls	
	Genitalia	Pubic hair	Genitalia	Pubic hair	Breast	Pubic hair	Breast	Pubic hair
9	12.7	4.0	27.0	8.1	20.0	13.8	15.8	3.1
10	43.3	35.9	67.2	59.0	47.2	41.6	36.5	36.5
11	73.3	65.8	72.5	71.0	75.3	67.9	69.2	66.2
12	88.6	88.6	88.7	98.5	94.3	93.1	94.4	95.8
13	95.5	95.5	100.0	100.0	99.4	98.8	100.0	100.0
14	98.9	97.9	100.0	100.0	100.0	100.0	100.0	100.0

4.2.2 Deriving age at initiation for breasts/genitalia and pubic hair development

Figures 4.3 and 4.4 show the logistic curves that were fitted to cumulative percentage data for age at the initiation of pubertal development as measured by the transition from Tanner stage 1 to Tanner stage 2 for breasts/genitalia and pubic hair development. Median age at the initiation of genitalia development was 10.4 years (SEE = 1.0; 95% CI = 8.4, 12.4) for Black boys and 9.8 years (SEE = 0.2; 95% CI = 9.4, 10.2) for White boys. Median age for the initiation of pubic hair development for Black males was 10.8 years (SEE = 0.6; 95% CI = 9.6, 12.0) compared to White males, which was 10.2 years (SEE = 0.9; 95% CI = 8.4, 12.0). Median age at the initiation of breast development in Black females was 10.1 years (SEE = 0.4; 95% CI = 9.3, 10.9) compared to White females which was 10.2 years (SEE = 0.9; 95% CI = 8.2, 12.2). Median age for the initiation of pubic hair was 10.3 years (SEE = 0.5; 95% CI = 9.3, 11.3) and 10.5 years (SEE = 0.9; 95% CI = 8.7, 12.3) for Black and White girls respectively. Within this urban South African cohort, there were no statistically or biologically significant differences in the timing of pubertal initation between Black and White adolescents.

Table 4.10 shows the derived percentiles for the age at initiation of breasts/genitalia and pubic hair development of the sample. Fifty percent of Black boys achieved genitalia stage 2 between the ages of 9.5 and 11.3 years, a range of 1.8 years; compared to 9.1 and 10.4 years, a range of 1.3 years for White boys. For pubic hair development, fifty percent of Black boys achieved stage 2 between the ages of 10.0 and 11.6 years, a range of 1.6 years compared to 9.6 and 10.7 years, a range of 1.1 years for White boys. White boys were not only in advance of Black boys in the timing of the initiation of puberty, but a higher proportion of White boys achieved initiation in a shorter period of time. This trend is slightly different for

girls, with Black girls being in advance of White girls for average age at initiation of breast and pubic hair development; however a higher proportion of White girls achieved initiation in a shorter period of time. Fifty percent of Black girls achieved breast stage 2 between the ages of 9.4 and 10.7 years, a range of 1.3 years compared to 9.6 and 10.8 years, a range of 1.1 years for White girls. For pubic hair development, fifty percent of Black girls achieved stage 2 between the ages of 9.7 and 10.9 years, a range of 1.2 years compared to 10.0 and 11.0 years, a range of 1.0 year for White girls. Both genders, on average, achieve breasts/genitalia initiation prior to pubic hair initiation.

Figure 4.3 Logistic curves fitted to cumulative percentage data for age at the initiation of male genitalia and pubic hair development grouped by ethnic group

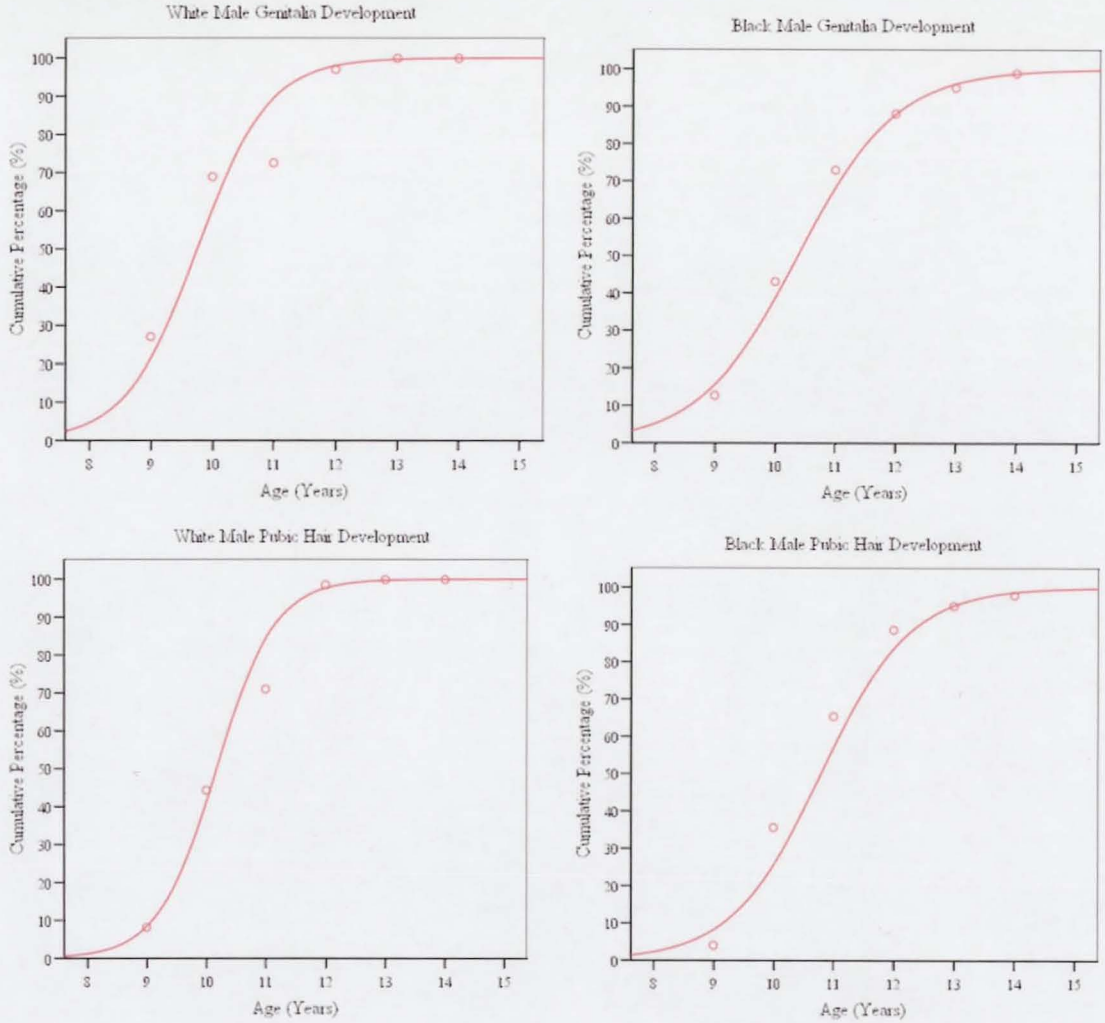


Figure 4.4 Logistic curves fitted to cumulative percentage data for age at the initiation of female breast and pubic hair development, grouped by ethnic group

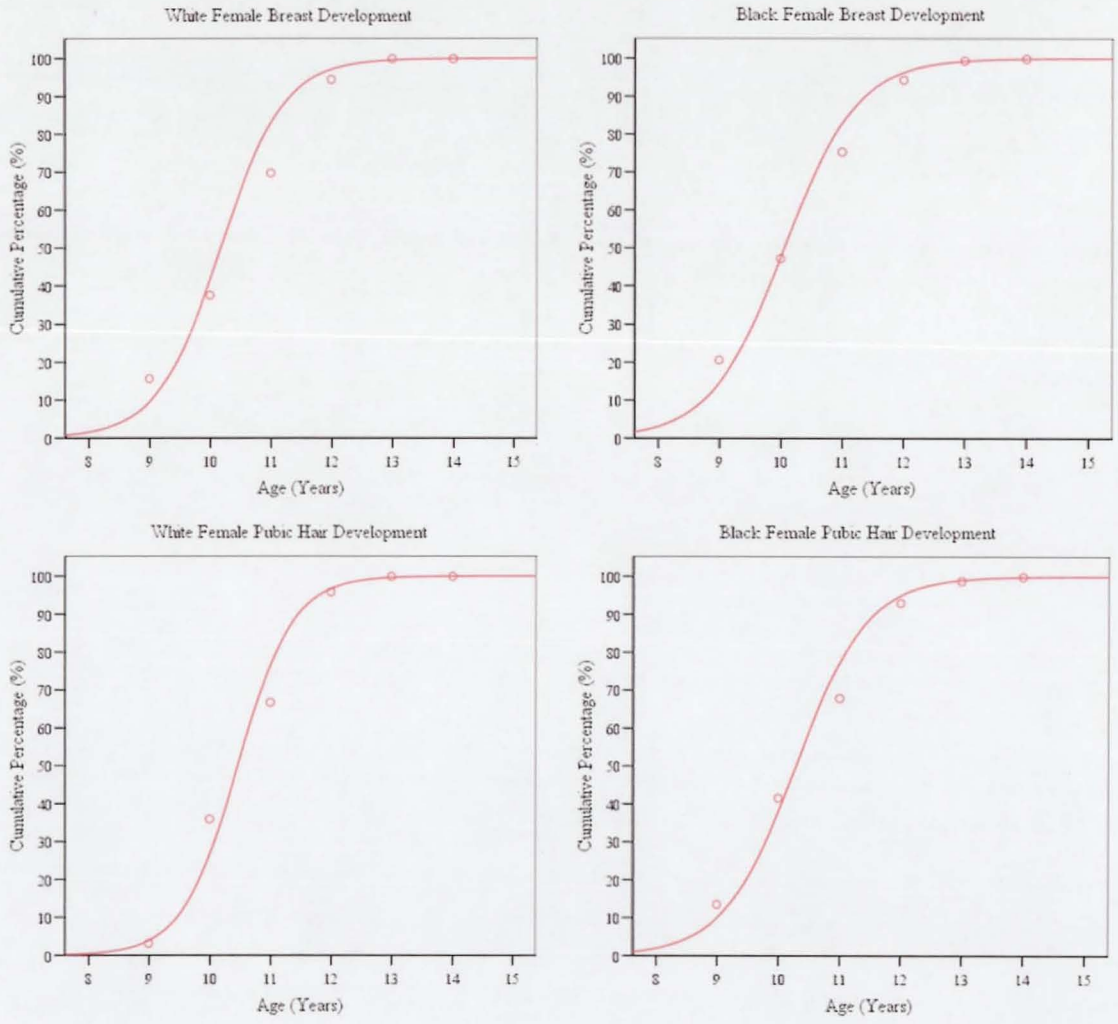


Table 4.11 shows the sample size and percentage of early and late developers for breasts/genitalia and pubic hair development grouped by gender and ethic group. These figures are derived from the data rather than derived from the model, therefore the groups are not of equal size as some adolescents were missing key transition data and thus could not be allocated into a group.

Table 4.10 Percentile estimations for age at breasts/genitalia and pubic hair initiation grouped by gender and ethnic group

Achieved Puberty	White Male Pubic Hair (Years)	Black Male Pubic Hair (Years)	White Male Genitalia (Years)	Black Male Genitalia (Years)	White Female Pubic Hair (Years)	Black Female Pubic Hair (Years)	White Female Breast (Years)	Black Female Breast (Years)
10%	9.1	9.2	8.5	8.6	9.5	9.0	9.0	8.7
25%	9.6	10.0	9.1	9.5	10.0	9.6	9.6	9.4
50%	10.2	10.8	9.8	10.4	10.5	10.3	10.2	10.1
75%	10.7	11.6	10.4	11.3	11.0	10.9	10.7	10.7
90%	11.3	12.4	11.0	12.2	11.5	11.6	11.3	11.4

Table 4.11 Sample size and percentage of early and late initiation of breasts/genitalia and pubic hair development grouped by gender and ethnic group

Pubertal Indicator	Timing	Male				Female			
		n	Black (%)	n	White (%)	n	Black (%)	n	White (%)
Breasts/genitalia	Early	77	37.6	43	51.8	65	37.6	66	36.9
	Late	128	62.4	40	48.2	108	62.4	113	63.1
Pubic Hair	Early	89	43.8	21	26.6	35	41.7	30	41.1
	Late	114	56.2	58	73.4	49	58.3	43	58.9

4.2.3 Secular trends in age at the initiation of puberty

Table 4.12 shows the average age (95% CI) at breast and pubic hair initiation for Black girls from the Soweto-Johannesburg area between 1983 and 2007. It also shows the average age (95% CI) at genitalia and pubic hair initiation for Black boys from the Soweto-Johannesburg area between 1993 and 2007. There were limited data available for White children and therefore they were not included in this analysis. Data from a total of five previous studies of age at initiation of girls born in the Soweto-Johannesburg area were utilised in combination with data from the current study (Chaning-Pearce & Solomon 1987, Cameron & Wright 1990, Cameron et al. 1993, Norris & Richter 2005). There is potentially evidence for a secular trend towards earlier pubertal initiation within urban Black South African females. Average age at initiation of breast development has decreased from 11.5 years (95% CI = 11.4, 11.6) in 1987; to 10.4 years (95% CI = 10.3, 10.5) in 1990, to 10.1 years (95% CI = 9.3, 10.9) in the current study. This represents an average decline of 0.3 years per decade. Average age at initiation of pubic hair development for Black females has decreased from 12.1 years (95% CI = 12.0, 12.2) in 1987 to 10.3 years (95% CI = 9.3, 11.3) in the current study, an average decline of 0.9 years per decade.

There are relatively less data available for Black boys (Table 4.12), but average age at genitalia initiation has decreased very slightly from 10.5 years (95% CI = 10.3, 10.7) in 1993

to 10.4 years (95% CI = 8.4, 12.4) in the current study. Examination of the available data shows an average increase in age at genitalia initiation for urban Black South African boys between 1993 and 2007, this may however be due to the nature of the methodology of Norris and Richter's (2005) paper which reported an average age of 12.6 years (95% CI = 12.0, 13.0). However, this was a cross sectional study using very small sample sizes from 10 to 18 years of age and therefore may not be truly representative of transition from Tanner stage one to Tanner stage two. The trend for pubic hair initiation in Black boys is more like that seen in Black girls, with average age declining from 12.4 years (95% CI = 12.3, 12.6) in 1993 to 10.8 years (95% CI = 9.6, 12.0) in the current study. This represents an average decline of 1.1 years per decade. There is a greater amount of variability seen in the trend of pubertal initiation compared to the trend of age at menarche (see Figure 4.2) which may be reflective of the difficulties in accurately assessing pubertal status both by physician and self assessment as compared to the more easily reported age at menarche.

Table 4.12 Average age (95% confidence interval) at breasts/genitalia and pubic hair development of Black adolescents from previous studies conducted within the Soweto-Johannesburg area between 1977 and 2007

Year of study	Males		Females	
	Genitalia development	Pubic hair development	Breast development	Pubic hair development
	Average age (†denotes median) at menarche (95% confidence interval)			
1987	-	-	11.5 (11.4, 11.6)	12.1 (12.0, 12.2)
1990	-	-	10.4 (10.3, 10.5)	-
1993	10.5 (10.3, 10.7)	12.4 (12.3, 12.6)	10.1 (10.0, 10.2)	10.1 (10.0, 10.2)
2005	12.6 (12.2, 13.0)	12.4 (12.2, 12.6)	11.2 (11.0, 11.4)	11.5 (11.3, 11.7)
2007	10.4† (8.4, 12.4)	10.8† (9.6, 12.0)	10.1† (9.3, 10.9)	10.3† (9.3, 11.3)

Data sources: (Chaning-Pearce & Solomon 1987; Cameron & Wright 1990; Cameron, Grieve, Kruger & Leschner 1993; Norris & Richter 2005)

4.2.4 Key demographic, socio-economic and growth characteristics of the pubertal development sample

Table 4.13 shows the key peri-natal and post-natal growth characteristics of Black males and females, grouped by early and late achievement of breasts/genitalia and pubic hair development. There was one statistically significant difference between the early and late breasts/genitalia groups: weight velocity between five and eight years was significantly greater for early maturing adolescents (2.3 vs. 2.1 kg/yr^{-1}) compared to later maturing adolescents. There were several statistically significant differences between early and late maturers for pubic hair development. Weight velocity between birth and 12 months of age was significantly greater for early maturers (6.6 vs. 6.2 kg/yr^{-1}), as was weight at one year

(9.7 vs. 9.3 kg), height at two years (83.7 vs. 82.5 cm), weight at five years (18.9 vs. 18.2 kg), height at five years (109.4 vs. 107.8), weight at eight years (25.7 vs. 24.2 kg), height at eight years (125.5 vs. 123.6 cm), BMI at eight years (16.3 vs. 15.8 kg/m^2) and weight velocity between the ages of five and eight years (2.3 vs. 2.1 kg/yr^{-1}) compared to later maturing adolescents. Weight velocity between the ages of one and two years was significantly less for early maturers (1.8 vs. 2.2 kg/yr^{-1}) compared to later maturers. Whilst not statistically significant, there were several trends within these data namely early maturing adolescents for both breasts/genitalia and pubic hair development were heavier, taller and had a higher BMI at one, two, four, five and eight years of age.

Table 4.14 shows the key socio-economic characteristics of Black adolescents, grouped by early and late achievement of breasts/genitalia and pubic hair development. For breasts/genitalia development, early maturing adolescents were significantly more likely to live in a high SES environment (as measured by an SES index) at both birth (65.9 vs. 40.9%) and at 9/10 years (62.4 vs. 40.9%) compared to later maturing adolescents. There were no significant differences in socio-economic variables between early and late pubic hair achievers.

Table 4.13 Key peri-natal and post-natal growth characteristics of Black adolescents grouped by early and late achievement of breasts/genitalia and pubic hair

Variable	Breasts/genitalia Development				Pubic Hair Development			
	n	Early	n	Late	n	Early	n	Late
Birth Weight (kg) (Mean [SD])		3.1 (0.4)		3.1 (0.5)		3.1(0.5)		3.1 (0.5)
Low Birth Weight (% [95% CI])	138	10.9 (5.7, 16.1)	235	11.1 (7.1, 15.1)	152	11.1 (6.2, 16.2)	225	10.7 (6.6, 14.7)
Average Birth Weight (% [95% CI])		88.4 (83.1, 93.7)		84.3 (79.6, 88.9)		86.2 (80.7, 91.7)		85.3 (80.7, 90.0)
High Birth Weight (% [95% CI])		0.7 (0.0, 2.1)		4.7 (2.0, 7.4)		2.6 (0.1, 5.2)		4.0 (1.4, 6.6)
Gestational Age (Weeks) (Mean [SD])		37.9 (1.6)		38.0 (1.8)		37.5 (4.5)		37.6 (4.6)
Pre-term (<36 Weeks) (% [95% CI])	140	14.3 (8.5, 20.1)	232	13.4 (9.0, 17.7)	154	14.3 (8.8, 19.8)	227	12.3 (8.1, 16.6)
Term (37-41 Weeks) (% [95% CI])		85.0 (79.1, 90.9)		85.3 (80.8, 89.9)		85.1 (79.4, 90.7)		86.3 (81.9, 90.8)
Post-term (>42 weeks) (% [95% CI])		0.7 (0.0, 2.1)		1.3 (0.0, 2.7)		0.6 (0.0, 1.9)		1.3 (0.0, 2.8)
Size For Gestation								
Appropriate For Gestational Age (% [95% CI])	140	88.6 (83.3, 93.8)	232	88.8 (84.7, 92.9)	152	90.1 (85.4, 94.9)	224	87.9 (83.7, 92.2)
Small For Gestational Age (% [95% CI])		11.4 (6.2, 16.7)		11.2 (7.1, 15.3)		9.9 (5.1, 14.6)		12.1 (7.8, 16.3)
Parity		1.9 (1.2)		2.2 (1.4)		2.0 (1.2)		2.2 (1.4)
Primaparous (% [95% CI])	138	48.9 (40.7, 57.2)	235	39.6 (33.3, 45.8)	154	45.5 (37.6, 53.3)	226	60.2 (53.8, 66.6)
Non-primaparous (% [95% CI])		51.1 (42.8, 59.3)		60.4 (54.2, 66.7)		54.5 (46.7, 62.4)		39.8 (33.4, 46.2)
Weight at 1 Year (kg) (Mean [SD])		9.5 (1.5)		9.4 (1.4)		9.7 (1.4)		9.3 (1.4)*
Height at 1 Year (cm) (Mean [SD])	97	73.4 (3.2)	158	73.5 (3.4)	106	73.9 (3.3)	147	73.2 (3.3)
BMI at 1 Year (kg/m2) (Mean [SD])		17.6 (2.0)		17.4 (1.9)		17.7 (1.9)		17.3 (1.9)
Stunted at 1 Year *(% [95% CI])*		11.3 (5.0, 17.7)		12.7 (7.5, 17.8)		8.5 (3.2, 13.8)		12.9 (7.5, 18.3)
Weight Velocity 0 to 12 Months (kg/yr^{-1}) (Mean [SD])	97	6.4 (1.2)	158	6.3 (1.3)	106	6.6 (1.2)	147	6.2 (1.3)*
Weight Velocity 6 to 12 Months (kg/yr^{-1}) (Mean [SD])	21	2.6 (1.3)	37	3.3 (1.3)	24	3.3 (1.3)	35	3.0 (1.4)
Height Velocity 6 to 12 Months (cm/yr^{-1}) (Mean [SD])	21	15.0 (4.0)	37	16.9 (6.9)	24	16.7 (6.7)	35	15.7 (5.5)
Weight at 2 Years (kg) (Mean [SD])		11.6 (1.8)		11.5 (1.6)		11.6 (1.8)		11.5 (1.5)
Height at 2 Years (cm) (Mean [SD])	100	83.3 (4.0)	157	82.9 (3.8)	104	83.7 (3.9)	156	82.4 (3.7)*
BMI at 2 Years (kg/m2) (Mean [SD])		16.8 (2.5)		16.8 (1.9)		16.6 (2.4)		16.9 (1.9)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.13 continued Key peri-natal and post-natal growth characteristics of Black adolescents grouped by early and late achievement of breasts/genitalia and pubic hair

Variable	Breasts/genitalia Development				Pubic Hair Development			
	n	Early	n	Late	n	Early	n	Late
Stunted at 2 Years *(% [95% CI])*		23.0 (14.8, 31.2)		21.0 (14.6, 27.4)		11.5 (5.4, 17.7)		23.7 (17.0, 30.4)
Year 2 Normal/Overweight/Obese								
Normal Weight (% [95% CI])	69	78.3 (68.5, 88.0)	112	76.8 (69.0, 84.6)	76	78.9 (69.8, 88.1)	107	76.6 (98.6, 84.7)
Overweight/Obese (% [95% CI])		21.7 (12.0, 31.5)		23.2 (15.4, 31.0)		21.1 (11.9, 30.2)		23.4 (15.3, 31.4)
Weight Velocity 1 to 2 Years (kg/yr^{-1}) (Mean [SD])	76	2.0 (1.4)	109	2.0 (1.1)	76	1.8 (1.3)	108	2.2 (1.2)*
Height Velocity 1 to 2 Years (cm/yr^{-1}) (Mean [SD])		9.5 (3.0)		8.8 (2.7)		9.1 (3.1)		9.1 (2.7)
Growth rate (0-2 years)								
Catch up Growth (% [95% CI])		25.3 (16.7, 33.8)		22.3 (15.8, 28.8)		26.9 (18.4, 35.4)		20.6 (14.3, 27.0)
Same Growth Trajectory (% [95% CI])	99	33.3 (24.0, 42.6)	157	35.0 (27.6, 42.5)	104	28.8 (20.1, 37.6)	155	39.4 (31.7, 47.0)
Catch Down Growth (% [95% CI])		41.4 (31.7, 51.1)		42.7 (34.9, 50.4)		44.2 (34.7, 53.8)		40.0 (32.3, 47.7)
Weight at 4 Years (kg) (Mean [SD])		15.5 (2.2)		15.3 (2.0)		15.8 (2.3)		15.1 (1.8)
Height at 4 Years (cm) (Mean [SD])	129	99.1 (4.0)	214	98.7 (4.2)	137	99.8 (4.1)	207	98.2 (4.0)
BMI at 4 Years (kg/m2) (Mean [SD])		15.7 (1.9)		15.7 (1.3)		15.8 (1.5)		15.6 (1.3)
Stunted at 4 Years *(% [95% CI])*		6.2 (2.0, 10.4)		11.2 (7.0, 15.4)		6.6 (2.4, 10.7)		12.1 (7.6, 16.5)
Year 4 Normal/Overweight/Obese								
Normal Weight (% [95% CI])	128	92.2 (87.5, 96.8)	214	94.4 (91.3, 97.5)	136	93.4 (89.2, 97.6)	207	93.7 (90.4, 97.0)
Overweight/Obese (% [95% CI])		7.8 (3.2, 12.5)		5.6 (2.5, 8.7)		6.6 (2.4, 10.8)		6.3 (3.0, 9.6)
Weight Velocity 2 to 4 Years (kg/yr^{-1}) (Mean [SD])	96	2.0 (0.8)	148	2.1 (0.7)	98	2.2 (0.8)	147	2.0 (0.7)
Height Velocity 2 to 4 Years (cm/yr^{-1}) (Mean [SD])		8.6 (1.9)		8.6 (1.6)		8.7 (1.7)		8.4 (1.7)
Weight at 5 Years (kg) (Mean [SD])		18.5 (2.2)		18.4 (2.7)		18.9 (2.8)		18.2 (2.2)*
Height at 5 Years (cm) (Mean [SD])	113	108.6 (4.5)	191	108.2 (4.4)	118	109.4 (4.5)	188	107.8 (4.3)*
BMI at 5 Years (kg/m2) (Mean [SD])		15.7 (1.2)		15.7 (1.7)		15.8 (1.4)		15.6 (1.4)
Stunted at 5 Years *(% [95% CI])*		7.1 (2.4-11.8)		5.2 (2.1-8.4)		4.2 (0.6-7.9)		6.4 (2.9, 9.9)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.13 continued Key peri-natal and post-natal growth characteristics of Black adolescents grouped by early and late achievement of breasts/genitalia and pubic hair

Variable	Breasts/genitalia Development				Pubic Hair Development			
	n	Early	n	Late	n	Early	n	Late
Year 5 Normal/Overweight/Obese								
Normal Weight (% [95% CI])	113	91.2 (85.9, 96.40	191	89.0 (84.6, 93.4)	118	89.8 (84.4, 95.3)	188	89.9 (85.6, 94.2)
Overweight/Obese (% [95% CI])		8.8 (3.6, 14.1)		11.0 (6.6, 15.4)		10.2 (4.7, 15.6)		10.1 (5.8, 14.4)
Weight Velocity 4 to 5 Years (kg/yr^{-1}) (Mean [SD])	107	2.5 (0.8)	181	2.4 (1.0)	112	2.5 (0.9)	176	2.5 (1.0)
Height Velocity 4 to 5 Years (cm/yr^{-1}) (Mean [SD])		7.5 (1.6)		7.4 (1.5)		7.3 (1.2)		7.5 (1.7)
Weight at 8 Years (kg) (Mean [SD])	110	25.3 (3.9)	204	24.6 (3.7)	131	25.7 (4.4)	187	24.2 (3.3)*
Height at 8 Years (cm) (Mean [SD])		124.8 (5.4)		124.2 (5.4)		125.5 (5.5)		123.6 (5.3)*
BMI at 8 Years (kg/m2) (Mean [SD])		16.2 (1.7)		15.9 (1.6)		16.3 (1.9)		15.8 (1.4)*
Stunted at 8 Years *(% [95% CI])*		7.3 (2.4, 12.1)		7.4 (3.8, 10.9)		53.8 (26.7, 80.9)		8.6 (4.5, 12.6)
Year 8 Normal/Overweight/Obese								
Normal Weight (% [95% CI])	110	92.7 (87.9, 97.6)	204	93.6 (90.3, 97.0)	131	88.5 (83.1, 94.0)	187	95.7 (92.8, 98.6)
Overweight/Obese (% [95% CI])		7.3 (2.4, 12.1)		6.4 (3.0, 9.7)		11.5 (6.0, 16.9)		4.3 (1.4, 7.2)
Weight Velocity 5 to 8 Years (kg/yr^{-1}) (Mean [SD])	90	2.3 (0.7)	172	2.1 (0.7)*	104	2.3 (0.7)	159	2.1 (0.6)*
Height Velocity 5 to 8 Years (cm/yr^{-1}) (Mean [SD])		5.7 (0.9)		5.4 (1.0)		5.6 (1.0)		5.4 (1.0)
Last BMI† (kg/m2) (Mean [SD])	45	16.1 (2.0)	206	17.1 (2.7)	68	16.4 (2.3)	188	17.0 (2.6)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.14 Key socio-economic characteristics of Black adolescents grouped by early and late achievement of breasts/genitalia and pubic hair

Variable	Breasts/genitalia Development				Pubic Hair Development			
	n	Early	n	Late	n	Early	n	Late
Maternal Age at Birth (Years) (Mean [SD])	141	24.7 (5.8)	236	25.5 (5.9)	154	25.6 (6.0)	227	24.9 (5.8)
Maternal Education at Birth								
< Grade 10/High School (% [95% CI])	124	12.1 (6.4, 17.8)	212	14.6 (9.9, 19.4)	140	11.4 (6.2, 16.7)	203	15.8 (10.8, 20.8)
> Grade 10/High School (% [95% CI])		87.9 (82.2, 93.6)		85.4 (80.6, 90.1)		88.6 (83.3, 93.8)		84.2 (79.2, 89.2)
Maternal Marital Status at Birth								
Married/Cohabiting (% [95% CI])	141	22.7 (15.8, 29.6)	236	25.4 (19.9, 31.0)	154	25.3 (18.5, 32.2)	227	23.8 (18.2, 29.3)
Not married/Cohabiting (% [95% CI])		77.3 (70.4, 84.2)		74.6 (69.0, 80.1)		74.7 (67.8, 81.5)		76.2 (70.7, 81.8)
1° Caregiver's Education at 9/10 Years								
< Grade 10/High School (% [95% CI])	139	41.7 (33.5, 49.9)	229	50.2 (43.7, 56.7)	154	45.5 (37.6, 53.3)	216	48.1 (41.5, 54.8)
> Grade 10/High School (% [95% CI])		58.3 (50.1, 66.5)		49.8 (43.3, 56.3)		54.5 (46.7, 62.4)		51.9 (45.2, 58.5)
1° Caregiver's Marital Status at 9/10 Years								
Married/Cohabiting (% [95% CI])	140	55.0 (46.8, 63.2)	230	57.0 (50.6, 63.4)	153	51.6 (43.7, 59.6)	219	44.3 (37.7, 50.9)
Not married/Cohabiting (% [95% CI])		45.0 (36.8, 53.2)		43.0 (36.6, 49.4)		48.4 (40.4, 56.3)		55.7 (49.1, 62.3)
SES Index at Birth								
Low (% [95% CI])	132	34.1 (26.0, 42.2)	223	59.1 (52.8, 65.5)*	143	39.2 (31.2, 47.2)	217	44.2 (37.6, 50.8)
High (% [95% CI])		65.9 (57.8, 74.0)		40.9 (34.5, 47.2)*		60.8 (52.8, 68.8)		55.8 (49.2, 62.4)
SES Index at 9/10 years								
Low (% [95% CI])	141	37.6 (29.6, 45.6)	230	59.1 (52.8, 65.5)*	154	46.1 (38.2, 54.0)	219	54.8 (48.2, 61.4)
High (% [95% CI])		62.4 (54.4, 70.4)		40.9 (34.5, 47.2)*		53.9 (46.0, 61.8)		45.2 (38.6, 51.8)

* P < 0.05, ** P < 0.01, *** P < 0.001

4.2.5 Logistic regression analysis – predictors of puberty initiation

Each of the variables in Tables 4.13 and 4.14 were entered into individual logistic regression models for both the binary outcome of early vs. late breasts/genitalia development and early vs. late pubic hair development. For the breasts/genitalia outcome there were a total of four individual significant predictors of age at initiation for Black adolescents. Table 4.15 shows the unadjusted odds ratios (OR) and 95% confidence intervals (95% CI) for these significant predictors. Sex, year 5 weight and year 5 height (see Methods section 3.1.4.5 for a detailed description of how these models were constructed), were included as control variables within the next set of models that were constructed. The following two variables significantly increased the odds of achieving early breasts/genitalia development: a greater weight velocity between five and eight years (OR = 1.35; 95% CI 1.04, 1.74; $P < 0.05$) and a greater height velocity between five and eight years (OR = 1.32; 95% CI 1.01, 1.73; $P < 0.05$). The following variables significantly reduced the odds of achieving early breasts/genitalia development: a low year 9/10 SES index (OR = 0.42; 95% CI 0.27, 0.64; $P < 0.001$) and the primary caregiver at year 9/10 not being married or cohabiting (OR = 0.62; 95% CI 0.41, 0.94; $P < 0.05$).

Table 4.15 Unadjusted odds ratios (OR) and 95% confidence intervals (95%) for predictors of early vs. late breasts/genitalia development for Black adolescents

Variable	Categories	n	Unadjusted OR (95% CI)	Cox & Snell R^2	Nagelkerke R^2	Wald Statistic
Sex	Male	205	1.00 (0.67, 1.52)	0.00	0.00	0.00
	Female (r)	173	-			
Year 5 weight (kg)		304	1.02 (0.93, 1.12)	0.00	0.00	0.15
Weight velocity 5 to 8 years (kg/yr^{-1})		262	1.35* (1.04, 1.74)	0.03	0.03	5.09
Year 5 height (cm)		303	1.02 (0.97, 1.08)	0.00	0.00	0.62
Height velocity 5 to 8 years (cm/yr^{-1})		262	1.32* (1.01, 1.73)	0.02	0.02	3.99
SES Index (9/10 Years)	Low	189	0.42*** (0.27, 0.64)	0.04	0.06	15.93
	High (r)	182	-			
1° caregiver's marital status (9/10 Years)	Other	194	0.62* (0.41, 0.94)	0.01	0.02	4.96
	Married/Cohabit (r)	176	-			

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category

A total of seven (Model A to Model F) logistic regression models were constructed to examine the predictors of the timing of breasts/genitalia development (see Methods section 3.1.4.5 for a detailed description of how these models were constructed). Tables 4.16 and 4.17 show the adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for each of

the models constructed. When controlling for sex, and the starting age weight or height in the growth velocity models (Models A and B), a greater weight velocity from five to eight years significantly increased the odds of achieving breasts/genitalia development early (OR = 1.46; 95% CI = 1.09, 1.97; $P < 0.05$). Height velocity from five to eight years became insignificant when controlling for year 5 height and sex. When socio-economic status (as measured by an index) was added into the same models (Models C and D) with weight and height velocity from five to eight years, a greater weight velocity significantly increases the odds of achieving early breasts/genitalia development (OR = 1.44; 95% CI = 1.07, 1.94; $P < 0.05$) as did a greater height velocity (OR = 1.35; 95% CI = 1.03, 1.79; $P < 0.05$). Socio-economic status at year 9/10 was also a significant predictor in both Model C and Model D with a lower SES significantly reducing the odds of early breasts/genitalia achievement (OR = 0.53; 95% CI 0.31, 0.89; $P < 0.05$ and OR = 0.49; 95% CI 0.29, 0.82; $P < 0.01$ respectively). Model E combines both year 9/10 SES and year 9/10 primary caregiver marital status and highlights that the year 9/10 SES index (OR = 0.41; 95% CI; 0.27, 0.64; $P < 0.001$) is a more significant predictor of the timing of breasts/genitalia development, as year 9/10 marital status becomes insignificant. Models F and G combine sex, starting weight or height, weight or height velocity from five to eight years and year 9/10 primary caregiver marital status. Only weight velocity from five to eight years remained a significant predictor, with a greater weight velocity significantly increasing the odds of early achievement of breasts/genitalia development (OR = 1.43; 95% CI = 1.07, 1.93; $P < 0.05$).

Table 4.16 Odds ratios (OR) and 95% confidence intervals(95% CI) for the predictors of early vs. late breasts/genitalia development for Black adolescents

Variable	Categories	Model A Cox & Snell R^2 = 0.03 Nagelkerke R^2 = 0.04			Model B Cox & Snell R^2 = 0.02 Nagelkerke R^2 = 0.02			Model C Cox & Snell R^2 = 0.05 Nagelkerke R^2 = 0.07			Model D Cox & Snell R^2 = 0.04 Nagelkerke R^2 = 0.06		
		n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald
Sex	Male	147	1.06 (0.63, 1.79)	0.05	146	1.02 (0.60, 1.71)	0.05	147	1.06 (0.62, 1.80)	0.05	146	1.02 (0.60, 1.72)	0.00
	Female (r)	115	-		115	-		115	-		115	-	
Year 5 weight (kg)		262	0.93 (0.82, 1.05)	1.46		-		262	0.93 (0.82, 1.05)	1.37		-	
Weight velocity 5 to 8 years (kg/yr^{-1})		262	1.46* (1.09, 1.97)	6.39		-		262	1.44* (1.07, 1.94)	5.83		-	
Year 5 height (cm)			-		261	1.01 (0.95, 1.07)	0.06		-		261	1.01 (0.93, 1.06)	0.00
Height velocity 5 to 8 years (cm/yr^{-1})			-		261	1.32 (1.00, 1.73)	3.79		-		261	1.35* (1.03, 1.79)	4.56
SES Index (9/10 Years)	Low		-			-		136	0.53* (0.31, 0.89)	5.70	136	0.49** (0.29, 0.82)	7.25
	High (r)		-			-		126	-		125	-	

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category
Model A = Sex + yr 5 weight + weight velocity 5 to 8 yrs
Model B = Sex + yr 5 height + height velocity 5 to 8 yrs
Model C = Sex + yr 5 weight + weight velocity 5 to 8 yrs + Yr 9/10 SES index
Model D = Sex + yr 5 height + height velocity 5 to 8 yrs + Yr 9/10 SES index

Table 4.17 Odds ratios (OR) and 95% confidence intervals (95% CI) for the predictors of early vs. late breasts/genitalia development for Black adolescents

Variable	Categories	Model E Cox & Snell R^2 = 0.06 Nagelkerke R^2 = 0.08			Model F Cox & Snell R^2 = 0.03 Nagelkerke R^2 = 0.04			Model G Cox & Snell R^2 = 0.04 Nagelkerke R^2 = 0.06		
		n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald
Sex	Male	198	0.95 (0.61, 1.48)	0.05	147	1.01 (0.59, 1.72)	0.00	146	0.95 (0.56, 1.62)	0.03
	Female (r)	171	-		114	-		114	-	
Year 5 weight (kg)			-		261	0.93 (0.82, 1.05)	1.39		-	
Weight velocity 5 to 8 years (kg/yr^{-1})			-		261	1.43* (1.07, 1.93)	5.65		-	
Year 5 height (cm)			-			-		260	1.01 (0.95, 1.07)	0.08
Height velocity 5 to 8 years (cm/yr^{-1})			-			-		260	1.31 (1.00, 1.73)	3.72
SES Index (9/10 Years)	Low	188	0.41*** (0.27, 0.64)	15.85		-			-	
	High (r)	176	-			-			-	
1° caregiver's marital Status (9/10 Years)	Other	193	0.65 (0.42, 1.00)	3.82	143	0.72 (0.43, 1.22)	1.51	142	0.69 (0.41, 1.16)	2.00
	Married/Cohabit (r)	176	-		118	-		118	-	

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category
Model E = Sex + caregiver marital status Yr 9/10 + Yr 9/10 SES index
Model F = Sex + yr 5 weight + weight velocity 5 to 8 yrs + caregiver marital status Yr 9/10
Model G = Sex + yr 5 height + height velocity 5 to 8 yrs + caregiver marital status Yr 9/10

For pubic hair development, there were a total of 12 individual significant predictors of age at initiation for Black adolescents. Table 4.18 shows the unadjusted odds ratios (OR) and 95% confidence intervals (95% CI) for these predictors. Sex, birth weight, and year 2 weight were included as control variables within the next set of models that were constructed. In general, a greater weight, height and/or weight velocity during infancy and childhood significantly increased the odds of early pubic hair development.

