

Predicting physical activity behaviour across early adolescence

by

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Abstract

Physical activity (PA) has been labelled the ‘miracle drug’ (Pimlott, 2010) and participating in regular PA has ample physical and mental wellbeing benefits. However, physical inactivity remains a critical public health concern, particularly across adolescence. In England the proportion of adolescents aged 13-15 years meeting the recommended guidelines for PA decreased significantly from those at a younger age (Health and Social Care Information Centre, 2009; 2012; 2015). The adolescent years (13 – 18 years) have been identified as the age of greatest decline in PA, although it is possible that large declines can also be seen at younger ages (Sallis, 2000). Among girls the decline in PA is greater at younger ages (9–12 years old) and among boys it is greater at older ages (13–16 years old) (Dumith, Gigante, Domingues, & Kohl, 2011). Thus, examining behaviour of early adolescents (aged 11-13 years) is a primary focus of this thesis. Researchers have called for a more comprehensive grasp of PA correlates and determinants and their impact on behaviour (Biddle & Mutrie, 2001, 2008). This broader picture needs to incorporate longitudinal study designs to accurately portray developmental changes (Evenson & Mota, 2011). This thesis aims to work towards a better understanding of associations among variables across aspects of the ecological model in relation to PA behaviour during early adolescence. Early adolescents within their first year of secondary school (year 7, aged 11–12 years) were recruited through schools across the East Midlands, United Kingdom (UK). These participants completed various measures across an 18 month period to compile all data required for the thesis.

The thesis begins with a focus on active transport as a means of commuting to school which can significantly contribute to overall PA levels (Aibar, Bois, Generele, Bengoechea, & Paillard, 2015; Slingerland, Borghouts, & Hesselink, 2012). The distance from home to school is an important influence on the decision to use active transport; however, ecological perspectives would suggest this variable may interact with individual, interpersonal and environmental factors. Therefore, the first study of this thesis investigates whether the relationship between distance to school and active transport is moderated by (i) gender, (ii) biological maturation, (iii) perceived family support for PA and (iv) multiple deprivation. Cross-sectional results from the baseline data collected demonstrated that the relationship between distance to school and the likelihood to actively travel to school is moderated by biological maturation, multiple deprivation and family support of PA in adolescents. Further analysis revealed that late-maturing children, those from less socio-economically deprived

backgrounds and children with low family support of PA are less likely to actively commute to school as distance to school increases. Due to the interaction between these variables described above, the second study focused on the variables collectively using a person-oriented approach, which aimed to classify distinct profiles of early adolescents based on correlates of PA. The outcome variables were also broadened to include active transport and overall PA across two time points. Findings from this second study illustrate that the ‘highly supported, shortest commuters’ produced the highest levels of self-reported PA and that ‘affluent, short commuters’ were the most likely to use active transport to travel to school. The ‘affluent, short commuters’ lived a relatively short distance to school in areas of the lowest deprivation and had relative moderate family support of PA. The ‘highly supported, shortest commuters’ were characterised by the highest family support of PA and lived the shortest distance to school in areas of low deprivation.

Study 1 evidenced an association between biological maturation and PA behaviour; however, study 2 displayed that biological maturation did not meaningfully contribute to the class characteristics, and were not a predictor of PA. Previous evidence as to whether early, average or late maturing adolescents are more likely to disengage from PA is mixed and tends to focus on one gender only (Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina 2010; Bacil, Mazzardo, Rech, Legnani, & Campos, 2015). Thus for the third study a more focused inspection of biological maturity was undertaken. Biological maturity status was investigated as a predictor of PA behaviour at two subsequent time points (6 – 9 months after baseline and 12 – 18 months after baseline) and whether there was variation across genders. Findings displayed that biological maturity status does not predict subsequent PA, with no distinction across genders. To conclude, the final study examined additional forms of PA behaviour. For children to develop and maintain healthy PA behaviours, their PA during the school day, particularly during physical education (P.E) classes is important (Owen, Smith, Lubans, Ng, & Lonsdale, 2014). Self-reported PA was divided into school-time PA (during P.E. lessons, break and lunchtimes) and leisure-time PA (after school, during evenings and weekends). The final study fully utilised the longitudinal data collected and utilised longitudinal growth modelling to describe the changes in PA behaviour across 12-18 months during early adolescence. Results displayed that school-time PA and leisure-time PA are distinct. Males; those from less deprived backgrounds and individuals with higher family support of PA all separately reported more school-time PA than their counterparts (females, those from higher deprived backgrounds and individuals with lower family support of PA) at baseline. Males and those with higher family support of PA also reported more leisure-time

PA than their respective counterparts at baseline. On average, both genders decreased in school-time PA across 18 months yet for leisure-time PA, on average, there was no change over time and no significant difference in the rate of change between genders. There were no observed significant differences in the rate of change between multiple deprivation status and biological maturation across the 18 months for both behaviours. For family support, on average school-time PA decreased over time and results showed significant difference in the rate of change between individuals with lower or higher levels of family support of PA across the 18 months. On average, there was no change over time for leisure-time PA yet there was a significant difference in the rate of change between individuals and their family support of PA across 18 months. Further analysis demonstrated if an individual's family support increases, so does their leisure-time PA and vice versa.

These overall key findings demonstrate the complexity of PA behaviour throughout early adolescence. This thesis works towards predicting individuals, correlates and determinants that may be susceptible to physical inactivity and/or a decrease in activity over time. Results can be used to target and direct PA intervention work.

Key words: Physical activity, active transport, early adolescent, moderation effects, latent class analysis, biological maturation.