A total of nine (Model A to Model I) logistic regression models were constructed to examine the predictors of the timing of pubic hair development (see Methods section 3.1.4.5 for a detailed description of how these models were constructed). Tables 4.19 to 4.21 show the adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for each of the models constructed. A greater weight velocity between birth and one year of age significantly increased the odds of achieving early pubic hair development, after controlling for sex and birth weight (OR = 1.35; 95% CI = 1.03, 1.77; $P < 0.05$). A greater weight velocity between the ages of two and four years significantly increased the odds of achieving early pubic hair development; after controlling for sex and year two weight (OR = 1.36; 95% CI = 1.04, 1.78; $P < 0.05$). Year four weight (OR = 1.17; 95% CI = 1.05, 1.30; $P < 0.01$), year four height (OR = 1.20; 95% CI = 1.04, 1.16; $P < 0.01$), year eight weight (OR = 1.11; 95% CI = 1.04, 1.18; $P < 0.01$), year eight height OR = 1.07; 95% CI = 1.02, 1.11; $P < 0.01$) and year eight BMI (OR = 1.18; 95% CI = 1.03, 1.36; $P < 0.01$) all remained significant and significantly increased the odds of early pubic hair development after controlling for sex. Weight velocity between five and eight years became non-significant once sex and year 5 weight were controlled for within the model.

Table 4.18 Unadjusted Odds ratios (OR) and 95% confidence intervals (95%) for predictors of early vs. late pubic hair development for Black adolescents

Variable	Categories	n	Unadjusted OR (95% CI)	Cox & Snell R^2	Nagelkerke R^2	Wald Statistic
Sex	Male Female (r)	203 179	1.34 (0.87, 2.02)	0.005	0.01	1.91
Birth weight (kg)		377	1.14 (0.76, 1.72)	0.001	0.00	0.42
Weight velocity 0 to 12 months (kg/yr^{-1})		253	1.36* (1.04, 1.77)	0.020	0.03	5.03
Year 1 weight (kg)		253	1.21* (1.01, 1.45)	0.018	0.02	4.43
Weight velocity 1 to 2 years (kg/yr^{-1})		184	0.69* (0.51, 0.95)	0.030	0.04	5.31
Year 2 weight (kg)		260	1.07 (0.92, 1.24)	0.003	0.00	0.71
Weight velocity 2 to 4 years (kg/yr^{-1})		245	1.32* (1.01, 1.71)	0.017	0.02	4.18
Year 4 weight (kg)		344	1.18** (1.06, 1.31)	0.026	0.04	8.51
Year 4 height (cm)		333	1.11** (1.04, 1.16)	0.034	0.05	10.89
Year 5 weight (kg)		306	1.13* (1.03, 1.27)	0.021	0.03	6.17
Weight velocity 5 to 8 years (kg/yr^{-1})		263	1.29* (1.01, 1.66)	0.016	0.02	4.03
Year 5 height (cm)		305	1.09** (1.03, 1.15)	0.031	0.04	9.25
Year 8 weight (kg)		318	1.11** (1.05, 1.19)	0.038	0.05	11.31
Year 8 height (cm)		318	1.07** (1.02, 1.12)	0.029	0.04	9.10
Year 8 BMI (kg/m^2)		318	1.19* (1.03, 1.37)	0.018	0.03	5.64

Table 4.19 Adjusted Odds ratios (OR) and 95% confidence intervals (95%) for the predictors of early vs. late pubic hair development for Black adolescents (Models A to D)

Variable	Categories	Model A Cox & Snell R^2 = 0.02 Nagelkerke R^2 = 0.03			Model B Cox & Snell R^2 = 0.05 Nagelkerke R^2 = 0.07			Model C Cox & Snell R^2 = 0.03 Nagelkerke R^2 = 0.04			Model D Cox & Snell R^2 = 0.03 Nagelkerke R^2 = 0.04		
		n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI))	Wald	n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald
Sex	Male	134	1.01 (0.60, 1.70)	0.00	100	1.11 (0.60, 2.06)	0.12	134	1.35 (0.80, 2.29)	1.25	182	1.30 (0.84, 2.02)	1.34
	Female (r)	119	-		84	-		111	-		162	-	
Birth weight (kg)		253	1.13 (0.68, 1.89)	0.23		-			-			-	
Weight velocity 0 to 12 months (kg/yr^{-1})		253	1.35* (1.03, 1.77)	4.81		-			-			-	
Year 1 weight (kg)			-		184	1.22 (0.98, 1.52)	3.29		-			-	
Weight velocity 1 to 2 years (kg/yr^{-1})			-		184	0.74 (0.54, 1.01)	3.55		-			-	
Year 2 weight (kg)			-			-		245	1.12 (0.96, 1.32)	2.03		-	
Weight velocity 2 to 4 years (kg/yr^{-1})			-			-		245	1.36* (1.04, 1.78)	5.01		-	
Year 4 weight (kg)			-			-					344	1.17** (1.05, 1.30)	7.87

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category
Model A = Sex + birth weight + weight velocity 0 to 12 months
Model B = Sex + yr 1 weight + weight velocity 1 to 2 yrs
Model C = Sex + yr 2 weight + weight velocity 2 to 4 yrs
Model D = Sex + yr 4 weight

Table 4.20 Adjusted Odds ratios (OR) and 95% confidence intervals (95%) for the predictors of early vs. late pubic hair development for Black adolescents (Models E to F)

Variable	Categories	Model E Cox & Snell R^2 = 0.04 Nagelkerke R^2 = 0.05			Model F Cox & Snell R^2 = 0.03 Nagelkerke R^2 = 0.04		
		n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald
Sex	Male	177	1.14 (0.73, 1.79)	0.332	145	1.03 (0.62, 1.72)	0.02
	Female (r)	156	-		118	-	
Year 4 height (cm)		333	1.20** (1.04, 1.16)	10.52		-	
Year 5 weight (kg)			-		263	1.13* (1.01, 1.28)	4.20
Weight velocity 5 to 8 years (kg/yr^{-1})			-		263	1.14 (0.86, 1.50)	0.81

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category
Model E = Sex + yr 4 height
Model F = Sex + yr 5 weight + weight velocity 5 to 8 yrs

Table 4.21 Adjusted Odds ratios (OR) and 95% confidence intervals (95%) for the predictors of early vs. late pubic hair development for Black adolescents (Models G to I)

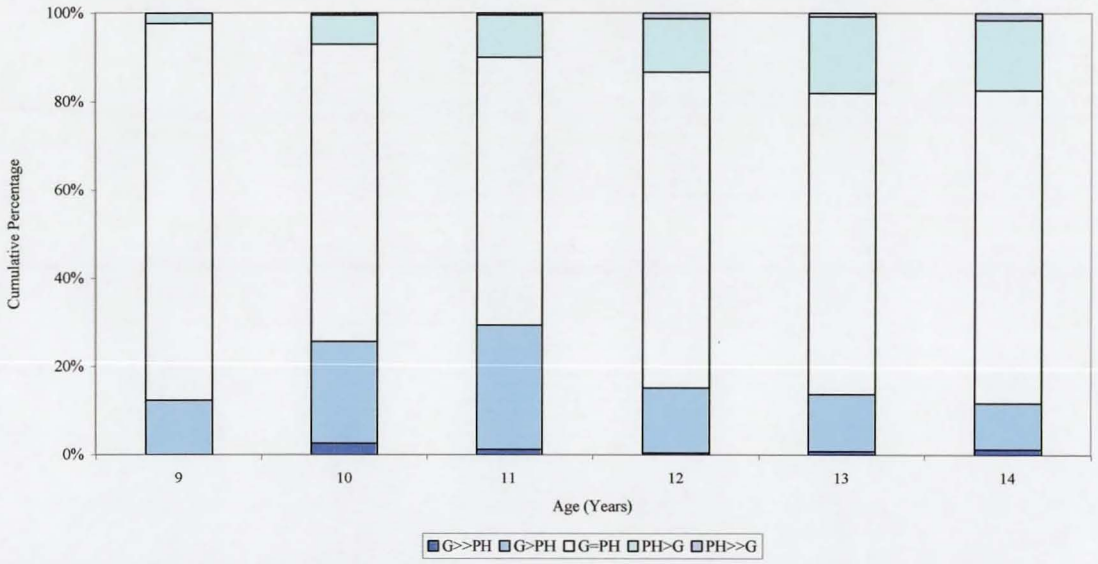
Variable	Categories	Model G Cox & Snell R^2 = 0.04 Nagelkerke R^2 = 0.05			Model H Cox & Snell R^2 = 0.03 Nagelkerke R^2 = 0.04			Model I Cox & Snell R^2 = 0.02 Nagelkerke R^2 = 0.03		
		n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald	n	Adjusted OR (95% CI)	Wald
Sex	Male	165	1.17 (0.74, 1.85)	0.46	165	1.16 (0.73, 1.82)	0.39	165	1.22 (0.77, 1.91)	0.71
	Female (r)	153	-		153	-		153	-	
Year 8 weight (kg)		318	1.11** (1.04, 1.18)	10.99		-			-	
Year 8 height (cm)			-		318	1.07** (1.02, 1.11)	8.68		-	
Year 8 BMI (kg/m^2)			-			-		318	1.18* (1.03, 1.36)	5.54

* P < 0.05, ** P < 0.01, *** P < 0.001/(r) is the reference category
Model G = Sex + yr 8 weight
Model H = Sex + yr 8 height
Model I = Sex + yr 8 BMI

4.2.6 Concordance and discordance of pubertal development

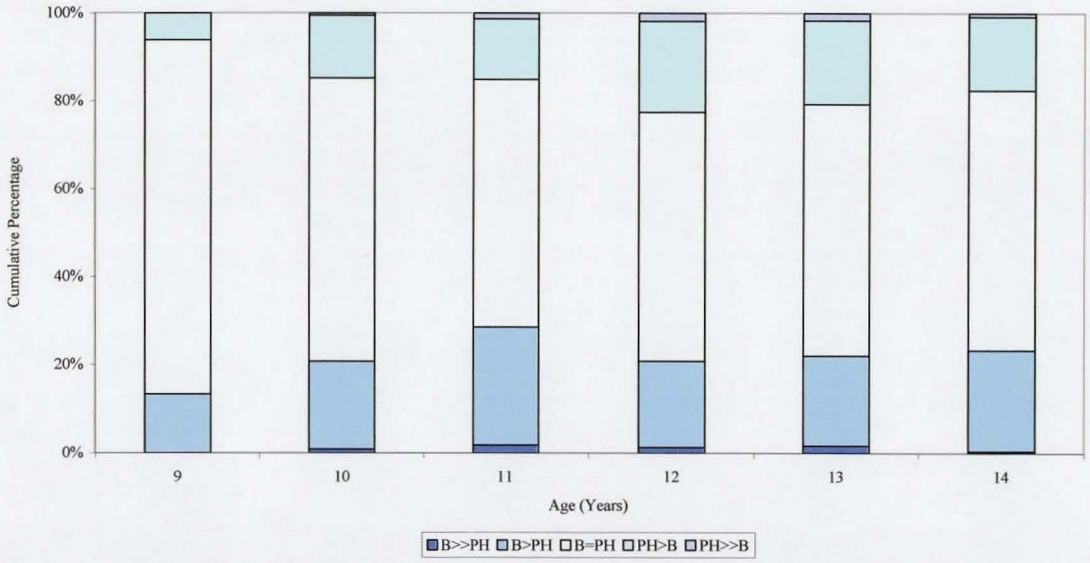
Figures 4.5 to 4.10 show the proportion of concordance and discordance grouped by gender (Figures 4.5 and 4.6) and by gender and ethnic group (Figures 4.7 to 4.10) for each age group. Approximately 62.5% of girls and 70.4% of boys were concordant across the age groups. This ranged from a maximum of 85.0% for nine year old girls to a minimum of 57.0% for 11 year old boys. When grouped by ethnic group and gender, on average 17.4% of Black boys were discordant and had a genitalia rating that was one (G>PH) or two (G>>PH) stages greater than their pubic hair development rating. This was compared to 20.6% of White boys across the age groups. For Black girls, on average 24.3% were discordant with their breast rating being one (B>PH) or two (B>>PH) stages greater than their pubic hair development rating compared to 14.6% of White girls across the age groups. Both genders and ethnic groups were more likely to be discordant with a greater genitalia/breast rating compared to the pubic hair rating. For Black boys, an average of 11.3% were discordant with their pubic hair rating being one (PH>G) or two (PH >> G) stages greater than their genitalia development rating compared to 11.4% of White boys across the age groups. For Black girls, 13.6% were discordant with their pubic hair rating being one (PH>B) or two stages (PH>>B) greater than their breast development rating compared to 21.9% for White girls across the age groups. Black and White boys show similar levels of concordance (71.3 vs. 68.1%) as do Black and White girls (62.0 vs. 63.6%); however, boys were more likely to be concordant compared to girls.

Figure 4.5 Proportion of boys with concordant/discordant Tanner ratings by age



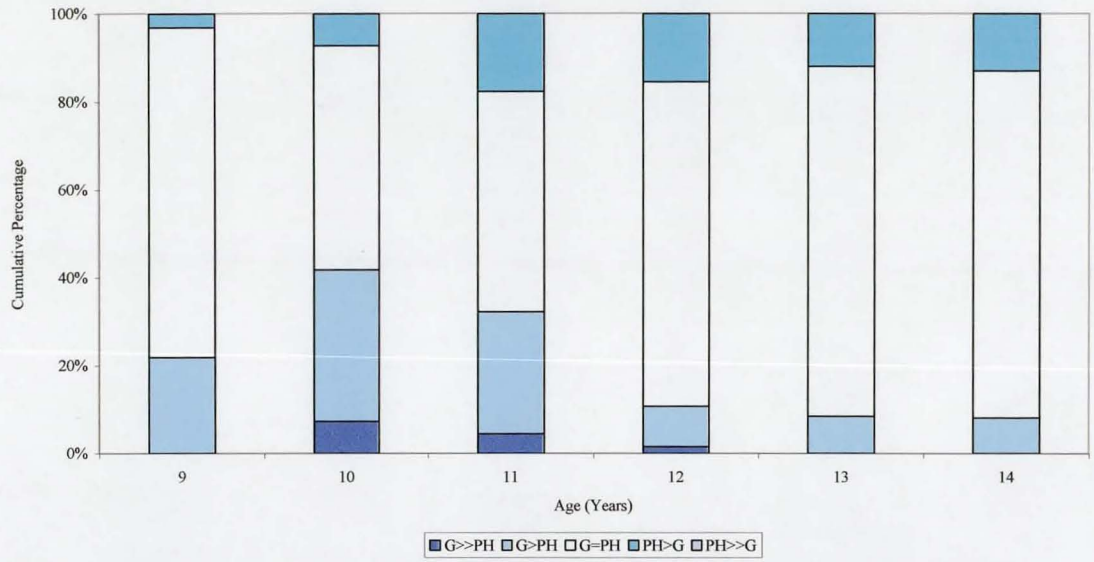
Key: G>>PH = genitalia rating two stages greater than pubic hair rating, G>PH = genitalia rating one stages greater than pubic hair rating, G=PH = genitalia rating equals pubic hair rating, PH>G = pubic hair rating one stage greater than genitalia rating, PH>>G = pubic hair rating two stages greater than genitalia rating

Figure 4.6 Proportion of girls with concordant/discordant Tanner ratings by age



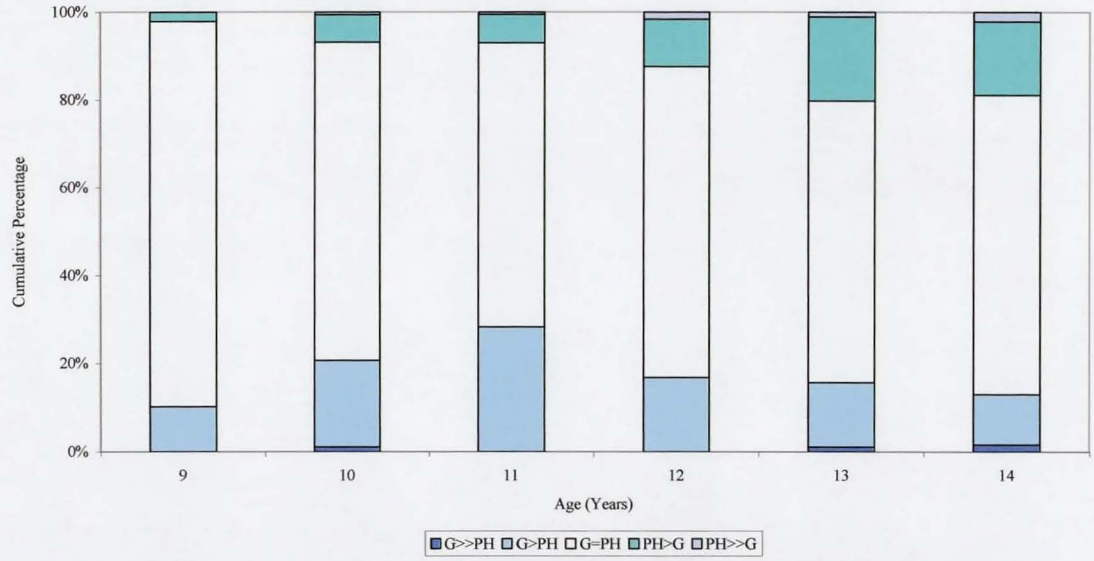
Key: B>>PH = breast rating two stages greater than pubic hair rating, B>PH = breast rating one stages greater than pubic hair rating, B=PH = breast rating equals pubic hair rating, PH>B = pubic hair rating one stage greater than breast rating, PH>>B = pubic hair rating two stages greater than breast rating

Figure 4.7 Proportion of White boys with concordant/discordant Tanner ratings by age



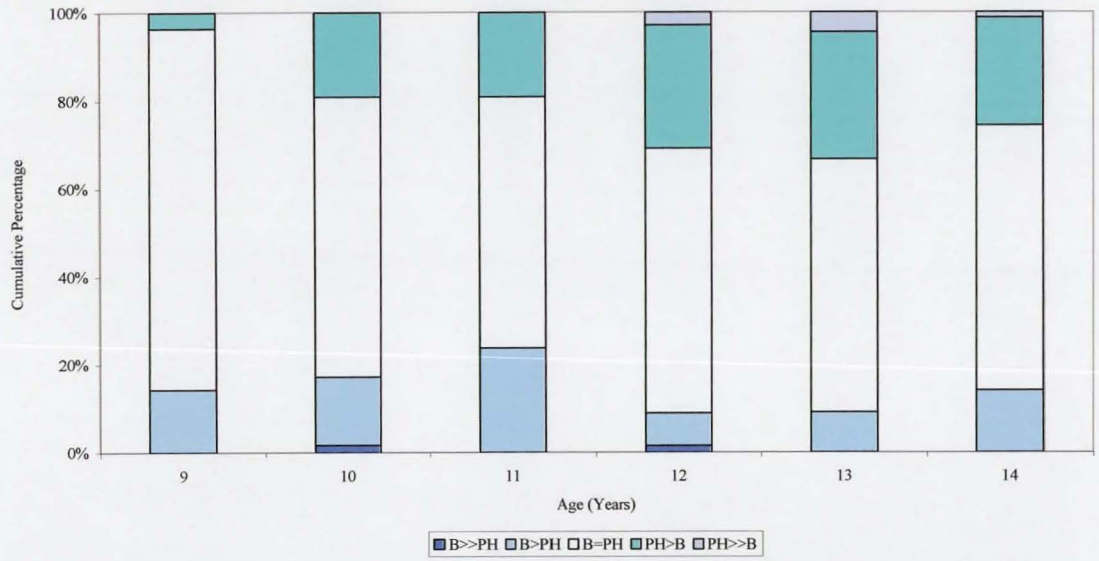
Key: G>>PH = genitalia rating two stages greater than pubic hair rating, G>PH = genitalia rating one stages greater than pubic hair rating, G=PH = genitalia rating equals pubic hair rating, PH>G = pubic hair rating one stage greater than genitalia rating, PH>>G = pubic hair rating two stages greater than genitalia rating

Figure 4.8 Proportion of Black boys with concordant/discordant Tanner ratings by age



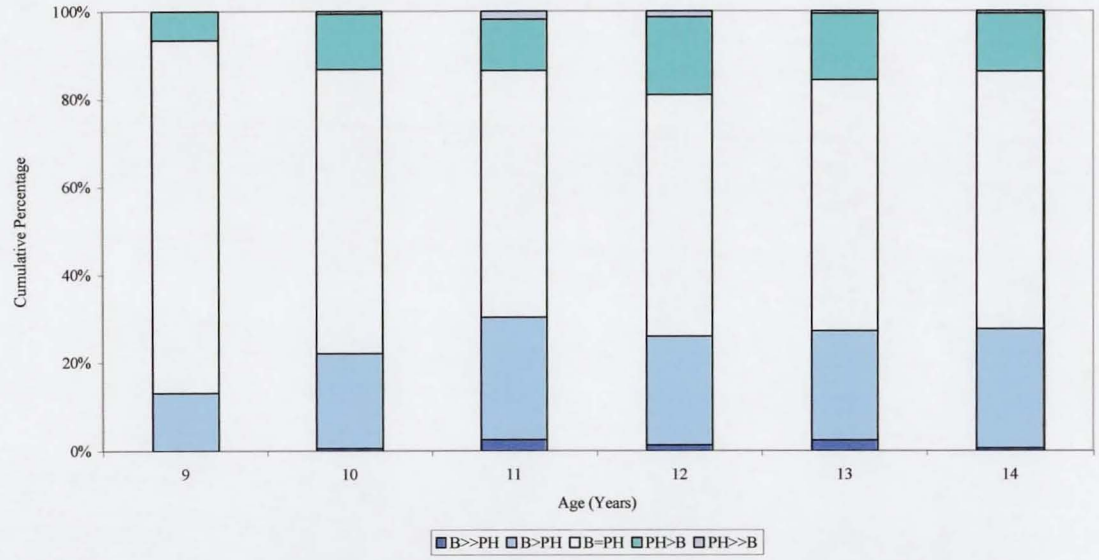
Key: G>>PH = genitalia rating two stages greater than pubic hair rating, G>PH = genitalia rating one stages greater than pubic hair rating, G=PH = genitalia rating equals pubic hair rating, PH>G = pubic hair rating one stage greater than genitalia rating, PH>>G = pubic hair rating two stages greater than genitalia rating

Figure 4.9 Proportion of White Girls with concordant/discordant Tanner ratings by age



Key: B>>PH = breast rating two stages greater than pubic hair rating, B>PH = breast rating one stages greater than pubic hair rating, B=PH = breast rating equals pubic hair rating, PH>B = pubic hair rating one stage greater than breast rating, PH>>B = pubic hair rating two stages greater than breast rating

Figure 4.10 Proportion of Black Girls with concordant/discordant Tanner ratings by age



Key: B>>PH = breast rating two stages greater than pubic hair rating, B>PH = breast rating one stages greater than pubic hair rating, B=PH = breast rating equals pubic hair rating, PH>B = pubic hair rating one stage greater than breast rating, PH>>B = pubic hair rating two stages greater than breast rating

4.3 External validity of the analysis samples

The samples used in the above analysis are drawn from the Bone Health sub-sample of the original Bt20 cohort study. To examine how representative these analysis samples (both the menarche and pubertal development) were, external validity checks were run to examine the socio-economic, demographic and growth characteristics against the original Bt20 cohort.

South Africa experiences high levels of socio-economic inequality and so the reduction in analysis sample size may decrease the range of socio-economic profiles within the cohort. Investigations of those Bt20 infants that were included in the analysis and those who were excluded show significant differences in key demographic and growth characteristics (Table 4.22[****]) and household socio-economic status indicators (Tables 4.23).

There were six statistically significant differences between those included in the menarche sample compared to those remaining in the Bt20 sample: weight at one year of age was significantly greater for those excluded (9.5 vs. 9.2kg), as was height at one year (73.9 vs. 72.5cm), weight velocity between birth and one year age (6.4 vs. 6.2 kg/yr^{-1}), height at two years (83.2 vs. 82.4cm) and height velocity from one to two years of age (9.7 vs. 9.4cm/yr^{-1}) were also significantly greater for those excluded compared to those that were included in the menarche sample. Weight velocity between four and five years was significantly greater for those included in the menarche sample compared to those excluded (2.5 vs. 2.3 kg/yr^{-1}). Maternal age at the time of the birth of the Bt20/BH infant was significantly greater (26.0 vs. 25.0 years) for those excluded from the sample and those mothers were significantly more likely to be married or cohabiting at this time (44.9 vs. 19.0%).

There were six statistically significant differences in demographic and growth characteristics between those included in the pubertal development sample and those who were excluded. Parity was significantly less for those included in the sample (2.1 vs. 2.3 children). BMI at four years (15.7 vs. 15.5 kg/m^2), weight at five years (18.5 vs. 18.0 kg), BMI at five years (15.7 vs. 15.5 kg/m^2), weight velocity from four to five years (2.5 vs. 2.3 kg/yr^{-1}) and BMI at eight years (16.0 vs. 15.8 kg/m^2) were all significantly greater for those included in the analysis compared to those excluded. There were four statistically significant differences in socio-economic indicators between those included in the pubertal development analysis compared to those excluded from the analysis. Maternal age at the time of the birth of the Bt20/BH infant was significantly less (25.2 vs. 26.1 years) for those included in the sample and those mothers were significantly less likely to be married or cohabiting at this time (75.4 vs. 46.0%). Those included in the analysis sample were significantly more likely to live in a house compared to other forms of accommodation (89.0 vs. 54.0%), but significantly less likely to own a car (26.3 vs. 33.6%).

[****] Please note that the sample size of excluded adolescents varies for each variable of interest as data may not have been collected in each data collection wave

In summary, those included in the menarche sample, were smaller and lighter, and had younger mothers that were less likely to be married compared to those that were excluded, thus may have had a lower SES. Those included in the pubertal development sample, were taller, heavier and grew quicker in infancy, had younger mothers that were less likely to be married, although they were more likely to live in a house compared to those excluded from the analysis.

Table 4.22 Key demographic and growth characteristics of those infants who were included in the menarche/pubertal development samples compared to those remaining in the original Birth to Twenty (Bt20) cohort

Variable	Menarche Sample				Pubertal Development Sample			
	n	Excluded	n	Included	n	Excluded	n	Included
Birth Weight (g) (Mean [SD])	3094	3.1 (0.5)	173	3.0 (0.5)	2887	3.1 (0.5)	380	3.1 (0.5)
Low Birth Weight (% [95% CI])		11.7 (10.6-12.9)		13.3 (8.2-18.4)		12.0 (10.8-13.1)		10.8 (7.7-13.9)
Average Birth Weight (% [95% CI])		85.7 (84.5-87.0)		86.1 (81.0-91.3)		85.7 (84.4-86.9)		86.6 (83.2-90.0)
High Birth Weight (% [95% CI])		2.5 (2.0-3.1)		0.6 (0.0-1.7)		2.4 (1.8-2.9)		2.6 (1.0-4.2)
Gestational Age (Weeks) (Mean [SD])	2997	38.2 (1.9)	174	(38.0 (1.9)	2789	38.2 (1.9)	382	38.0 (1.7)
Pre-term (<36 Weeks) (% [95% CI])		12.0 (10.8-13.1)		16.7 (11.1-22.2)		12.0 (10.8-13.3)		13.6 (10.2-17.1)
Term (37-41 Weeks) (% [95% CI])		87.7 (86.5-88.9)		82.8 (77.1-88.4)		87.7 (86.5-88.9)		85.3 (81.8-88.9)
Post-term (>42 weeks) (% [95% CI])		0.3 (0.1-0.5)		0.6 (0.0-1.7)		0.3 (0.1-0.4)		1.0 (0.0-2.1)
Size For Gestation	2995		173		2788		380	
Appropriate for Gestational Age (% [95% CI])		85.5 (84.2-86.7)		89.6 (85.0-94.1)		85.2 (83.9-86.5)		89.5 (86.4-92.6)
Small For Gestational Age (% [95% CI])		14.5 (13.3-15.8)		10.4 (5.9-15.0)		14.8 (13.5-16.1)		10.5 (7.4-13.6)
Parity	3098	2.3 (1.4)	174	2.1 (1.3)	2890	2.3 (1.4)	382	2.1 (1.3)*
Primaparous (% [95% CI])		36.2 (34.5-37.8)		44.8 (37.4-52.2)		35.8 (34.1-37.6)	382	42.4 (37.5-47.4)
Non-primaparous (% [95% CI])		63.8 (62.2-65.5)		55.2 (47.8-62.6)		64.3 (62.4-65.9)		57.6 (52.6-62.5)
Weight at 1 Year (kg) (Mean [SD])	1315	9.5 (1.4)	119	9.2 (1.5)*	1177	9.5 (1.4)	257	9.5 (1.4)
Height at 1 Year (cm) (Mean [SD])		73.9 (3.2)		72.5 (3.1)***		73.9 (3.2)		73.5 (3.3)
BMI at 1 Year (kg/m2) (Mean [SD])		17.3 (2.0)		17.5 (1.3)		17.3 (2.0)		17.5 (2.0)
Height for Age at 1 Year	1315		119		1177		257	
Stunted at 1 Year (% [95% CI])		8.3 (6.8-9.8)		9.2 (4.0-14.4)		7.6 (6.1-9.2)		11.7 (7.7-15.6)
Not Stunted at 1 Year (% [95% CI])		91.7 (90.2-93.2)		90.8 (85.6-96.0)		92.4 (90.8-93.9)		88.3 (84.4-92.3)
Weight Velocity 0 to 12 Months (kg/yr^{-1}) (Mean [SD])	1312	6.4 (1.3)	119	6.2 (1.2)*	1174	6.4 (1.3)	257	6.4 (1.3)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.22 continued Key demographic and growth characteristics of those infants who were included in the menarche/pubertal development samples compared to those remaining in the original Birth to Twenty (Bt20) cohort.

Variable	Menarche Sample				Pubertal Development Sample			
	n	Excluded	n	Included	n	Excluded	n	Included
Weight Velocity 6 to 12 Months (kg/yr^{-1}) (Mean [SD])	378	3.7 (1.4)	24	3.2 (1.3)	343	3.7 (1.4)	59	3.1 (1.3)
Height Velocity 6 to 12 Months (cm/yr^{-1}) (Mean [SD])		16.7 (6.2)		17.6 (7.5)		16.8 (6.3)		16.1 (1.3)
Weight at 2 Years (kg) (Mean [SD])	1027	11.5 (1.7)	115	11.4 (1.5)	880	11.5 (1.7)	262	11.5 (1.7)
Height at 2 Years (cm) (Mean [SD])		83.2 (4.1)		82.4 (3.7)*		83.1 (4.1)		82.9 (3.9)
BMI at 2 Years (kg/m2) (Mean [SD])		16.6 (2.3)		16.8 (2.0)		16.6 (2.3)		16.8 (2.1)
Height for Age at 2 Year								
Stunted at 2 Years (% [95% CI])	1027	19.3 (16.9-21.7)	115	18.3 (11.2-25.3)	880	19.2 (16.6-21.8)	262	19.1 (14.3-23.8)
Not Stunted at 2 Years (% [95% CI])		80.7 (78.3-83.1)		81.7 (74.7-88.8)		80.8 (78.2-83.4)		80.9 (76.2-85.7)
Year 2 Normal/Overweight/Obese								
Under/Normal Weight (% [95% CI])	755	80.7 (77.8-83.5)	75	77.3 (67.9-86.8)	646	81.1 (78.1-84.1)	184	77.7 (71.7-83.7)
Overweight/Obese (% [95% CI])		19.3 (16.5-22.2)		22.7 (13.2-32.1)		18.9 (15.9-21.9)		22.3 (16.3-28.3)
Weight Velocity 1 to 2 Years (kg/yr^{-1}) (Mean [SD])	583	2.0 (1.2)	84	2.1 (1.0)	482	2.0 (1.1)	185	2.0 (1.2)
Height Velocity 1 to 2 Years (cm/yr^{-1}) (Mean [SD])		9.7 (2.8)		9.4 (3.0)*		8.7 (2.9)		9.1 (2.8)
Growth rate (0-2 years)								
Catch up Growth (% [95% CI])	1024	21.2 (18.7-23.7)	115	24.3 (16.5-32.2)	878	21.1 (18.4-23.8)	261	23.0 (17.9-28.1)
Same Growth Trajectory (% [95% CI])		34.0 (31.1-36.9)		40.9 (31.9-49.9)		34.6 (31.5-37.8)		34.9 (29.1-40.6)
Catch Down Growth (% [95% CI])		44.8 (41.8-47.9)		34.8 (26.1-43.5)		44.3 (41.0-47.6)		42.1 (36.2-48.1)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.22 continued Key demographic and growth characteristics of those infants who were included in the menarche/pubertal development samples compared to those remaining in the original Birth to Twenty (Bt20) cohort

Variable	Menarche Sample				Pubertal Development Sample			
	n	Excluded	n	Included	n	Excluded	n	Included
Weight at 4 Years (kg) (Mean [SD])	1283	15.3 (2.1)	160	15.2 (2.1)	1095	15.3 (2.1)	348	15.4 (2.1)
Height at 4 Years (cm) (Mean [SD])		99.2 (4.5)		98.6 (4.0)		99.2 (4.5)		98.8 (4.0)
BMI at 4 Years (kg/m2) (Mean [SD])		15.5 (1.4)		15.6 (1.4)		15.5 (1.4)		15.7 (1.4)*
Height for Age at 4 Years								
Stunted at 4 Years (% [95% CI])	1283	11.6 (9.9-13.4)	160	8.1 (3.9-12.4)	1095	11.7 (9.8-13.6)	348	9.8 (6.7-12.9)
Not Stunted at 4 Years (% [95% CI])		88.4 (86.6-90.1)		91.9 (87.6-96.1)		88.3 (86.4-90.2)		90.2 (87.1-93.3)
Year 4 Normal/Overweight/Obese								
Under/Normal Weight (% [95% CI])	1281	93.1 (91.7-94.4)	160	92.5 (88.4-96.6)	1094	92.8 (91.2-94.3)	347	93.7 (91.1-96.2)
Overweight/Obese (% [95% CI])		6.9 (5.6-8.3)		7.5 (3.4-11.6)		7.2 (5.7-8.8)		6.3 (3.8-8.9)
Weight Velocity 2 to 4 Years (kg/yr^{-1}) (Mean [SD])	582	2.1 (0.8)	109	2.0 (0.7)	444	2.0 (0.8)	247	2.1 (0.8)
Height Velocity 2 to 4 Years (cm/yr^{-1}) (Mean [SD])		8.5 (1.6)		8.5 (1.6)		8.5 (1.5)		8.6 (1.7)
Weight at 5 years (kg) (Mean[SD])	1214	18.1 (2.6)	134	18.2 (2.3)	1038	18.0 (2.6)	310	18.5 (2.9)*
Height at 5 Years (cm) (Mean [SD])		107.9 (4.8)		107.9 (4.4)		107.7 (4.8)		108.3 (4.5)
BMI at 5 Years (kg/m2) (Mean [SD])		15.5 (1.5)		15.6 (1.3)		15.5 (1.4)		15.7 (1.4)*
Height for Age at 5 Years								
Stunted at 5 Years (% [95% CI])	1214	7.1 (5.6-8.5)	134	5.2 (1.5-9.0)	1038	7.2 (5.7-8.8)	310	5.8 (3.2-8.4)
Not Stunted at 5 Years (% [95% CI])		92.9 (91.5-94.4)		94.8 (91.0-98.5)		92.8 (91.2-94.3)		94.2 (91.6-96.8)
Year 5 Normal/Overweight/Obese								
Under/Normal Weight (% [95% CI])	1214	90.4 (88.7-92.0)	134	88.1 (82.6-93.6)	1038	90.3 (88.5-92.1)	310	89.7 (86.3-93.1)
Overweight/Obese (% [95% CI])		9.6 (8.0-11.3)		11.9 (6.4-17.4)		9.7 (7.9-11.5)		10.3 (6.9-13.7)
Weight Velocity 4 to 5 Years (kg/yr^{-1}) (Mean [SD])	900	2.3 (1.0)	128	2.5 (1.0)**	736	2.3 (1.0)	292	2.5 (0.9)**
Height Velocity 4 to 5 Years (cm/yr^{-1}) (Mean [SD])		7.4 (1.5)		7.5 (1.7)		7.4 (1.5)		7.4 (1.5)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.22 continued Key demographic and growth characteristics of those infants who were included in the menarche/pubertal development samples compared to those remaining in the original Birth to Twenty (Bt20) cohort

Variable	Menarche Sample				Pubertal Development Sample			
	n	Excluded	n	Included	n	Excluded	n	Included
Weight at 8 Years (kg) (Mean [SD])	1175	24.5 (4.3)	150	24.6 (4.0)	1002	24.4 (4.4)	323	24.8 (3.8)
Height at 8 Years (cm) (Mean [SD])		124.3 (6.0)		123.9 (5.0)		124.1 (6.1)		124.4 (5.4)
BMI at 8 Years (kg/m2) (Mean [SD])		15.8 (1.9)		16.0 (1.8)		15.8 (1.9)		16.0 (1.6)*
Height for Age at 8 Years								
Stunted at 8 Years (% [95% CI])	1175	8.9 (7.3-10.6)	150	4.7 (1.3-8.0)	1002	8.9 (7.1-10.6)	323	7.1 (4.3-9.9)
Not Stunted at 8 Years (% [95% CI])		91.1 (89.4-92.7)		95.3 (92.0-98.7)		91.1 (89.4-92.9)		92.9 (90.1-95.7)
Year 8 Normal/Overweight/Obese								
Under/Normal Weight (% [95% CI])	1175	92.8 (91.3-94.2)	150	94.0 (90.2-97.8)	1002	92.9 (91.3-94.5)	323	92.9 (90.1-95.7)
Overweight/Obese (% [95% CI])		7.2 (5.8-8.7)		6.0 (2.2-9.8)		7.1 (5.5-8.7)		7.1 (4.3-9.9)
Weight Velocity 5 to 8 Years (kg/yr^{-1}) (Mean [SD])	734	2.1 (0.7)	116	2.2 (0.7)	583	2.1 (0.7)	267	2.2 (0.7)
Height Velocity 5 to 8 Years (cm/yr^{-1}) (Mean [SD])		5.4 (1.0)		5.4 (1.0)		5.4 (1.0)		5.5 (1.0)

* P < 0.05, ** P < 0.01, *** P < 0.001

Table 4.23 Key socio-economic characteristics of those infants who were included in the menarche/pubertal development samples compared to those remaining in the original Birth to Twenty (Bt20) cohort

Variable	Menarche Sample				Pubertal Development Sample			
	n	Excluded	n	Included	n	Excluded	n	Included
Maternal Age at Birth (Years) (Mean [SD])	3096	26.0 (6.1)	174	25.0 (6.1)*	2888	26.1 (6.1)	382	25.2 (5.9)**
Maternal Education at Birth								
< Grade 10/High School (% [95% CI])	2761	58.2 (56.4-60.1)	171	60.2 (52.9-67.6)	2553	58.6 (56.7-60.5)	379	56.7 (51.7-61.7)
> Grade 10/High School (% [95% CI])		41.8 (39.9-43.6)		39.8 (32.4-47.1)		41.4 (39.5-43.3)		43.3 (38.3-48.3)
Maternal Marital Status at Birth								
Married/Cohabiting (% [95% CI])	3076	44.9 (43.1-46.7)	174	19.0 (13.1-24.8)**	2868	54.0 (52.2-55.8)	382	24.6 (20.3-28.9)**
Not married/Cohabiting (% [95% CI])		55.1 (55.3-56.9)		81.0 (75.2-86.9)**		46.0 (44.2-47.8)		75.4 (71.1-79.7)**
Type of Home								
Other	3099	43.6 (41.8-45.3)	174	12.1 (7.2-16.9)	2891	46.0 (44.2-47.8)	382	11.0 (7.9-14.1)**
House		56.4 (54.7-58.2)		87.9 (83.1-92.8)		54.0 (52.2-55.8)		89.0 (85.9-92.1)**
Water Facilities								
Other	3099	59.5 (57.8-61.3)	174	51.1 (43.7-58.6)	2891	59.8 (58.1-61.6)	382	53.4 (48.4-58.4)
Indoor		40.5 (38.7-42.2)		48.9 (41.4-56.3)		40.2 (38.4-41.9)		46.6 (41.6-51.6)
Toilet Facilities								
Other	3099	72.4 (70.8-74.0)	174	76.4 (70.1-82.7)	2891	72.0 (70.4-73.7)	382	77.0 (72.7-81.2)
Indoor		27.6 (26.0-29.2)		23.6 (17.3-29.9)		28.0 (26.3-29.6)		23.0 (18.8-27.3)
Television Ownership								
No	2276	26.8 (24.9-28.6)	170	20.6 (14.5-26.7)	2073	27.0 (25.1-28.9)	373	22.8 (18.5-27.0)
Yes		73.2 (71.4-75.1)		79.4 (73.3-85.5)		73.0 (71.1-74..9)		77.2 (73.0-81.5)
Car Ownership								
No	2276	67.3 (65.4-69.2)	170	71.2 (64.4-78.0)	2074	66.4 (64.4-68.5)	373	73.7 (69.3-78.2)*
Yes		32.7 (30.8-34.7)		28.8 (22.0-35.6)		33.6 (31.5-35.6)		26.3 (21.8-30.7)*
Fridge Ownership								
No	2278	29.8 (27.9-31.7)	170	26.5 (19.8-33.1)	2076	30.4 (28.4-32.4)	372	25.0 (20.6-29.4)
Yes		70.2 (68.3-72.1)		73.5 (66.9-80.2)		69.6 (67.6-71.6)		75.0 (70.6-79.4)

5 Qualitative Results

The following chapter presents results from eight focus groups (FG) that were conducted with Birth to Twenty (Bt20) adolescents and staff.

5.1 Focus groups

5.1.1 Participant background information

Prior to the commencement of focus groups, all participants completed background questionnaires on demographics and the adolescents also completed questionnaires on socio-economic status (SES) and a physical development in adolescence questionnaire (see Appendix VII for a copy of these questionnaires). These data allowed the composition of each focus group to be examined. Table 5.1 shows the demographic and socio-economic composition of the adolescent focus groups and Table 5.2 shows the pubertal development of these adolescents. Table 5.3 shows the composition of the staff focus groups.

5.1.2 Focus group composition

5.1.2.1 Adolescent focus groups

5.1.2.1.1 Focus group 1: female community adolescents

A total of nine Black females attended the community adolescent FG, their ages ranged from 14 to 17 years and they were currently in school grades nine to 11. Five lived in low SES areas and four were from middle/high SES areas of residence (see Methods section 3.2.7 for a discussion of how these groups were categorised). All nine of these girls had achieved menarche. Three girls were in early puberty (Tanner stages 2-3) for breast development and six were in early puberty for pubic hair development. Six girls were in late puberty (Tanner stages 4-5) for breast development and three were in later puberty for pubic hair development.

5.1.2.1.2 Focus group 2: male community adolescents

A total of six Black males attended the community adolescent FG. Their ages ranged from 14 to 16 years and they were currently in school grades ten to 12. There was an equal split between low and middle/high SES with three males in each group. Five of this group had

experienced their voice breaking. One male reported being in early puberty (Tanner stages 2-3) for genitalia development and two in late puberty (Tanner stages 4-5). Three males reported being in late puberty for pubic hair development. Three males did not report their pubertal status.

5.1.2.1.3 Focus group 3: female early puberty Bt20 adolescents

Focus group three consisted of 12 Black Bt20 females, two of whom were 15 and ten of whom were 16 years of age. Each of these girls had been seen in the data collection wave for year 15 at the Baragwanath site and reported being in Tanner stages 2-3 for Breast development. They were therefore recruited into the female "early puberty" focus group. They were currently in school grades nine to 12. Eight of these girls lived within a middle/ high SES area and four lived in a low SES area. All 12 girls had achieved menarche. Four and seven girls reported being in early puberty for breast and pubic hair development respectively. Eight were in late puberty for breast development and five for pubic hair development. The audio recording of this focus group was faulty and therefore direct quotes were not available in the following transcript analysis. However, notes were taken during this focus group and any relevant information has been incorporated into the following results.

5.1.2.1.4 Focus group 4: male early puberty Bt20 adolescents

Focus group four consisted of 11 Black Bt20 males, eight of whom were 15 and three of whom were 16 years of age. Each of these boys had been seen in the data collection wave for year 15 at the Baragwanath site and reported being in Tanner stages 2-3 for genitalia development. They were therefore recruited into the male "early puberty" focus group. The majority of this group (five) were in school grade nine or lower, with four being in grade ten and two in grade 11 or higher. There was an even split between low and middle/high SES groups. Just over half (six) of these boys did not report voice breaking. Seven boys reported being in early puberty for genitalia and six for pubic hair development.

5.1.2.1.5 Focus group 5: female late puberty Bt20 adolescents

Focus group five consisted of 13 Black Bt20 females, six of whom were 15 and seven of whom were 16 years of age. Each of these girls had been seen in the data collection wave for year 15 at the Baragwanath site and reported being in Tanner stages 4-5 for Breast development. They were therefore recruited into the female "late puberty" focus group. Six of this group lived in middle to high SES areas with the other seven lived in low SES areas.

Seven girls were in school grades 11 to 12 and the remaining members of the group in lower grades. All of these girls had achieved menarche. One and three girls reported being in late puberty for breast and pubic hair development respectively.

5.1.2.1.6 Focus group 6: male late puberty Bt20 adolescents

Focus group six consisted of 13 Black Bt20 males, seven of whom were 15 and six of whom were 16 years of age. Each of these boys had been seen in the data collection wave for year 15 at the Baragwanath site and reported being in Tanner stages 4-5 for genitalia development. They were therefore recruited into the male "late puberty" focus group. Of the 13 members in this focus group seven members lived in low SES areas. Nine participants reported experiencing voice breaking. Eleven of this group reported being in late puberty for both genitalia and pubic hair development.

5.1.2.2 Staff focus groups

Within Bt20 there are two different sites where the adolescents and their caregivers attend for data collection, (Baragwanath hospital (Bara), Soweto and the University of the Witwatersrand Medical School, Johannesburg). Typically, Bt20 adolescents attend the Baragwanath hospital and BH adolescents attend the Medical school site. Due to this split, two separate staff focus groups were conducted, one with Bara staff and one with medical school staff (BH staff).

5.1.2.2.1 Focus group 7: Baragwanath staff

Four members of Baragwanath staff (two male) made up the seventh focus group. One member had less than five years of experience working at Bt20, with the other three having six or more years of experience. All four members of the group reported being involved in pubertal development data collection on either a daily or weekly basis. Three members self-rated themselves as being experienced and one self-rated as being very experienced in pubertal development data collection.

5.1.2.2.2 Focus group 8: Bone Health staff

Four members of Bone Health staff (one male) participated in the eighth focus group; with two members having less than five years of experience and two members having more than ten years of experience working for Bt20. All four members of the group reported being involved in pubertal development data collection on either a daily or weekly basis. Two

members self-rated themselves as being experienced and two self-rated as being very experienced in pubertal development data collection.

Table 5.1 Adolescent focus group participant background information

Variable	FG 1 Female Community Adolescents	FG 2 Male Community Adolescents	FG 3 Female Early Puberty	FG 4 Male Early Puberty	FG 5 Female Late Puberty	FG 6 Male Late Puberty	Total
n	9	6	12	11	13	13	64
Age range							
14	1	1					2
15	2	4	2	8	6	7	29
16	4	1	10	3	7	6	31
>17	2						2
SES (according to area of residence)							
Low	5	3	4	5	7	7	31
Middle/ High	4	3	8	5	6	6	32
Missing				1			1
Current school grade							
≤9	3		1	5	2	6	17
10	3	3	6	4	4	4	24
11-12	3	2	5	2	7	3	22
Missing		1					1
Maternal marital status							
Married	2	1	8	4	8	2	25
Single	5	3	2	2	4	5	21
Divorced/ Widowed/ Other	2	2	1	2	1	3	11
Missing			1	1		3	5
Maternal highest school grade achieved							
≤6				1			1
7-8			1		2		3
9-10	3		1	1	2	2	9
11-12	2	6	6	3	7	7	31
Missing	4		4	6		4	18
Ownership of consumer durables†							
≤4		1			2		3
5-9	6	4	7	10	5	6	38
≥10	3	1	5	1	6	7	23

† This categorised variable was derived from the questionnaire where the ownership of 13 consumer durables: electricity, TV, radio, car, fridge, washing machine, landline phone, mobile phone, video player, DVD player, microwave, MNET (internet access) and DSTV (cable television) was determined.

Table 5.2 Adolescent focus group pubertal development information

Variable	FG 1 Female Community Adolescents	FG 2 Male Community Adolescents	FG 3 Female Early Puberty	FG 4 Male Early Puberty	FG 5 Female Late Puberty	FG 6 Male Late Puberty	Total
n	9	6	12	11	13	13	64
Menarche achieved (females only)							
No							
Yes	9		12		13		34
Age menarche achieved (females only)							
9-11					2		2
12-13	6		3		8		17
≥14	3		8		3		14
Missing			1				1
Voice started breaking (males only)							
No		1		6		4	11
Yes		5		5		9	19
Missing		1		6		4	11
Tanner breast rating (females only)							
Early puberty (2-3)	3		4		1		8
Late puberty (4-5)	6		8		12		26
Tanner genitalia rating (males only)							
Early puberty (2-3)		1		7		2	10
Late puberty (4-5)		2		3		11	16
Missing		3		1			4
Tanner pubic hair rating							
Early puberty (2-3)	6		7	6	3	2	24
Late puberty (4-5)	3	3	5	4	10	11	36
Missing		3		1			4

Table 5.3 Staff focus group participant information

Variable	FG 7	FG 8	Total
	Bara Staff	Bone Health Staff	
n	4	4	8
Gender			
Male	2	1	3
Female	2	3	5
Total time at Birth to Twenty			
≤5 years	1	2	3
6-10 years	1		1
≥10 years	2	2	4
Regularity of pubertal development data collection			
Daily	2	2	4
Weekly	2	2	4
Monthly			0
Never			0
Self rated experience of pubertal development data collection			
Little experience			0
Some experience			0
Experienced	3	2	5
Very experienced	1	2	3

5.2 Adolescents views

5.2.1 Comments on the current Bt20 questionnaire & procedure

The questions relating to the current questionnaire and procedures elicited a range of comments both positive and negative from the adolescents. The majority of the positive comments referred to how easy the questionnaire was to understand and follow; typically because the adolescents understand their own body and the changes that occur during puberty and adolescence.

> *"Straight forward, it was easy coz we understand our body changes and know our body changes" (Community female)*

> *"It's easy to fill" (Community male)*

> *"Yes it's easy because it's just information that we know" (Community male)*

There were negative and positive comments on how the pictures help the adolescents to understand the different stages of development, although they appear to cause some embarrassment and others commented that words should be used rather than pictures.

> *"Moderator. then the pictures, do you think were helpful the drawings in that questionnaire?*
>
> *MPFG. yes" (Community male)*

> *"Yes the picture is helpful, but it embarrasses us" (Late puberty male)*

> *"Moderator: So we'd like to know what you think of these questionnaires.*
>
> *Yes, sometimes they bore us with the pictures they must put it in words" (Late puberty male)*

Whilst the majority of adolescents found the current questionnaire and procedure easy to follow, some adolescents, particularly the males, highlighted some language related issues and problems with self-rating.

> *"It is difficult because sometimes normally see what are changes in your body, nothing and you touch yourself and say bravo" (Early puberty male)*

> *"They must not speak about biology coz some of us don't know biology" (Late puberty male)*

The late puberty males identified problems with the language, whilst initially one participant requested the questionnaire in vernacular, the interaction within the group lead to the comment that vernacular was not required if the questionnaire was made simpler.

"LPMFG. And they must stop using like one language they must use another language like Zulu, seSotho or Setwana...

LPMFG. ...they must make it as simple as can be not some spectrum or what, what, what, what we don't know.

Moderator. So you are saying the language is sometimes a problem?

LPMFG. Yes.

Moderator. You say yes to vernacular.

LPMFG. Not in vernacular if they could make it more simple. Not the spectrum, the bayton what, what" (Late puberty males)

Another example of where the language was not the main issue, but rather certain individuals were embarrassed or shy when answering the questionnaire, particularly if they felt that they were 'small' compared to their peers.

"Moderator. Do you have difficulties in filling it in, like in terms of language?

EPMFG. No...I'm shy to answer it.

Moderator. So you are shy to answer that?

EPMFG. Yes it's like you're ... is small then you have difficulty to answer" (Early puberty male)

There was some evidence to suggest that the Bt20 adolescents were becoming 'over-exposed' to these questionnaires, having seen them for a number of years and that this may have lead to some of the negative comments. This was in comparison to the community adolescents who had not seen the current Bt20 questionnaire prior to attending the focus groups and who did not elicit any negative views.

"...Eish we see it every year" (Late puberty male)

"It's from maybe two years back" (Late puberty male)

5.2.2 Rating of the questionnaire

The adolescents were asked to rate the current Bt20 questionnaire on a Likert scale from one to five, with one being easy to understand and five being hard to understand. This exercise produced a generally positive response with the majority of adolescents rating between one and two (including the early puberty females). Probing as to why they rated the questionnaire positively was typically met with the simple response that it is easy to understand.

> *"LPFFG. 1.*
>
> *LPFFG. 1.*
>
> *Moderator. So all of you, should I take it that all of you found this easy?*
>
> *LPFFG. Yes" (Late puberty females)*

The late puberty males were the only group not to rate one or two. On average they rated the questionnaire as three and suggested that there is potentially some area for improvement.

> *"Moderator. Okay why do you rate it like that like lets say I think 3 comes up like too many times why do you rate it that 3?*
>
> *LPMFG. Because we think they should make a huge change or give us a dictionary when we answer the questionnaires.*
>
> *Moderator. Okay, okay so you it's a matter of maybe some of the words?*
>
> *LPMFG. Yes.*
>
> *Moderator. Okay.*
>
> *LPMFG. Not all of them, some" (Late puberty males)*

5.2.3 Previous experiences of Bt20 questionnaire & procedure

The Bt20 adolescents were asked to give their views on their previous experiences of attending Bt20 and completing the pubertal development questionnaire. A range of positive

and negative views were elicited, with the main comments revolving around interviewer explanation and privacy.

> *"Moderator. Okay so did the interviewer at some point explain to you what you ask them about the questionnaire or if you have difficulty with the questionnaire can you go to him and then he'd explain?*
>
> *LPMFG. Always" (Late puberty males)*

> *"Moderator. did anybody explain to you to complete the questionnaire previously?*
>
> *EPMFG. Yes" (Early puberty male)*

> *"Moderator. Yes okay so were you like so were you given like sufficient privacy?*
>
> *EPMFG. Yes" (Early puberty male)*

5.2.4 Suggested changes to the current Bt20 questionnaire

One of the key questions posed to the participants was to ascertain if they thought that changes should be made to the current questionnaire. Different views were elicited between the groups with both female groups (including the early puberty females) stating that no changes were necessary.

> *"Moderator. You wouldn't change anything?*
>
> *LPFFG. No.*
>
> *Moderator. No questions to be changed?*
>
> *LPFFG. No" (Late puberty females)*

> *"Moderator. So would you recommend that we change anything in that questionnaire?*
>
> *FPFG. No" (Community females)*

The early puberty males also stated that they would not make changes to the language for example putting the questionnaire in vernacular.

> *"Moderator. Would you change the language of the questionnaire maybe put it in vernacular?*
>
> *EPMFG. I won't change the language.*
>
> *Moderator. You won't change a thing...why?*
>
> *EPMFG. Because I do understand the language that is used in there" (Early puberty males)*

In general the community males voiced that no changes were needed; however, one member of the group suggested that the pictures be removed as they were not necessary.

> *"I think these pictures of the penis is not necessary. Like not the questions just the pictures I think it's not necessary" (Community male)*

The late puberty males raised the question about language and the fact that they are used to simple language. In addition, they suggested adding the testicular volume question that had been used in a previous version of the Bt20 pubertal development in adolescence questionnaire.

> *"Moderator. Okay so if you could change that questionnaire in any way how would you change it?*
>
> *LPMFG. We are used to simple words" (Late puberty male)*

> *"LPMFG. There's this other one they took out the one about 'balls' (laughing).*
>
> *Moderator. Okay so you want them to bring back testicular volume question.*
>
> *LPMFG. Yes" (Late puberty male)*

5.2.5 Suggested changes to the current Bt20 procedure for assessing pubertal development

Following on from suggested changes to the questionnaire, the adolescents were asked if they would make any changes to the current Bt20 procedure. Again, the general consensus was that very few, if any changes were required.

> *"Moderator. Okay so you don't need anybody to explain this to you before, I can just give it to you?*
>
> *FPFG. Yes we know our body changes" (Community female)*

> *"Moderator. Anything else would you change the procedures of completing that questionnaire?*
>
> *EPMFG. No" (Early puberty male)*

The main change suggested related to privacy and the need for the provision of a cubicle or special room where the adolescent could complete the questionnaire on their own, or with members of the same sex without fear of other people looking at what they were doing and for this area to also allow them to examine themselves if needed.

> *"LPMFG. Ahh it's like the multiple-choice questionnaire that we are used to and you must see for yourself how are you doing it.*
>
> *Moderator. Okay so you'd like to do it without being interrupted or in privacy but how about if you make in front of girls so they can see?*
>
> *LPMFG. No.*
>
> *LPMFG. No they will do their own" (Late puberty males)*

> *"Moderator. Okay so do you guys feel like you gonna need a special room to fill this questionnaire or you just fill it?*
>
> *LPFFG. Special room.*
>
> *LPFFG. No it's all the same as long as we all girls.*
>
> *Moderator. So you want a special room where there are girls only?*
>
> *LPFFG. Yes" (Late puberty females)*

> *"EPMFG: I think it's better if I am doing it somewhere" (Early puberty male)*
>
> *Moderator: So it's better if you doing it somewhere else in privacy"*

5.3 Staff views

5.3.1 Comments on the stages of the current Bt20 procedure

The staff were asked to describe the normal day-to-day procedure currently used for the collection of pubertal development data at Bt20. This was to try and determine if staff have been following the recommended procedure taught during Bt20 interviewer training and to identify any potential differences between the two data collection sites. Both the Bone Health (BH) and Baragwanath (Bara) staff articulated similar comments on the current procedure, with the main emphasis being placed on explanation, privacy, and confidentiality.

> *"We just give the questionnaire to the child and then just tell the child that they should complete it on their own and if there's anything they don't understand they can come and ask us. And then they go and sit somewhere and fill it on their own. That's what happens day-to-day" (Bone Health female)*

> *"We give the questionnaires, the pubertal questionnaires, and then they have a privacy, private room, where they answer the questions in individuals but explain if the first two-or-three questions explain and then they can carry on and help" (Bara female)*

> *" Well it's mostly emphasised that it's private and confidential and that it's not a test and nobody else will know who develops like this, like they are going to be studied as a group not as individuals and their names won't be written on their questionnaires, so, but we don't go very much into detail as to the questions, on the questions, because they are most likely to give them what I consider answers, or options, so we only ask them to call for help if only they have anything to ask" (Bara male)*

The staff were probed as to what the adolescents were told to do once they had completed the questionnaire. The BH staff said that the adolescents were told to take the questionnaire back to a member of staff in comparison to the Bara staff who reported that the adolescents

placed the completed questionnaire in an envelope and then the envelope was placed in a box.

> *"Moderator. So what happens once they've completed the questionnaire, do they bring it back to you? Do they put it in the box outside or...*
>
> *BHFGF3. They bring it back to us" (Bone health female)*

> *"Moderator. So what happens when they finish the questionnaire? Do they give it back to you? Do they put it in a box? Do they...*
>
> *BSFGM1. They first put it in an envelope, after they fill it where they are staged, then they put it in a box" (Bara male)*

When probed about whether a tutorial was given to each adolescent prior to the completion questionnaire, the BH staff stated that no, no tutorials were given.

> *"Moderator. So what do you say to them before? Do you tutor them in how to fill it in or do you just give it to them?*
>
> *BHFGF3. No, there's no tutoring before" (Bone Health, female)*

When asked if the adolescents had access to a cubicle in which they could examine themselves, the BH staff highlighted that this was a problem and whilst they used to have access to a rest room, it was no longer available. The Bara staff indicated that the adolescents had access to cubicles in which they completed the questionnaire and in which they could examine themselves if required.

> *"BHFGF3. No, we don't have such-*
>
> *BHFGF1. _____ unfortunately.*
>
> *BHFGM1. Currently, but it used to be like that here for the other years.*
>
> *BHFGF3. We've got a change room that we used for that" (Bone Health staff)*

> *"BSFGF1. Exactly what BSFGF2 and BSFGF3 have said and we like give them space that even each, each other of them they shouldn't like see what the next one does. We have like-*
>
> *BSFGM2. Cubicles.*
>
> *BSFGF1. Cubicles in our, the private room which they use that the other one doesn't see what the other one does" (Bara staff)*

5.3.2 Identification of problems with the current Bt20 questionnaire/procedure

The participants discussed problems that have arisen whilst trying to collect pubertal development data. This lead to some interesting discussions with different opinions being articulated, both within and between focus groups. Some of the problems that were highlighted related to language and cognition.

> *"Some of them they don't understand what they're reading, they just tick the box and sometimes we go to them and ask them 'do you understand why you ticked those?' and then the child will just look at you, "because I had to tick" so there are some language problems there" (Bone Health female)*

> *"To me I don't think it's a matter of the language problem but it's the understanding of the context itself. Because I believe even if you can administer it in vernacular I don't think some of these kids will understand what they are supposed to be doing. I don't think it's a matter of language" (Bone Health male)*

In addition, participants identified differences in cognition and response between male and female adolescents. With boys being more likely to over rate themselves and girls underrate.

"One thing that I've realised when I'm capturing†††† with the female and the male return is that girls understand it much better than boys. For instance here... yeah like they usually don't tick or don't write the year which... for instance here 'Has your voice started breaking?', they will tick yes; 'If you are speaking in a deeper voice for more than two years', they wouldn't answer it, and they'll tick maybe 15 here, so 15 is a lie because he's already said 'yes' here or 'no' here. I don't know why, I've only noticed that when I capture, because we obviously don't have access to this information until we capture it, so I've only noticed with the boys that they don't understand this more specially this part of the question, Question 5: "has your voice started breaking? 'No'. If 'Yes' have you been speaking in a deeper voice for more than two years?" and then he writes "15". So it gets like confusing to boys, but it doesn't happen as much as it does with the girls. And one other thing, I don't know whether they feel embarrassed not to tick anything, like tick everything, 'No', 'Yes', 'A little', 'A lot', you know" (Bara male)

"Moderator: OK. That's a really interesting point. And that leads me into, do you think that, that adolescents rate themselves as you see them?

BSFGF1: Boys, I think so, by one or two.. They either feel that they've grown more bigger than their age group, and they think that this was, how are they supposed to look" (Bara female)

"Moderator: Do you think that differs between boys and girls? Do you think, do you think girls are better are rating themselves more accurately, or are they the same as boys, or are boys better at doing it?

BSFGM1: I think that they do, they are able to rate themselves, but sometimes they are falsifying what they are, some of these questions does make them, just a few millimetres" (Bara male)

†††† Capturing is where data from the paper questionnaire are inputted into a computerised database

"BSFGF1: In fact like in the past years, when we had the boys doing, we did some wooden...

Moderator: A Prader orchidometer###

BSFGF1: They used to put a bigger number, which they were not supposed... I think they want to be there, they want to be older, they think that if you have chosen a bigger number than you are, you have grown as a man by this stage, and yet they are still not exactly...

Moderator: So you think that's a boy thing?

BSFGF1: Ja, that's a boy thing. And the girls keep rating themselves smaller.

BSFGF2: Smaller. Girls likes to be smaller.

Moderator: So girls under-rate, and boys over-rate.

BSFGF1: Yes.

Moderator: And that's the consensus that you all have?

BSFGF1: Ja" (Bara staff)

"Again, we are not like to be judgemental of them. Sometimes... We, we don't actually look at those questionnaires, but sometimes we come up close to , a girl [?] who has like a full breast, and unfortunately somewhere she has ticked not her exact size, she has full breasts, at the last picture here, and you see her ticking the, like in the middle, where you can see this person already wears a 36 bra, or a 38 bra, but she ticks where it's like at only number 3" (Bara female)

When discussing if the adolescents understand terms used in the questionnaire like 'texture' and 'density' the general consensus was yes they do understand, although it is potentially dependent on the education of the child. In addition, the participants suggested that the language is not a problem as the adolescents merely look at the pictures and do not read the description.

A Prader orchidometer {{556 Prader, A 1966/a;}} consists of 12 solid ellipsoid models ranging in volume from 1 to 25 mL (1–6, 8, 10, 12, 15, 20, and 25 mL), against which the testis is compared in order to assess testicular volume

> *"I think they do understand. And like most of these kids are, they are familiar with the English language in school, even if they don't attend a, a private school. Even if they are public schools they still speak and learn English" (Bara female)*

> *"It depends on the education of the child. Some go to these private schools, they are well-versed with these terms, it's only those few adolescents who don't quite understand" (Bone Health female)*

> *"BSFGM2: No, I don't think so. I don't think so. I don't even think they do bother themselves to read this.*
>
> *Moderator: They just look at the pictures?*
>
> *BSFGM2: ...ja" (Bara male)*

This lead to further discussions as to whether there was a need for questionnaires to be available in local South African vernaculars in addition to English. These are available however, it was reported these are rarely requested by the adolescents.

> *"BSFGM2: Ja, but they're in translated languages it's just that it hasn't been put into practice properly, but we have translated it into Zulu the most spoken language, and then the second most spoken language which is Southern Sotho, and Tsonga as well...*
>
> *Moderator: So they're available if an adolescent should request that?*
>
> *BSFGF1: Yes.*
>
> *Moderator: Does that happen very often?*
>
> *BSFGM2: No (Bara staff)*

The overriding issue articulated by the participants was the difficulty that staff have in identifying adolescents who may be having problems completing the pubertal development questionnaire.

"Well I don't have anything to add per se, but I think it's, it's a problem for us to identify children who can't understand the questionnaires, if they don't come to us and say I can't understand what the question, question says. And I don't know how to, how we can solve that" (Bone Health female)

"BHFGF3: I don't know now because we never read through these things, they just tick and then we put them-

BHFGF2: That's the other problem is we don't know how they answer the questions exactly, unless when there's a problem, when the child can't answer the questions properly.

BHFGF3: Otherwise we don't know how they answer" (Bone Health staff)

5.3.3 Dealing with potential problems & suggested changes to the current Bt20 questionnaire/ procedure

The staff were asked how they deal with some of the issues raised earlier in the FG and if they could suggest potential changes to the current questionnaire/procedure that may help to increase the accuracy and reliability of pubertal development data collection and to make collection of these data easier in general. Initially, both groups were of the opinion that the questionnaire should not be changed. This however changed as the focus group progressed.

"BHFGF3: I don't think I would change anything, especially because we don't, it's very private.

Moderator: Yeah, you think that they understand it well enough to be able to leave it as it is?

BHFGF3: Yeah, at this age they do understand it" (Bone Health female)

"I don't think it can be improved as much as it is now" (Bara male)

When staff were asked how they deal with adolescents who do not understand the questionnaire, they explained that they have got to know the families that attend data collection over a period of time and can therefore identify those adolescents who may require assistance. These adolescents are given additional translation and support, for instance

sitting back to back while the interviewer reads the question and the adolescents gives the response.

> *"The other advantage is that we mostly know these children or these parents, and do at times know the slow learner or a specific adolescent, in case they need helping more. Be able to cope with them, like we would be able to help them who comes back to see if they have filled it in" (Bara male)*

> *"BSFFG1. Explain unless we do get a child who's one out of ten, who could be maybe a slow learner, which we say OK can I help you then, then we do get a procedure of helping them. If they don't understand or they don't actually doesn't know how to read-*
>
> *Moderator: So what do you do? If somebody can't read the questionnaire, what would you do?*
>
> *BSFGF1: We read it and translate it.*
>
> *Moderator: You read it out?*
>
> *BSFGF1: And translate.*
>
> *BSFGM2: And there's a back-to-back thing like behind you and who reads the questionnaire and then you tick as to what his or her response is" (Bara staff)*

> *"BHFGF3: And they can't read.*
>
> *Moderator: OK. So what do you do in the situation where they can't read?*
>
> *BHFGF3: Just explain it to them.*
>
> *Moderator: Do you sit with them and go through the questionnaire?*
>
> *BHFGF3: Ja, we sit with the child and go through the questionnaire" (Bone Health female)*

Another suggestion on how to deal with adolescents who are having problems was to introduce or ensure that a tutorial is given to the adolescent about how to complete the questionnaire properly. However, this raised the issue of time. Typically the adolescents are at the data collection site for around two hours, the staff argued that introducing a tutorial

would increase the time taken to complete the process and may lead to complaints from both adolescents and their caregivers.

> *"It would take time, already they're complaining about the time they spend here. In fact with most of them when we do, what we need is time to be cut in half, they say they spend too much time. So adding something else, unless if we just checked them afterwards. But even so you don't know if they understood the questions or not" (Bara male)*

> *"That would help, but, but, because when the families first come it's a long procedure explaining to them what is going to be happening, and... 20 minutes later they're still there" (Bone Health female)*

One of the cognition issues was that some of the adolescents have a problem with the format of the current questionnaire which involves 'ticking' boxes. The staff suggested that one way to over come this problem would be put a statement at the top of the questionnaire that makes it clear to only tick one box.

> *"BSFGM2: And one other thing was the two years like they tick 'very' if it started in the last six months. He or she will tick 'x' 'No' and then will tick maybe 'a little', you know, make a tick and then on no he'll make something like a cross.*
>
> *Moderator: So why do you think that happens? Why do they do that?*
>
> *BSFGM2: I think a cross means no and a tick means yes.*
>
> *BSFGM1: They still say yes for a yes but you know like a cross would still say maybe yes, like a tick it can be make a cross or an 'x' or question, but with them they take an 'x' as a no.*
>
> *BSFGM2: So I think it should be emphasised that you should tick one block. It's not written, even though it-*
>
> *Moderator: So we should write at the top of this questionnaire, 'please only tick one box'.*
>
> *BSFGM2: Tick one box, yeah" (Bara staff)*

The Bone Health team highlighted that a checking process should be implemented, whereby each questionnaire is checked to see if it has been completed, although this did raise a

further issue that the staff still cannot establish if the questionnaire has been completed correctly, just completed.

> *"BHFGF3: Like afterwards, maybe afterwards you can change it.*
>
> *BHFGM1: But I think the only changing that we do is to make sure that the questions are filled in, it's done correctly, because you never know whether they did understand it...*
>
> *BHFGF3: Understand it.*
>
> *BHFGM1: Ja, what they have... so only check that it's complete.*
>
> *BHFGF3: Yeah, not us really, but the people who are, like...*
>
> *BHFGF1: Someone is doing the analysis...*
>
> *BHFGF3: Yeah.*
>
> *BHFGF1: ...better the analysis sooner than two years later, then people ask for feedback, if maybe there's something wrong that you can adjust" (Bone Health staff)*

The Bara team suggested the introduction of cubicles with mirrors and pictures in which the adolescents could examine themselves to try and improve accuracy. Whist this appeared to be good in theory, further discussion, and interaction between the group lead to the outcome that it would not be feasible.

> *"BSFGM2: There should be a, other cubicles that would, just got mirrors that would make it much easier for them to judge themselves. They are rating themselves to tick the most appropriate blocks.*
>
> *Moderator: Do you...What, how do you think that would impact the, the kind of accuracy, would that increase accuracy? Would it increase accuracy, would it decrease...?*
>
> *BSFGM2: It would, it would increase accuracy. Because, for instance now, if you were to take them from that room over there, the self-cognition [?] room, and they have to go to the male or female's room, you know it's embarrassing, it would be much more embarrassing for them. Whereas if there was a cubicle just next to this self-cognition [?] room, where they would look at themselves and then tick the spaces, it would be more...*

...Moderator: So, you'd have a cubicle with a mirror. Would there be anything else within that cubicle that you would have? Would you have pictures on the wall, or would you leave them with a questionnaire still?

BSFGM2: Pictures.

BSFGF2: Pictures on the wall.

BSFGM2: Pictures that you used to have before.

Moderator: Just pictures, or pictures and a description?

BSFGM2: Both.

Moderator: OK. Just in English, or in different languages?

BSFGM2: In English because they already be having the questionnaire. That explains everything in different languages

Moderator: OK. How would that work logistically for you guys, when you've got so many, if you just...? Would you have more than one cubicle, would you have...? Because, I guess you get a backlog in a way, because it takes a period of time for this child to go in, potentially undress, fill the questionnaire, get dressed again, and come out. Would, you know, would you see that as an issue? If you just had one room, would you be able to cope with one room?

BSFGF1: We would need two [?]. Especially through the _____ zones [?] and the like, where there are a lot of kids.

BSFGF2: One would not be enough.

BSFGM2: It wouldn't be effective. Imagine a boy queuing for, waiting for a female to come out, you know, she would be _____, so it won't be effective, she won't take as much time as possible to...

Moderator: So they now feel rushed. So how else could we get round that? How else can we get round this? This is about making this easier for you. Would it, you know, maybe you have the room where they fill in the questionnaire, now, but there is access to a cubicle, rather them going into the cubicle. You know, can you think of a way around...?

BSFGM1: Maybe only those with a problem need to go into a cubicle. But most of them. But at the same time, those that would have a problem, would they want to expose themselves that they do have a problem?! And then maybe nobody would want to go to the...

...Moderator: So you would like it, but it does seem that it would add to...

BSFGM2: Ja, it's not workable" (Bara staff)

5.3.4 Discussion on previous Bt20 questionnaires & procedures

The Bt20 pubertal development in adolescence questionnaire has changed since the initiation of pubertal development data collection in Year 9 (1999). Year 9 and Year 10 were physician assessed, Year 11 was the first year with a self-rated questionnaire, which was subsequently changed in Year 12 to include questions relating to somatic growth and development (see Methods section 3.1.2.4 for a more detailed explanation). The participants of the staff focus groups who had been employed by Bt20 since 1999 were asked to discuss these changes and how it has influenced pubertal development data collection. The general opinion about the previous procedures and questionnaires was negative, with the staff articulating that children may have left the study due to previous procedures, and that it made them uncomfortable.

"BHFGF3: It's changed in a way that at first there was something like, what year was it... they were doing also doing. Ja, and before that we had pictures on the walls, but we failed to the child because then they couldn't understand very well what was happening so you would show them the different stages and say and then 'you, which stage do you belong to?'; you explain when you say stage, 'this has happened, this has happened, this has happened' and then they choose the...

Moderator: And how did you feel about doing that?

BHFGF3: Felt uncomfortable.

Moderator: So you prefer to use the current questionnaire?

BHFGF3: Ja, and the kids hated it, because we have some children who dropped out of the class because of it.

Moderator: Specifically because of that...

...BHFGF3: They said, yeah I think we had, that time because officially, like BHFGF2 said, that we're having charts on the wall and the kids were looking a bit [blip in recording] I remember one of the parents said to us that that's not good for a child to do that, so they didn't want, used to carry on with those charts" (Bone Health female)

5.4 Summary of focus group findings

Table 5.4 provides a summary across the different focus groups of the main views on the current Bt20 questionnaire and procedure for collecting pubertal development for adolescents and staff. In addition, it summarises the main suggestions for changes to the current questionnaire and procedure that may aid future collection of pubertal development data.