Sections from this thesis have been published as journal articles and conference presentations, these are as followed:

Journal Article

Garnham-Lee, K. P., Falconer, C. L., Sherar, L. B., & Taylor, I. M. (2016). Evidence of moderation effects in predicting active transport to school. *Journal of Public Health*, 38(2), 1-10.

Conference Presentations

Garnham-Lee, K. P., Falconer, C. L., Sherar, L. B., & Taylor, I. M. (2015, June). Evidence of moderation effects in predicting active transport to school. *International Society of Behavioral Nutrition and Physical Activity (ISBNPA) 2015 Annual Meeting, Edinburgh, United Kingdom (poster presentation)*.

Garnham-Lee, K. P., & Taylor, I. M. (2016, June). Associations between BMI, the desire to be larger and self-reported physical activity in 12-year-old children. *International Society of Behavioral Nutrition and Physical Activity (ISBNPA) 2016 Annual Meeting, Cape Town, South Africa (short oral presentation)*.

Garnham-Lee, K. P., Stenling, A., Sherar, L. B., & Taylor, I. M. (2016, June). A latent class analysis of physical activity correlates in early adolescence. *International Society of Behavioral Nutrition and Physical Activity (ISBNPA) 2016 Annual Meeting, Cape Town, South Africa (poster presentation)*.

“Education is the great engine of personal development. It is through education that the daughter of a peasant can become a doctor, that the son of a mine worker can become the head of the mine, that a child of farm workers can become the president of a great nation. It is what we make out of what we have, not what we are given, that separates one person from another” - Nelson Mandela

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General Introduction and Literature Review

Physical activity (PA) is a significant contributor to good health and physical inactivity has been identified as the fourth leading risk factor for global mortality (World Health Organisation, 2016). Regular PA can help control weight, lower blood pressure, improve cholesterol levels, reduce the risk of cardiovascular disease, reduce the risk of type 2 diabetes, metabolic syndrome and some cancers; it can strengthen bones and muscles, improve the ability to do daily activities and prevent falls (Centre for Disease Control and Prevention, 2015). Regular PA also impacts and improves academic performance and mental health in terms of improved cognition, reduction of stress, anxiety and depression (The Lancet, 2013). PA has been termed the ‘miracle drug’ (Pimlott, 2010) and can increase overall life longevity and expectancy (Wen et al., 2011). Irrespective of age, ethnicity, shape or size; anyone is able to gain the above health benefits PA offers (Centre for Disease Control and Prevention, 2015).

Physical Activity is defined as “any bodily movement produced by skeletal muscles that result in caloric expenditure above resting levels” (Caspersen, Powell, & Christenson, 1985, p. 126). The total amount of PA completed by an individual is a combination of the frequency, duration and intensity of activity (Haskell, 2001; Welk, Corbin, & Dale, 2000). Frequency of PA refers to how often it is performed; for example how many times a day, week, month or year (Welk et al., 2000). Duration is the total time, in seconds, minutes or hours, spent physically active during a pre-defined period of time (e.g., day, week) (Welk et al., 2000). Intensity of PA is the effort required to perform the activity; light, moderate or vigorous effort (Welk et al., 2000). Intensity is also associated with energy expenditure based on an individual’s assigned metabolic equivalent of task (MET) value (Ainsworth et al., 2000). PA can be done either with or without the intention to receive health benefits and there are various reasons for being physically active throughout the day (Bauman et al., 2012). Individuals may also choose to spend their time sedentary, which is distinct from physical inactivity. “Sedentary behaviour is any waking behaviour characterised by an energy expenditure ≤ 1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture” (Tremblay et al., 2017, p. 9). This thesis does not examine sedentary behaviour; however, it is acknowledged that sedentary behaviour is an important behaviour for health during early adolescence. The SLOTH model categorises all 24 hours of the day into five domains: Sleep, Leisure, Occupation, Transportation, and Home; during each of the domains, excluding sleep,

individuals may choose to be either physically active or inactive (Pratt, Macera, Sallis, O'Donnell, & Frank, 2004). Transportation is a key domain to PA; actively commuting or the use of active transport (i.e., primarily walking and cycling for the purpose of functional, rather than leisure travel) is a significant factor of PA behaviour. Actively commuting to school can provide children and adolescents with convenient and meaningful contributions to increase overall PA levels and energy expenditure (Aibar et al., 2015; Slingerland, Borghouts, & Hesselink, 2012). The focus outcomes of this thesis are on habitual PA and active transport. In order to identify the correlates and determinants of PA behaviours, valid methods of assessing PA are required that are reliable (i.e., objective, accurate, and precise), unobtrusive, and practical to administer (Dishman, Washburn, & Schoeller, 2001). There is still no consensus "gold standard" for the measurement of PA (Dishman et al., 2001; Hills, Mokhtar & Byrne, 2014), however, the next section will describe and explore various measurements of PA and active transport in terms of strengths, limitations and acceptability to early adolescents.

Physical Activity Measurement

Calorimetry. Calorimetry can be direct or indirect. Direct calorimetry is a measurement of the energy expenditure and involves the measurement of heat production or heat loss directly; early calorimeters for the measurement of human energy expenditure were typically direct (Hills, Mokhtar, & Byrne, 2014). Indirect calorimetry is the measurement of a proxy of heat production or loss by measuring oxygen consumption and/or carbon dioxide production (Leonard, 2012). Mostly the measurement of energy expenditure nowadays is via indirect calorimetry in either laboratory or field settings, typically by measuring oxygen consumption (Hills et al., 2014). Direct calorimetry can only be measured via a sealed insulated chamber where the heat is transferred to surrounding water, thus this method is not appropriate for large population studies that wish to measure 'free-living' PA. Doubly labelled water (DLW) is a method of indirect calorimetry that measures energy expenditure over several consecutive days (typically 4 – 21 days) when the subject is under normal life conditions, within a 'free-living' environment (Schoeller, 1988). This technique uses water labelled with stable isotopes of oxygen and hydrogen; it then calculates the activity-related energy expenditure by combining the measurement of total energy expenditure alongside the minimal rate of energy expenditure (basal metabolic rate) (Schoeller & van Santen, 1982). Urine and saliva specimens are required before and after drinking an initial dose of the labelled water and after the experiment a final urine specimen is required. This technique is