Table 5.4 Summary Table of adolescent and staff views on the current Birth to Twenty questionnaire and procedure for collecting pubertal development data

Comments	FG 1 Female Community Adolescents	FG 2 Male Community Adolescents	FG 3 Female Early Puberty	FG 4 Male Early Puberty	FG 5 Female Late Puberty	FG 6 Male Late Puberty	FG 7 Bara Staff	FG 8 Bone Health Staff
Positive views on the current questionnaire	Straight forward	Easy to fill in	Easy to complete/ understand	Understand the information	Easy to complete/ understand	Pictures helpful	Adolescents do understand the current questionnaire as they are familiar with English	No consent problems
	Easy to Understand as know own body changes	Easy as information that they know		Easy to follow		Easy to follow		No privacy issues
		Pictures Helpful		Simple to go through				No space issues
				Pictures helpful				No rating issues with females
				Understand the language				
Negative views on the current questionnaire	No comments	Pictures of the penis not necessary	No comments	Difficult as can't see changes, can only tell through touching	No comments	Pictures helpful but embarrassing	Are available in vernacular but this has not been put into practice properly - although rarely requested by adolescents	Language problems
				Shy to answer questionnaire		Pictures boring, should have words	Girls much quicker than boys	Lack of cognition

Table 5.4 cont. Summary Table of adolescent and staff views on the current Birth to Twenty questionnaire and procedure for collecting pubertal development data

Comments	FG 1 Female Community Adolescents	FG 2 Male Community Adolescents	FG 3 Female Early Puberty	FG 4 Male Early Puberty	FG 5 Female Late Puberty	FG 6 Male Late Puberty	FG 7 Bara Staff	FG 8 Bone Health Staff
Negative views on the current questionnaire cont.	No comments	No comments	No comments	Only understand some of the words like texture, density	No comments	Should not talk about biology, as they don't know the biology	Girls understand the questionnaire better than boys	Some adolescents cannot read
						Needs to be simpler	Confusion between ticks and crosses	Males rate inaccurately as they do not want to be seen as boys
						Needs to be in more than just English	Males tend to over rate	Understanding is dependent on the education of the child
						See the questionnaire every year	Females tend to under rate	Do not know if there are completion issues unless a problem arises
						Provide dictionary to help with understanding		
						Language sometimes a problem		
						Some of the words cause problems		

Table 5.4 cont. Summary Table of adolescent and staff views on the current Birth to Twenty questionnaire and procedure for collecting pubertal development data

Comments	FG 1 Female Community Adolescents	FG 2 Male Community Adolescents	FG 3 Female Early Puberty	FG 4 Male Early Puberty	FG 5 Female Late Puberty	FG 6 Male Late Puberty	FG 7 Bara Staff	FG 8 Bone Health Staff
Positive views on the current procedure	No comments	No comments	No comments	Given sufficient privacy Given explanation before left with questionnaire	No comments	Interviewer always explained that they could ask if they needed help	Have access to private cubicles Procedure never changes even when really busy No time pressure as first process	No consent problems No privacy issues No space issues
Negative views on the current procedure	No need for a tutorial as know body changes	No comments	No comments	Not told that they could use the restroom Did not seek help from interviewer if had problem	No comments	No comments	No comments	No tutorial given No access to private cubicles
Suggested questionnaire changes	No changes required	Pictures of the penis should be removed as not necessary	No changes required	No changes required No language changes required	No changes required	Make the words simpler Bring back the testicular volume question	Cannot be improved Put statement on the top of the questionnaire that states "tick only one box"	No need to make changes

Table 5.4 cont. Summary Table of adolescent and staff views on the current Birth to Twenty questionnaire and procedure for collecting pubertal development data

Comments	FG 1 Female Community Adolescents	FG 2 Male Community Adolescents	FG 3 Female Early Puberty	FG 4 Male Early Puberty	FG 5 Female Late Puberty	FG 6 Male Late Puberty	FG 7 Bara Staff	FG 8 Bone Health Staff
Suggested questionnaire changes cont.				Add questions not relating to pubertal development			Keep questionnaire in English	
	No changes required		No changes required		Provide special room for girls only	Ensure privacy to complete on own	Need cubicles with mirrors and pictures to help improve accuracy - however in practice this would not work	Addition of a tutorial - however this would lead to time problems
Suggested procedure changes								Ensure that each questionnaire is quality checked before the adolescent leaves to ensure that all questions have been completed
								Start analysis of these data straight after completion rather than after a period of time so that problems can be identified and resolved

Table 5.4 cont. Summary Table of adolescent and staff views on the current Birth to Twenty questionnaire and procedure for collecting pubertal development data

Comments	FG 1 Female Community Adolescents	FG 2 Male Community Adolescents	FG 3 Female Early Puberty	FG 4 Male Early Puberty	FG 5 Female Late Puberty	FG 6 Male Late Puberty	FG 7 Bara Staff	FG 8 Bone Health Staff
Comments of the previous questionnaires/ procedures	Not applicable	Not applicable	No comments	No comments	No comments	No comments	No comments	Failed children because hard to understand Made interviewers uncomforTable Made children drop out of the study Parents unhappy

6 Discussion

This chapter provides a discussion on age at menarche and the timing of puberty, and discusses the evidence for a positive secular trend in pubertal development. It examines the importance of proximate rather than more distal predictors of pubertal development and compares findings from the Birth to Twenty (Bt20) data with contemporary literature on developing and developed countries. In addition, it discusses the findings from the qualitative work and makes suggestions about the assessment of pubertal development in an urban South Africa setting. The limitations and policy implications of the current study, and future research plans are also identified.

6.1 Age at menarche and the timing of pubertal development

6.1.1 Age at menarche

Median age at menarche was determined using *status quo* techniques in a longitudinal sample of Black and White urban South African females. Median ages for Black females were 12.4 years (95% CI = 12.2, 12.6) and 12.5 years (95% CI = 11.7, 13.3) for White females. These ages were significantly ($P < 0.05$) younger for Black girls than any other previous study of age at menarche conducted within South Africa. The most recent papers (circa 1988) reported mean ages of 13.0 years (95% CI = 12.7, 13.3) (Norris & Richter 2005) and 13.2 years (95% CI = 13.0, 13.4) (Cameron & Wright 1990, Cameron et al. 1993) for urban Black females with low/medium socio-economic status (SES). A previous study of high SES urban White females reported a mean age of 13.1 years (95% CI = 12.9, 13.3) (Chaning-Pearce & Solomon 1987) some 0.6 years older than the current study, although this was not statistically significantly different. In comparison to other sub-Saharan African countries, mean age at menarche is significantly ($P < 0.05$) younger in this study compared to contemporaneous urban Black females in Ghana (14.0 years; 95% CI = 13.9, 14.1) (Adadevoh et al. 1989) and Cameroon (13.2 years; 95% CI = 13.0, 13.4) (Pasquet et al. 1999). For White females, in comparison to developed countries, the mean ages are slightly younger compared to those reported in the UK (12.9 years; no 95% CI reported) (Whincup et al. 2001), the Netherlands (13.2 years; no 95% CI reported) (Mul et al. 2001) and Sweden (12.8 years; no 95% CI reported) (Edgardh 2000). Whilst these findings appear to present mean ages that are younger than those reported for sub-Saharan Africa and Europe, these

comparisons must be interpreted with care as they are dependent on a number of factors including SES, ethnic group, the temporal context and assessment methods. Evidence suggests that determining age at menarche using recall is reliable, particularly if the girls involved are still in adolescence or early adulthood. Each of these studies used similar research designs, although some were physician assessed (Chaning-Pearce & Solomon 1987, Adadevoh et al. 1989, Cameron & Wright 1990, Cameron et al. 1993, Pasquet et al. 1999, Mul et al. 2001) and some, including the current study (although the baseline measurements were physician assessed) were self-rated (Edgardh 2000, Whincup et al. 2001). The samples were all drawn from urban areas and ethnic groups reported separately, thus it appears that Black urban South African girls are achieving menarche significantly earlier than girls in sub-Saharan Africa. In comparison, White urban South African girls are achieving menarche slightly earlier or at around the same time as White European girls. However, because previous studies have not reported data on variance, it is difficult to assess the significance of these differences.

The pattern is less clear when comparisons are made with American data. The publication of the Pediatric Research in Office Settings (PROS) study in 1997 (Herman-Giddens et al. 1997) caused some controversy. This study examined 17 000 girls and reported a mean age at menarche of 12.2 years (95% CI = 12.1, 12.3) for Black girls and 12.9 years (95% CI = 12.8, 13.0) for White girls. The results from this study must be interpreted carefully as the sample was not representative of the American population; 15% of the sample were excluded as they had not achieved menarche at 13 years, thus the ages reported may be underestimated, and these girls were seen in private clinics and so the sample may be socio-economically biased. More recent, nationally representative American studies reported mean ages of 12.1 years (no 95% CI reported) (Chumlea et al. 2003) and 12.2 years (no 95% CI reported) (Wu, Mendola & Buck 2002) years for Black girls, some 0.2-0.3 years earlier than the South African cohort; however, these differences were not statistically significant. For White US girls mean menarcheal age was reported as 12.6 years (no 95% CI reported) (Wu, Mendola & Buck 2002) years for White girls, some 0.1 years later than the South African cohort although this difference was not statistically significant. Table 6.1 shows a summary of studies of age at menarche for American, sub-Saharan African and European females.

Table 6.1 Average age at menarche (95% confidence interval) in American, Sub-Saharan African and European females

Country/ Year of study	Ethnic Group	Average age (†denotes median) at menarche (95% confidence interval)	Reference
America			
1997	Black	12.2 (12.1, 12.3)	(Herman-Giddens et al. 1997)
	White	12.9 (12.8, 13.0)	
1988-1994	Black	12.1 (11.9, 12.3)	(Chumlea et al. 2003)
1988-1994	Black	12.2 (12.0, 12.4)	(Wu, Mendola & Buck 2002)
	White	12.6 (12.4, 12.8)	
Sub-Saharan Africa			
South Africa			
1976-77	White	13.1 (12.9, 13.3)	(Chaning-Pearce, Solomon 1987)
1988	Black	13.2 (13.0, 13.4)	(Cameron & Wright 1990)
1992	Black	13.2 (13.0, 13.4)	(Cameron et al. 1993)
2003	Black	13.0 (12.7, 13.3)	(Norris & Richter 2005)
1999-2005	Black	12.4† (12.2, 12.6)	Current Study
	White	12.5† (11.7, 13.3)	
Ghana			
1987	Black	14.0 (13.9, 14.1)	(Adadevoh et al. 1989)
Cameroon			
1994	Black	13.2 (13.0, 13.4)	(Pasquet et al. 1999)
Europe			
United Kingdom			
1998-1999	White	12.9 (12.7, 13.2)	(Whincup et al. 2001)
Netherlands			
1997	White	13.2 (No 95% CI reported)	(Mul et al. 2001)
Sweden			
1990	White	12.8 (No 95% CI reported)	(Edgardh 2000)

It is intuitive that menarche may occur earlier in South Africa compared to other sub-Saharan African countries such as Ghana and Cameroon as South Africa is relatively more developed. Whilst all three countries fall into the medium human development category, South Africa is ranked number 121 (Human Development Index§§§§ (HDI) score = 0.674), Ghana 135 (HDI score = 0.553) and Cameroon 144 (HDI score = 0.532) in the 2007/8 HDI report (United Nations 2007). The 2007/8 indices were selected as the results from this study show that there was a greater association between age at menarche and proximate determinants such as late childhood body composition and SES, as opposed to distal determinants like SES at the time of the infant's birth and birth weight. A discussion relating

§§§§ The HDI utilises three dimensions of human development: living a long and healthy life (measured by life expectancy), being educated (measured by adult literacy and enrolment at the primary, secondary and tertiary level) and having a decent standard of living (measured by purchasing power parity, PPP, income) to create a composite index score (United Nations 2007). The higher the HDI score (range 0 to 1), the higher the social and economic development of the country, thus South Africa has a higher HDI in comparison to the other countries.

to the differences between European, American, and South African adolescents follows the section on the timing of pubertal development as the patterns and suggested explanations are similar.

6.1.2 The timing of pubertal development

Median age at the initiation of genitalia development was 10.4 years (95% CI = 8.4, 12.4) for Black boys and 9.8 years (95% CI = 9.4, 10.2) for White boys. Median age for the initiation of pubic hair development for Black males was 10.8 years (95% CI = 9.6, 12.0) compared to White males, which was 10.2 years (95% CI = 8.4, 12.0). Median age at the initiation of breast development in Black females was 10.1 years (95% CI = 9.3, 10.9) compared to White females which was 10.2 years (95% CI = 8.2, 12.2). Median age for the initiation of pubic hair was 10.3 years (95% CI = 9.3, 11.3) and 10.5 years (95% CI = 8.7, 12.3) for Black and White girls respectively. Within this urban South African cohort, there were no statistically or biologically significant differences in age at the initation of pubertal development between Black and White adolescents. On average, both genders and ethnic groups initiated puberty through the breasts/genitalia pathway compared to the pubic hair pathway. This supports previous studies, who have reported that B2 occurs prior to PH2 for girls, by on average, 0.4 years (Eveleth & Tanner 1990). Both the current study and that of Cameron et al. (1993) show that on average Black South African's enter B2/G2 prior to PH2. Based on the findings of this study, this is also true for White South African males and females.

Compared to age at menarche, there are relatively less data available within the literature for the onset of puberty, particularly for males. This perhaps, reflects the relative ease of assessment of menarche. It should also be noted that the majority of the supporting evidence for findings in this study are based on findings from studies of menarcheal age; however, it is assumed that if age at menarche has declined then a decline in the preceding events of sexual maturation such a breast development can also be anticipated. This assumption is correct in the current study, as early breast development ($\chi^2(1, N = 168) = 36.1, P < 0.001$)) and early pubic hair development ($\chi^2(1, N = 174) = 13.5, P < 0.001$)) were significantly associated with earlier menarche.

It was only possible to compare these ages for Black adolescents to previous South African literature, as there is a dearth of published data relating to pubertal development in White

urban adolescents. In the three studies of pubertal development of Black males, the results from this study were significantly ($P < 0.05$) younger for pubic hair initiation and the youngest reported age for genitalia initiation. Cameron et al. (1993) reported a mean age of genitalia initiation at 10.5 years (95% CI = 10.2, 10.8) and pubic hair initiation of 12.4 years (95% CI = 12.2, 12.6). In comparison Norris and Richter (2005) reported mean ages of 12.6 years (95% CI = 12.2, 13.0) and 12.4 years (95% CI = 12.2, 12.6) for genitalia and pubic hair development respectively.

There are relatively more data available for girls, and data from the most recent studies show similar ages of initiation in comparison to the current study. Mean ages for breast development were 10.1 years (95% CI = 9.9, 10.3) (Cameron et al. 1993) and 11.2 years (95% CI = 11.0, 11.4) (Norris & Richter 2005) and for pubic hair development, 10.1 years (95% CI = 9.9, 10.3) (Cameron et al. 1993) and 11.5 years (95% CI = 11.3, 11.7) (Norris & Richter 2005). The results from the Norris and Richter study reported older ages at initiation compared to the 1993 study by Cameron et al. and that of the current study and this may reflect different research designs. The Norris and Richter (2005) study used a self-rated cross sectional design and thus may over-estimate age at initiation as it does not allow for cross-referencing between time points to ensure accurate rating, unlike the longitudinal design of the current study. Therefore it may have reduced sensitivity to identify true transition from stage one to stage two, as the adolescents may have been in stage two for a significant period of time before they were enrolled into the study (participant ages ranged from ten to eighteen years).

In comparison to estimates of age of pubertal development in European countries, on average both Black and White South African adolescents are entering puberty at a similar or slightly younger age (it was not possible to determine if these differences were statistically significant). Black and White South Africans are similar in the timing of their development to their American peers, although Black adolescents are on average, very slightly delayed. This follows a similar pattern as that seen for age at menarche. Table 6.2 shows a summary of studies of pubertal development for urban South African, American and European adolescents.

Table 6.2 Average age (95% confidence intervals) at initiation of secondary sexual characteristics (years) in American, South African and European adolescents

Country/Year of study	Females				Males				Reference
	Average age (†denotes median) at initation of breasts/genitalia and pubic hair (95% confidence interval)								
	Black		White		Black		White		
	B2	PH2	B2	PH2	G2	PH2	G2	PH2	
America									
1997	8.9 (8.8, 9.0)	8.8(8.7, 8.9)	10.0 (9.9, 10.1)	10.5 (10.4, 10.6)	-	-	-	-	(Herman-Giddens et al. 1997)
2001	-	-	-	-	9.5 (9.0, 10.0)	11.2 (11.0, 11.4)	10.1 (9.4, 10.6)	12.0 (11.7, 12.3)	(Herman-Giddens, Wang & Koch 2001)
1988-94	9.4 (9.1, 9.7)	9.5 (9.2, 9.8)	10.4(10.1, 10.7)	10.6(10.3, 10.9)	9.2 (8.8, 9.6)	11.2 (11.0, 11.4)	10.0 (9.6, 10.4)	12.0 (11.7, 12.3)	(Sun et al. 2002)
South Africa									
1976-77	11.5 (11.4, 11.6)	-	11.5 (11.4, 11.6)	-	-	-	-	-	(Chaning-Pearce, Solomon 1987)
1988	10.4 (10.2, 10.6)	-	-	-	-	-	-	-	(Cameron, Wright 1990)
1992	10.1 (9.9, 10.3)	10.1 (9.9, 10.3)	-	-	10.5 (10.2, 10.8)	12.4 (12.2, 12.6)	-	-	(Cameron et al. 1993)
2003	11.2 (11.0, 11.4)	11.5 (11.3, 11.7)	-	-	12.6 (12.2, 13.0)	12.4 (12.2, 12.6)	-	-	(Norris, Richter 2005)
1999-2005	10.1† (9.3, 10.9)	10.3† (9.3, 11.3)	10.2† (8.2, 12.2)	10.5† (8.7, 12.3)	10.4† (8.4, 12.4)	10.8† (9.6, 12.0)	9.8† (9.4, 10.2)	10.2† (8.4, 12.0)	Current Study

B2 = Tanner breast stage 2/PH2 = Tanner pubic hair stage 2/G2 = Tanner genitalia stage 2

Table 6.2 cont. Average age (95% confidence intervals) at initiation of secondary sexual characteristics (years) in American, South African and European adolescents

Country/Year of study	Females				Males				Reference
	Average age (†denotes median) at initation of breasts/genitalia and pubic hair (95% confidence interval)								
	Black		White		Black		White		
	B2	PH2	B2	PH2	G2	PH2	G2	PH2	
Europe									
Netherlands									
1997	-	-	10.7 (No 95% CI reported)	-	-	-	11.5 (No 95% CI reported)	-	(Fredriks et al. 2000)
Sweden									
1980	-	-	10.8 (No 95% CI reported)	-	-	-	11.6 (No 95% CI reported)	-	(Lindgren 1996)
Denmark									
1991-93	-	-	10.9 (No 95% CI reported)	-	-	-	11.8 (No 95% CI reported)	-	(Juul et al. 2006)

B2 = Tanner breast stage 2/PH2 = Tanner pubic hair stage 2/G2 = Tanner genitalia stage 2

The girls within this study achieved menarche and both genders achieved pubertal development slightly earlier than their European peers; this is in agreement with Eveleth and Tanner (1990) who speculated that Black African girls who experience good environmental conditions may achieve menarche earlier than European girls. This assumption could also be extrapolated to include other measures of maturation such as pubertal development. Whilst Eveleth and Tanner's hypothesis related to Black African girls, it is anticipated that this could also be true for White African girls. It is appropriate to suggest that the majority of White girls living in the Gauteng province would be of high SES (as measured by proxies such as maternal education and household assets) and thus "experience good environmental conditions" (Department of Health - Republic of South Africa 2002). This point is also relevant for White South Africans when comparing them to White Americans, as both groups appear to achieve menarche and pubertal development at similar times. The SES experienced by these two groups may be comparable and thus if age at menarche and the initiation of puberty is socio-economically driven, then it could be anticipated that menarche and puberty would occur at parallel ages. In addition, SES may explain the finding that White boys are in advance of Black boys within the current study. Whilst there are a few studies that compare Black and White pubertal development in boys, those that do, report Black boys to be in advance of White boys (e.g. Herman-Giddens, Wang & Koch 2001, Sun et al. 2002). Using cross-sectional data (n = 1333, 797 African American) on males aged eight to 19 years from the National Health and Nutrition Examination Survey III (NHANES III, 1988-994), Herman-Giddens et al. (2001) reported that African American boys were on average 0.6 years older for genitalia development and 0.8 years older for pubic hair development in comparison to White boys. This difference was statistically significant ($P < 0.05$) for genitalia development, but not for pubic hair development. Sun et al. (2002) also used cross-sectional data (n = 1335, 798 African American) from 1988-1994 NHANES III survey. The authors reported a similar pattern to Herman-Giddens et al. (1997) with African American boys being advanced by 0.8 years for both genitalia and pubic development in comparison to their White peers. However, this difference was only statistically significant ($P < 0.05$) for pubic hair development. These estimates, although using the same data are slightly different and this has been attributed to different statistical techniques employed by the authors. White boys in the current study were found to be on average, 0.6 years older at the onset of genitalia and pubic hair development in comparison to Black boys. The Black boys within this study are of lower SES in comparison to White boys and thus this may have lead to a delay in Black male pubertal development. The authors of the American studies mentioned above, do not

provide any discussion on SES and how this may have influenced the findings from their research and state simply that they "cannot explain the ethnic differences" (Herman-Giddens, Wang & Koch 2001) The only suggestions for potential reasons as to why African American boys are advanced of White boys in pubertal development relates to differences in diet, lifestyle and exposure to endocrine disrupting chemicals. It is clear that there is a need for additional studies to help explain ethnic differences in the timing of pubertal development.

The pattern for Black adolescents is slightly different to those for Whites. Black girls present with a significantly younger age at menarche and at a younger age for breast and pubic hair initiation in comparison to previous South African data, but are delayed in comparison to American Black girls. This is also similar for Black South African boys who are younger in comparison to previous SA data, but are delayed in comparison to American Black boys for genitalia development; however, they are advanced for pubic hair development. A proportion of this variance may be attributable to SES, in that Blacks living in South Africa may still experience the residual effects of the Apartheid legislation, thus may live in lower SES environments when compared to their Americans peers. Although South Africa has undergone rapid political, social and economic transition since the end of the Apartheid regime, a residual influence of this legislation remains and continues to facilitate poverty and perpetuate inequality (May 2000).

A reason for the advancement of pubic hair for all South African boys in comparison to American boys remains elusive. The development of secondary sexual characteristics occurs via two pathways which are independently regulated (1) hypothalamic-pituitary-gonadal axis (HPG) for gonadarche which leads to breasts/genitalia development and (2) hypothalamic-pituitary-adrenal (HPA) axis for adrenarche which leads to pubic hair development. Gonadarche refers to the activation of gonadal sex steroid secretion from the gonads. Adrenarche refers to the increase in androgen secretions from the adrenal cortex (Nussey & Whitehead 2001). Results from the current study that will be discussed in more detail later in this chapter, suggest that environmental influences (such as SES and body composition) promote or constrain these hormonal pathways in different ways. Thus the South African environment may promote the advancement of adrenarche in relation to gonadarche. An alternative explanation relates to potential rating differences. The majority of the American studies are physician assessed and thus may have produced more reliable pubic hair ratings compared to the self-assessment used in the current study.

6.2 Secular trends

6.2.1 Secular trends in age at menarche

The results from the current study indicate that there is evidence for a statistically significant secular trend in age at menarche in Black, but not White urban South African females. The decline in age at menarche is more pronounced for Black girls compared to White girls, with an average decline of 0.56 years and 0.32 years per decade respectively. The evidence for a positive secular trend (although not statistically significant) for South African white girls must be considered within the context of there being only two studies. The 1987 study by Chaning-Pearce and Solomon (1987) reported a mean age at menarche of 13.1 years (95% CI = 13.0, 13.2) for White South African girls, which was 0.6 years older than the 12.5 years (95% CI = 11.7, 13.3) reported in the current study. A critical review of the 1987 paper would suggest that the study is methodologically robust although it is cross-sectional in nature compared to the longitudinal nature of the current study. The Chaning-Pearce study had a total sample size of 355, split into ten age group bands (8-17 years, average n per age group = 35), compared to a total longitudinal sample of 99 for the Bt20 study. Menarcheal data for the Chaning-Pearce study were collected via a recall method and mean age was calculated by probit analysis. The methodologies are similar for both studies and therefore it is reasonable to conclude that there is potentially evidence for a positive secular trend in age at menarche for White South African girls in the previous 20 years, although this is not statistically significant. These data show the same trend as that shown by Anderson et al. (2003) who reported a decline of 0.1 years per decade between the 1960's and 1990's in age at menarche for White US girls based on data from two nationally representative samples.

In addition, numerous other developed country studies have shown that there is evidence for a positive secular trend in age at menarche (Kaplowitz & Oberfield 1999, Wattigney et al. 1999, Freedman et al. 2002, Sun et al. 2002). A study in urban Cameroon (n = 205), Pasquet et al. (1999) reported a mean age at menarche of 13.2 years and demonstrated a secular trend of approximately 0.25 years per decade between 1946 and 1986. This estimate shows a much slower decline in mean age at menarche in comparison to the current South African data. In a study of Black urban South African females, Cameron et al. (1991) reported a decline of 0.73 years per decade between 1960 and 1990. This is very similar to the findings of this study which report an average decline of 0.56 years per decade between 1960 and 2007 and would indicate that South Africa is continuing to show a rapid

decline in menarcheal age and as yet, has not experienced the plateau seen in some developed countries (e.g. America and the UK) in age at menarche (Whincup et al. 2001, Chumlea et al. 2003). This suggests that environmental factors continue to influence this biological process in South Africa. Whereas, in countries that have experienced a plateau, these environmental factors may have little if any influence on age at menarche and a lower limit may have been reached due to a genetic "ceiling".

6.2.2 Secular trends in pubertal development

The results from this analysis indicate that there is potentially evidence for a positive secular trend in age of pubertal development in Black urban South African females. There are however less consistent data for Black males. Whilst there is evidence for decline in age at pubic hair initiation, there is insufficient evidence to report the same for genitalia development. Mean age for breast development in females has declined from 11.5 (95% CI = 11.4, 11.6) in 1987 (Chaning-Pearce & Solomon 1987) to 10.1 years (95% CI = 9.3, 10.9) in the current study, a fall of 0.7 years per decade. Age at the initiation of pubic hair development has fallen from 12.1 years (95% CI = 12.0, 12.2) in 1987 (Chaning-Pearce & Solomon 1987) to 10.3 years (95% CI = 9.3, 11.3) in the current study, representing a decline of 0.9 years per decade. For boys, pubic hair initiation was reported at 12.4 years (95% CI = 12.2, 12.6) in 1993 (Cameron et al. 1993), falling to 10.8 years (95% CI = 9.6, 12.0) in the current study, a decline of 1.1 years per decade. Age at the initiation of genitalia development has remained fairly constant, with Cameron et al. (1993) reporting a mean age of 10.5 years (95% CI = 10.2, 10.8), some 0.1 years later than the current study (10.4 years [95% CI = 8.4, 12.4]). Unlike the menarche data, it is difficult to make direct cross country comparisons in the rate of decline of pubertal development due to limited data availability and methodological differences. The studies of American adolescents have methodological issues and it is therefore important that care is taken when making inferences and comparisons with the current study. For example, as previously discussed there were several problems with the PROS study (Herman-Giddens et al. 1997) with reference to age at menarche, this is also true for the assessment of breast development. This study reported a mean age at B2 for Black girls at 8.9 years and 10.0 years for White girls. Some what earlier than previous reports in America, for example 10.9 years (no 95% CI reported) (Tanner & Davies 1985). The PROS study involved multiple physicians without taking into account inter-observer variability, and did not correct for the under representation of African

American girls (10%) within the sample. Another large American study (Sun et al. 2002) reported median age at B2 of 10.4 years (95% CI = 10.1, 10.7) and 9.5 years (95% CI = 9.1, 9.8) for White and Black girls respectively using NHANES III data. One potential methodological flaw in both of these studies and the current study was a lack of breast palpation, this occurred in the baseline years of nine and ten for the Bt20 study, but not for the self-rated study unless the adolescents felt the need to physically rather than visually examine themselves. A lack of breast palpation may lead to an over estimation of age at breast development due to poor differentiation between adipose and glandular tissue (Rosenfield et al. 2000, Lee, Guo & Kulin 2001). Previously, this may have been more of a problem for American studies due to higher levels of adolescent overweight and obesity, thus potentially explaining why African-Americans achieved breast development at a younger age compared to their national and international peers. However, a recent report states that childhood obesity levels are now higher in a number of developing countries including South Africa compared to America (Deckelbaum & Williams 2001) and so this may present a growing problem in studies of pubertal development in both developed and developing nations.

Several studies have reported that the duration or *tempo* of puberty is changing in addition to a declining average age of initiation as measured by the time it takes to progress from the boundary of Tanner stage one/two to the boundary of Tanner stage four/five (de Muinck Keizer-Schrama & Mul 2001). It is not possible to assess this variable with accuracy in the Bt20 cohort as a significant proportion of the sample had yet to attain stage five at the time of this study and so any estimate would be biased. However, it is possible to compare previous South African data for Black adolescents to African Americans. Cameron et al. (1993) reported mean durations of 3.5 years for female breast development and 6.1 years for pubic hair. Sun et al. (2002) reported an average duration of 4.4 years and 5.3 years for breast development and pubic hair development respectively. Duration times are available for breast development in European and American White females born around 1980. American girls take on average 5.1 years, Dutch 3.7, Swedish 4.0, and English 3.2 years (Lindgren 1996, Sun et al. 2002). These results suggest that breast development is shorter and pubic hair development longer for Black South African girls in comparison to African American girls and that, on average, Black girls take longer to progress through the stages of breast development in comparison to European White girls. This variation could however, be a reflection of the increased difficulty of assessing pubic hair accurately in Black adolescents

compared to White adolescents (Cameron et al. 1993). This would not explain the differences found in breast development though. One potential explanation for this, could relate to Black girls being hormonally more sensitive to oestrogens than androgens, although there is little if any empirical evidence available within the literature to support this suggestion. Whilst there is some evidence for differences in the *tempo* of puberty between adolescents from different countries, these estimates are potentially biased by the research design of the study. Each of the above studies was cross-sectional in nature. Therefore, they may have a reduced sensitivity to detect the timing of the transition between pubertal stages and an increased estimate error. As the assessment of *tempo* involves using data from two transitions (stage 1 to stage 2 and stage 4 to stage 5), estimate error is increased when compared to estimates that only use data from one transition i.e. mean age at the initiation of breast development. Further research using longitudinal data may help to reduce these estimation biases and help to provide more accurate estimates of pubertal *tempo*.

6.2.3 Supporting evidence for a positive secular trend

One must highlight that the evidence for a secular trend is based on the assumption that the relationship is linear. This relationship may actually be curvilinear as there may be a lower limit to which age at menarche/pubertal development is reached. This is perhaps evident in developed countries such as America and the UK, where a plateau in age at menarche and pubertal development appears to have been reached, with several papers reporting that there is limited evidence for a secular trend in recent decades (Whincup et al. 2001, Viner 2002, Chumlea et al. 2003). As discussed in detail in Background Section 2.7, Ong and colleagues (2006) have opposed this view by stating that they believe that it is unhelpful to say that downward trends have stopped, particularly in Europe, and that there is no lower limit to the age at which puberty and menarche can occur. This is reflected by the fact that countries who have experienced the removal of nutritional and socio-economic constraints are still reporting a reduction in age at menarche. Whilst the authors do provide further explanation for this comment by simply stating that there is a wide normal distribution in age at menarche, they do not take into account the fact that averages across a population do not reflect differences within a population such as SES. For example, average age at menarche for a population may have initially decreased as a result of higher SES adolescents' age declining. After the removal of constraining factors, lower SES adolescents' age may have then declined. This would lead to a further reduction in the population average, but the

higher SES group age may have remained the same i.e. the variation within a population may be reduced over this period of time that constraining factors were removed. This may be true of the South African context and the data presented within the current study, particularly for Black girls. Socio-economic and nutrition constraints have been reduced since Apartheid legislation was removed and so this may have further fuelled the decline in age at menarche. Whist White girls, were not constrained by Apartheid legislation *per se.* they were potentially constrained through the developing status of the country. Recent improvements in environmental conditions through the transitioning economy could account for the slight decline in average age at menarche for White girls since Apartheid legislation was removed.

The interpretation of secular trends is difficult, particularly as geographical location, methodologies and sampling techniques vary between studies. Each of the studies within this secular trend analysis has been critically reviewed and whilst there are differences, for example physician vs. self-rating, it is thought that they are robust and this is a true secular trend in age at menarche and breast development within urban South Africa, rather than simply geographical or methodological variation. Indicators of child health in South Africa have shown consistent improvements in the past 50 years. For example, infant mortality rate (IMR) has fallen from 79 per 1000 live births in 1980 to 59.4 per 1000 live births in 2007 (Department of Health - Republic of South Africa 2002) and under five mortality rate (U5MR) has dropped from 89 per 1000 live births in 1978 to 60 per 1000 live births in 1996 (US Census Bureau 2008). The reduction in age at menarche and breast development, running parallel to the improvements seen in infant and child mortality appears to be reflective of a continuing trend towards better health and improving environmental conditions within South Africa and particularly within the Black population.

One of the interesting findings from this study is that Black and White urban South African females achieve menarche at a similar time. This is contrary to reports from developed countries, where numerous studies have shown that Black girls are advanced compared to White girls (Herman-Giddens et al. 1997, Kaplowitz et al. 2001, Freedman et al. 2002, Sun et al. 2002, Wu, Mendola & Buck 2002, Chumlea et al. 2003, Anderson, Dallal & Must 2003). The advancement of Black girls has been shown consistently between different countries, time periods and between different study designs. It has been reported that this difference between ethnic groups is independent of relative weight, with several studies showing that

ethnic group is an independent predictor of the timing of menarche, having controlled for body composition and age (Wattigney et al. 1999, Kimm et al. 2001, Anderson & Must 2005). The aetiology of these differences remains speculative and the similarity shown in the current study may again be reflective of the different socio-economic environments to which the Black and White girls are exposed. The Black girls within this study are low SES compared to the White girls. At the time of the infant's birth, mothers of Black girls were significantly younger (25.1 vs. 29.4 years $P < 0.01$), less likely to be married or cohabiting (20.2 vs. 87.8% $P < 0.01$) and more likely to have left full-time education without completing high school (57.8 vs. 6.3% $P < 0.01$) compared to White mothers. By the time the Black girls were nine/ten years of age, their mothers were still significantly less likely to be married or cohabiting (59.7 vs. 19.3% $P < 0.01$) and were significantly more likely to be classified in the low SES group (74.2 vs. 2.3% $P < 0.01$) based on an SES index constructed from consumer durable and sanitation facilities compared to their White peers. Thus the transitioning economy and removal of Apartheid legislation, may have contributed to the rapid decline in age at menarche for Black girls, in comparison to the slower reduction in age at menarche for White girls, whose socio-economic environment may have remained relatively unchanged in recent years. If the secular trend is linear and the rate of decline continues at a similar tempo to that shown in the current study, it could be suggested that the next generation of Black girls may experience menarche significantly earlier than their White peers, therefore showing the same pattern as seen in developed countries such as America.

Whilst SES may explain a proportion of the variance in age at menarche between different groups, it is important to consider other factors that may influence this maturational event. Since the original publication of Frisch and McArthur's (1970) paper, which was subsequently changed (Frisch & McArthur 1974) suggesting that a critical level of fat mass is required for menstruation to occur, female nutritional status and more specifically body fat content has been debated within the literature and the "critical fat mass theory" developed. Frisch and McArthur (1974) suggested that a minimum BMI of 22.3 kg/m^2 and a minimum total body fat mass of 16 kg was required for menarche to occur. Ellison (1981, 1990) has since shown that Frisch's hypotheses were based on flawed interpretation of data. The results from this study show that early maturing Black girls were significantly heavier, taller, and more likely to be classified as overweight and/or obese compared to later maturing girls from infancy through to adolescence. This is supportive of evidence that shows that girls who are overweight and/or obese experience menarche at a younger age in comparison to their

leaner peers (Garn, LaVelle & Pilkington 1983, Adair & Gordon-Larsen 2001, Kaplowitz et al. 2001, Anderson, Dallal & Must 2003). However, there is limited evidence to suggest that there is a "critical fat mass" required for the initiation and maintenance of regular menstrual cycles (Scott & Johnston 1982). It is possible to hypothesise that the positive secular trend in age at menarche within South Africa could be partly due to the rising levels of overweight and obesity. Within the menarche sample used in the current analysis, at 14 years of age 13.1% of White girls and 21.8% of Black girls, were classified as overweight or obese according to Cole's International cut-offs (Cole et al. 2000). Several papers have reported a progressive increase in the prevalence of obesity within the South African population in recent decades (van der Merwe & Pepper 2006), particularly among adolescent females (Walker 1995, Labadarios et al. 2005). The authors of the above papers do not report direct percentages of overweight and/or obese by age or ethnic groups, so it is not possible to make direct comparisons with the sample used in the current study.

Another potential reason for Black girls experiencing menarche at a similar time to White girls, given their higher body fat level, relates to leptin. Leptin has been shown to be associated with earlier menarche (Matkovic et al. 1997) and pubertal development, particularly in African-American girls, as they exhibit higher levels compared to White girls after controlling for maturational status, fat mass and physical activity levels (Wong et al. 1998). Leptin is only produced in fat cells and is encoded by the Obesity (*ob*) gene (Zhang et al. 1994). Body fat stores are reflected by serum concentration levels of leptin; the higher the concentration, the greater the body fat mass. As Black girls vs. White girls and early maturing Black girls vs. later maturing Black girls exhibit greater fat mass, it is appropriate to suggest that they may also exhibit higher serum concentration of leptin. This may lead to earlier menarche as leptin has been proposed as a regulator of menarche in humans (Bray 1996) and more recently as a mediator between adipose tissue and the hypothalamic-pituitary-gonadal (HPG) axis (Carlsson et al. 1997). Evidence for this typically comes from animal models, for example *ob/ob* female mice have been shown to remain pre-pubertal and infertile if they lack bioactive leptin due to an *Ob* gene mutation (Chehab, Lim & Lu 1996). This suggests that leptin is a trigger for the maturation of the reproductive system, and may have direct or indirect influences on the area of the anterior hypothalamus which secrets gonadotrophin releasing hormone (GnRH) (Carlsson et al. 1997), changes in which are thought to be the initial trigger for pubertal development (Odell 1995). It is important to note, that leptin secretion may be significantly different between animal and human models, and

therefore, increased serum leptin concentrations may be the result of pubertal development as opposed to the trigger.

6.3 Determinants of age at menarche and pubertal development

To further investigate the potential predictors of age at menarche within this cohort, a series of logistic regression models were constructed. The main findings showed that proximate variables such as body composition at the end of childhood were more important than distal predictors such as birth weight. For example being taller, fatter, and heavier at eight years of age significantly increased the odds of achieving early menarche after controlling for SES. SES was a significant individual predictor of early menarche; however, when it was combined with body composition variables it became insignificant. This finding should be interpreted with care, as it does not mean that SES is not important, but rather SES acts through a body composition pathway and thus is perhaps indirectly associated with the timing of menarche in this cohort. The finding that SES was mediated through body composition may be reflective of the current economic and nutritional transition being experienced in South Africa. The nutrition transition refers to a shift from a diet low in fat and refined carbohydrates to a diet high in fat and low in fibre, with consequential increases in obesity and non-communicable diseases (Popkin & Gordon-Larsen 2004). Economic changes facilitate the nutrition transition through increased urbanisation, globalisation of food production, and increased media and marketing, increased sedentary behaviours and changes to working patterns and hours (Lang 2002). Living in urban areas and improving socio-economic conditions have been shown to be associated with greater food availability, less seasonal fluctuations, increased access to and consumption of fast foods (Popkin & Bisgrove 1988, Popkin et al. 1995). These changes in diet and physical activity levels have been linked with improving socio-economic conditions and in turn with increasing levels of obesity, thus it is plausible that SES may act through a body composition pathway as increasing obesity may be a secondary consequence of improving socio-economic conditions and the nutrition transition.