deemed accurate and valid across a variety of settings and populations (Schoeller, 1988; Ainslie, Reilly, & Westerterp, 2003). The DWL method is costly and demanding on participants and researchers. Furthermore, although this technique provides an accurate measure of total energy expenditure, it cannot provide information about patterns of PA in terms of type, frequency, duration, intensity or context. Consequently, such an approach would not be feasible for investigating PA behaviour longitudinally in a large cohort of early adolescents.

Direct Observation. Direct observation is a method that assesses behavioural aspects of PA and can be very appropriate for child research (Welk et al., 2000). The detail provided from direct observation is contextually-rich and can be highly beneficial for characterising children's activity (McKenzie, 2002; 2010). There are various techniques and systems for observation and data recording that are dependent on study design and population. Nevertheless, this method requires considerable time and is labour intensive (Montoye, Kemper, Saris, & Washburn, 1996; Welk et al., 2000). Appropriate training must be provided for observers. This training ought to ensure observers will be objective and non-judgmental as well as accurate; because of the observer element, data collection can thus be expensive in terms of observer time and training (McKenzie, 2010). Additionally, observations cannot be made in certain environments (e.g., in bathrooms during home observations), and there is the possibility people may behave differently when an observer is present (i.e., reactivity) (McKenzie, 2010).

Motion Sensors. Accelerometry. The use of accelerometers has become one of the most commonly utilised methods for assessing PA for subjects within a 'free-living' environment (Trost & Rice, 2012). Typically worn on the hip or wrist, accelerometers can measure the acceleration of the body in the vertical (top to bottom), anteroposterior (front to back) and medial-lateral (towards and away from the middle) plane. Accelerometers present few burdens to participants and are capable of detecting intermittent activity patterns characteristic of children (Trost, 2001). A well-documented limitation of accelerometers is that they are not able to account for the increased energy cost associated with walking upstairs or an incline and do not accurately measure activities such as cycling, skating and lifting or carrying objects (Trost & O'Neil, 2013; Trost & Rice, 2012; Sallis, 2010). Yet, it is assumed that the contribution of these activities to the overall PA is modest (Trost & O'Neil, 2013; Trost & Rice, 2012; Sallis, 2010).

Pedometers. Pedometers are another motion sensor method which can be less expensive than accelerometers. A pedometer is an electronic device most often worn on the waist or hip, similar to an accelerometer, that counts each step a person takes by detecting the acceleration of the body's centre of mass during the gait cycle (Trost & O'Neil, 2013). When this acceleration surpasses the set threshold, the device counts a step (Trost & O'Neil, 2013). The primary limitation of pedometers, as with accelerometers, is that they cannot consider the extent of the movement detected and also do not detect the increased energy cost associated with various activities. When using pedometers a movement that passes the threshold is considered a step regardless of whether it occurs during walking, running or jumping (Trost & O'Neil, 2013) which can sometimes be viewed as a limitation. Many studies have been published on adolescence PA behaviour that utilised pedometers and this method has been supported (Lubans, Plotnikoff, Miller, Scott, Thompson, & Tudor-Locke, 2015).

Self-report assessments. Before the development of motion sensors, common assessment methods for PA were self-reported (Biddle, Gorely, Pearson, & Bull, 2011). These techniques come in different mediums including questionnaires, surveys and diaries. There are a large number of self-report techniques for adolescents that vary in format and gather various data (Biddle et al., 2011). Different instruments measure overall PA (e.g., The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) (Kowalski, Crocker, & Faulkner, 1997) or just leisure PA (e.g., Godin Leisure-Time Exercise Questionnaire) (Godin & Shephard, 1985). Numerous limitations of self-reports have been discussed (Ainsworth, Cahalin, Buman, & Ross, 2015), such as social desirability bias leading to over-reporting of PA (Aggio et al., 2016). Recalling PA is a highly complex cognitive task (Baranowski, 1988), and instruments vary in their cognitive demands. On the other hand, this method is widespread as it is inexpensive, relatively easy to administer to a large population and has a low participant burden (Dugdill & Stratton, 2007).

Physical Activity: the Current Picture

Due to the advantages of regular PA it is important that children and young people establish an active lifestyle early on in their life to track into adulthood (Telama, Yang, Viikari, Välimäki, Wanne, & Raitakari, 2005). Children and young people (aged 5-18 years) in the UK are recommended to adhere to established government guidelines for PA. These guidelines recommend participating in at least 60 minutes of moderate to vigorous intensity PA (MVPA) every day (Department of Health, 2011). Additionally, it is recommended that children perform vigorous intensity activities, including those that strengthen muscle and

bone, at least three days a week and to minimise the amount of time spent being sedentary (sitting) for extended periods (Department of Health, 2011). Despite the well-established physical and mental health benefits, children - particularly adolescents - across the UK are not currently achieving the UK guidelines outlined above. Self-reported data from the Health Survey for England, conducted in 2015, concluded that just 24% of boys and 18% of girls aged 5–15 years met the current PA guidelines (Health and Social Care Information Centre, 2015). Across both genders, the proportion of children meeting the recommended guidelines was lower in older children. In boys, children meeting the guidelines decreased from 24% for those aged 5-7 years to 15% for those aged 13-15 years and for girls the decrease was from 23% to 9%. Objectively measured PA data from the Health Survey for England, conducted in 2008, displayed that 33% of boys and 21% of girls aged 5–15 years met the current UK guidelines (Health and Social Care Information Centre, 2009). Furthermore, the declines in PA are proportionally similar across genders; however, the objective data measured using accelerometers, showed considerable variation by age. For boys aged 11-15 years, only 7% met the recommended guidelines whereas over half (51%) of boys aged 4–10 years met the recommended guidelines. Among girls aged 4-10 years, 34% met the recommended government guidelines; whereas no girls aged 11-15 years did so (Health and Social Care Information Centre, 2009). These statistics and others reveal that many adolescents are not completing sufficient PA to meet the current government guidelines and that participation in PA decreases as children continue towards adulthood (Sallis, Prochaska, & Taylor, 2000; Epstein, Roemmich, Paluch, & Raynor, 2005; Nader, Bradley, Houts, McRitchie, & O'Brien, 2008).

Based on the evidence above, English adolescents aged 13-15 years are least likely to meet the guidelines for PA. The adolescent years (13 – 18 years) have been identified as the age of greatest decline in PA, although it is also possible that large declines can also be seen at younger ages (Sallis, 2000). Typically PA participation rates for girls decline prior to their adolescence years, between the ages of 9 to 12 years old; whereas in boys the decline characteristically occurs during early-mid adolescence, between the ages of 13–16 years (Dumith, Gigante, Domingues, & Kohl, 2011). However, across both genders a decline in PA has been evidenced at 12 years old (Cairney, Veldhuizen, Kwan, Hay, & Faught, 2014). Consequently, intervention work ought to take place prior to these age-related PA declines. Hence the following thesis will be examining the PA behaviour of early adolescents aged 11-13 years. Normally, 11 year olds in England are transitioning from primary to secondary

school, which has been shown to impact PA levels both positively and negatively (Jago, Page, & Cooper, 2012; De Meester, Van Dyck, De Bourdeaudhuij, Deforche, & Cardon, 2014; Marks, Barnett, Strugnell, & Allender, 2015).

Correlates and Determinants of PA and a Multidisciplinary approach

Individuals of all age groups, including early adolescents, vary in their PA levels. PA behaviour is affected by diverse factors, correlates and determinants (Bauman et al., 2012). Correlates of PA are factors that are associated with the PA, i.e. one thing affects or depends on another; this differs from determinants of PA which are factors with a causal or contributory relationship i.e. one event is a result of the other event (Bauman et al., 2012). The majority of research that explores PA behaviours across early adolescence follows a cross-sectional study design (Bauman et al., 2012). This cross-sectional study design typically investigates correlations and examine if variables are statistically associated with PA behaviour; they do not demonstrate evidence of causal relationships between factors and PA, but may generate hypotheses for further study (Bauman, Sallis, Dzewaltowski, & Owen, 2002). To establish true causality, research must be experimental and longitudinal; longitudinal work alone can explore the direction of relationships but not prove causality. Identified factors that have causal associations with PA behaviour are described as determinants (Bauman et al., 2002).

Understanding the potential correlates and determinants that contribute to the uptake, maintenance and reduction of PA is essential for development and improvement of interventions (Sallis, Owen, & Fotheringham, 2000). In order to explain the variation of PA behaviour across early adolescence, there is a need to look at the ‘bigger picture’ when it comes to the determinants and correlates of PA (Biddle & Mutrie, 2001, 2008). Adopting a wider research perspective can be attempted through multidisciplinary or interdisciplinary approaches. Both perspectives have been called for in health and obesity science and policy (Robertson, Martin, & Singer, 2003; Butland et al, 2007; Choi & Pak, 2006; Public Health England, 2014; Gerike et al., 2016). These approaches are also repeatedly called for across funding bids and opportunities (e.g., Medical Research Council). However, the two terms are regularly used interchangeably and equivocally defined (Whitfield, & Reid, 2004; Choi & Pak, 2006). “Multidisciplinary, being the most basic level of involvement, refers to different (hence “multi”) disciplines that are working on a problem in parallel or sequentially, and without challenging their disciplinary boundaries” (Choi & Pak, 2006, p. 359). On the other hand, “interdisciplinary brings about the reciprocal interaction between (hence “inter”)

disciplines, necessitating a blurring of disciplinary boundaries, in order to generate new common methodologies, perspectives, knowledge, or even new disciplines” (Choi & Pak, 2006, p. 359). This thesis adopts a multidisciplinary approach to build towards an ecological ‘bigger picture’ of the influences on PA behaviour for early adolescents. Specifically, this thesis does not challenge disciplinary boundaries but instead it draws on their knowledge and applies different aspects of health and PA research to form multidisciplinary research questions.

An Ecological Approach

Another approach utilised to examine the ‘bigger picture’ is the ecological approach. The ecological model applied to human development advocates that in order to understand human development and behaviour, the entire ecological system needs to be taken into account (Bronfenbrenner, 1977). Using this ecological framework suggests that no particular factor can completely explain PA behaviour but an array of correlates across the ecological system need to be considered. Utilising the ecological model will gather a more complete understanding and comprehensive grasp of PA correlates and their associations with PA behaviours. The ecological approach is utilised as an organising framework across the thesis to combine the use and examination of different layers of influence and their effect on PA behaviour. Ecological and socio-ecological models have been adapted throughout the literature to suit various public health topics focused on behaviour change; for example, family violence prevention (Reilly & Gravdal, 2012), vaccine uptake (Kumar et al., 2012), healthy eating in schools (Townsend & Foster, 2013) and PA behaviour (Sallis & Owen, 2015). Different variations of the ecological model have been previously published that contain multiple levels of influences (Sallis et al., 2006; Sallis et al., 2012). Ecological models specific to PA are typically organised around the four key domains of PA behaviour; active transport, occupational activities, household activities and active recreation/leisure PA (Sallis, Floyd, Rodríguez, & Saelens, 2012; Sallis & Owen, 2015). Across this particular thesis, three of these domains are studied; active transport (walking to school), occupational activity (or school-based PA in children) and leisure-time PA. Gender and biological maturation were chosen as the individual influences focused across the thesis and two variables are used to represent the social/culture environment across the thesis, namely family support of PA and multiple deprivation. As a representative of the built environment, distance to school is examined. Figure 1.1 below displays how the variables across the present thesis are organised. Each of these variables will be explored in further depth below.