A similar analysis was constructed to examine the predictors of the timing of pubertal development for Black adolescents. Two outcomes were investigated: early vs. late breasts/genitalia development and early vs. late pubic hair development. As gender was combined in this analysis (to reduce power loss through small sample sizes), sex was included in each model as a control variable. The results for the breasts/genitalia models

show that growing faster and gaining more weight in mid to late childhood (five to eight years) and coming from a high socio-economic group (as measured by an SES index) significantly increased the odds of achieving early breasts/genitalia development. For the pubic hair analysis, being taller, fatter, and heavier at four, five and eight years all significantly increased the odds of achieving earlier pubic hair initiation. SES was not a significant predictor of the timing of pubic hair development. These results suggest that body composition is the most important factor for the prediction of early pubertal development in Black urban South African adolescents. However, whilst these variables were significant, the models explained a very small amount of the variance in the timing of pubertal development. This suggests that other factors, not assessed in the current study, may be more important for the prediction of the timing of pubertal development. The primary importance of body composition has also been reported in a recent review by Parent et al. (2003) who examined the association between body composition and pubertal timing as part of a wider review of the limits of sexual precocity.

The finding that there were no peri- or early post-natal predictors of age at menarche or of breasts/genitalia development within this cohort, is contrary to other reports, who have shown an association, particularly between being born small for gestational age (SGA) and the timing of pubertal development in girls (Persson et al. 1999, Ibáñez & de Zegher 2006a, Ibáñez & de Zegher 2006b). Growth velocity in infancy was a significant predictor of pubic hair development within this sample, but there were no peri-natal associations. It is hard to explain this finding as none of the studies within the literature that examine early life predictors of pubertal development split the development of secondary sexual characteristics into breasts/genitalia and pubic hair categories. This is a clear limitation because these analyses do not control for the fact that puberty can be achieved via two pathways (1) gonadarche or (2) adrenarche. The achievement of Tanner stage 2 for breasts/genitalia or pubic hair should be taken as the initiation of puberty and does not require concordance of both characteristics. Environmental influences, such as nutritional insult may influence these pathways differently. This has been shown within the current study as different variables are associated with the development of these secondary sexual characteristics. A limitation within the current study may be that gender was combined in the analysis. Analysis by gender may have led to the identification of different predictors of pubertal development for each of the genders as shown by other studies (Persson et al. 1999, Ibáñez & de Zegher 2006a, Ibáñez & de Zegher 2006b). However, it appears that the splitting of breasts/genitalia

and pubic hair development into two categories is more intuitive, as the development of these secondary sexual characteristics occurs via two independently regulated pathways.

There is evidence within the literature that suggests that the HPG axis is sensitive to a range of environmental stimuli such as nutrition, stress, and exposure to endocrine disrupting chemicals (EDC) (Rhind, Rae & Brooks 2001). Foetal programming and early life exposure to insults such as poor nutrition may impact long term reproductive health mediated through changes to the HPG and/or the HPA axis (Clark 1998, Davies & Norman 2002, Schoeters et al. 2008). The link between early life HPG and HPA programming and the timing of pubertal development is complex and not clearly understood. It was not possible to assess the impact of these changes within the scope of the current study, but it should be noted that it is possible that programming of these axes may have influenced the results. However, the fact that there were no early life predictors of age at menarche or breasts/genitalia development and very few for pubic hair development in Black South Africans would indicate that the proximate environment is more important in comparison to distal predictors. Therefore, the influence of early life HPG/HPA axes programming may not play a major role in the differences reported within the current study. It could be hypothesised that the greater importance of the proximate environment is representative of the transitioning economy within South Africa and changing environmental conditions experienced by these adolescents since their birth in 1990, and even though they may have been constrained during early peri- and post-natal periods, the improving socio-economic and nutritional environments promoted growth in childhood, thus these childhood variables were more important in the prediction of pubertal development and age at menarche. This finding, could be referred to as an example of "developmental plasticity" (Gluckman & Hanson 2006a), in that the HPG/ HPA axes remain sensitive to current influences thus providing an adaptive advantage by maximising the adolescent's ability to survive (and successfully reproduce) rather than having a fixed growth tempo or trajectory that is dictated by distal factors that may no longer be relevant.

6.4 Other factors associated with age at menarche and pubertal development not measured in the current study

The results from this study show that being taller, fatter, and heavier in late childhood was associated with the achievement of earlier menarche. In addition, they showed that mid to

late childhood body composition and growth velocities were associated with earlier breasts/genitalia development and pubic hair development in urban Black adolescents. There is some evidence for a secular trend in age at menarche and pubertal development in urban South African females. The secular trend was less clear for urban South African males. It is possible to link these findings with improving environmental conditions, increasing stature, increasing rates of overweight and obesity and better socio-economic conditions. Whilst the current analysis cannot provide further evidence for the reasons as to why pubertal development and menarche are being achieved earlier within this cohort due to the small amount of variance explained by the logistic regression models, several studies have provided other potential explanations which were not measured in this study. Depending on definition of heritability and the research design, heritability coefficients range from 50 to 80% (Meyer et al. 1991, Palmert & Hirschhorn 2003, Towne et al. 2005, van den Berg & Boomsma 2007). Other factors associated with pubertal development include; hormonal secretions by the HPG axis (Apter 1997), organic pollutants such as phthalates that are regularly found in cosmetics, toys and plastic food containers (Colón et al. 2000), social stress such as parental divorce and conflict (Wierson, Long & Forehand 1993) and more obscurely, hair products that contain certain hormones such as oestrogens (Li et al. 2002). Other studies have highlighted that exposure to pollutants and other endocrine-disrupting chemicals may contribute to earlier achievement of female pubertal development and menarche (Colburn, Dumanoski & Myers 1996, Blanck et al. 2000, Schell et al. 2006). It is probable that an interaction between a number of these factors has influenced the secular trend in pubertal development and age at menarche within this cohort of Black urban South African adolescents in addition to the factors that were measured and found to be associated with these outcomes.

6.5 Potential consequences of the timing of pubertal development

As discussed previously (see Background section 2.9 for a detailed review) a large number of negative consequeneces have been attributed with the timing of pubertal development. Research has suggested that late achieving boys are at an increased risk for delinquency, criminal activity, and substance abuse in a bid to raise self-esteem, gain popularity amongst their peers and to achieve autonomy (Graber et al. 2004, Williams & Dunlop 1999). These potential consequences have particular relevance in the context of the current study given the "culture of violence" particularly amongst young males in urban South Africa. For young

Black males, the legacy of apartheid has resulted in familial instability, limited access to educational and employment opportunities and the denial of their political rights (Vogelman 1990). This has lead to the establishment of youth gangs to provide an adolescent male with "indentity" and as a means to rebel against margilisation encouraging their beliefs of male dominance, supremacy, and aggression (Vogelman & Lewis 1993).

The consequences of early pubertal development for females are multifaceted and include amongst others: social, sexual, psychosocial, medical, and educational factors (See for example Caspi & Moffitt 1991, Graber et al. 1997, Stice, Presnell & Bearman 2001, Graber et al. 2004, Mendle, Turkheimer & Emery 2007). Females who are overweight in adolescence have also been shown to achieve lower educationally, earn a lower income as adults and are less likely to get married in comparison to leaner females (Gortmaker et al. 1993). This is particularly relevant to the current cohort, where 18.8% of the girls were categorised as overweight and/or obese by 14 years of age. South Africa is a country experiencing social, economic and nutrition transition and so it is anticipated that obesity levels will continue to rise. This could result in a generation of women who achieve a lower standard of education, earn less financially and who are at a greater risk of developing non-communicable diseases. Each of these factors has negative implications for the women, their offspring and for South African society as a whole. However, whilst the list is relatively long for potential detrimental outcomes of early puberty in females and later puberty in males, it should be stated that not all these early or late developers exhibit negative sequelae and that the timing of puberty in itself may not be the causal mechanism, but a by product of the environment in which the adolescents were exposed during infancy and childhood.

6.6 Policy Implications

Given the evidence from the current study for a declining age at menarche and pubertal development in South African adolescents and the associated negative sequelae, one must consider the potential need for renewed research and resources for intervention strategies and policy programmes. The two main negative outcomes that have the potential for intervention include:

1. Earlier initiation of sexual activity, increased number of sexual partners, poor contraceptive use and an increased risk of teenage pregnancy and sexually transmitted infections (STI) and HIV/AIDS

2. Increased risk of overweight and obesity with a subsequent increased risk of non-communicable diseases such as cardiovascular disease and type II diabetes

The above negative health outcomes which have been associated with earlier pubertal development and age at menarche, are major public health concerns, particularly in the South African context given the HIV/AIDS epidemic and the rising levels of obesity.

6.6.1 The need for better sex education

There is a clear need to provide better sex education to South African adolescents. Young people have a right to sex education and it is important for adolescents to acquire information to allow them to form attitudes and beliefs about sex, sexuality, and relationships. In addition, sex education helps to build life skills relating to negotiation, decision making and assertion. This is particularly important for females in societies where female autonomy and relationship decision making is low. Sex education has been shown to be effective in altering behavioural outcomes including delaying first intercourse, reducing the frequency of sex, the number of new partners and the incidence of unprotected sex and increasing contraceptive use in those who are already sexually active (Alford 2003, Kirby 2001, 2005). There is a concern, particularly for parents, that providing sex education may increase sexual activity and lead to earlier sexual debut; however, the results from the majority of studies do not support this hypothesis (Wellings et al. 1995). The topic of adolescent sexual and reproductive health is however, politically and culturally sensitive (Xu & Shtarkshall 2004), therefore intervention programmes need to be culturally and contextually specific (Singh, Bankole & Woog 2005). The teaching of "life skills" became mandatory in all South African schools in 2005 (South African Department of Health 2005). The "life skills" programme is designed to significantly impact adolescents decision-making in the areas of relationships, sex and AIDS, as well as in the field of religious tolerance, human rights, prejudice, reconciliation, family relationships, violence, crime, and substances abuse (Meyer-Weitz & Steyn 1992). As yet there has been limited evaluation of this project.

Knowledge about the timing of pubertal development may help policy developers to target specific groups within the population. There is a need to provide sex education both prior to puberty and for it to be sustained throughout the period of adolescence. The information that is provided needs to be shaped by the group of adolescents to whom it is being presented.

For example, males and females may need to be educated separately to help foster an environment in which adolescents feel that they can ask questions. Those who are in early puberty may need to be separated from those in late puberty as they may be experiencing different physical and psychological events and thus may have different concerns.

6.6.2 Tackling the rising levels of obesity

The rising level of obesity in South Africa, particularly in children and urbanised Black women, is a major public health concern (Steyn, Fourie & Temple 2006). The co-morbid diseases associated with obesity such as type II diabetes, hypertension and cardiovascular disease are becoming increasingly prevalent amongst all South African population groups (Mollentze et al. 1995, Bourne, Lambert & Steyn 2002, Vorster 2002). Poor health information and media messages in South Africa between 1960 and 1980 resulted in the concept of "benign obesity" (Walker et al. 1990). The concept has compounded the policies established to try and tackle the rising levels of obesity. The problem of obesity cannot be managed on an individual level, but rather it needs to be tackled using a multi-sector approach involving communities, governments, the food industry and the media (Kruger et al. 2005). These groups need to work together to create policy aimed at creating an environment that is more conductive and supportive for change. Prevention should be the primary goal to tackling childhood obesity, which in turn will help to reduce adult obesity levels (Doak et al. 2006). Deckelbaum and Williams (2001) have suggested that three levels of prevention should be employed to address childhood obesity: (1) primordial prevention which aims to help maintain a healthy BMI throughout childhood and adolescence, (2) primary prevention which aims to prevent overweight children from becoming obese and (3) secondary prevention which aims to treat obese children. To achieve these aims, particularly in South Africa, intervention policies need to encourage appropriate food labelling, nutritional and physical activity education, the control and management of advertising and the prevention of local markets being flooded with cheap and unhealthy foods (Kruger et al. 2005). Whilst there are few studies in South Africa that have successfully targeted the reduction of childhood obesity, successful studies from other countries which have focused on activity intervention (Killen et al. 1988, Manios et al. 1999), particularly the reduction of television watching (Gortmaker et al. 1999, Robinson 2001) can be used as a starting point for future South African policy development.

6.7 Concordance and discordance of pubertal development

There is evidence within the literature for discordance between Tanner stages for both boys and girls (Reynolds, Wines 1948, Harlan et al. 1979, Harlan, Harlan & Grillo 1980, Herman-Giddens et al. 1997, Karpati et al. 2002, Biro et al. 2003). It appears to be a common phenomena and is found consistently in both physician assessed and self-assessed studies, although is rarely reported in these studies. The percentage of adolescents who were discordant in the current study was similar to those reported by Shubert and colleagues (2005) who used data from the 1988-1994 NHANES survey. Both studies found that for both Black and White adolescents, girls were more likely to be discordant in comparison to boys. One of the differences observed between the results for the Schubert study and the current study showed that South African boys were less likely to be genitalia discordant (38.0% vs. 48.6%) compared to their American peers. In a study of White females, Biro et al. (2003) reported discordance rates of 51.6% in comparison to White Bt20 females who exhibited 36.5% discordance.

These results should be considered within the context of the difficulties in accurately assessing secondary sexual development. Tanner ratings were determined by physician assessment for the NHANES sample and for Years 9/10 in the Bt20 sample. From Year 11 onwards the Bt20 sample used self-assessment techniques. Neither study utilised breast palpation techniques which may have reduced breast rating accuracy and thus explain the potential differences in discordance proportions between males and females. Another potential problem, that may have lead to an under reporting of discordance is that the breasts/genitalia and pubic hair ratings are done almost simultaneously, thus a physician or adolescent may unintentionally introduce bias by anticipating identical ratings (Harlan et al. 1979, Harlan, Harlan & Grillo 1980, Schubert et al. 2005).

6.8 Quantitative study limitations

There were several limitations with these data on age at menarche that need to be taken into account when placing the results in the context of previous literature. The main problem related to the collection of menarcheal data and the subsequent analysis. In the Bt20 study, age at menarche was determined through a self-complete questionnaire. The question relating to menarche, asks simply for an age in years as opposed to a date which would allow the calculation of a decimal age at menarche. Data from the current study therefore fell

into categorical yearly age group bands. From these data, cumulative frequency plots were constructed and logistic curves fitted. This meant that median age at menarche was derived from these curves (model derived) rather than being derived from continuous data (data derived) and may have introduced bias in the estimate of menarcheal age. It is clear from the standard error of the estimate values (SEE) that the model applied to the Black data (SEE = 0.09) fitted these data better in comparison to the model for the White girls (SEE = 0.24) although this may reflect the smaller sample size available for White girls. Further examination of the white model would suggest, that median age at menarche was slightly over estimated in the current study, although this is relatively small and may still show that there is no significant different in age at menarche between Black and White urban South African adolescents.

These model fitting problems were also apparent for the pubertal development data. Median age at initiation was determined using the same methods as for age at menarche. The SEE values ranged from a minimum of 0.2 to 0.9, suggesting some variability in the model fitting. Further examination of these models suggest that they may slightly over estimate median age at entry into G2 and PH2 for Black males. This is however relatively small and the same conclusions can still be drawn. One point that is apparent from the majority of these models (see Quantitative Results section 4.2.2 for a copy of these graphs) is that year 11 estimates (the year that self-report questionnaires were introduced) were lower than that predicted by the model. This may suggest that there was a general level of under rating specifically by White boys and Black and White girls. This was not apparent for Black boys. As the median ages were derived from the model, it would appear that the potential under reporting at year 11 would not have had a significant impact on the median age estimates.

It is not possible to ascertain the exact age at which a specific stage of development (i.e. B2/G2) is reached, unless a child is seen at frequent and regular intervals. This is also true of the menarche data within the current study due to the nature of data collection. If a girl was seen at 10.1 years of age in stage B1 and age at 11.1 years of age in B2, the attainment of B2 could have been at any point between 10.1 and 11.1 years. The margin for error, therefore, is a maximum of 0.98 years (10.11 to 11.09 years). To reduce this error to a maximum of 0.5 years, age at initiation was calculated as the mid point between the ages before and after the change of indicator (e.g. B1 to B2, menarche etc). Participants could

then be categorised into early and late achievement groups for the initiation of pubertal development and age at menarche.

Prior to the building of logistic regression models, discrete-time hazard modelling was investigated as an appropriate method to identify the associations between early life factors and pubertal development. Theoretically, discrete-time hazard modelling would be the most appropriate method of analysis because it has the facility to deal with certain problems associated with longitudinal data; censored observations and time-variant explanatory variables (Allison 1984). However, there were problems; specifically a lack of power due to small sample sizes with the Bt20 data that prevented the correct usage of the technique and thus logistic regression was used. The issue of sample sizes was also apparent with regards to the logistic regression modelling for White adolescents. Due to a lack of SES data availability at birth, White adolescents were excluded from the logistic regression analysis and thus it was not possible to establish if the determinants of menarche and of pubertal initiation were the same for Black and White adolescents within this study.

The current study has a reduced sample size, in comparison to the original Bt20 cohort and thus may not be socio-economically representative of adolescents living within Johannesburg-Soweto. South Africa experiences high levels of economic inequality and so these reduced sample sizes may decrease the range of socio-economic profiles within the cohort. The external validity of the menarche and of the pubertal development samples was investigated by comparing those individuals included in the analysis with those who were excluded. Those included in the menarche sample, were smaller and lighter, and had younger mothers that were less likely to be married compared to those that were excluded. Thus these individuals may have had a lower SES. Those included in the pubertal development sample, were taller, heavier and grew quicker in infancy, had younger mothers that were less likely to be married, although they were more likely to live in a house/cottage (vs. flat/shack) compared to those excluded from the analysis.. Only a small number of the variables tested for external validity were statistically significantly different. Those SES variables that were significantly different indicate that the analysis samples may over represent the low SES groups within the Bt20 sample. Therefore, these findings may not be representative of the Bt20 sample and that of adolescents living within Johannesburg-Soweto. As previously discussed, higher SES groups, on average, achieve puberty and

menarche at a younger age compared to lower SES groups, thus the ages estimated within the current study may be upwardly biased.

In addition to the issue of a small sample not being socio-economically representative, sample size also influences the power to detect statistically significant differences in the logistic regression models. As discussed in Methods section 3.1.1.4 this study was under powered and therefore the results must be considered within the context of this limitation. A lack of power means that there may have been times when the null hypothesis was accepted when it should in fact have been rejected. Therefore, variables that have been shown to be consistently associated with the timing of pubertal development in the literature, but not important in the current study may have been important if the sample available for analysis was greater. Having said this, the variables that were found to be significantly associated with the timing of pubertal development and age at menarche within the current study were highly significant given the small sample size.

6.9 Cultural perspectives on age at menarche and pubertal development in South African adolescents

In addition to the quantitative longitudinal data, this study used focus group methods to explore views and opinions on the current Bt20 questionnaire and procedures for collecting pubertal development data from Black urban South African adolescents at varying stages of maturity and from a range of socio-economic backgrounds. Data were also collected from Bt20 and BH staff with varying levels of knowledge and experience. As far as the author is aware, there are no published qualitative data relating to the self-assessment of pubertal development. However, focus groups have been shown to be an important and useful vehicle to help gain adolescent perspectives on health and well-being (Peterson-Sweeney 2005), particularly for sensitive issues (Morgan 1997) such as discussions relating to pubertal development. There are numerous studies within the literature that have examined sensitive topics with adolescents using focus group techniques, these typically relate to amongst others, eating behaviours, teenage pregnancy, sex and sexuality, substance abuse, HIV-related risk behaviours and living with chronic disease (see for example Brown et al. 1998, Hinds et al. 1999, Neurman-Sztainer et al. 1999, Aquilino & Bragadottir 2000, Weinger, O'Donnell & Ritholz 2001).

Although there is no direct comparison with previous literature, the results from the current study provide a unique insight into the positive and negative aspects of collecting pubertal development data in an urban developing country setting. Within the quantitative literature it is well known that it is hard to collect reliable and accurate data on pubertal development using self-complete questionnaires (Hergenroeder et al. 1999, Litt 1999, Desmangles et al. 2006). The reasons behind this are not well known and few if any authors discuss whether the adolescents being asked to rate themselves actually understand the questionnaire and/or data collection process. Few authors have engaged the user's perspective on the design of such tools. By gauging adolescent and staff perspectives on the current questionnaire and procedures, the subsequence methodological changes could help to improve reliability and accuracy of self-assessed pubertal development, especially within the South African context.

There was a general consensus between adolescents that the current questionnaire is easy to complete as they know and understand their body changes. This was particularly true for females who had very few negative comments about the current questionnaire and procedure. The late puberty males were the most verbal group. This is in contrast to other research which has shown that adolescent boys are less likely to articulate problems and feelings in comparison to their female peers (Buhrmester & Furman 1993). One explanation for this may have been the environment that was fostered by the moderator, who may have helped to create a permissive atmosphere and the interactions between group members may have promoted further discussions. Another reason as to why this particular group may have been the most verbal, could relate to peer pressure, particularly for boys in late adolescence, who may have felt the need to "impress" the other members of the group. Peer pressure can positively or negatively influence focus groups. Individuals with differing views from their peers may withhold or be more open with comments in a bid to conform to "socially accepted norms" or to appear more like their peers (Horner 2000). To try and reduce this potential influence groups were split by gender, maturational status and all participants were from the same ethnic group (as were the moderators).

The negative views on the current questionnaire centred on the language and the pictures/line drawings. Whilst nearly all the groups found the pictures helpful, the boys reported that they were embarrassing and unnecessary. This is perhaps counter intuitive, as the pictures are intended to help the adolescent to decide which stage they are in. This issue was also raised in the staff focus groups, and one member of the group believed that the

pictures should be removed to help with embarrassment issues. This view point was argued against within the staff focus group as the other participants believed that the pictures were helpful and that the majority of adolescents do not even read the description but merely look at the pictures and tick the appropriate box. In addition, one member of staff believed that the pictures should stay because they help the adolescents who have problems with reading by preventing them from having to acknowledge that they have reading difficulties. As previously discussed in the quantitative section, drawings require abstract thinking and the ability to read and understand the description given, in comparison to a photograph which is self illustrative (Hergenroeder et al. 1999). The results from these focus groups suggest that the line drawings, whilst requiring interpretation and abstract thinking, are helpful and should be included in self-assessed pubertal development questionnaires. This supports the work of Norris and Richter who validated the use of these line drawings with Black South African adolescents. The question still remains however, as to whether ethnic group specific line drawings should be employed. Whilst not specifically discussed within these focus groups the general thoughts from conversations between the main researcher and members of the Bt20 team (personal communication) suggest that it is inappropriate to highlight ethnic group differences and so having to establish ethnicity in order to give the appropriate questionnaire may cause offence to certain individuals and potentially place staff in difficult situations.

Language issues were raised in the adolescent male and both staff focus groups. An interesting discussion between members of the Bone Health staff focus group raised the issue of language vs. cognition. One member of staff believed that language was not the main problem, but rather the context and further clarified this point by adding that even if the questionnaire was available in vernacular, some of the adolescents would still not understand it. The late puberty males said that the questionnaire should not involve biology as they do not understand biology, that it needs to be in other languages in addition to English and that some of the words are a problem. When probed, there was little suggestion as to how this could be improved and the main comment was to suggest that a dictionary be provided. Whilst the comment was perhaps made as a joke, it does actually hold some merit. The key words that were highlighted as being problematic were: texture, density, and distribution. It would be possible to add a simple definition of the meaning of each of these words to the questionnaire to aid understanding. An alternative suggestion could be to use simpler wording in the first place. This would require further qualitative and quantitative research, but

could prove useful in helping to collect more reliable and accurate pubertal development data.

Another problem raised by the staff was the conflict between giving the adolescents sufficient space and privacy to complete the questionnaire and being able to help should there be a problem. The adolescents are encouraged to complete the questionnaire on their own and to come back to the interviewer should they have any problems. The adolescents said that they did not know that they could seek help or that if they did, they did not seek help anyway. Therefore, adolescents are not seeking help and because they complete it on their own, the staff are unaware if there are problems and so are unable to provide clarification if needed. It is very difficult to overcome this problem and this is potentially one of the biggest problems with self-complete questionnaires. Suggestions from the staff to try and overcome this involved the checking of questionnaires before the adolescent leaves the testing site. This quality control procedure would reduce the number of missing data (i.e. questions left blank), but would still not provide any evidence for how accurately the questionnaire had been completed. The only way to give an indication of how accurately questionnaires are being completed is to have a randomly selected sub-sample of physician assessed adolescents and to calculate reliability coefficients. This is however ethically problematic. The assessment of secondary sexual characteristics by a physician is an invasive procedure as it invades the privacy of the adolescent. In a non clinical setting, such as a growth study where the adolescent's growth is deemed to be "normal", ethical committees consider it inappropriate to use clinical assessments and suggest that self-report questionnaires are used (Cameron 2002). In addition, as shown in the qualitative work within this thesis, some adolescents and their parents are reluctant to give informed consent to allow physical assessments of pubertal development as they feel that is inappropriate.

Following on from this, both staff focus groups reported gender differences in cognition and completion. It was suggested that girls understand the questionnaire better than boys and complete it more quickly. This may support evidence of the female cognitive advantage for verbal tasks in comparison to male advantage for spatial tasks (e.g. Mann et al. 1990). Staff also suggested that boys tend to overrate themselves compared to girls who rate more modestly. The suggested reasons for inaccurate rating related to cultural and peer influences, in that boys may rate themselves as being adult as they do not want to be seen as a boy or viewed as being delayed in comparison to their peers. This finding of boys

overrating and girls underrating was also shown in the study by Norris and Richter (2005), who validated the use of self-rating questionnaires in a Black urban South African cohort. The authors showed that boys tended to overrate their genitalia development when compared to physician assessments and that this overrating was greatest in later adolescence (16-18 years) compared to earlier adolescence, confirming that this age group is potentially the most biased. Girls within the study slightly underrated pubic hair development, but rated more consistently for breast development. These differences in rating may need to be integrated into the procedure/questionnaire for collecting pubertal development data. A solution could be to add a statement at the top of the questionnaire explaining that "you should not compare yourself with your friends, it is completely normal for you to be the same age as them but at difference stages of pubertal development". This also needs to be emphasised in the tutorial given to participants prior to the completion of the questionnaire.

There were mixed responses about tutorials in the focus groups. Before data collection commences each year, Bt20 and BH staff attend training sessions on how to administer each of the questionnaires within the battery of assessments given to each adolescent. They are trained on how to administer the pubertal development questionnaire and informed that a tutorial should be given to each adolescent, before they are left to complete the questionnaire. This tutorial should explain the procedure using non-scientific language, in a vernacular appropriate to the adolescent and the interviewer should invite questions to ensure that the adolescent understands. The Bone Health staff categorically stated that no tutorials are given. It is difficult to judge how this may have influenced the results, although it is thought to be negative. For example an adolescent who does not understand and is just left to complete the questionnaire without any form of explanation, may do so incorrectly simply because they do not feel that they can ask questions. In comparison if a child is unsure of how to complete the questionnaire, the tutorial may provide the answer to their questions and if not, the interviewer would invite questions and thus the adolescent is given an opportunity to gain clarification. The interviewers need to ensure that they are giving a tutorial to all adolescents before they are left to complete the questionnaire in order to improve reliability and to foster an environment in which adolescents feel that they can ask questions.

In general, there were few suggestions on how the current procedure could be improved and the majority of the groups articulated that no improvements could be made. The late puberty males said that they wished that the interviewers could ensure their privacy when completing the questionnaire and this was similar to comments from the late puberty females who requested a special room for girls only. Both of these observations relate to the provision of cubicles for the self-assessment of pubertal development, a discussion point raised in the staff focus groups. A member of the Bara staff focus group proposed the idea of cubicles and suggested that cubicles should be made available for adolescents, with mirrors, appropriate lighting and with large descriptions (in English) of the different stages of development. The remaining members of the group thought that this was a worthwhile idea. Further discussions resulted in the general opinion that this idea, whilst reasonable was not practical. The explanations given suggest that this would increase time taken to complete the questionnaire as queues would form outside the cubicles and that they could not imagine a male waiting outside for a female to finish without causing her embarrassment or vice versa. Although this idea was not practical for the Bt20 study due to time problems (see next paragraph for further discussion), the idea of cubicles should be considered carefully when initiating a study of pubertal development, where time constraints are not such an issue. The use of gender specific cubicles with mirrors, appropriate lighting, and diagrams would help to ensure privacy, allows adolescents to examine themselves should they need to, and would potentially increase accuracy and reliability of self-assessed pubertal development data.

The final problem raised by the staff focus groups related to time. This was particularly relevant when discussing potential changes to the procedure and questionnaire. Staff were adamant that any suggested changes should not increase the length of time required to complete the pubertal development questionnaire and/or the total time taken for adolescents to be on site for data collection. Thus, when the addition of a tutorial was suggested to the BH team, the response was negative as it would increase time. Time is a continual pressure for staff, not only from the adolescents but from their caregivers as well. Due to the nature of the Bt20 study, adolescents and their families may be present at the data collection site for a relatively long period of time (upwards of four hours), on an annual basis. Thus adding additional tasks increases this time and the pressure on staff. A potential way to overcome this is to spend a greater amount of time and resources on staff training prior to data collection. This would help to emphasise the research outcomes of these data and the need to ensure accuracy and reliability. By explaining why it is important to give a short, but

effective tutorial prior to the collection of pubertal development data, the staff may be encouraged to ensure that this is done and see the long term benefits.

6.9.1 Changes to the pubertal development questionnaire

The Bt20 adolescents and staff were asked to comment on the questionnaire and procedure used by Bt20 prior to the introduction of the current self-assessed questionnaire. Pubertal development was assessed by physicians in years nine and ten, this was then changed to a self-assessed questionnaire with guidance from the interviewer in year 11 and then to the current self-rated questionnaire from year 12 onwards. There were very few comments from the adolescents, who seemed to have problems remembering, this may be a reflection of the large number of questionnaires that these adolescents have seen annually for a number of years. The comments from the staff were negative in relation to previous procedures and highlighted that they felt a number of adolescents had dropped out of the study because they were unhappy with the manner in which pubertal development was assessed. They also articulated that parents were unhappy and that the procedure made the interviewers themselves uncomfortable as it invaded the privacy of the adolescents. It can therefore be assumed that the current questionnaire is the most appropriate to use.

6.10 Qualitative study limitations

One of the issues that became apparent when the focus group transcripts were analysed, was that the adolescents' provided numerous monosyllabic responses to questioning from the moderator. One potential explanation for this is that this age group, particularly those in early adolescence may have problems responding to open ended questions, as they may have difficulty formulating and articulating responses that involve opinions (Dixon & Stein 2000). However, within a group situation, Morgan (1997) indicated that adolescents are better at describing experiences, hence the semi-structured nature of the focus groups used within the current research. In addition, the limited time available to train the focus group moderators may have inhibited responses because of a lack of appropriate facilitation by the moderator, who did not have prior experience of running adolescent focus groups.

Only Black adolescents were invited to participate in the focus groups and so any potential ethnic differences in opinions could not be reported. Only Black adolescents were recruited

for the focus groups due to time, moderator availability, and space restrictions. There was a limited amount of time available to train the moderators, and the Bt20 staff that were available to work at the weekends were of Black ethnic origin. While the main researcher could have moderated White female focus groups, there were no White male staff available to moderate White male adolescent discussions. Furthermore, the only space available to conduct the focus groups was at the Baragwaneth Hospital site in Soweto. It is very difficult to get White adolescents to attend this site due to its location. Due to these issues, a decision was taken to recruit only Black adolescents.

The composition of the focus groups was carefully considered prior to recruitment as this has been shown to be important for the facilitation of discussion, confidence, and interaction within an adolescent group setting (Horner 2000). The adolescents were split into early (Tanner stages 2-3) and late (Tanner stages 4-5) groups based on their year 15 pubertal development ratings to try and create a permissive atmosphere for discussion between adolescents who were experiencing similar maturational events. However, when the assessment forms were analysed after the focus groups were conducted there was some variability in this. The progression of some adolescents from early to late puberty was to be expected as the year 15 ratings may have been taken some nine months prior to the focus group recruitment. The adolescents who reported being in late puberty at year 15 and then in early puberty at the time of the focus groups further suggests consistency problems with self-rated questionnaires. This problem has been controlled in the quantitative strand as these data were longitudinal and so cross-referencing to the previous assessment allowed cleaning to be conducted where appropriate to ensure that no child had gone backwards between two assessments. It should be noted however, that this could still be a problem because there is potential for the initial assessment to be inaccurate. SES or social status (based on area of residence) was also taken into account with a combination of low and middle/high SES adolescents being recruited into each focus group. This may have lead to inhibition in the sharing of views between adolescents; however, it is thought that because the majority came from similar neighbourhoods and were of Black ethnic origin this did not have a negative influence on the results.

Another problem relates to language. The adolescent focus groups were conducted in a variety of languages (mainly English and Zulu) as the adolescents had been instructed to talk in whichever language that they felt most comfortable and which allowed them to explain

their view most effectively. Due to this, the audio tapes had to be transcribed and then translated into English. This was done by the female note taker who spoke all of these languages, her native tongue was Zulu, but had qualifications in English. She also had experience in the area, had participated in moderator training, and had taken part in the staff focus groups. She was therefore aware of the culturally specific expressions and slang relating to pubertal development in the South African context and was able to translate the words as well as the context into English. Any problems relating to language and or culturally specific expressions were cross checked between the main researcher and the transcriber prior to analysis. Therefore, it is hoped that these potential threats to validity were minimised.

The number of participants within the groups may have influenced the discussions. Reiskin (1992) recommends that groups are large enough to allow contrasting views, but small enough to encourage all participants to contribute. Recommended groups sizes range from four/five (Quine & Cameron 1995) to ten/twelve (DeWolf 1985). The adolescent focus group sizes ranged from six to 13 with a mean of ten participants per group; and from four to five for the staff focus groups. Each of the focus groups was "over" recruited, in anticipation that some adolescents who had given a positive response via telephone, would not attend on the day. This however was not the case and approximately 95% of those recruited attended, hence the larger than expected numbers. The larger groups may have prevented the quieter participants from contributing; however, when asked, the moderators said that none of the focus groups were dominated by certain individuals and that when encouraged even the quietest participants were willing to share their views.

6.11 Future research

During the process of completing the current study a number of further research questions were raised but were not explored due to the nature of the data and/ or time restrictions. Therefore, the following comments relate to potential future research projects.

6.11.1 Quantitative research

- There is a clear need for the establishment of South African pubertal development references, to allow clinicians to identify those adolescents who are truly precocious

or truly delayed in their development compared to their South African peers. This would allow interventions to be targeted appropriately.

- The current study only investigated the factors that were associated with the timing of pubertal development and age at menarche in a sample of Black adolescents. The factors associated with pubertal development and age at menarche may be different in other ethnic groups and therefore this should be investigated.
- There are a lack of studies on the pubertal development of boys and this may reflect the lack of a clearly discernable maturational event, unlike girls who experience menarche. Better knowledge of pubertal development in boys may help to target interventions to reduce the negative sequelae associated with late development in boys such as substance abuse and delinquency.
- Other studies have investigated how the hormonal pathway through which an adolescent enters puberty (hypothalamic-pituitary-gonadal vs. hypothalamic-pituitary-adrenal) is associated with body composition and the timing of other pubertal events such as menarche. There is potential to investigate this using the Bt20 dataset. This might also have important implications for future research as the results from this study show that the early life predictors of breast/genitalia development are different to those that predict pubic hair development in Black adolescents.
- Given the negative sequelae that are associated with early pubertal development, there is a need to enhance our understanding of the factors that are associated with early pubertal development in order that appropriate interventions and subsequent policy interventions can be targeted appropriately.
- Few if any studies can explain why Black adolescents, on average, achieve puberty and menarche prior to White adolescents. There is a need for additional studies to examine the factors that are associated with the timing of pubertal development and menarche between different ethnic groups.

6.11.2 Qualitative research

Each of the questionnaire changes recommended in the conclusions section and in the section below would require validation in order to assess the impact on improvements to accuracy and reliability.

- There is a need to investigate and explore adolescent views on the type of language that is used in self-rated pubertal development questionnaires. One recommendation from the focus groups within the current study was to use "simpler words"; however, it was difficult to ascertain examples. Further focus groups could be used to look specifically at what words would be more appropriate from an adolescent's point of view.
- It has been suggested that there is a need for ethnic group specific line drawings to be used in self-rated pubertal development questionnaires. Whilst not appropriate in the South African setting, this may be beneficial in studies of only one ethnic group or in studies where the identification of ethnic group is not as culturally problematic. Although, there may be a need to use qualitative methods to determine if this would be culturally acceptable in the local area of a particular research study.
- Due to the time restrictions of the current research project only a small amount of the focus group data were analysed. Analysis of the remaining data will provide further insight into the cultural perspectives of pubertal development in urban South African adolescents.

7 Summary of conclusions

7.1 Summary of quantitative research

The main conclusions from the quantitative results are:

- Median age at menarche was 12.4 years (95% confidence interval [CI] = 12.2, 12.6) for Black girls and 12.5 years (95% CI = 11.7, 13.3) for White girls. Unlike findings from some developed countries like the US, there was no statistically significant difference in menarcheal age between the two ethnic groups within this study.
- Black South African girls are achieving menarche significantly earlier than Black girls in other sub-Saharan African countries and at around the same time or slightly later than their African-American peers.
- White South African girls are achieving menarche at around the same time as their European and American counterparts.
- Median age at the initiation of genitalia development was 10.4 years (95% CI = 8.4, 12.4) for Black boys and 9.8 years (95% CI = 9.4, 10.2) for White boys. Median age for the initiation of pubic hair development for Black males was 10.8 years (95% CI = 9.6, 12.0) compared to White males, which was 10.2 years (95% CI = 8.4, 12.0). Median age at the initiation of breast development in Black females was 10.1 years (95% CI = 9.3, 10.9) compared to White females which was 10.2 years (95% CI = 8.2, 12.2). Median age for the initiation of pubic hair was 10.3 years (95% CI = 9.3, 11.3) and 10.5 years (95% CI = 8.7, 12.3) for Black and White girls respectively. There were no statistically significant differences in age at initiation between genders or ethnic groups.
- Black South African males are achieving genitalia and pubic hair development younger than any previous study in South Africa and slightly younger than African-American boys.
- Black South African females are achieving breast and pubic hair development slightly younger or at around the same time as previous South African, European and American studies.
- The results from this study indicate that there is evidence for a statistically significant positive secular trend in age at menarche in Black, but not White South African females. The average decline in menarcheal age was 0.56 and 0.32 years per decade for Black and White girls respectively.