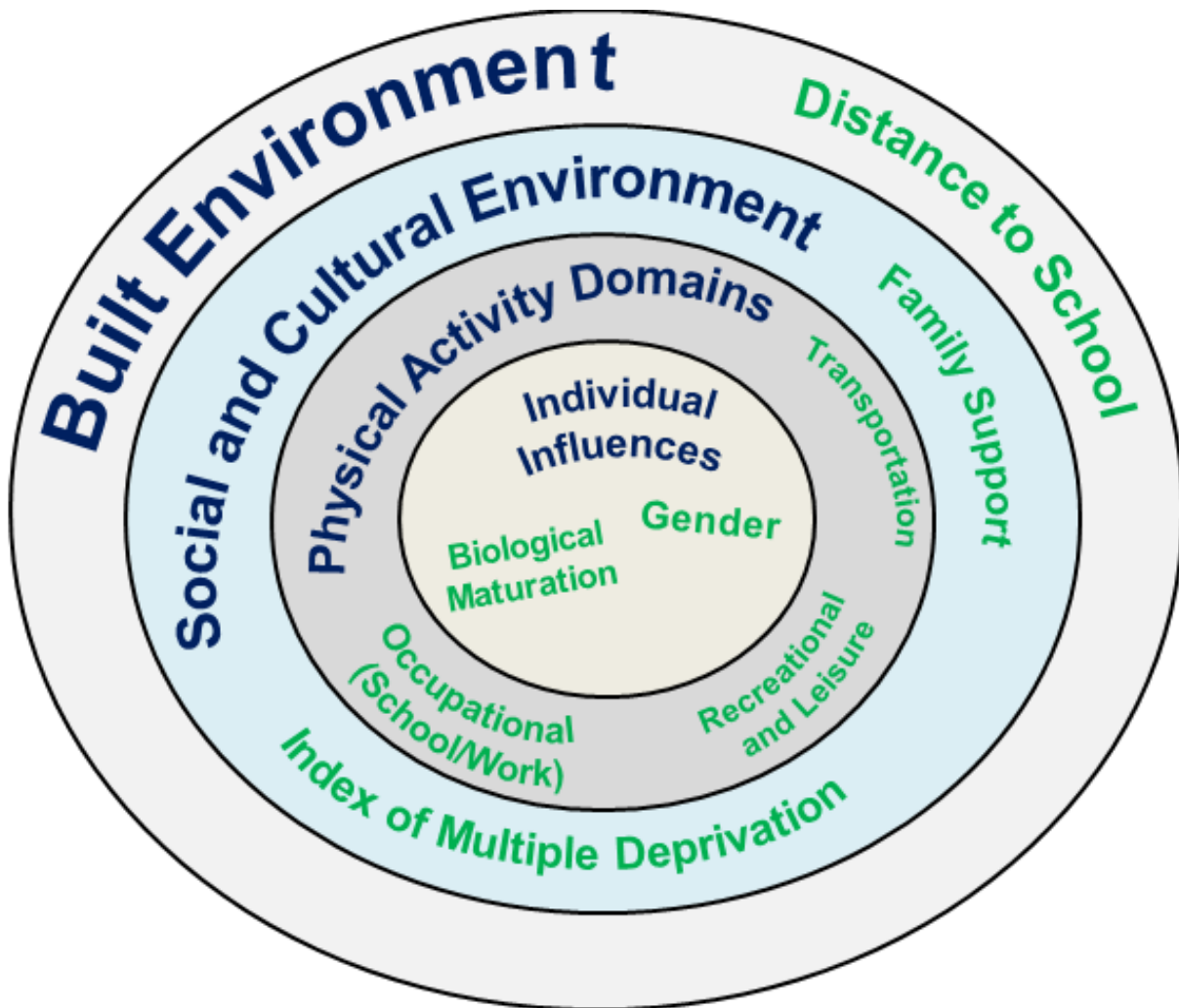


Figure 1.1. The ecological model of Physical Activity for the present thesis, adapted from Sallis et al. (2012).

Individual Influences

Gender

Girls are commonly found to be less physically active than their male counterparts (Sallis et al., 2000; Bailey, Wellard, & Dismore, 2004; Hallal, Andersen, Bull, Guthold, Haskell, & Ekelund, 2012). Reasons for this have been attributed to lesser enjoyment of physical education (Cairney, Kwan, Veldhuizen, Hay, Bray, & Faught, 2012), smaller participation levels across organised sport (Vella, Cliff, & Okely, 2014), less social support to engage in PA (Edwardson, Gorely, Pearson, & Atkin, 2013) and increased maturity (Wickel, Eisenmann, Welk, 2009; Craggs, Corder, Van Sluijs, & Griffin, 2011).

Biological Maturation

Biological maturation is the process each individual experiences whilst developing to a state of maturity or adulthood and describes how biologically developed a child is. Biological maturity can be measured in terms of tempo and/or timing (Malina, Bouchard, & Bar-Or, 2004). Tempo refers to the speed at which the maturation process occurs and timing refers to the time of when certain maturity-related events occur (e.g., ages at menarche or age at peak height velocity) (Malina et al., 2004). Older children and adolescents of the same chronological age can vary substantially in their biological age (up to 5 years), with particular individuals or groups maturing much earlier or later than others (Malina et al., 2004; Sherar et al., 2010; Cumming et al., 2012a). Girls, for example, on average, enter puberty two years earlier than boys (Malina et al., 2004).

Physical and Cognitive development of Children

Typically, early adolescents are in the pre-pubertal stage when large physical changes start to occur (Stang & Story, 2005). Pre-puberty, puberty and the advancement of biological maturation characteristically impacts upon PA negatively (Bacil et al., 2015). From a cognitive perspective, the formal operational stage begins approximately at age 11 years which suggests children are able to think more independently and abstractly (Inhelder & Piaget, 1958), and correspondingly drive for increased autonomy (Eccles, 1999). During this stage the prefrontal cortex is still developing (full development is not until around the age of 25; Walsh, 2004), which is believed to aid the growth of higher cognitive abilities such as decision making (Casey, Thomas, Davidson, Kunz, & Franzen, 2002; Hare & Casey, 2005). With increased independent, autonomous thinking and brain development, early adolescents have further control over their own behaviours and the decisions they can make for themselves. With these biological and cognitive developments in mind, early adolescents (aged 11-13 years) should be a primary focus for PA research work.

Biological Maturation and Physical Activity

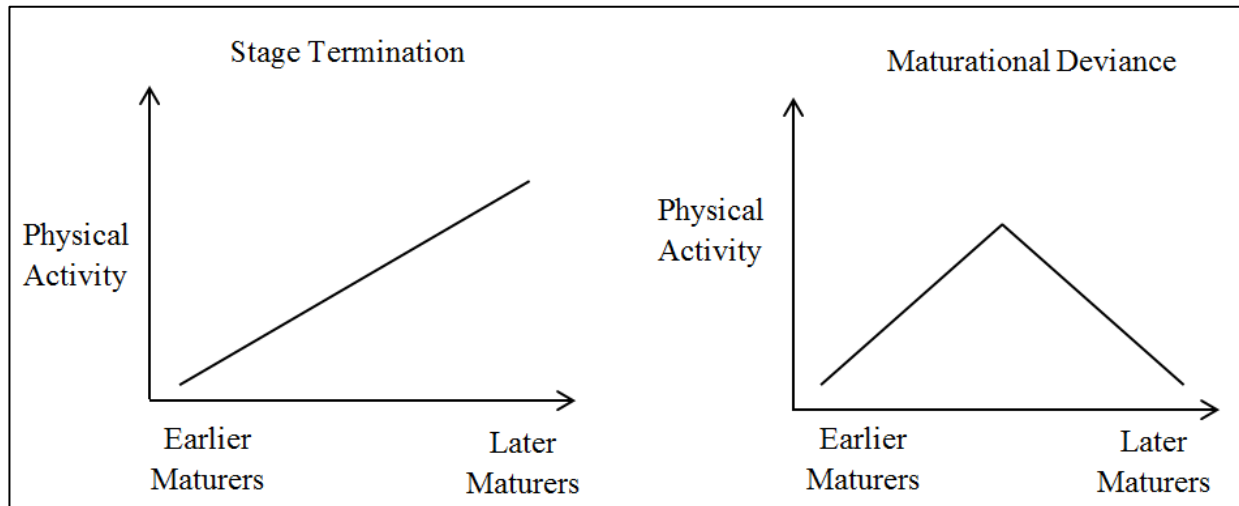
A body of literature is emerging to suggest that PA may have a biological basis (Eisenmann & Wickel, 2009; Rowland, 1998; Thorburn & Proietto, 2000). An argument for an inherent control centre, or activity regulatory centre, was recognised which controls the amount of PA an individual performs (Rowland, 1998). This concept was related to energy homeostasis or a relatively stable equilibrium, and coined the term “activity stat” (Rowland, 1998). Activity stat is a term that suggests homeostasis requires a particular monitoring of

energy-in versus energy-out to maintain balance and prevent depletion of energy stores (Rowland, 1998).

There are key theories and mechanisms that underpin the association between biological maturity and health behaviours that can be applied to PA. In regards to theories, across the timing of biological maturity and health behaviours; two hypotheses have been offered; the stage termination hypothesis (Petersen & Taylor, 1980) and the maturational deviance hypothesis (Alsaker, 1995). The stage termination hypothesis suggests that adolescents classed as ‘early maturing’ are at risk for the acceptance of unhealthy behaviours, such as substance abuse and in this case, physical inactivity (Petersen & Taylor, 1980). The theory suggests that early maturers are not sufficiently developed prior to the beginning of puberty and in result may be insufficiently prepared for the new pressures puberty may bring. Early timing of maturity in females and males has been connected with greater levels of depressive symptoms during puberty (Copeland et al., 2010; Mendle, Harden, Brooks-Gunn, & Graber, 2010). Specifically, during puberty females are physically maturing into young women and are at a higher risk of early sexual behaviour (Graber, 2013). For both genders, particularly boys, early maturation demonstrates a risk factor for substance abuse (Kaltiala-Heino, Koivisto, Marttunen, & Fröjd, 2011; Graber, 2013). For both genders, early developing adolescents may experience enhanced difficulties as the physical changes displayed may cause other individuals (their peers, parents, teachers) to view them as older and more socially and cognitively advanced than they are (Graber, 2013; Weir, 2016).