- South Africa is continuing to show a rapid decline in menarcheal age and as yet, has not experienced the plateau seen in some developed countries like America and the UK. This suggests that environmental factors such as nutrition and socio-economic status (SES) continue to influence this biological process in South Africa, where as in the US and UK these environmental factors may have less influence and a lower limit of age at menarche may have been reached due to a genetic "ceiling".
- There is potentially evidence for a positive secular trend in age of pubertal development in Black South African females, but not for Black males as the data are less consistent. These inconsistencies in pubertal development data may reflect the difficulties in comparing data from studies with different temporal contexts and assessment methods.
- It is possible to link the evidence for a secular trend in South Africa with improving environmental conditions, increasing stature, increasing rates of overweight and obesity and better socio-economic conditions.
- In the current study, Black and White South African girls on average, achieved menarche at the same time. This finding is contrary to previous literature from developed countries who have reported that Black girls achieve menarche earlier than their White peers within a population. This finding may be related to the differing socio-economic environments experienced by the two ethnic groups in South Africa. The Blacks girls in this study experienced a low SES at the time of their birth and at 9/10 years of age in comparison to the high SES environment experienced by the Whites. The transitioning economy and removal of *Apartheid* legislation which oppressed the Blacks, may have driven the rapid decline in Black menarcheal age, in comparison to the slower decline experienced by the Whites, whose socio-economic environment may have remained relatively unchanged in recent years.
- There are a number of negative sequelae associated with the timing of pubertal development and age at menarche including an increased risk of overweight/obesity, particularly in females. Females who are overweight in adolescence have also been shown to achieve lower educationally, earn a lower income as adults and are less likely to get married in comparison to leaner females (Gortmaker et al. 1993). This is particularly relevant to the current cohort, where 18.8% of the girls were categorised as overweight and/or obese by 14 years of age. South Africa is a country experiencing social, economic and nutrition transition and so it is anticipated that

obesity levels will continue to rise. Resulting in a generation of women who achieve a lower standard of education, earn less financially and who are at a greater risk of developing non-communicable diseases. Each of which has negative implications for the women, their offspring and for South African society as a whole.

- Being taller, fatter, and heavier at eight years of age significantly increased the odds of achieving early menarche in Black females in this sample. There were no peri-natal or infant factors associated with the timing of menarche in this cohort.
- Results from logistic regression showed that a greater weight and height velocity in late childhood significantly increased the odds of achieving early breast/genitalia development for adolescents within this cohort. Furthermore, a low SES index at 9/10 years significantly reduced the odds of achieving early breast/ genitalia development. For pubic hair development, a greater weight, height, BMI and growth rate during infancy and childhood significantly increased the odds of achieving early initiation. There was no other peri-natal, post-natal, or infantile body composition factors associated within the timing of pubertal development within this cohort. Childhood body composition and growth trajectories were the most sensitive indicators of the timing of pubertal development in urban South African adolescents.
- This finding suggests that the greater importance of the proximate environment is representative of the transitioning economy within South Africa and changing environmental conditions experienced by these adolescents since their birth in 1990, and even though they may have been constrained during early peri- and post-natal periods, the improving socio-economic and nutritional environments promoted growth in childhood, thus these childhood variables were more important in the prediction of pubertal development and age at menarche. It could be said that this is an example of "developmental plasticity" in that the HPG/ HPA axes remain sensitive to current influences thus providing an adaptive advantage by maximising the adolescent's ability to survive (and successfully reproduce) rather than having a fixed growth tempo or trajectory that is dictated by distal factors that may no longer be relevant.

7.2 Summary of qualitative research

The main conclusions from the qualitative results are:

- In general, the current questionnaire used to collect pubertal development data is easy to understand and complete.
- Males and females differ in their opinions of the current questionnaire, with females articulating few negative comments, in contrast, the males particularly the late puberty males, expressed a number of negative views. These related to embarrassment due to the pictures and difficulty in understanding some of the words.
- Staff reported gender differences in cognition and completion, with females understanding the questionnaire better than males. This suggests that males may require more help from the interviewer when completing the questionnaire.
- In addition, the results show that males tend to overrate their genitalia and pubic hair development compared to females who tend to underrate their pubic hair development. Female breast development is more consistent. This again, highlights the need to provide more help to males when completing the questionnaire.
- The majority of the participants found the pictures/line drawings helpful and therefore, they should be included in self-rated pubertal development questionnaires even though they require interpretation and abstract thinking.
- Discussions with Bt20 staff suggest that the pictures/line drawings used for the self-rated questionnaires should not be ethnic group specific in the South African context, because it is culturally inappropriate to highlight ethnic group differences.
- Both staff and study participants reported that it is appropriate to keep the questionnaires in English and that a vernacular version is not required. By having the questionnaires in only one language, reproduction costs are kept to a minimum and it also helps to reduce translation errors that may influence the accuracy and reliability of data collection.
- Although the questionnaire has changed in recent years, it appears that the current questionnaire is the most appropriate tool for assessing pubertal development in this setting, as previous questionnaires that involved the adolescent being asked to pick the appropriate picture with the interviewer present made the staff, parents, and adolescent feel uncomfortable.

- Key words from the current questionnaire that were highlighted as being problematic were: "texture", "density", and "distribution". It is recommended that a simple definition of these words is provided on the questionnaire.
- Adolescents and staff felt that the tick box system was sometimes problematic as it is hard to know how many boxes to tick or cross. A statement of "mark only one box" at the top of the questionnaire should be added to help make this clearer.
- The main problem with using self-rated pubertal development questionnaire is that the interviewer does not know if the adolescent understands what is required of them if they do not ask for help, simply because they complete them on their own. It is very difficult for researchers to establish whether the questionnaire has been completed accurately, one potential way to help reduce missing data is to adopt a quality checking procedure (QCP). This type of procedure, where each questionnaire is checked for missing data before the study participants leaves the data collection sight should be employed to try and reduce inaccuracies.
- Adolescents highlighted the need for interviewers to ensure their privacy whilst completing the questionnaire and this is an important component of collecting reliable pubertal development data. The use of gender specific cubicles, with appropriate lighting, mirrors and wall mounted pictures and line drawings was suggested. Whilst this is a good idea in theory, it appears that it is not appropriate given the nature of data collection in the Bt20 study. This idea may work in other studies where time constraints are less.
- Whilst there are often time constraints when collecting a battery of assessments in one day, like the system employed by Bt20, there is a clear need to provide a tutorial before an adolescent is left with a self-assessed pubertal development questionnaire. There are two important points that derive from tutorials. The first is the need to adequately train interview staff in how to administer a short but effective tutorial and the second is to ensure that this tutorial is given to each adolescent attending the site for data collection. Administering a tutorial helps to foster an environment in which adolescents feel that they can ask questions and helps to improve the reliability of data collection.
- There is a need to keep the amount of time taken to complete the pubertal development questionnaire to a minimum. Therefore, any changes that are made to the current questionnaire, whilst increasing reliability and accuracy must not increase the overall completion time. Evidence from the current study suggests that the

introduction of a tutorial, the addition of descriptions and clearer instructions on the actual questionnaire, would actually decrease the time taken to completion and yield more reliable results.

7.3 Overall thesis conclusion

The results from this study provide the most recent estimates of age at the initiation of puberty and age at menarche for urban Black and White South African adolescents. This is particularly important given the social, nutritional, and economic transition currently occurring in this country as these key maturity indicators reflect population health. This study has also added to our knowledge of the factors that are associated with pubertal development, showing that proximate (such as late childhood body composition) rather than distal factors (such as birth weight) are the most sensitive indicators in this urban transitioning environment. In addition, the results from the focus groups provided a unique insight into how pubertal development data are assessed and how these methods can potentially be improved to enhance reliability and accuracy. The negative health outcomes which have been associated with earlier pubertal development and age at menarche are major public health concerns, particularly in the South African context given the HIV/AIDS epidemic and rising levels of obesity. This study highlights the need for renewed research and resources for intervention strategies and policy programmes which target appropriate sex and obesity education in urban South African children.

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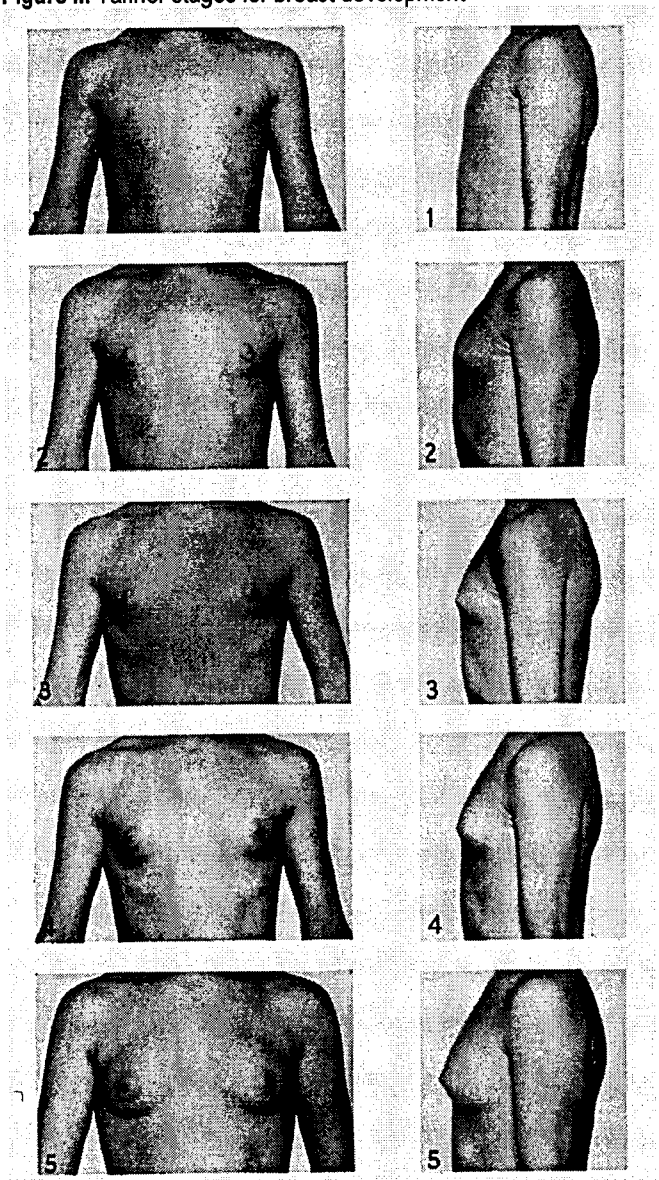
Appendix I Tanner Staging Technique

Stages of breast development (Figure I.I)

1. Preadolescent: Elevation of papilla only.
2. Breast bud stage: Elevation of breast and papilla as small mound. Enlargement of areolar diameter.
3. Further enlargement and elevation of breast and areolar, with no separation of their contours.
4. Projection of areolar and papilla to form a secondary mound above the level of the breast.
5. Mature stage: Projection of papilla only, due to recession of areolar to the general contour of the breast.

Figure I.I Tanner stages for breast development

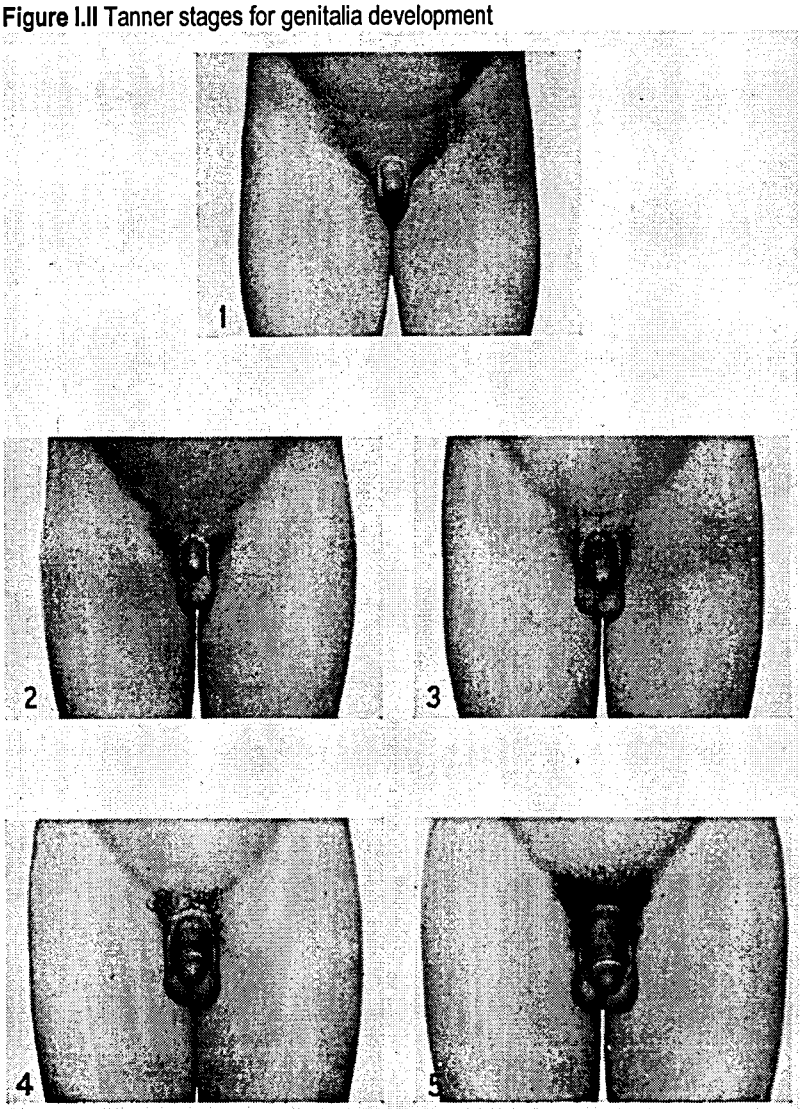


Source: Tanner JM. Growth at Adolescence. 2nd ed. Oxford: Blackwell Scientific Publications. 1962

Stages of genitalia development (Figure I.II)

1. Preadolescent: Testes, scrotum, and penis are of about the same size and proportion as in early childhood.
2. Enlargement of scrotum and testes: The skin of the scrotum reddens and changes in texture. There is little or no enlargement of the penis at this stage.
3. Enlargement of the penis: This occurs first mainly in length. Further growth of testes and scrotum.
4. Increased size of the penis with growth in breadth and development of glans. Further enlargement of testes and scrotum; increased darkening of scrotal skin.
5. Genitalia adult in size and shape.

Figure I.II Tanner stages for genitalia development

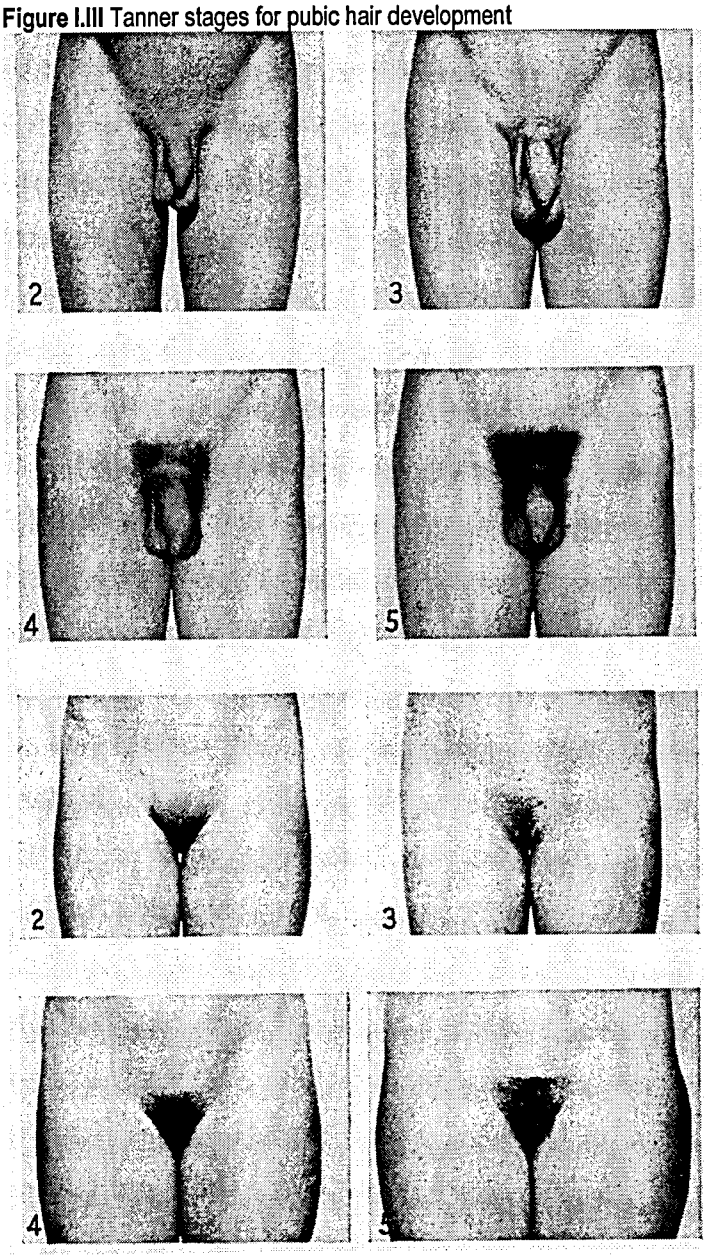


Source: Tanner JM. Growth at Adolescence. 2nd ed. Oxford: Blackwell Scientific Publications. 1962

Stages of pubic hair development (Figure I.III)

1. Preadolescent: The vellus over the pubes is not further developed than that over the abdominal wall; that is, no pubic hair.
2. Sparse growth of long, slightly pigmented downy hair, straight or only slightly curled, appearing chiefly at the base of the penis or along the labia.
3. Considerably darker, coarser, and more curled hair. The hair spreads sparsely over the junction of the pubes.
4. How now resembles adult in type, but the area covered by it is still considerably smaller than in the adult. No spread to the medial surface of the thighs.
5. Adults in quantity and type of hair with distribution of the horizontal or classically feminine pattern. Spread to the medial surface of the thighs but not up the linea alba or elsewhere above the base of the inverse triangle.

Figure I.III Tanner stages for pubic hair development



Source: Tanner JM. Growth at Adolescence. 2nd ed. Oxford: Blackwell Scientific Publications. 1962

Appendix II Author Data Contribution

This section provides a detailed description of the author's (Laura Jones) role and contribution to data collection, organisation, management, and analysis.

The data used within this thesis consisted of secondary quantitative data, which had been previously collected (1999-2004) by staff at Birth to Twenty (Bt20). These data were cleaned, managed, and analysed by the author. In addition, primary qualitative data were collected by the author between March and June 2006 as part of a three month fieldwork trip to the Bt20 site, Johannesburg-Soweto, South Africa.

Quantitative data management

The vast majority of data cleaning (see Methods section 3.1.3 for a detailed description of the specific tasks completed) was undertaken during my trip to South Africa. It was imperative that this work was carried out at the Bt20 offices to allow access to the raw paper files for each Bone Health (BH) case in order to systematically clean the pubertal development dataset. In total, approximately 2500 case files were pulled with over 10000 individual data points checked. The cleaning process itself involved five stages. The first involved running checks on the raw database to highlight potentially erroneous data. The BH case IDs were then flagged and cleaning sheets were created. These cleaning sheets were then completed by cross-referencing them with the paper files. Following this, erroneous data were corrected in the electronic database. Finally, a comprehensive record of every cleaning change and the reason why the change was made was documented in the form of a data cleaning report (see Appendix IV). The time taken to clean a dataset like the pubertal database is significant. In total there were some 36000 (607 cases, six time points, 10 variables per case) data points that needed to be checked. Approximately, one third of these cases were flagged and therefore needed checking against the paper file. If it takes approximately one minute to check each paper file, then in total the minimum time to clean these files would be 167 hours or approximately 5 weeks if one cleans continually for 7 hours a day. In addition, there is a substantial amount of time spent completing paperwork to provide an audit trail for future users of the dataset in terms of cleaning reports.

Having completed the cleaning of the pubertal development dataset, another part of my fieldwork involved creating an "analysis dataset" from which the analysis models within in my thesis could be constructed i.e. ensuring that the anthropometric, socio-economic, and demographic data were clean from birth to 9/10 years of age for my specific analysis sample. These data had been previously cleaned by other members of the Bt20 data team and so a 5% (30 cases) random sample check was carried out with a 1% error limit set. These data were found to contain less than 1% of errors and so were merged with the pubertal development data to create an analysis dataset.

Qualitative data collection and management

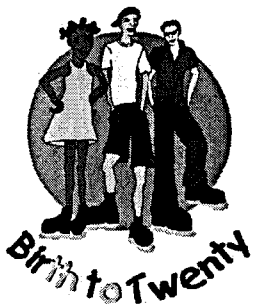
In addition to the cleaning of the pubertal development dataset, part of my fieldwork involved the collection of qualitative data using focus groups. A small team of Bt20 staff, lead by myself were involved in the process of setting up and moderating the focus groups. This process involved a number of steps (for a detailed summary see Methods section 3.2) including the identification of potential participants, recruitment through telephone contact, and establishing appropriate venues with the required equipment. I was involved in a preliminary meeting with a number of senior Bt20 staff to discuss appropriate topics of conversation for the adolescent focus groups and from this I developed the question routes for both the adolescent and staff discussions. I also lead a number of workshops to train staff on how to moderate focus groups such as how to engage quiet participants and how to ensure that they did not lead the participants but provided probes where appropriate to ensure maximum interaction. In addition, consent, SES, and background questionnaires were created and reproduced. I conducted the staff focus groups and other members of Bt20 staff conducted the adolescent focus groups as it was not appropriate for me as a White British female to discuss pubertal development with Black South African adolescents. Following the adolescent focus groups, I lead meetings with the other members of staff involved to discuss the focus groups and their thoughts. Given that the adolescent focus groups were not conducted in English, the female note taker transcribed the focus groups the translated them into English. Following this I met with her to discuss any contextual issues before I left South Africa.

Other data work for Bt20

In addition to the work undertaken for my PhD I have spent a significant proportion of time contributing to Bt20 database construction and management. I have been part of the Bt20

data management team since March 2006. A number of specific tasks have been completed during this time such as the population of the demographic database with historical data for the White children newly enrolled into the BH database at aged 9. This involved highlighting cases where data were missing, creating a telephonic questionnaire to allow population of these data, and contacting each BH family individually. I am still involved in data cleaning even though I am based in the UK. This involves creating and sending cleaning sheets to South Africa, where they are completed and then sent back to me in the UK where I make any necessary changes to the electronic database and then complete the data cleaning reports. Given my data cleaning experience I am now involved in teaching data cleaning workshops both in the UK and in South Africa to ensure that strategies put into place for the Bt20 database are used effectively and efficiently by other members of Bt20 staff. Finally, I am leading the consolidation of the current BH database so that body composition, anthropometric, pubertal development, skeletal maturity, socio-economic status, and demographic data are clean and available for analysis from birth to 17.9 years of age in some 600 South African adolescents.

Appendix III Adolescent Questionnaire



University of the Witwatersrand
Department of Paediatrics and Child Health

BIRTH TO TWENTY MEDICAL SCHOOL SITE: 14TH YEAR ADOLESCENT QUESTIONNAIRE

DATE : Day ☐☐ Month ☐☐ Year ☐☐☐☐

BTT ID NUMBER : ☐☐☐☐☐☐☐

BONE STUDY ID NUMBER : ☐☐☐

Consent Table	Yes	No
Questionnaire (Bt20 Services)		
Self – Complete Questionnaire		
Anthropometric Measurements		
Pubertal Assessment		
Adolescent DXA (if applicable)		
Adolescent pQCT (Medical School Only)		
Adolescent Urine (Medical School Only)		
Adolescent Blood (Medical School Only)		

INFORMED CONSENT

I agree to myself being a participant in the Birth to Twenty study.

The goals and methods of Birth to Twenty are clear to me.

I understand that the study will involve interviews, measures of growth, literacy and numeracy tests, educational development and school reports. All the details and purposes of these tests have been explained to me. I understand that I have the right to refuse to participate in the study.

I, the undersigned, hereby declare that I understand:
1. That the University of the Witwatersrand, Johannesburg (hereafter referred to as "the University" has insured itself against the acts and omissions of persons acting on its behalf insofar as it is liable in law therefore and that its registered students and staff are insured during the course and scope of their registered courses and/or within the scope of the University business, where the fault can be attributed to the University or its affiliates.

2. That in cases where no fault can be attributed to the University, I hereby indemnify, absolve and hold harmless the University, its officials, employees, students and invitees in respect of any damage to the property, death or bodily injury to/of myself and/or third parties, whether on/off the University precincts, or whilst engaged in any activity related to the University.

3. And undertake, for any period during which I am on the university precincts or during my participation in the Birth to Twenty Study, to be bound by the rules and regulations of the University for the time being in force and by any requirements or conditions imposed by the University on me.

I agree to participation in the study on the condition that:

1. I can withdraw from the study at any time voluntarily and that no adverse consequences will follow on withdrawal from the study.

2. I have the right not to answer any or all questions posed in the interviews and not to participate in any or all of the procedures / assessments.

3. The Committee for Research on Human Subjects at the University of the Witwatersrand has approved the study protocol and procedures.

4. All results will be treated with the strictest confidentiality.

5. Only group results, and not my/my child's individual results, will be published in scientific journals and in the media.

6. The Bt20 scientific team will do all they can to ensure my comfort and dignity.

7. I will receive a referral note to a health service if any result is out of the normal range or a problem is detected in the course of the study.

I understand that I attend and participate in Birth to Twenty on the (date)_____ at my own risk where the event falls outside the cover provided by the University. I acknowledge that I have read and understood the contents of this informed consent and indemnity in every respect

Youth participant _____
Research Assistant_____

There are 6 components that we are going to work through together; it will take about 2 hours

In this section of this questionnaire is about the Bt20 Health Services

At Birth to Twenty we are concerned with the health and wellbeing of our study participants. We have in the past offered services to both adolescents and caregivers, such as counselling as well as testing for cholesterol and diabetes. We have had many requests for other tests and we would like to ask you a series of questions around the Bt20 health service.

Question 1

Would you like Bt20 to continue to offer the following free services/tests/monitoring to you?

	YES	NO
Counseling		
Cholesterol		
Diabetes		
High Blood Pressure		

Question 2

Would you like Bt20 to offer the following free services/tests to you in the future?

	YES	NO
Heart disease		
Cancer/tumors		
Pregnancy		
Sexually transmitted infections		
HIV counseling and testing		

Question 3

Would you like to give consent (permission) to the following tests independently of your parent/caregiver?

	YES	NO
Heart disease		
Cancer/tumors		
Pregnancy		
Sexually transmitted infections		
HIV counseling and testing		

Question 4

Do you think it is easier (more convenient, more private) to answer questions around smoking, drugs, sex by yourself at HOME or at the BT20 site offices?

(Please tick only ONE)

It is easier at HOME	
It is easier at the Bt20 site office	
Both are equally the same	

Research Assistant name: Date:

ADOLESCENT MEASUREMENTS

ANTHROPOMETRY

STANDING HEIGHT: (mm)

SITTING HEIGHT: (mm)

WEIGHT: (kg)

WAIST CIRCUMFERENCE: (mm)

HIP CIRCUMFERENCE: (mm)

SHOULDER-ELBOW: (mm)

ELBOW-WRIST LENGTH: (mm)

THIGH LENGTH: (mm)

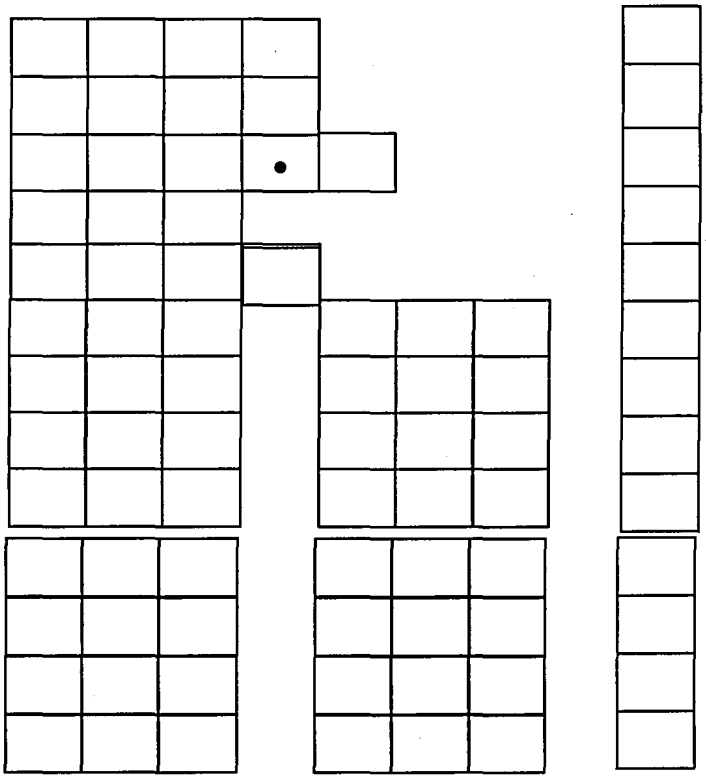
CALF LENGTH: (mm)

BICEP GIRTH: (mm)

BIEPI BREADTH HUMERUS (mm)

BIEPI BREADTH OF FEMUR (mm)

CALF GIRTH: (mm)



SKINFOLD MEASUREMENTS – LEFT SIDE (mm)

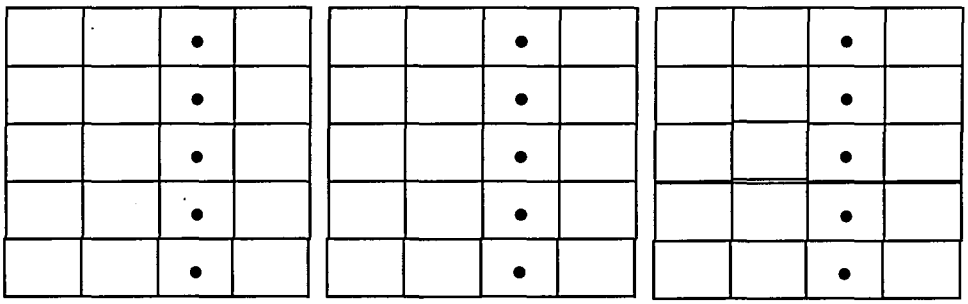
TRICEP:

BICEP:

SUBSCAPULAR:

SUPRA-ILIAC:

MEDIAL CALF

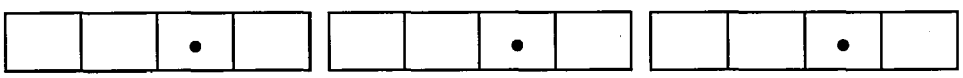


Research Assistant name:

Date:

FLEXIGRIP

NON-DOMINANT HAND: L OR R



Research Assistant name:

Date:

BLOOD PRESSURE

SYSTOLIC BP

DIASTOLIC BP

PULSE

TIME OF BP h

Research Assistant name:

Date:

BONE SCANS

DXA scan

PQCT

Operator name:

Date:

COLLECTION OF SPECIMENS

Urine 1

ROUTINE BLOOD SAMPLE

Lab Assistant's name:

Date:

PUBERTAL ASSESSMENT and SELF COMPLETION

Pubertal assessment Questionnaire

Self completion Questionnaire

Research Assistant name:

Date:

BONE AGE X-RAY

Quality checked by: Date:

NOTES

Appendix IV Data Cleaning Reports

Pubertal Development Data Cleaning Report for Year 9 and Year 10

Variable creation, name changes, and recoding

Variable	Variable Label
BoneID	Bone Health ID
Yr9_TANNER_Hair	Yr 9 Tanner hair rating
Yr9_TANNER_GenitaliaBreast	Yr 9 Tanner genitalia/breast rating
Yr9_MENSTRUAL_period	Yr 9 menarche (yes/no)
Yr9_MENSTRUAL_menarcheday	Yr 9 menarche day of the month occurred
Yr9_MENSTRUAL_menarchemonth	Yr 9 menarche month occurred
Yr9_MENSTRUAL_menarcheyear	Yr 9 menarche year occurred
Yr10_TANNER_Hair	Yr 10 Tanner hair rating
Yr10_TANNER_GenitaliaBreast	Yr 10 Tanner genitalia/breast rating
Yr10_MENSTRUAL_period	Yr 10 menarche (yes/no)
Yr10_MENSTRUAL_menarcheday	Yr 10 menarche day of the month occurred
Yr10_MENSTRUAL_menarchemonth	Yr 10 menarche month occurred
Yr10_MENSTRUAL_menarcheyear	Yr 10 menarche year occurred

Variable creation

The following variables were created for the menarcheal date data at both Yr 9 and Yr 10
Yr9_MENSTRUAL_menarcheday
Yr9_MENSTRUAL_menarchemonth
Yr9_MENSTRUAL_menarcheyear
Yr10_MENSTRUAL_menarcheday
Yr10_MENSTRUAL_menarchemonth
Yr10_MENSTRUAL_menarcheyear

Variable renaming

Yr 9
9YTanhair → 9Yr_TANNER_Hair
9YTangb → 9Yr_TANNER_GenitaliaBreast
9Ymen → 9Yr_MENSTRUAL_period

Yr 10
10YTanhair → 10Yr_TANNER_Hair
10YTangb → 10Yr_TANNER_GenitaliaBreast
10YMen → 10Yr_MENSTRUAL_period
10YMenage → (see three Yr10 menstruation variables above).

Recoding
Male cases were recoded as 98 for all menarcheal variables at both Yr 9 and Yr 10

Female cases were recoded as 97 for menarcheday, menarchemonth and menarcheyear variables when period variable was recorded as 0 for both Yr 9 and Yr 10

Longitudinal Cleaning

All cases have gone backwards between Yr 9 and Yr 10 – Yr 10 has been taken as the correct pubertal status.