The maturational deviance hypothesis opposes the stage termination hypothesis and proposes that any adolescent that deviates from the relative average maturity status (i.e., earlier or later maturing adolescents) is at risk of negative health behaviours (Alsaker, 1995). Evidence suggests that as well as early maturing girls, later maturing males have been associated with negative risk factors such as depression, substance abuse and disruptive behaviour disorders (Andersson and Magnusson, 1990; Kaltiala-Heino, Kosunen, & Rimpela, 2003; Graber, Seeley, Brooks-Gunn, & Lewinsohn, 2004; Conley & Rudolph, 2009). In contrast, late maturation within girls has been found positive for academic achievement rather than mental health (Graber et al., 2004; 2013). Figure 1.2 below illustrates both these hypotheses in terms of PA behaviour.

Figure 1.2. The stage termination and maturation deviance hypotheses in relation to PA behaviour.



Additional conceptual models include the ‘Mediated Effects Model of Psychological and Behavioural Adaptation to Puberty’ (Petersen & Taylor, 1980) and the ‘Framework for Understanding Adolescent Development and Adjustment’ (Holmbeck, 2002). The former examines the relationship between biological maturation and PA among adolescents, and suggests this relationship is mediated by physical self-concept; which are the emotions and beliefs that an individual has toward their physical self (Hunter-Smart et al., 2012). The latter model acknowledges the impact of individual differences and environmental factors on biological maturation (Holmbeck, 2002; Cumming et al., 2012b). The model suggests that the maturity status of an individual may directly and/or indirectly effect that individual’s psycho-behavioural development during adolescence (Holmbeck, 2002; Cumming et al., 2012b).

Plentiful research has demonstrated that PA decreases with an increase in biological age, even after controlling for chronological age (Cumming, Standage, Gillison, & Malina, 2008; Hunter-Smart et al., 2012; Bacil et al., 2015). Furthermore, evidence suggests that the well observed gender difference in PA (i.e. boys on average are more active than girls (Sallis et al., 2000; Bailey et al., 2004; Hallal et al., 2012) may be largely explained by the aforementioned gender difference in entering puberty (girls on average entering into puberty approximately 2 years before boys) (Cumming et al., 2008; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007; Bacil et al., 2015). This evidence further implicates biological maturity as a reason for adolescents’ disengagement from PA and would suggest that early/advanced maturing boys and girls at a given chronological age are at heightened risk for disengagement

from PA. However, the evidence around maturity timing and PA is mixed (Sherar et al, 2010; Bacil et al., 2015). There are several possible reasons for these equivocal findings. The relationship between PA and biological maturation has been said to be within a wider context, across an ecological perspective and various factors have differing impacts on PA behaviour. The influence that social, psychological and physical changes have on the associations of advanced maturation, rather than advanced maturation itself, may contribute to this difference in PA behaviour (Cumming et al., 2008; Eisenmann & Wickel, 2009). The investigation between biological maturity and PA in the past has been too one-dimensional with limited consideration of interaction, mediator and/or moderator effects (Sherar et al., 2010). Thus, it has been advocated that forthcoming multidisciplinary research ought to be encouraged to provide a better understanding of the biological basis of PA during early adolescent years (Eisenmann & Wickel, 2009). A biocultural model of PA has been proposed (Cumming et al., 2012b) which examines maturity-associated variance in adolescent PA and emphasises the understanding of the “biocultural” development of the child and its influence on PA behaviour (Eisenmann & Wickel, 2009). The model identifies the potential for both direct and indirect effects between biological maturity and PA; as well moderating factors (Cumming et al., 2012b).

The inconsistent findings between biological maturation and PA could also derive from the techniques used to measure biological maturity (Sherar et al., 2010). The gold standard technique to assess biological maturation is the use of x-rays to assess skeletal age. Other commonly used techniques include self-reported or physician assessed secondary sex characteristics development, menarche status (often recalled) and predicted or actual age at peak height velocity. The techniques chosen vary across research and are dependent on the study design, resources available and study population (Baxter-Jones & Sherar, 2007).

Biological Maturation Measurement

A skeletal age assessment, as mentioned, involves an x-ray to determine bone age and is considered the gold standard assessment of biological maturity (Malina, Bouchard, & Bar-Or, 2004). A radiograph of the hand and wrist and, less commonly, the knee is typically taken (Baxter-Jones & Sherar, 2007). All children at birth start with a skeleton of cartilage which continues to develop through childhood and adolescence into a full skeleton of bone. More advanced bone development and less cartilage indicates advanced biological maturity (Baxter-Jones & Sherar, 2007). Although this technique is the only method to span across the entire period from birth to full maturity (Baxter-Jones & Sherar, 2007) it is not always

feasible for field research. This assessment is expensive, requires specialist equipment and training, and raises ethical and recruitment issues around exposing children and adolescents to repeated radiation (Baxter-Jones & Sherar, 2007).

The assessment of secondary sex characteristics is a method of observing the development during the pubertal period. The range of sexual maturation between individuals of the same chronological age is large and especially emphasised around the adolescent growth spurt (Marshall & Tanner, 1969; 1970). The secondary sex characteristics typically measured are pubic hair development in both genders; breast development in females and penis and testes development in males (Baxter-Jones & Sherar, 2007). By tradition these characteristics were measured via direct observation which is deemed appropriate across clinical settings but not across non-clinical settings (Baxter-Jones & Sherar, 2007). Asking children and adolescents to rate their own sexual maturity using standardised photos and/or drawings also has ethical and privacy concerns, and can cause embarrassment. This method also has issues around social desirability and an over or under estimation of the stages of secondary sex characteristics (Baxter-Jones & Sherar, 2007).