BoneID # 137
Paper records Yr 9 PH1/G2
Yr 10 PH2/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH2/G1

BoneID # 144
Paper records Yr 9 PH1/B2
Yr 10 PH1/B1
Recorded within database as Yr 9 PH1/B1
Yr 10 PH1/B1

BoneID # 407
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 408
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 423
Paper records Yr 9 PH1/B3
Yr 10 PH1/B1
Recorded within database as Yr 9 PH1/B1
Yr 10 PH1/B1

BoneID # 424
Paper records Yr 9 PH1/B2
Yr 10 PH1/B1
Recorded within database as Yr 9 PH1/B1
Yr 10 PH1/B1

BoneID # 431
Paper records Yr 9 PH2/B2
Yr 10 PH1/B2
Recorded within database as Yr 9 PH1/B2
Yr 10 PH1/B2

BoneID # 437
Paper records Yr 9 PH2/G1
Yr 10 PH1/G2
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G2

BoneID # 446
Paper records Yr 9 PH1/G2

Yr 10 PH1/G2
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 448
Paper records Yr 9 PH2/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 461
Paper records Yr 9 PH1/B2
Yr 10 PH1/B1
Recorded within database as Yr 9 PH1/B1
Yr 10 PH1/B1

BoneID # 466
Paper records Yr 9 PH2/B2
Yr 10 PH2/B1
Recorded within database as Yr 9 PH2/B1
Yr 10 PH2/B1

BoneID # 467
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 474
Paper records Yr 9 PH2/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 487
Paper records Yr 9 PH2/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 494
Paper records Yr 9 PH2/G2
Yr 10 PH2/G1
Recorded within database as Yr 9 PH2/G1
Yr 10 PH2/G1

BoneID # 498
Paper records Yr 9 PH3/B1
Yr 10 PH2/B1
Recorded within database as Yr 9 PH1/B1
Yr 10 PH2/B1

BoneID # 499
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 515
Paper records Yr 9 PH1/G2

Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 533
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 545
Paper records Yr 9 PH1/G2
Yr 10 PH2/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH2/G1

BoneID # 554
Paper records Yr 9 PH1/G3
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 601
Paper records Yr 9 PH2/B2
Yr 10 PH1/B2
Recorded within database as Yr 9 PH1/B2
Yr 10 PH1/B2

BoneID # 641
Paper records Yr 9 PH1/B2
Yr 10 PH1/B1
Recorded within database as Yr 9 PH1/B1
Yr 10 PH1/B1

BoneID # 658
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 671
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 684
Paper records Yr 9 PH2/B2
Yr 10 PH1/B2
Recorded within database as Yr 9 PH1/B2
Yr 10 PH2/B2

BoneID # 685
Paper records Yr 9 PH1/G2
Yr 10 PH1/G1
Recorded within database as Yr 9 PH1/G1
Yr 10 PH1/G1

BoneID # 718
Paper records Yr 9 PH1/B2

Yr 10 PH2/B1
Recorded within database as Yr 9 PH1/B1
Yr 10 PH2/B1

BoneID # 736
Paper records Yr 9 PH2/G3
Yr 10 PH1/G2
Recorded within database as Yr 9 PH1/G2
Yr 10 PH1/G2

BoneID # 750
Paper records Yr 9 PH2/G3
Yr 10 PH2/G2
Recorded within database as Yr 9 PH2/G2
Yr 10 PH2/G2

Cross Sectional Cleaning

System missing BoneID's that have been populated for pubertal development data at Year 9

365
406
411
442
451
456
465
467
470
472
481
496
511
516
526
541
556
571
586
598
601
616
631
646
659
661
676
680
706
736

System missing BoneID's that have been populated for pubertal development data at Year 10

365
391
406
411
442
451
465
467
470
472
481
496
511
516
526
541
556
557
571
586
601
616
646
659
661
676
706
721
730
736
741
761
766
771
781
782
796
798
802
812
813
823
826
843
853

The following cases had conflicting data for the Tanner Questionnaire and for the Anthropometric Questionnaire at Year 9 and/or Year 10

BoneID # 203
- Paper Records Yr 10 — Tanner Questionnaire PH1/B3; Anthropometric Questionnaire PH2/B3
- Recorded in database — Yr 10 PH1/B3

BoneID # 455
- Paper Records Yr 9 — Tanner Questionnaire PH2/B1; Anthropometric Questionnaire PH1/B1
- Recorded in database — Yr 9 PH2/B1

BoneID # 491
- Paper Records Yr 10 — Tanner Questionnaire PH1/G2; Anthropometric Questionnaire PH2/G1
- Recorded in database — Yr 10 PH2/G1

BoneID # 505
- Paper Records Yr 10 — Tanner Questionnaire PH2/B2; Anthropometric Questionnaire PH1/B1
- Recorded in database — Yr 10 PH2/B2

BoneID # 508
- Paper Records Yr 9 — Tanner Questionnaire PH4/G4; Anthropometric Questionnaire PH1/G1
- Recorded in database — Yr 9 PH1/G1

BoneID # 558
- Paper Records Yr 9 — Tanner Questionnaire (A) PH1/B2; Tanner Questionnaire (B) PH2/B3; Anthropometric Questionnaire PH1/B1
- Recorded in database — Yr 9 PH1/B1

BoneID # 623
- Paper Records Yr 10 — Tanner Questionnaire PH2/G3; Anthropometric Questionnaire PH1/G1
- Recorded in database — Yr 10 PH1/G1

BoneID # 625
- Paper Records Yr 10 — Tanner Questionnaire PH2/G3; Anthropometric Questionnaire PH2/G2
- Recorded in database — Yr 10 PH2/G2

BoneID # 642
- Paper Records Yr 10 — Tanner Questionnaire PH2/G4; Anthropometric Questionnaire PH1/G2
- Recorded in database — Yr 10 PH1/G2

BoneID # 645
- Paper Records Yr 9 — Tanner Questionnaire PH2/G1; Anthropometric Questionnaire PH1/G1
- Recorded in database — Yr 9 PH1/G1; Yr 10 PH1/G1

BoneID # 650
- Paper Records Yr 10 — Tanner Questionnaire PH2/B1; Anthropometric Questionnaire PH1/B1
- Recorded in database — Yr 10 PH1/B1

BoneID # 654
Paper Records Yr 10 Tanner Questionnaire PH2/G2
Anthropometric Questionnaire PH1/G2
Recorded in database Yr 10 PH2/G2
BoneID # 663
Paper Records Yr 10 Tanner Questionnaire PH1/G2
Anthropometric Questionnaire PH1/G1
Recorded in database Yr 9 PH1/G1
Yr 10 PH1/G1
BoneID # 696
Paper Records Yr 10 Tanner Questionnaire PH1/G2 or 3
Anthropometric Questionnaire PH1/G1
Recorded in database Yr 10 PH1/G2

The BoneID's below have been changed within the database to the following:

BoneID's coded 99 for all pubertal development data variables at Year 9 and Year 10

107
111
120
827
829
830
842
846

BoneID's coded as 99 for Yr 10 menarche data

140
174
175
176
177
184
188
189
369
374
389
390
425
461
502
506
509
525
529
569
573

576
614
624
630
635
644
665
674
679
702
755
756
760
770
778
780
786
806
814
820
832

BoneID's coded 99 for Yr 9 pubertal development variables

118
167
459
486
597
664
717
742
753

BoneID's coded 99 for Yr 9 menarche data variables

114
144
146
151
152
194
212
468
469
488
498
641
670
694

743
746

BoneID's coded 99 for Yr 10 menarche date variables

102
378
383
384
392
712
716
719
729
732
757
762
769
785
810
852

BoneID's Yr 9 pubic hair rating changed from 1 to 2

199
400
419
443
452
455
475
477
494
531
546
553
603
608
657
748

BoneID Yr 9 breast rating changed from 1 to 2

591

BoneID's Yr 9 genitalia rating changed from 1 to 2

426
613
727

BoneID Yr 9 pubic hair and breast ratings changed from 1 to 2

724

BoneID's Yr 9 pubic hair and genitalia ratings changed from 1 to 2

192
208
750

BoneID's coded 99 for Yr 9 and Yr 10 menarche data variables

158
165
415
626
628
687
718

BoneID's Yr 10 pubic hair rating changed from 1 to 2

127
433
722
759

BoneID's where Yr10 data have been added

182
543
550
696
783
790
845
862

BoneID's coded 99 for Yr 10 pubertal development variables

857
859
999

BoneID Yr 10 genitalia rating changed from 1 to 2

583

BoneID's Yr 10 pubic hair rating changed from 2 to 1

110
168
645

BoneID Yr 10 breast rating missing

155

BoneID Yr 9 pubic hair rating changed from 2 to 1 and Yr 9 genitalia rating changed from 3 to 2

736

BoneID Yr 10 breast ratings changed from 2 to 1 and coded 99 Yr 10 menarche date

784

BoneID Yr 10 breast rating changed from 3 to 2 and Yr 9 & Yr 10 coded 99 for menarche data variables

738

BoneID's Yr 10 data added and coded 99 for Yr 10 menarche data variables

720
733
831

BoneID Yr 10 data added and coded 99 for Yr 10 menarche date variable

794

BoneID Yr 10 data added and coded 99 for Yr 9 and Yr 10 menarche variables

747

BoneID Yr 10 menarche variable changed from 1 to 0 (in B2/PH2)

728

BoneID Yr 10 pubic hair rating changed from 1 to 3 and Yr 10 genitalia rating changed from 1 to 2

611

BoneID Yr 10 pubic hair rating changed from 2 to 1 and Yr 10 breast rating changed from 1 to 2

616

BoneID Yr 10 pubic hair rating changed from 2 to 3

678

BoneID Yr 10 pubic hair rating changed from 4 to 1

381

BoneID Yr 9 and Yr 10 pubic hair rating changed from 1 to 2

510

BoneID Yr 9 and Yr 10 breast rating changed from 2 to 1

466

BoneID Yr 9 and Yr 10 pubic hair rating changed from 2 to 1

684

BoneID Yr 9 data added and coded 99 at Yr 9 and Yr 10 for menarche variables

655

BoneID coded 99 for Yr 9 pubertal development variables and coded 99 for Yr 10 menarche variables

113

BoneID Yr 9 genitalia rating changed from 2 to 1 and Yr 10 data added

658

BoneID coded 99 for Yr 9 pubertal development variables and coded 99 for Yr 10 menarche date variable

708

BoneID Yr 9 pubic hair rating changed from 1 to 2 and coded 99 for Yr 10 menarche variables

161

BoneID Yr 9 pubic hair rating changed from 1 to 2 and Yr 10 pubic hair and breast rating changed from 1 to 2

505

BoneID Yr 9 pubic hair rating changed from 1 to 2 and coded 99 for Yr 9 and Yr 10 menarche variables

615

BoneID Yr 9 pubic hair rating changed from 2 to 1

601

Subsequent changes to the database through longitudinal cleaning and database errors

BHID #'s 155, 792 Yr10_TANNER_Hair recoded 99 as missing Yr10_TANNER_GenitalBreast value

Pubertal Development Data Cleaning Report for Year 11

Variable creation, name changes, and recoding

Variable	Variable Label
BoneID	Bone Health ID
BttID	Bt20 ID
Gender	Gender
Ethnicity	Ethnicity
Yr11_Date	Yr 11 Annual Date
Yr11_TANNER_Hair	Yr 11 Tanner hair rating
Yr11_TANNER_GenitalBreast	Yr 11 Tanner genitalia/breast rating
Yr11_MENSTRUAL_Period	Yr11 Menstruating (yes or no)
Yr11_MENSTRUAL_MenarcheDayofWeek	Yr 11 Beginning Date of Menarche (Day of week)
Yr11_MENSTRUAL_MenarcheDayofMonth	Yr 11 Beginning Date of Menarche (Day of month)
Yr11_MENSTRUAL_MenarcheMonth	Yr 11 Beginning Date of Menarche (Month)
Yr11_MENSTRUAL_MenarcheYear	Yr 11 Beginning Date of Menarche (Year)
Yr11_MENSTRUAL_DayNr	Yr 11 Number of bleeding days of first period

Variable creation

The following variables were created for the menarcheal date data at Yr 11
Yr11_MENSTRUAL_MenarcheDayofWeek
Yr11_MENSTRUAL_MenarcheMonth*
Yr11_MENSTRUAL_MenarcheYear*
Yr11_MENSTRUAL_DayNr

Variable renaming

Yr11_MENSTRUAL_MenarcheDay → Yr11_MENSTRUAL_MenarcheDayofMonth
Yr11_MENSTRUAL_MenarcheMonthYear → (see * above)

Recoding

Male cases were recoded as 98 for all menarcheal variables at Yr 11

Female cases were recoded as 97 for menarchedayofweek, menarchedayofmonth, menarchemonth and menarcheyear variables when period variable was recorded as 0 for Yr 11

Longitudinal Cleaning

All cases have gone backwards between Yr 10 and Yr 11 for either pubic hair and/or genitalia/breast ratings – Yr 10 has been taken as the correct pubertal status.

BoneID # 117
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 118
Paper records Yr 10 G3
Yr 11 G1
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 127
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 137
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 161
Paper records Yr 10 PH3
Yr 11 PH2
Recorded within database as Yr 10 PH3
Yr 11 PH3

BoneID # 172
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 173
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 176
Paper records Yr 10 PH3/B3
Yr 11 PH2/B2
Recorded within database as Yr 10 PH3/B3
Yr 11 PH3/B3

BoneID # 177
Paper records Yr 10 B2
Yr 11 B1
Recorded within database as Yr 10 B2
Yr 11 B2

BoneID # 182
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 183
Paper records Yr 10 PH2/G3
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G3
Yr 11 PH2/G3

BoneID # 360
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 367
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 374
Paper records Yr 10 B3
Yr 11 B2
Recorded within database as Yr 10 B3
Yr 11 B3

BoneID # 377
Paper records Yr 10 PH2/G3
Yr 11 PH1/G2
Recorded within database as Yr 10 PH2/G3
Yr 11 PH2/33

BoneID # 387
Paper records Yr 10 G3
Yr 11 G1
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 390
Paper records Yr 10 PH3
Yr 11 PH2
Recorded within database as Yr 10 PH3
Yr 11 PH3

BoneID # 400
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 411
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 432
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 433
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 460
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 465
Paper records Yr 10 PH2/G3
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G3
Yr 11 PH2/G3

BoneID # 466
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 471
Paper records Yr 10 PH3
Yr 11 PH2
Recorded within database as Yr 10 PH3
Yr 11 PH3

BoneID # 472
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 478
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 489
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 494
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 501
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 507
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 517
Paper records Yr 10 PH3/B4
Yr 11 PH2/B3
Recorded within database as Yr 10 PH3/B4
Yr 11 PH3/B4

BoneID # 518
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 519
Paper records Yr 10 G3
Yr 11 G1
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 527
Paper records Yr 10 PH2/G3
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G3
Yr 11 PH2/G3

BoneID # 534
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 536
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 537
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 545
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 550
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 551
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 566
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 579
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 586
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 590
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 607
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 634
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 638
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 649
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 654
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 655
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 660
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 666
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 668
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 678
Paper records Yr 10 PH3/G3
Yr 11 PH2/G2
Recorded within database as Yr 10 PH3/G3
Yr 11 PH3/G3

BoneID # 683
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 693
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 696
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 697
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 709
Paper records Yr 10 G3
Yr 11 G1
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 711
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 718
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 721
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 722
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 723
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 752
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 758
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 760
Paper records Yr 10 B4
Yr 11 B3
Recorded within database as Yr 10 B4
Yr 11 B4

BoneID # 766
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 774
Paper records Yr 10 G3
Yr 11 G1
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 796
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 797
Paper records Yr 10 G2
Yr 11 G1
Recorded within database as Yr 10 G2
Yr 11 G2

BoneID # 802
Paper records Yr 10 PH2
Yr 11 PH1
Recorded within database as Yr 10 PH2
Yr 11 PH2

BoneID # 803
Paper records Yr 10 PH2/G2
Yr 11 PH1/G1
Recorded within database as Yr 10 PH2/G2
Yr 11 PH2/G2

BoneID # 807
Paper records Yr 10 G4
Yr 11 G1
Recorded within database as Yr 10 G4
Yr 11 G4

BoneID # 844
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

BoneID # 862
Paper records Yr 10 G3
Yr 11 G2
Recorded within database as Yr 10 G3
Yr 11 G3

Cross Sectional Cleaning

BoneID's that were coded as 99, but have been populated at Yr 11 for pubertal development variables

122
847

Female BoneID's that are missing Yr 11 Tanner ratings but have Yr 11 Menarche data

146
428
772

Female BoneID's that are missing Yr 11 Tanner Ratings but were coded as having Menarche variables which are actually missing (so coded 99)

156
427
505
571
650
738
773
778
798
863

Cross checking with Yr 11 Inventory

The following cases were coded as 96 within the database as they were not seen (or the child questionnaire was not completed) at Yr 11

100
101
102
103
106
107
108
113
114
116
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124
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135
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523
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619
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643
662
677
680
686
689
695
702
714
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725
727
739
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749
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763
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773
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782
792
799
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804
805
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811
813
821
825
827
845
851

864
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924

925
926
927
928
999

Yr 11 Pubertal Development Data added (these cases were coded as 1 in the inventory but were missing PD data)

598 (PH1/G1)
753 (PH1/B1, M=0)
830 (PH1/G2)
839 (PH1/G1)

Yr 11 pubertal development data deleted, as Yr 11 questionnaires not present within the files and therefore inventory changed from 1 to 0

207
352
849
857
858

Yr 11 pubertal development data deleted, as Yr 11 questionnaires not present within the files (these cases were coded 0 in the inventory but were in the datafile)

358
394
401
405
426
605
631
645
691
733
790
794
798
831
848

Yr 11 Inventory changed from 0 to 1 as Yr 11 child questionnaire present

161
201
398
439
596
703

Subsequent changes to the database through longitudinal cleaning and database errors

BHID # 123
Yr11_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 426
Yr11_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 522
Yr11_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 556
Yr11_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 636
Yr11_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 199
Yr11_TANNER_Hair rating changed from 1 to 2
BHID # 510
Yr11_TANNER_Hair rating changed from 2 to 1
BHID # 608
Yr11_TANNER_Hair rating changed from 2 to 1
BHID # 644
Yr11_MENSTRUAL_age changed from 99 to 11
BHID # 874
Yr11_MENSTRUAL_age changed from 11 to 10
BHID # 646
Yr11_MENSTRUAL_period rating changed from 1 to 0
Yr11_MENSTRUAL_age changed from 99 to 97
BHID #'s 422, 509 Yr11_TANNER_Hair recoded 99 as missing
Yr11_TANNER_GenitalBreast value

Year 12 Pubertal Development Data Cleaning Report

Variable creation, name changes and recoding

Variable	Variable Label
BHID	Bone Health ID
Yr12_TANNER_Hair	Tanner Hair Rating at 12 years
Yr12_TANNER_GenitalBreast	Tanner genitalia/breast rating at 12 years
Yr12_MENSTRUAL_period	Females: have you begun to menstruate? (yes/ no)
Yr12_MENSTRUAL_age	Females: what age did you begin to menstruate? (Years)

Variable renaming

Females
SecAQ6 → Yr12_MENSTRUAL_period
SexAQ7 → Yr12_MENSTRUAL_age
SecB → Yr12_TANNER_Hair
SecC → Yr12_TANNER_Breast

Males
MSECB → Yr12_TANNER_Hair
MSECC → Yr12_TANNER_Genitalia

Yr12_TANNER_Breast and Yr12_TANNER_Genitalia were then combined to form one variable → Yr12_TANNER_GenitalBreast

Recoding

Yr12_MENSTRUAL_period coding changed from 1 = no/ 2 = yes to 0 = no/ 1 = yes

Male cases were recoded as 98 for Yr12_MENSTRUAL_period and Yr12_MENSTRUAL_age at Yr 12 as these variables are not applicable

Female cases were recoded as 97 for Yr12_MENSTRUAL_age where Yr12_MENSTRUAL_period was coded as 0 at Yr 12

Cross-sectional cleaning

Inventory changed from 0 to 1 for the following cases as child questionnaire present in the paper files

144
146
161
175
383
398

415
437
510
548
563
694
784
907

Data added for the following cases as originally coded 1 in the inventory but no data in database, pubertal development questionnaire present

630
833

Pubertal development data deleted for the following cases as no PD questionnaire present in files, and inventory changed from 1 to 0

144
439
726

BHID# 827 was duplicated within the file, one coded as a boy and one as a girl. There are two BH cases that live within the same household. The girl is BHID 827 and the boy is BHID 999

BHID# 473 coded 0 for Yr12_MENSTRUAL_period but has an age for Yr12_MENSTRUAL_age so Yr12_MENSTRUAL_period recoded to 1

BHID# 422 Yr12_TANNER_Hair recoded from 1 to 99 as missing Yr12_TANNER_GenitalBreast value

BHID# 558 Yr12_TANNER_GenitalBreast recoded to 99 as Yr12_TANNER_Hair value missing

BHID# 422 Yr12_TANNER_Hair recoded to 99 as Yr12_TANNER_GenitalBreat value missing

Longitudinal Cleaning

Yr12_TANNER_GenitalBreast Variable Changes

BHID # 104
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 166
Yr12_TANNER_GenitalBreast rating changed from 3 to 2
BHID # 183
Yr12_TANNER_GenitalBreast rating changed from 2 to 3

BHID # 358
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 364
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 375
Yr12_TANNER_GenitalBreast rating changed from 1 to 3
BHID # 376
Yr12_TANNER_GenitalBreast rating changed from 3 to 2
BHID # 377
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 388
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 397
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 402
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 408
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 411
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 446
Yr12_TANNER_GenitalBreast rating changed from 3 to 2
BHID # 449
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 464
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 465
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 487
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 489
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 490
Yr13_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 511
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 512
Yr12_TANNER_GenitalBreast rating changed from 1 to 4
BHID # 515
Yr12_TANNER_GenitalBreast rating changed from 3 to 2
BHID # 519
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 527
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 534
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 539
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 549
Yr12_TANNER_GenitalBreast rating changed from 4 to 3

BHID # 558
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 574
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 590
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 596
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 598
Yr12_TANNER_GenitalBreast rating changed from 3 to 1
BHID # 633
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 641
Yr12_TANNER_GenitalBreast rating changed from 5 to 4
BHID # 564
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 651
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 656
Yr12_TANNER_GenitalBreast rating changed from 1 to 3
BHID # 660
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 666
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 668
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 669
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 670
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 690
Yr12_TANNER_GenitalBreast rating changed from 3 to 2
BHID # 697
Yr12_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 701
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 714
Yr12_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 774
Yr12_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 839
Yr12_TANNER_GenitalBreast rating changed from 3 to 2
BHID # 849
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 850
Yr12_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 853
Yr13_TANNER_GenitalBreast rating changed from 4 to 3
BHID # 862
Yr12_TANNER_GenitalBreast rating changed from 2 to 3

Yr12_TANNER_Hair Variable Changes

BHID # 350
Yr12_TANNER_hair rating changed from 3 to 2
BHID # 397
Yr12_TANNER_hair rating changed from 4 to 3
BHID # 446
Yr12_TANNER_hair rating changed from 3 to 2
BHID # 447
Yr12_TANNER_hair rating changed from 3 to 2
BHID # 462
Yr12_TANNER_hair rating changed from 1 to 2
BHID # 466
Yr12_TANNER_hair rating changed from 1 to 2
BHID # 471
Yr12_TANNER_hair rating changed from 2 to 3
BHID # 475
Yr12_TANNER_hair rating changed from 1 to 2
BHID # 476
Yr12_TANNER_hair rating changed from 1 to 2
BHID # 478
Yr12_TANNER_hair rating changed from 1 to 2
BHID # 498
Yr12_TANNER_hair rating changed from 2 to 3
BHID # 502
Yr12_TANNER_hair rating changed from 3 to 2
BHID # 506
Yr12_TANNER_hair rating changed from 2 to 3
BHID # 515
Yr12_TANNER_hair rating changed from 3 to 2
BHID # 527
Yr12_TANNER_hair rating changed from 1 to 2
BHID # 543
Yr12_TANNER_hair rating changed from 99 to 1
BHID # 598
Yr12_TANNER_hair rating changed from 3 to 1
BHID # 616
Yr12_TANNER_hair rating changed from 4 to 3
BHID # 622
Yr12_TANNER_hair rating changed from 4 to 3
BHID # 647
Yr12_TANNER_hair rating changed from 3 to 2
BHID # 670
Yr12_TANNER_hair rating changed from 4 to 3
BHID # 671
Yr12_TANNER_hair rating changed from 1 to 2
BHID # 718
Yr12_TANNER_hair rating changed from 99 to 2
BHID # 737
Yr12_TANNER_hair rating changed from 3 to 2

BHID # 806
Yr12_TANNER_hair rating changed from 4 to 3

Yr 12 Menstrual period and age variable changes

BHID # 473
Yr12_MENSTRUAL_period rating changed from 0 to 1
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 636
Yr12_MENSTRUAL_period rating changed from 0 to 1
Yr12_MENSTRUAL_age changed from 97 to 11
BHID # 110
Yr12_MENSTRUAL_age changed from 11 to 10
BHID # 140
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 144
Yr12_MENSTRUAL_age changed from 12 to 99
BHID # 165
Yr12_MENSTRUAL_age changed from 99 to 12
BHID # 176
Yr12_MENSTRUAL_age changed from 99 to 11
BHID # 354
Yr12_MENSTRUAL_age changed from 99 to 12
BHID # 374
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 384
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 445
Yr12_MENSTRUAL_age changed from 99 to 11
BHID # 452
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 538
Yr12_MENSTRUAL_age changed from 99 to 12
BHID # 546
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 552
Yr12_MENSTRUAL_age changed from 99 to 11
BHID # 670
Yr12_MENSTRUAL_age changed from 99 to 11
BHID # 706
Yr12_MENSTRUAL_age changed from 99 to 12
BHID # 738
Yr12_MENSTRUAL_age changed from 99 to 12
BHID # 742
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 676
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 684
Yr12_MENSTRUAL_age changed from 12 to 11

BHID # 760
Yr12_MENSTRUAL_age changed from 99 to 9
BHID # 827
Yr12_MENSTRUAL_age changed from 12 to 11
BHID # 843
Yr12_MENSTRUAL_age changed from 99 to 11

Year 13 Pubertal Development Data Cleaning Report

Variable creation and coding

Variable	Variable Label
BHID	Bone Health ID
Yr13_TANNER_Hair	Tanner Hair Rating at 13 years
Yr13_TANNER_GenitalBreast	Tanner genitalia/breast rating at 13 years
Yr13_MENSTRUAL_period	Females: have you begun to menstruate? (yes/ no)
Yr13_MENSTRUAL_age	Females: what age did you begin to menstruate? (Years)

Coding

Male cases were coded as 98 for Yr13_MENSTRUAL_period and Yr13_MENSTRUAL_age at Yr 13 as these variables are not applicable

Female cases were coded as 97 for Yr13_MENSTRUAL_age where Yr13_MENSTRUAL_period was coded as 0 at Yr 13

Cross-sectional cleaning

A database containing a percentage of captured values for the Yr13 pubertal development questionnaire was used as baseline information, and from this every case pulled from the paper file as a cross-reference

BHID # 110 all cases deleted as PD questionnaire missing within the paper records

BHID # 112
Yr13_MENSTRUAL_age changed from 12 to 11
Yr13_TANNER_hair rating changed from 3 to 5

BHID # 596
Yr13_TANNER_hair rating changed from 3 to 2

BHID # 783 this case was identically duplicated within the original data file and so one case was deleted

BHID # 796 this case had a pubertal development questionnaire; however, it was not completed by the adolescent

Data for Yr13 were added for the following 46 cases as they were found to be present in the paper file, but were not present in the original database file

350
365
391
411
442
456
465
467
470
481
496
511
516
526
541
557
571
586
598
601
616
631
646
659
661
676
691
700
706
721
736
751
761
766
781
802
823
826
828
841
843

853
863
873
886
888

Longitudinal Cleaning

Yr13_TANNER_GenitalBreast Variable Changes

BHID # 183
Yr13_TANNER_GenitalBreast rating changed from 96 to 3
BHID # 475
Yr13_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 527
Yr13_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 585
Yr13_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 656
Yr13_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 688
Yr13_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 709
Yr13_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 740
Yr13_TANNER_GenitalBreast rating changed from 1 to 2

Yr13_TANNER_Hair Variable Changes

BHID # 366
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 398
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 413
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 434
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 474
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 475
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 478
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 480
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 501
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 510
Yr13_TANNER_hair rating changed from 1 to 2

BHID # 574
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 583
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 617
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 633
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 636
Yr13_TANNER_hair rating changed from 1 to 3
BHID # 637
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 648
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 752
Yr13_TANNER_hair rating changed from 1 to 2
BHID # 797
Yr13_TANNER_hair rating changed from 1 to 2

Yr 13 Menstrual period and age variable changes

BHID # 110
Yr13_MENSTRUAL_period rating changed from 99 to 1
Yr13_MENSTRUAL_age changed from 99 to 10
BHID # 365
Yr13_MENSTRUAL_period rating changed from 0 to 1
Yr13_MENSTRUAL_age changed from 97 to 13
BHID # 646
Yr13_MENSTRUAL_period rating changed from 96 to 1
Yr13_MENSTRUAL_age changed from 96 to 12
BHID # 703
Yr13_MENSTRUAL_period rating changed from 0 to 1
Yr13_MENSTRUAL_age changed from 97 to 13
BHID # 863
Yr13_MENSTRUAL_period rating changed from 0 to 1
Yr13_MENSTRUAL_age changed from 97 to 11
BHID # 140
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 189
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 349
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 374
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 384
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 429
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 445
Yr13_MENSTRUAL_age changed from 12 to 11

BHID # 452
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 462
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 477
Yr13_MENSTRUAL_age changed from 99 to 11
BHID # 537
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 546
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 552
Yr13_MENSTRUAL_age changed from 13 to 11
BHID # 591
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 593
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 616
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 624
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 626
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 644
Yr13_MENSTRUAL_age changed from 13 to 11
BHID # 655
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 670
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 684
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 694
Yr13_MENSTRUAL_age changed from 13 to 11
BHID # 733
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 742
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 760
Yr13_MENSTRUAL_age changed from 11 to 9
BHID # 769
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 801
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 801
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 802
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 824
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 826
Yr13_MENSTRUAL_age changed from 13 to 12

BHID # 833
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 837
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 842
Yr13_MENSTRUAL_age changed from 13 to 12
BHID # 843
Yr13_MENSTRUAL_age changed from 12 to 11
BHID # 874
Yr13_MENSTRUAL_age changed from 11 to 10
BHID # 910
Yr13_MENSTRUAL_age changed from 13 to 12

Year 14 Pubertal Development Cleaning Report

Variable creation and coding

Variable	Variable Label
BHID	Bone Health ID
Yr14_TANNER_Hair	Tanner Hair Rating at 14 years
Yr14_TANNER_GenitalBreast	Tanner genitalia/breast rating at 14 years
Yr14_MENSTRUAL_period	Females: have you begun to menstruate? (yes/ no)
Yr14_MENSTRUAL_age	Females: what age did you begin to menstruate? (Years)

Variable renaming

Females
Y14AQ6begunmenstruate → Yr14_MENSTRUAL_period
Y14AQ7whatage → Yr14_MENSTRUAL_age
Y14BQ1pubichair → Yr14_TANNER_FHair
Y14CQ1developmentofbreasts → Yr14_TANNER_Breast

Males
Pubichair → Yr14_TANNER_MHair
Genitaldevelopment → Yr14_TANNER_Genitalia

Yr14_TANNER_Breast and Yr14_TANNER_Genitalia were then combined to form one variable → Yr14_TANNER_GenitalBreast
Yr14_TANNER_FHair and Yr14_TANNER_MHair were then combined to form one variable → Yr14_TANNER_Hair

Recoding

Yr14_MENSTRUAL_period coding changed from 1 = no/ 2 = yes to 0 = no/ 1 = yes

Male cases were recoded as 98 for Yr14_MENSTRUAL_period and Yr14_MENSTRUAL_age at Yr 14 as these variables are not applicable

Female cases were recoded as 97 for Yr14_MENSTRUAL_age where Yr14_MENSTRUAL_period was coded as 0 at Yr 14

Cross-Sectional

BHID #'s 173, 180, 472, 509, 726, 823 Yr14_TANNER_Hair recoded to 99 as Yr14_TANNER_GenitalBreast value missing

BHID #'s 362, 458, 738, 807 Yr14_TANNER_GenitalBreast recoded to 99 as Yr14_TANNER_Hair value missing

BHID # 113 Yr14_MENSTRUAL_period recoded to 99 as Yr14_MENSTRUAL_age value missing

BHID # 365 Yr14_MENSTRUAL_age value recoded from 99 to 13

BHID # 703 Yr14_MENSTRUAL_age value recoded from 99 to 13

BHID # 656 Yr14_TANNER_GenitalBreast rating changed from 1 to 2

Duplicate Cases

BHID # 425 duplicated within the Yr14 pubertal development file, case 1 = PH4/ B4/ Men 1/ Age 14 and case 2 = PH4/ G4/ Men 98/ Age 98. This case is a female and so case 2 deleted.

BHID # 450 duplicated within the Yr14 pubertal development file, case 1 = PH4/ B4/ Men 1/ Age 12 and case 2 = PH4/ G4/ Men 98/ Age 98. This case is a female and so case 2 deleted.

Longitudinal Cleaning

Yr14_TANNER_Hair Variable Changes

BHID # 112
Yr14_TANNER_hair rating changed from 3 to 5
BHID # 418
Yr14_TANNER_hair rating changed from 4 to 5
BHID # 441
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 456
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 462
Yr14_TANNER_hair rating changed from 4 to 5
BHID # 471
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 479
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 480
Yr14_TANNER_hair rating changed from 1 to 2
BHID # 483
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 500
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 519
Yr14_TANNER_hair rating changed from 4 to 5
BHID # 538
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 541
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 551
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 553
Yr14_TANNER_hair rating changed from 3 to 4

BHID # 560
Yr14_TANNER_hair rating changed from 1 to 2
BHID # 571
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 582
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 583
Yr14_TANNER_hair rating changed from 1 to 2
BHID # 601
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 606
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 609
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 615
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 637
Yr14_TANNER_hair rating changed from 1 to 2
BHID # 693
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 656
Yr12_TANNER_hair rating changed from 1 to 4
BHID # 696
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 742
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 757
Yr14_TANNER_hair rating changed from 2 to 3
BHID # 761
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 794
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 843
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 910
Yr14_TANNER_hair rating changed from 3 to 4
BHID # 928
Yr14_TANNER_hair rating changed from 3 to 4

<u>Yr14_TANNER_Genital/breast Variable Changes</u>

BHID # 349
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 354
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 359
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 363
Yr14_TANNER_GenitalBreast rating changed from 3 to 4

BHID # 373
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 384
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 431
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 441
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 456
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 459
Yr14_TANNER_GenitalBreast rating changed from 4 to 5
BHID # 480
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 488
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 508
Yr14_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 519
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 551
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 560
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 568
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 574
Yr14_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 583
Yr14_TANNER_GenitalBreast rating changed from 1 to 2
BHID # 588
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 637
Yr14_TANNER_GenitalBreast rating changed from 2 to 4
BHID # 656
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 672
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 699
Yr14_TANNER_GenitalBreast rating changed from 2 to 3
BHID # 701
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 711
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 736
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 750
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 765
Yr14_TANNER_GenitalBreast rating changed from 4 to 5

BHID # 784
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 786
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 802
Yr14_TANNER_GenitalBreast rating changed from 3 to 5
BHID # 814
Yr14_TANNER_GenitalBreast rating changed from 3 to 4
BHID # 880
Yr14_TANNER_GenitalBreast rating changed from 4 to 5

Yr14_MENSTRUAL_period and Yr14_MENSTRUAL_age changes

BHID # 636
Yr14_MENSTRUAL_period changed from 0 to 1
Yr14_MENSTRUAL_age changed from 97 to 11
BHID # 708
Yr14_MENSTRUAL_period changed from 0 to 1
Yr14_MENSTRUAL_age changed from 97 to 12

Yr14_MENSTRUAL_age variable changes
BHID # 107
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 110
Yr14_MENSTRUAL_age changed from 11 to 10
BHID # 112
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 152
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 165
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 176
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 180
Yr14_MENSTRUAL_age changed from 14 to 12
BHID # 349
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 354
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 360
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 362
Yr14_MENSTRUAL_age changed from 7 to 13
BHID # 374
Yr14_MENSTRUAL_age changed from 13 to 11
BHID # 384
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 403
Yr14_MENSTRUAL_age changed from 13 to 12

BHID # 419
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 428
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 431
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 445
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 452
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 456
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 462
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 477
Yr14_MENSTRUAL_age changed from 13 to 11
BHID # 488
Yr14_MENSTRUAL_age changed from 14 to 13
BHID # 502
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 505
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 511
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 517
Yr14_MENSTRUAL_age changed from 12 to 10
BHID # 526
Yr14_MENSTRUAL_age changed from 14 to 13
BHID # 528
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 529
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 546
Yr14_MENSTRUAL_age changed from 13 to 11
BHID # 548
Yr14_MENSTRUAL_age changed from 14 to 13
BHID # 552
Yr14_MENSTRUAL_age changed from 14 to 11
BHID # 556
Yr14_MENSTRUAL_age changed from 13 to 11
BHID # 588
Yr14_MENSTRUAL_age changed from 14 to 13
BHID # 593
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 615
Yr14_MENSTRUAL_age changed from 14 to 13
BHID # 624
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 643
Yr14_MENSTRUAL_age changed from 13 to 12

BHID # 644
Yr14_MENSTRUAL_age changed from 13 to 11
BHID # 646
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 667
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 670
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 676
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 694
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 700
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 719
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 724
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 742
Yr14_MENSTRUAL_age changed from 13 to 11
BHID # 760
Yr14_MENSTRUAL_age changed from 10 to 9
BHID # 769
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 802
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 806
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 827
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 829
Yr14_MENSTRUAL_age changed from 13 to 11
BHID # 840
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 863
Yr14_MENSTRUAL_age changed from 12 to 11
BHID # 910
Yr14_MENSTRUAL_age changed from 13 to 12
BHID # 928
Yr14_MENSTRUAL_age changed from 13 to 12

Appendix V Logistic Regression Variables

Variables included in the building of logistic regression models to examine predictors of age at menarche and age at the initiation of puberty

Variable	Unit	Variable Type	Categories
Birth weight	kg	Continuous	
Birth weight (Cat)	kg	Categorical	(1) Low birth weight (< 2.5kg) (2) Average birth weight (2.51-4.0kg) (3) High birth weight (> 4.01kg)
Gestational age	weeks	Continuous	
Gestational age (Cat)	weeks	Categorical	(1) Pre-term (≤ 36 weeks) (2) Term (37-41 weeks) (3) Post-term (≥ 42 weeks)
Size for gestational age	Percentiles	Categorical	(1) Small for gestational age (2) Average for gestational age
Parity	Previous live births	Continuous	
Parity (Cat)	Previous live births	Categorical	(1) Primaparous (2) Non-primaparous
Weight at 1 year	kg	Continuous	
Height at 1 year	cm	Continuous	
BMI at 1 year	kg/ m^2	Continuous	
Stunting at 1 year	%	Categorical	(1) Stunted (≥ -2SD) (2) Not-stunted (≤ -2SD)
Weight velocity 0 to 12 Months	kg/ yr^{-1}	Continuous	
Weight Velocity 6 to 12 Months	kg/ yr^{-1}	Continuous	
Height Velocity 6 to 12 Months	cm/ yr^{-1}	Continuous	
Weight Velocity 0 to 2 Years	kg/ yr^{-1}	Continuous	
Weight at 2 Years	kg	Continuous	
Height at 2 Years	cm	Continuous	
BMI at 2 Years	kg/ m^2	Continuous	
Stunting at 2 Years	%	Categorical	(1) Stunted (≥ -2SD) (2) Not-stunted (≤ -2SD)
Year 2 Normal/ Overweight/ Obese	%	Categorical	(1) Under/ Normal Weight (2) Overweight/ Obese
Weight Velocity 1 to 2 Years	kg/ yr^{-1}	Continuous	
Height Velocity 1 to 2 Years	cm/ yr^{-1}	Continuous	
Growth rate (0-2 years)	%	Categorical	(1) Catch up growth (2) Same Growth Trajectory (3) Catch down growth
Weight at 4 Years	kg	Continuous	
Height at 4 Years	cm	Continuous	
BMI at 4 Years	kg/ m^2	Continuous	
Stunting at 4 Years	%	Categorical	(1) Stunted (≥ -2SD) (2) Not-stunted (≤ -2SD)

Cont...Variables included in the building of logistic regression models to examine predictors of age at menarche and age at the initiation of puberty

Variable	Unit	Variable Type	Categories
Year 4 Normal/ Overweight/ Obese	%	Categorical	(1) Under/ Normal Weight (2) Overweight/ Obese
Weight Velocity 2 to 4 Years	kg/ yr^{-1}	Continuous	
Height Velocity 2 to 4 Years	cm/ yr^{-1}	Continuous	
Weight at 5 years	kg	Continuous	
Height at 5 Years	cm	Continuous	
BMI at 5 Years	kg/ m^2	Continuous	
Stunting at 5 Years	%	Categorical	(1) Stunted (≥ -2SD) (2) Not-stunted (≤ -2SD)
Year 5 Normal/ Overweight/ Obese	%	Categorical	(1) Under/ Normal Weight (2) Overweight/ Obese
Weight Velocity 4 to 5 Years	kg/ yr^{-1}	Continuous	
Height Velocity 4 to 5 Years	cm/ yr^{-1}	Continuous	
Weight at 8 Years	kg	Continuous	
Height at 8 Years	cm	Continuous	
BMI at 8 Years	kg/ m^2	Continuous	
Stunting at 8 Years	%	Categorical	(1) Stunted (≥ -2SD) (2) Not-stunted (≤ -2SD)
Year 8 Normal/ Overweight/ Obese	%	Categorical	(1) Under/ Normal Weight (2) Overweight/ Obese
Weight Velocity 5 to 8 Years	kg/ yr^{-1}	Continuous	
Height Velocity 5 to 8 Years	cm/ yr^{-1}	Continuous	
Maternal Age at Birth	years	Continuous	
Maternal Education at Birth	%	Categorical	(1) < Grade 10/ High School (2) > Grade 10/ High School
Maternal Marital Status at Birth	%	Categorical	(1) Married/ Cohabiting (2) Not married/ Cohabiting
SES Index at birth	%	Categorical	(1) Low (2) High
1° Caregiver Education at 9/ 10 Years	%	Categorical	(1) < Grade 10/ High School (2) > Grade 10/ High School
1° Caregiver Marital Status at 9/ 10 Years	%	Categorical	(1) Married/ Cohabiting (2) Not married/ Cohabiting
SES Index at 9/ 10 Years	%	Categorical	(1) Low (2) High

Appendix VI Focus Group Question Routes

Adolescent Pubertal Development Question Route

Identify participant characteristics and arrange seating accordingly – quiet participants directly opposite moderator and dominant participants beside moderator.

Introduction

- Welcome and thank participants for attending and for continuing to be part of Birth to Twenty.
- Introduce self (moderator) and observer/note taker.
- Explain focus group aim – we are interested in finding out more about puberty and how you feel about the changes that occur within your body when you are changing from a child to an adult.
- Tell participants why they were chosen and importance of their contribution – we want to hear as many points of view as possible and there are no right or wrong answers to the questions we are asking you.
- Explain why the session is being recorded – we are recording the session so that we do not miss anything that is said.
- Assure participants of confidentiality – we will only use first names in the discussion and there will be no way of identifying any individual in the reports of this research.
- Explain that we are interested in how they feel about puberty and transition in general rather than it being specifically related to their own person experience of puberty.
- Please turn off all cell phones etc.
- Explain strategies for encouraging a good discussion – only one person to talk at a time with no side conversations so that we can identify the information more clearly on the recording. We would like everyone to participate with no-one dominating. We would like to request that any of the information we share in today's discussion is not repeated outside of this session so that we can respect each other's privacy.
- Tell participants the expected length of the session – 90 minutes.
- Any questions?

Ice breaker

- Let's start by introducing yourself and telling the group a little about yourself – first name, how old are you and where you are from?
- Are you all aware of the Soccer World Cup that is taking place in South Africa in 2010? By then you will be 20! How do you feel about that? In the year 2000 you were 10. A lot of changes happen to you between the ages of 10 and 20 and we are now going to discuss some of those changes and how you feel about them.

Section One: Defining puberty and adolescence

1. So what physical and psychological changes have you experienced in the last 5 years, between the age 10 and 15 years? (Write answers on the flip chart)
    - Probe: what physical changes occur?
    - Probe: what emotional changes occur?
    - Probe: does your identity change?

2. What physical and psychological changes do you think you are going to go through in the next 5 years? From the age of 16 to 20 years? (Write answers on the flip chart)
    - Probe: what physical changes occur?

- Probe: what emotional changes occur?
- Probe: does your identity change?

3. We have now created a list on the board of all the physical and psychological changes that you think occur between the ages of 10 and 20 years. Let's try and label each of the points with one of the three options (a) occurs during puberty only, (b) occurs during adolescence only, or (c) occurs during both puberty and adolescence.

NB. If the group allocates the changes into separate "puberty" and "adolescence" groups rather than just "occurs during puberty and adolescence" please ask question 4. If not, please proceed to question 5.

4. You have split some of the changes into occurring either just during puberty or just during adolescence. Do you think that there is a difference between puberty and adolescence?
   - Probe: could you describe puberty?
   - Probe: could you describe adolescence?

5. So why do you think that we go through the processes of adolescence and puberty?
   - Probe: what is the purpose of puberty/adolescence?
   - Probe: does everybody go through the same changes?
   - Probe: does everybody go through these changes at the same time?
   - Probe: do all people start puberty at the same time?
   - Probe: does it take the same amount of time for all people to change from being a child to becoming an adult?
   - Probe: does everybody finish puberty at the same time?
   - Probe: do girls start puberty at the same time as boys?
   - Probe: do boys and girls finish puberty at the same time?

6. If you see a person walking down the street in front of you, how do you know if they are a child or an adult?
   - Probe: are they physically different?
   - Probe: are they emotionally different?

7. So how you do know when somebody is an adult?
   - Probe: how old you think somebody is when they become an adult?
   - Probe: is this age different for boys and girls?
   - Probe: are there any clear indicators of adulthood e.g. breasts, facial hair?
   - Probe: when they act and/or think in a mature manner?
   - Probe: when they are emotionally mature?
   - Probe: when they have a mature attitude?

Section Two: How do you feel about puberty?

8. Now that we have discussed the changes that happen to us during puberty and adolescence, we would like to know how you feel about these changes.
   - Probe: does going through puberty make you excited, apprehensive, scared, happy, sad etc?
   - Probe: does this change at different times in your life?
   - Probe: are you looking forward to becoming an adult? If yes, why? If no, why not etc?

9. Have you felt embarrassed at any point about the changes that are happening to you?
    - Probe: e.g. being taller/shorter than your friends?
    - Probe: e.g. having pimples etc?
    - Probe: e.g. when getting changed for P.E. at school etc?
    - Boys probe: e.g. when your voice was breaking?
    - Probe: you have different opinion on things to your friends?

10. Do you think that girls find it harder to make the transition from childhood to adulthood compared to boys, or the other way around? Or do you think that boys and girls find it equally easy/hard?
    - Probe: e.g. is it harder for girls as there are more easily visible signs that she is going through puberty e.g. breast development?

11. Has going through puberty ever made you have to change what you wanted to do?
    - Probe: e.g. prevented you from participating in certain sports?

Section Three: Pubertal/Adolescent development questionnaire

12. You all have a copy of the physical development during adolescence questionnaire that is currently used by the Birth to Twenty Team in front of you. We would like to know what you think of this questionnaire.
    - Probe: do you understand the questionnaire? E.g. it is in English which may not be your first language
    - Probe: do you understand what information we are trying to collect with this questionnaire?
    - Probe: do you find it easy to follow?
    - Probe: are the pictures helpful?
    - Probe: are the descriptions clear?

13. If you could rate this questionnaire on a scale from 1 to 5 (1 being good and easy to understand to 5 hard and not easy to understand) how would you rate it?

14. What are your previous experiences (if any) of the procedure that Birth to Twenty uses regarding the physical development during adolescence questionnaire?
    - Probe: did anybody explain to you how to complete the questionnaire?
    - Probe: where you given sufficient privacy to complete the questionnaire?
    - Probe: were you told that you could use the restroom should you need to examine yourself in order to complete the questionnaire accurately?
    - Probe: did the interviewer explain to you that you could ask them questions at any point?

15. If you could change the questionnaire in any way, how would you change it?
    - Probe: would you change the language, pictures or descriptions etc?
    - Probe: would you add any further questions?
    - Probe: would you remove any questions?

16. If you could change the procedure of completing this questionnaire in any way, how would you change it?
    - Probe: would you like the interviewer to give you tuition in how to complete the questionnaire?

- Probe: would you like to complete the questionnaire in a private cubicle in which you could examine yourself, without fear of being interrupted?

Section Four: Education

17. We would now like to know where you learnt about puberty and adolescence?
    - Probe: did you learn about puberty from your caregiver, mother, father, sisters, brothers other family members etc?
    - Probe: did you learn about puberty from friends, peers etc?
    - Probe: did you learn about puberty from teachers, counsellors etc?
    - Probe: did you learn about puberty through school classes?
    - Probe: did you learn about puberty from books, magazines, television, the internet etc?

18. With whom did you discuss puberty when you were younger?
    - Probe: family?
    - Probe: friends?
    - Probe: teacher/counsellors?
    - Probe: other?

19. With whom do you most regularly discuss puberty with now?
    - Probe: family?
    - Probe: friends?
    - Probe: teacher/counsellors?
    - Probe: other?

20. Do you feel like you can openly discuss the changes that you are going through with friends and family?
    - Probe: does talking about puberty make you uncomfortable? Or are you happy to discuss it?
    - Probe: do you wish that you could talk more openly with certain members of your family and friends?
    - Probe: are there any aspects of puberty/adolescence that you find more or less difficult to talk about with members of your family and friends?

21. Have you ever attended any classes at school that discussed puberty?
    - Probe: what kinds of things were discussed in these classes?
    - Probe: did you find these classes informative?
    - Probe: in which grade did you attend these classes?
    - Probe: do you think this was too early/late/just about right?
    - Probe: would you like to be able attend more of these types of classes?

Conclusion

- Sweep up any remaining issues.
- Oral summary and ask whether missed anything.
- De-brief/referral – please feel free to talk to one of us afterwards if the discussion has raised any issues that you would like to discuss further (potential to refer to social worker/counsellor).
- Thank for time and contribution.

Adolescent Focus Group Discussion Report

Date:

Place:

Participants:

Moderator:

Length:

Participant Selection:

Setting:

Group Dynamics:

Comments and Feedback (including main themes and difficulties):

Seating Sketch:

N.B. Keep any flip chart material etc and indicate which FGD from.

Staff Pubertal Development Question Route

Identify participant characteristics and arrange seating accordingly – quiet participants directly opposite moderator and dominant participants beside moderator.

Introduction

- Welcome and thank you for finding time to participate in our research on pubertal development in South African adolescents.
- Aim of the focus group – the main aim of this staff focus group is to discuss the practicalities and challenges of pubertal development data collection and management. You are all involved, at some level in the collection or management of pubertal development data and thus can provide the most informative discussion and offer "real life" views on potential problems.
- We would like to hear as many points of view as possible and there are no right or wrong answers. Please feel free to talk openly about any issues and concerns etc that you have. The ultimate aim is to help you by making pubertal development data collection easier.
- The session is being recorded so that we don't miss anything and so at a later date it can be analysed.
- ET has kindly agreed to help us by taking notes.
- Please note that whatever is said within this focus group is completely confidential and you will be referred to simply with a code name within my research and thesis and so there will be no way of identifying who has said what.
- Please turn off all cell phones etc.
- Explain strategies for encouraging a good discussion – only one person to talk at a time with no side conversations so that we can identify the information more clearly on the recording. We would like everyone to participate with no-one dominating. We would like to request that any of the information we share in today's discussion is not repeated outside of this session so that I can ensure confidentiality both for you and for my research.

Ice breaker

- Lets start by introducing yourselves and telling the group at what level you are involved in pubertal development data collection. For example do you undertake interviews with adolescents and how much experience do you have of this?

Section One: Key concepts

1. Firstly, let's make a list of the changes that adolescents go through during puberty/adolescence (write on flip board/white board)
    - Probe: what physical changes occur?
    - Probe: what emotional changes occur?
    - Probe: does identity change?

2. We have now created a list on the board of all the physical and psychological changes that you think occur during puberty/adolescence. Let's try and label each of the points with one of the three options: (a) occurs during puberty only, (b) occurs during adolescence only, or (c) occurs during both puberty and adolescence

3. You have split some of the changes into occurring either just during puberty or just during adolescence. Can you tell me what you understand by the terms "puberty" and "adolescence"?
    - Probe: do you think that they have the same meaning?
    - Probe: do you think that they have different meanings?
    - Probe: could you describe what "puberty" means to you in one sentence?
    - Probe: could you describe what the word "adolescence" means to you in one sentence?

Section Two: Current (and past) Birth to Twenty procedures for collection of pubertal development data

4. Can you explain the current procedure for collecting pubertal development data at the hospital?
    - Probe: what happens when the adolescent is ready to complete the questionnaire?
    - Probe: are adolescents tutored before they are left with the questionnaire?
    - Probe: where do they sit, it is private etc?
    - Probe: do they have access to a private cubicle? Should they need to examine themselves?
    - Probe: are adolescents given sufficient time to complete the questionnaire?
    - Probe: is help given should there be a language problem?
    - Probe: what happens to the questionnaire once it has been completed? Put in envelope/box etc or just handed back to the interviewer?

5. Has this procedure changed at all since it was implemented in Year 11?
    - Probe: were the same questions asked? If no, how were they different?
    - Probe: If the procedure has changed, why has is changed? Because of staff feedback, adolescent feedback, time, space issues etc.

Section Three: Issues/problems with the current procedures

6. What are the most common problems that you face on a day-to-day basis when you are trying to collect pubertal data?
    - Probe: time, space, privacy, language etc?
    - Probe: lack of understanding, lack of cooperation by adolescent etc?

7. What other less common issues have arisen in your experience?
    - Probe: for example refusal to complete etc?
    - Probe: lack of parental/adolescent consent?

8. On numerous questionnaires that I have looked at, I have seen adolescents tick the "no" box on the front of the questionnaire when asked if they have started puberty. On the second page of the questionnaire they self-rate as being in stage 4 for breast/genitalia development, thus are clearly pubertal. Why do you think this might happen?
    - Probe: adolescents do not understand the questionnaire, or what the questionnaire is asking?
    - Probe: adolescents rate themselves as what they would like to be rather than what they actually are?
    - Probe: adolescents are not tutored sufficiently before they are left with the questionnaire?
    - Probe: there are language issues with the questionnaire.

Section Four: Potential for change?

9. If you could change the procedure for collecting pubertal development, how would you change it?
    - Probe: have a script from which you could tutor before leaving the adolescent with the questionnaire?
    - Probe: be able to provide the questionnaire in numerous languages?
    - Probe: be able to provide a private cubicle for the adolescent to self-complete?
    - Probe: Go back to using physician assessment rather than using self-completion?

10. If you could change the questionnaire in any way, how would you change it?
    - Probe: would you change the language, pictures or descriptions etc?
    - Probe: would you add any further questions?
    - Probe: would you remove any questions?

Conclusion

- Sweep up any remaining issues.
- Oral summary and ask whether missed anything.
- De-brief/referral – please feel free to talk to one of us afterwards if the discussion has raised any issues that you would like to discuss further (potential to refer to social worker/counsellor).
- Thank for time and contribution.

Staff Focus Group Discussion Report

Date:

Place:

Participants:

Moderator:

Length:

Participant Selection:

Setting:

Group Dynamics:

Comments and Feedback (including main themes and difficulties):

Seating Sketch:

N.B. Keep any flip chart material etc and indicate which FGD from.

Appendix VII Background Questionnaires

Bt20 ID:	_____
ADFG D ID:	_____

Adolescent Development Focus Group Day
Study Information Sheet

Welcome and thank you for coming today!

Your participation in this study is greatly appreciated. This information sheet serves as a brief explanation of Birth to Twenty and of the adolescent development research. It also provides a brief overview of the procedures that we will be doing today.

What is Birth to Twenty?

As you know, Birth to Twenty is the largest and longest running study of children's health and development in Africa and we continue to make a difference through the research we do. We have been working together with children and their families in the Greater Johannesburg metropolitan area for over 15 years and we have produced information about children, families and services that has been helpful to health and education authorities. We are now studying young people during puberty/adolescence. The teenage years involve dramatic physical and psychological changes, which are strongly related to how well young people are able to tackle the challenges of adulthood. We hope to develop and improve tools that enable researchers to better study the pubertal/adolescent period.

What do you have to do?

- Participate in a moderated focus group discussion with 9 other adolescents of the same age as you at the Baragwanath hospital site.
- The discussion will last for approximately 90 minutes and will involve topics concerning pubertal/adolescent development including physical and mental changes and how you feel about the questionnaire that we use to assess pubertal/adolescent development at the moment.
  - We want to hear as many points of view as possible and there are no right or wrong answers to the questions that we will ask you.
  - The sessions will be recorded so that we do not miss anything that is said but we want to assure you that anything said is completely confidential.
  - We will only use first names in the discussion and there will be no way of identifying any individuals in the reports of this research.
  - We would like to request that any information we share in today's discussion is not repeated outside of this session so that we can respect each other's privacy.

Will my participation in this research study be of value?

YES, by participating in this study you will help us improve our understanding of how you feel about puberty and the kind of changes that you undergo both physically and mentally.

How will I benefit from the study?

We will send you a newsletter explaining the issues identified in the focus group discussions, and you will get refreshments during your visit to the site.

Whom can I contact for further information?

You can contact Laura Jones on 011 488 3246 or Birth to Twenty Freephone on 0800 1318 18 for further information.

Thank you again for your invaluable time and contribution.

Bt20 ID:	_____
ADFG D ID:	_____

Adolescent Development Focus Group Day

Informed Consent

I, _____

agree to participate in the study on adolescent development.

Date of birth: _____
Gender (male/female): _____

I agree to participate in the study on the condition that:

1. The Committee for Research on Human Subjects at the University of the Witwatersrand has approved the study protocol and procedures.
2. All results will be treated with the **strictest confidentiality**.
3. Only group results, and not my/my child's individual results, will be published in scientific and professional journals.
4. The Birth to Twenty scientific team will do all they can to ensure my comfort and dignity.
5. I can withdraw from the study at any time, and that no adverse consequences will follow on withdrawal from the study.

Signatures: (Adolescent): _____
(RA): _____

Contact details: (Home): _____
(Cell): _____

Bt20 ID:	_____
ADFG D ID:	_____

Adolescent Development Focus Group Day

Contact Information

Name: _____
Gender: _____
Date of Birth: _____
School: _____
Current School Grade: _____

Physical Address
Street: _____
Suburb: _____
Zone: _____
Area: _____

Postal Address
Street: _____
Suburb: _____
Zone: _____
Area: _____

Contact Phone Numbers
Home: _____
Cell: _____

Staff ID: _____

Adolescent Development Research

Staff Focus Group Questionnaire

Personal Information

Name: _____

Gender: _____

Contact number: _____

Email address: _____

Current Employment Information

1. At which Bt20 site are you currently based (BH, Bara, HUB)? _____
2. Do you work regularly at any of the other Bt20 sites (BH, Bara, HUB)? _____
   2a. If yes, please provide a brief description of how you split you time between the sites: _____
3. What is your current role within Bt20? _____
4. How long have you been in your current role (YY/MM)? _____
5. Please provide a brief description of what your current role involves: _____
6. Have you held any previous roles within Bt20? _____
7. How long were you in your previous role/(s) (YY/MM)? _____
8. Please provide a brief description of what your previous role/(s) involved: _____
9: Total time at Bt20 (YY/MM)? _____

Adolescent Development Data Collection

(Please tick the circle that is most applicable)

10. How regularly are you involved in the collection of adolescent development data? (i.e. administering the physical development in adolescence questionnaire [Tanner])

- ○ Daily
- ○ Weekly
- ○ Monthly
- ○ Never

11. At which site do you most regularly participate in adolescent development data collection?

- ○ Bone Health
- ○ Baragwanath Hospital
- ○ Both sites equally
- ○ Neither site

12. How much experience do you consider yourself to have in administering the physical development in adolescence questionnaire (Tanner)?

- ○ Little experience
- ○ Some experience
- ○ Experienced
- ○ Very experienced
- ○ None

13. At the following time points, did you participate in adolescent development data collection at either site, both sites or neither site? (please tick as appropriate)

	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
BH							
Bara							
Both							
Neither							

Appendix VIII Methodology Codebook

Adolescent development questionnaire & procedures

1.0 Adolescents comments about the questionnaire
- 1.1 Negative comments
  - 1.1.1 Boring/ see it every year
  - 1.1.2 Do not understand the biology
  - 1.1.3 Wording difficult to understand/ wording issues
  - 1.1.4 Pictures are embarrassing
  - 1.1.5 Feel shy when answering
  - 1.1.6 Would like words/ description rather than pictures
  - 1.1.7 Provide other languages, not just English
  - 1.1.8 Needs to be simple/ simpler
  - 1.1.9 Language is an issue/ problem
  - 1.1.10 Difficult as looking is different to touching when rating
  - 1.1.11 May rate incorrectly as embarrassed about being small
- 1.2 Positive comments
  - 1.2.1 Easy to follow/ complete/ understand/ straightforward/ simple
  - 1.2.2 Pictures are helpful
  - 1.2.3 Understand the information
  - 1.2.4 Do not need an explanation of how to complete
  - 1.2.5 Easy as know own body/ body changes
- 1.3 Other comments
  - 1.3.1 Provide dictionary

2.0 Adolescents rating the questionnaire
- 2.1 Positive ratings (0/1/2)
- 2.2 Indifferent rating (3)
- 2.3 Negative ratings (4/5)

3.0 Adolescents previous experience of the Birth to Twenty (Bt20) procedure
- 3.1 Positive experiences
  - 3.1.1 Given sufficient privacy
  - 3.1.2 Interviewer explained sufficiently well/ always gave explanation
  - 3.1.3 Were told that they could ask the interviewer if they had difficulties/ problems
- 3.2 Negative experiences
  - 3.2.1 Not told that could use the restroom
  - 3.2.2 Did not ask questions, even though did not understand
- 3.3 Other comments
  - 3.3.1 Do not want to complete in front of others
  - 3.3.2 Do not want others to know size/ development stage
  - 3.3.3 Request privacy

4.0 Adolescents suggested questionnaire changes
- 4.1 Changes suggested

- 4.1.1 Simpler wording
- 4.1.2 Simple language
- 4.1.3 Provide dictionary
- 4.1.4 Bring back the testicular volume questions
- 4.1.5 Add questions (relating to pubertal development)
- 4.1.6 Add questions (not relating to pubertal development)
- 4.1.7 Remove pictures as not necessary/ embarrassing

4.2 Do not need to/ would not make any changes
- 4.2.1 Would not add/ remove/ change any questions
- 4.2.2 Would not change language
- 4.2.3 Would not change anything on the questionnaire

5.0 Adolescents suggested procedural changes
- 5.1 Do it for self/ without interviewer/ explanation
- 5.2 Not in front of others/ opposite sex
- 5.3 Ensure no interruptions
- 5.4 Ensure privacy
- 5.5 Would not change current procedure
- 5.6 Provision of special room
- 5.7 Do not need a special room if all the same sex

6.0 Staff comments on the current Bt20 procedure/ questionnaire

6.1 Stages of the current Bt20 procedure
- 6.1.1 Child/ adolescent given the questionnaire & informed to complete on their own
- 6.1.2 Informed to ask if do not understand
- 6.1.3 Child/ adolescent given space/ left to complete
- 6.1.4 No tutorial/ tutoring is given to the child/ adolescent
- 6.1.5 Child/ adolescent informed that they can have access to cubicle/ restroom
- 6.1.6 On completion, child/ adolescent informed to return the questionnaire to the interviewer/ place questionnaire in envelope/ into a box
- 6.1.7 Emphasized that private & confidential/ do not put name on questionnaire
- 6.1.8 Informed that not a test & results will be analysed as a group

6.2 No consent problems

6.3 No space/ privacy issues

6.4 Try to ensure same sex interviewers

6.5 Current questionnaires are available in additional languages
- 6.5.1 Adolescents rarely request the questionnaire in vernacular

6.6 No language issues as the pictures make it simpler/ adolescents do not read the description, just look at the pictures

6.7 Knowledge of parents and children, can identify those children/ adolescents who need additional support during their visit

6.8 Procedure does not change, even when interviewers are very busy

7.0 Staff identification of problems with the current procedure/ questionnaire

7.1 Used to/ or have no access to restrooms/ cubicle where the child/ adolescent can examine themselves
7.2 Language & cognition issues/ problems
- 7.2.1 Lack of understanding of the questions/ context rather than "language" *per se*
- 7.2.2 Adolescents who cannot read/ slow learners
- 7.2.3 Gender differences in cognition e.g. boys rating incorrectly due to peer/ cultural influences
- 7.2.4 Understanding is dependent on the education of the child/ adolescent
- 7.2.5 Understand English well because of school, therefore do not need questionnaires in vernacular

7.3 Hard for staff to know if the adolescent understands the questionnaire as complete on their own/ only become apparent when capture questionnaire
- 7.3.1 Staff only aware of issues if the adolescent acknowledges that they have a problem

7.4 Vernaculars available for the current questionnaire, but not put into practice properly
7.5 Adolescent confusion between ticks and crosses
7.6 Space/ privacy issues
7.7 Time
- 7.7.1 Girls complete questionnaire faster than boys
- 7.7.2 Do not feel time pressure to complete

7.8 Cannot always ensure same sex interviewers
7.9 Adolescents embarrassed to just tick one or none, so tick everything/ embarrassed to complete questionnaire
7.10 Missing data
7.11 Inaccurate rating (both genders)
- 7.11.1 Girls underrate and boys overate

7.12 Consent issues/ specific groups refusing to complete questionnaire

8.0 Staff comments on dealing with issues/ problems with the current procedure/ questionnaire
8.1 Children/ adolescents who do not understand/ cannot read
- 8.2.1 Give further explanation/ clarification
- 8.2.2 Interviewer would go through questionnaire with adolescent on an individual basis
- 8.2.3 Interviewer would sit "back to back" with adolescent so the child still completes questionnaire privately
- 8.2.4 Translate questionnaire as appropriate

9.0 Staff comments on changes to the procedure/ questionnaire in recent years
9.1 Unaware that it has changed
9.2 Procedure/ questionnaire has changed
- 9.2.1 Old procedure unsuccessful/ didn't work/ failed children
- 9.2.2 Parents unhappy with previous procedure of child selecting stage from photographs/ posters with interviewer
- 9.2.3 Children stopped attending Bt20 because of old procedure
- 9.2.4 Prefer to use the current self-rated questionnaire
- 9.2.5 Made the interviewers uncomfortable

10.0 Staff suggested questionnaire/ procedure changes
- 10.1 Changes suggested
  - 10.1.1 Introduction of tutorial prior to adolescent completion/ give tutorial in vernacular/ help adolescent to complete the questionnaire
  - 10.1.2 Staff checking of questionnaires before adolescent leaves
  - 10.1.3 Staff make changes to the questionnaire once completed
  - 10.1.4 Staff who undertake analysis check questionnaire
  - 10.1.5 Analyse quickly after the event so that problems can be identified and resolved
  - 10.1.6 Highlight that need to "tick one box" at top of the questionnaire
  - 10.1.7 Change section order so that all questions for section A on one page
  - 10.1.8 Remove descriptions and leave just the pictures
  - 10.1.8 Provision of cubicles with mirrors, would increase accuracy
    - 10.1.8.1 Have pictures &/ or descriptions on the walls in the cubicles
    - 10.1.8.2 Would need more than one cubicle
    - 10.1.8.3 Would not be logistically feasible/ take too much time
  - 10.1.9 Try to ensure same sex interviewers
- 10.2 Would not make any changes to the current procedure/ questionnaire
  - 10.2.1 Keep questionnaire in English
  - 10.2.2 Cannot improve current questionnaire

Appendix IX Validation of qualitative codebook

Validation of qualitative codebook between Laura Jones (LJ) and Dr Zoë Sheppard (ZS)

LJ created a codebook from all 7 focus group (FG) transcripts (2 staff & 5 adolescent) and provided ZS with one adolescent FG transcript (early puberty male) and one staff FG transcript (Bone Health staff). ZS was then provided with the code book and asked to code the methodology sections in both transcripts. LJ and ZS then compared notes and held discussions where coding was disputed and if any amendments were required to the codebook.

ZS raised the fact that she found it easier to code the adolescent FG transcript compared to the staff FG transcript. LJ agreed with this and the following potential reasons for this were discussed

- The adolescents gave shorter responses
- Staff highlighted more issues/ problems with the questionnaire/ procedure
- There was greater interaction between participants in the staff FGs
- ZS thought this may be due to coding the staff FG transcript prior to the adolescent FG and was therefore less familiar with the codebook.

<u>Early puberty male FG transcript</u>

Page 13

Moderator: So you are shy to answer that?

EPMFG: Yes it's like you're ... is small then you have difficulty to answer.

ZS coded 1.1.5 and 1.1.11/ LJ coded 1.1.11

LJ agreed that this section should be coded both 1.1.5 and 1.1.11 as it refers to shyness and to embarrassment about being small.

Page 13

Moderator: Okay and then the pictures do you think that they helpful the pictures about the testicular size about the hair texture... but you understand the language that is used like hair texture like density of the pubic hair. Do you understand those words?

EPMFG: Some

ZS coded 1.1.3/ LJ did not code (through error). LJ agreed that this section should be coded 1.1.3 as it refers to wording difficulties.

Page 13

Moderator: So do you think that some of the words are more difficult to understand? Or it's quite simple for you to understand?

EPMFG: We find its fine.

Moderator: Hmm you all find it simple to go through?

EPMFG: Yes.

ZS coded 1.1.3/ LJ coded 1.2.1. Both coders agreed that this section should be coded 1.1.3 and 1.2.1 as it refers to wording difficulties via the moderator and to the questionnaire being easy to follow.

Page 14

EPMFG: Three over five.

ZS coded as 2.2/ LJ coded incorrectly as 2.2 (through error). Coding error corrected.

Page 14

Moderator: If you saying five are you saying that it's difficult to understand.

EPMFG: No it's easy.

ZS did not code (through error)/ LJ coded as 1.2.1. ZS would have coded as 1.2.1.

Page 14

Q14 Moderator: So what are your previous experiences if there were any regarding the procedures that Birth to Twenty used...ehh...regarding the physical development questionnaire did anybody explain to you to complete the questionnaire previously?

EPMFG: Yes.

Moderator: Yes okay so were you like so were you given like sufficient privacy?

EPMFG: Yes.

Moderator: To complete the questionnaire?

EPMFG: Yes.

ZS coded 3.1.1 for this whole section/ LJ coded 3.1.2 for the first section and 3.1.1 for the second section. After discussion, ZS would have coded as LJ, it was that she coded it at the higher level, rather than subdividing the positive experiences into categories.

Page 15

Moderator: Okay so did anyone of you went to the interviewer to find out or to get an explanation?

EPMFG: No

ZS coded 3.1.3/ LJ coded 3.2.2. ZS argued that this made an assumption about the adolescent's actually needing help. It might be that the adolescent did not go to the interviewer, simply because they did not require help. Coding changed to 3.1.3.

Page 15

Moderator: You won't change a thing...why?

EPMFG: Because I do understand the language that is used in there.

ZS coded 4.2.2/ LJ coded 4.2.3. ZS argued that this statement referred to language changes rather than not changing anything on the questionnaire. Coding changed to 4.2.2.

Page 16

Q16 Moderator: So if you could change maybe the procedures of completing this questionnaire in any way how would you change the procedures of completing or maybe you want to do it in front of everyone or how would you change the procedures?

EPMFG: I think it's better if I am doing it somewhere.

ZS coded 5.5/ LJ coded 5.4 and 5.6. Following discussions code 5.6 was removed as there was no reference to a "special room", code 5.4 was kept as the statement refers to the need for privacy and code 5.5 was removed as the statement refers to making changes to the current procedure.

There were no other differences in coding between ZS and LJ for this transcript.

<u>Bone Health staff FG transcript</u>

Page 7

Moderator: Do they have access to anywhere that they could go, for instance if they needed to examine themselves? Do you say to them beforehand that you know, you can use the bathroom?

BHFGF3: No, we don't have such-

BHFGF1: _____ unfortunately.

BHFGM1: Currently, but it used to be like that here for the other years.

BHFGF3: We've got a change room that we used for that.

ZS coded as 6.1.5/ LJ coded as 7.1. ZS said that she coded as 6.1.5 as she was looking at what the moderator had said rather than the response, LJ argued that whilst the moderator provides context, we should be coding the participant's responses. The 6.1.5 code was removed.

Page 7

Moderator: Can you explain to me what kind of language problems that you?

BHFGF3: Some of them they don't understand what they're reading, they just tick the box and sometimes we go to them and ask them 'do you understand why you ticked those?' and then the child will just look at you, "because I had to tick" so there are some language problems there.

BHFGM1: Well I tend to disagree with BHFGF3 here. To me I don't think it's a matter of the language problem but it's the understanding of the context itself. Because I believe even if you can administer it in vernacular I don't think some of these kids will understand what they are supposed to be doing. I don't think it's a matter of language.

ZS coded as 7.2.1/ LJ coded as 7.2.1 and 7.5. LJ and ZS agreed that 7.5 should be removed as the statement does not actually refer specifically to confusions about ticks.

Page 8

BHFGF3: Ja _____ and before that we had _____ but we failed to the child [?] because then they couldn't understand very well what was happening so you would show them the different stages and say and then 'you, which stage do you belong to?'; you explain when you say stage, 'this has happened, this has happened, this has happened' and then they choose the _____

ZS coded as 9.2.1 and 7.2/ LJ coded as 9.2.1. The blanks make it hard to understand this statement, although it is fairly clear that it involves/ language and cognition issues and so the code 7.2 should be included. ZS also raised that it is not clear if the adolescents do not understand the questionnaire or if the staff were referring to their lack of understanding of puberty as a whole.

Page 9

Moderator: Specifically because of that?

BHFGF3: They said, yeah I think we had _____ that time because officially, like BHFGF2 said, that we're having charts _____ on the wall and the kids were looking a bit [blip in recording] I remember one of the parents said to us that that's not good for a child to do that, so they didn't want [blip in recording] used to carry those charts.

ZS coded as 9.2.3/ LJ coded as 9.2.2. After discussions it was decided to removed the code 9.2.3 and keep 9.2.2 as LJ thought that ZS was making an assumption that children dropped out of the study.

Page 9

Moderator: So nothing else comes up? What about things like privacy and time and space? You know, does that ever cause an issue?

BHFGF3: No, it doesn't.

BHFGF2: It was an issue at _____ the privacy thing, because they needed privacy when doing that. Maybe that is why [blip in recording]

ZS coded the highlighted section as 7.6 and 7.7/ LJ coded as 7.7. ZS explained that time is mentioned in the moderator statement and thus the participants were responding to privacy, time and space issues, thus 7.6 should be included. LJ agreed.

Page 10

Moderator: On quite a lot of the questionnaires we've already kind of talked about cognition; on the front I notice that they, on the puberty question 'are you pubertal?' and they tick 'no' and then when they turn over they tick '4' and say that they're in Stage 4, so we're assuming that they're nearly adult. I'm not quite sure I understand why that happens, and I just wondered if you had any ideas why they're saying no they're not pubertal on the front and then they're ticking '4'.

BHFGF3: I never used to do that, it was a male thing _____

BHFGF2: Maybe they're thinking of being adolescent and then being on puberty, or maybe they don't understand what the sentence says.

BHFGM1: _____ understanding the context, like I said earlier.

ZS coded the highlighted section as 7.2.1/ LJ coded the highlighted area as 7.2. After a discussion it was decided that the statement was more specific to 7.2.1 and not the more general code of 7.2 and so was changed.

Page 10

Moderator: You don't seem to pick up on that? What about girls, do you think girls, how do you think girls rate themselves?

BHFGF3: There's no problem with girls so far.

ZS did not code (through error)/ LJ coded as 7.1.1. ZS would have coded as 7.1.1.

Page 11

Moderator: Yeah, you think that they understand it well enough to be able to leave it as it is?

BHFGF3: Yeah, at this age they do understand it.

ZS coded 10.2 and 7.2/ LJ coded as 10.2. After discussions it was decided to remove the code 7.2 and add the code 6.6 as the statement was suggesting that there were no language problems with the current questionnaire

Page 11

Moderator: So there are adolescents who do not understand those terms, do you think?

BHFGF3: I don't know now because we never read through these things, they just tick and then we put them-

BHFGF2: That's the other problem is we don't know how they answer the questions exactly, unless when there's a problem, when the child can't answer the questions properly.

BHFGF3: Otherwise we don't know how they answer

ZS coded as 7.2 and 7.3/ LJ coded 7.3 and 7.3.1. LJ agreed that these statements highlighted language issues/ problems and so 7.2 should be added. ZS agreed that 7.3.1 should be kept as the statement suggests that the staff are only aware of how the adolescent's complete the questionnaire if there is a problem.

Page 12

Moderator: So do you think we should change the procedure that we use and perhaps introduce a tutorial beforehand, so that you know that they know how to fill it in? Or do you think we should leave the procedure how it is?

BHFGF3: It would take time, already they're complaining about the time they spend here.

ZS coded 10.1.1 and 7.7/ LJ coded 7.7. LJ agreed that the main focus of the statement was the introduction of a tutorial, thus code 10.1.1 was added.

Page 12

Moderator: So time is an issue with _____

BHFGF3: In fact with most of them when we do _____ what we need is time to be cut in half, they say they spend too much time. So adding something else, unless if we just checked them afterwards. But even so you don't know if they understood the questions or not.

BHFGF2: And because they've been doing this for a long time and if maybe they did _____ from the beginning, maybe they _____ it's wrong, we don't know.

ZS coded as 10.1.2, 7.2 and the final section as 1.1.1/ LJ coded as 7.2 and 7.3. LJ argued that 1.1.1 should be removed as that refers to adolescent comments rather than staff comments. LJ agreed that 10.1.2 should be added as the statements refer to staff checking the questionnaires before the adolescents leave. ZS agreed that she would add 7.3 as the statements highlighted that it's hard for staff to know if the adolescents understand the questionnaire.

Page 12

Moderator: So how do you think we could address the kind of problems like that?

BHFGF3: Like afterwards, maybe afterwards you can change it.

BHFGM1: But I think the only changing that we do is to make sure that the _____ are filled in, it's done correctly, because you never know whether they did understand it...

BHFGF3: Understand it.

BHFGM1: Ja, what they have... so only check that _____.

ZS coded the highlighted sections as 7.2, 10.1.2 and 10.1.3/ LJ coded as 10.1.2. LJ agreed that both 7.2 and 10.1.3 should be added as the statement talks about language cognition issues and staff making changes to the questionnaire.

Page 13

Moderator: OK. We're actually coming towards the end of the questionnaire, does anyone have anything that they'd like to add on what we've talked about so far?

BHFGF3: Well I don't have anything to add per se, but I think it's, it's a problem for us to identify children who can't understand the questionnaires, if they don't come to us and say I can't understand what the question, question says. And I don't know how to, how we can solve that...

ZS coded as 7.2/ LJ coded as 7.3. Following discussions, Zs agreed that should would code as 7.3 rather than 7.2 as 7.3 was a more specific code about staff not being able to identify children who are having problems completing the questionnaire, rather than language or cognition issues.

Page 13

Moderator: Do you think tutoring before they, they are left with the questionnaire would help? I know that increases your time, but do you think that is a potential...?

BHFGF2: That would help, but, but, because when the families first come it's a long procedure explaining to them what is going to be happening, and... 20 minutes later they're still there...

ZS coded as 7.7/ LJ coded as 10.1.1. It was decided that both code 7.7 and code 10.1.1 were applicable to this statement as it refers to time issues and the introduction of a tutorial.

There were no other differences in coding between ZS and LJ for this transcript.

Codebook changes

Original coding for 6.6 "no language issues as the pictures make it simpler/ adolescents do not read the description, just look at the pictures" has been further sub-divided. Validated coding for 6.6 "no language issues/ problems" and 6.6.1 "pictures make it simpler/ adolescents do not read the description, just look at the pictures". This change was made as ZS and LJ both suggested that perhaps these were actually two different points, although interrelated.

Original coding for 7.3 "hard for staff to know if the adolescent understands the questionnaire as complete on their own/ only becomes apparent when capture questionnaire" and 7.3/1 Staff only aware of issues in the adolescent acknowledges that they have a problem". Validated coding for 7.3 "hard for staff to know if the adolescent understands the questionnaire as they complete it on their own" and 7.3.1 "staff only aware of issues if the adolescent acknowledges that they have a problem" and 7.3.2 "problems only become apparent when staff capture questionnaire". These changes were made as ZS suggested that the original 7.3 coding covered too broader area and needed further subdividing. LJ agreed upon reflection.

There was a discussion between ZS and LJ as to whether the original code 7.2 "Language and cognition issues/ problems" should be combined, or if language and cognition form two separate issues. LJ argued that these two points were often interlinked, particularly within the staff FG transcripts and so it would be very difficult to disentangle the statements to conform to one or the other. It was therefore decided to leave code 7.2 as it was in the original codebook.

ZS suggested that for original code 8.2.2 "interviewer would go through questionnaire with adolescent on an individual basis" that it be changed to "interviewer would go through questionnaire with adolescent" and remove the on an individual basis as this caused confusion when coded, if that particular part of the code was not stated. LJ agreed with this upon reflection and the validated code was changed to 8.2.2 "interviewer would go through questionnaire with adolescent".

ZS expressed confusion about original codes 6.2 "no consent problems", 6.3 "no space/ privacy issues" and 7.6 "space/ privacy issues". ZS found it difficult to decipher between the two codes. LJ explained that codes 6.2 and 6.3 were staff comments on the current procedure and that they stated that there were no problems consent, space or privacy. Where as code 7.6 was where staff had highlighted problems with the current procedure with regards to consent, space and privacy. The decision was taken to keep the original coding.