A frequently reported biological development and measure of maturity across female adolescence is age at menarche (the age at first menstrual period) (Baxter-Jones & Sherar, 2007). Establishing age at menarche can be determined prospectively (at a time menarche is likely to occur). This method is best done longitudinally so the researcher can follow a female from before menarche to when it occurs (Malina, Rogol, Cumming, Coelho-e-Silva, & Figueiredo, 2015). A relative age at menarche can also be examined using the mean and standard deviation of a sample to conclude an early, on-time or late status. However using relative, mean ages at menarche can be biased as not all individuals would have reached menarche yet (Baxter-Jones & Sherar, 2007). Recall can be used also at a time menarche has occurred for the majority of females, typically around age 17, although this method is subject to recall error and accuracy (Baxter-Jones & Sherar, 2007). A major limitation to this method is that there is no corresponding maturity indicator in males and it is narrowed to later adolescence (Baxter-Jones & Sherar, 2007).

Peak height velocity (PHV) is the time period in which an individual experiences their maximum upward growth in stature; this typically occurs during adolescence. Age at peak height velocity (APHV) is the most commonly used indicator of maturity in longitudinal studies with adolescents (Malina, Bouchard, & Bar-Or, 2004). To predict APHV and estimate when an individual will reach PHV, a maturity offset (years from PHV) calculation can be

used. To predict APHV the following variables are required: gender, date of birth, height, sitting height, leg length (height minus sitting height), weight and associated interaction terms (Mirward et al, 2002). Based on APHV individuals can be classified as early, average or late maturers (Baxter-Jones, & Sherar, 2007). Drawbacks to this method include that as it is ultimately a prediction; all predictions have accompanying errors and applications to individuals and require attention (Malina & Kozieł, 2014a; 2014b). Variations in timing and tempo of individual's growth spurts are significant (Malina & Kozieł, 2014a; 2014b). The prediction equation was based on a sample population from a white background; thus when applying the equation to other ethnic groups there is a need for caution as proportions of sitting height and leg length differ (Malina, 2009). In spite of the limitations, this method is validated, non-intrusive, inexpensive, easier to administer and is gender specific (Baxter-Jones & Sherar, 2007), thus an appropriate measure for non-clinical populations and field research.

Interpersonal and Social Influences

To extend the use of the ecological perspective within this thesis the examination of interpersonal and social influences was undertaken as a subsequent layer. In this thesis, the index of multiple deprivation and family support of PA represent these layers. Social inequality exists across health behaviours. Those from more deprived backgrounds tend to adopt unhealthier behaviours, such as physical inactivity when compared to those from higher socioeconomic groups (Woodward, Oliphant, Lowe, & Tunstall-Pedoe, 2003; Hanson & Chen, 2007, Pampel, Krueger, & Denney, 2010). Consequently adolescents from more deprived backgrounds tend to display lower levels of PA (Hanson & Chen, 2007). Reasons for this have been attributed to adolescents from more deprived backgrounds living in urban, unsafe neighbourhoods (Bennett et al., 2007) compelling parents to contain their children indoors and not allow their children to use active transport (Timperio, Crawford, Telford, & Salmon, 2004). These types of environments also have a lack of green spaces in which to be physically active (Estabrooks, Lee, & Gyurcsik, 2003; Weir, Etelson, & Brand, 2006). Furthermore, early adolescents from more deprived households may spend their after-school time within part-time employment to earn spending money or contribute to their family's income; whereas those from less deprived backgrounds can use their time to take further advantage of extra-curricular physical activities within, but not exclusive to, the school environment (Van Matre, Valentine, & Cooper, 2000; Bélanger et al., 2011). Adolescents from households with a higher annual income are more likely to be involved in organised

club sports, which can provide additional opportunities to be active (Kantomaa, Tammelin, Näyhä, & Taanila, 2007; Vandermeersch, Vos, & Scheerder, 2015). Explanations for this have been credited to the cost of organised sports clubs (registration, equipment, clothing, travel) (Mitchell et al., 2012; Eime, Charity, Harvey, & Payne, 2015) and time constraints for parents to take children to activities, especially those with busy work schedules and/or single parents (Mitchell et al., 2012). Despite the above literature, the mechanisms behind the association between deprivation and PA are multifaceted and inconsistent as measures for both variables can complicate explanations and interpretations of the findings (Stalsberg & Pedersen, 2010). In a systematic review, forty-two percent of the included studies reported an atypical relationship (those with a higher socioeconomic status produced less PA) or no relationship between PA and socioeconomic status (Stalsberg & Pedersen, 2010). These mixed findings reinforce that relationships between PA behaviour and correlates are complex.

Regardless of spending a large amount of time at school, early adolescents accumulate more PA outside of the school environment (Loucaides, Chedzoy, & Bennett, 2003; Alderman, Benham-Deal, Beighle, Erwin, & Olson, 2012). Therefore, a central interpersonal guidance on adolescence PA behaviour is the individual's family. Based on the social cognitive theory (Bandura, 1986), to engrain and sustain positive health behaviours, a supportive environment is essential and learning is directly associated with the observation of models. This modelling can include the observation of family members' attitudes towards and their practice of PA. Family support of PA has consistently been associated with child PA and there is strong evidence that family support is both a positive correlate and determinant for PA behaviour (Trost & Loprinz, 2011; Morrissey, Janz, Letuchy, Francis, & Levy, 2015). A review of 71 studies suggests that parents can enhance their child's PA behaviour through numerous mediums which include; actively playing with their child, watching them perform PA, encouraging the uptake of PA programmes, providing transportation to PA related facilities, reinforcing PA participation, and teaching them how to play active games and sports (Trost & Loprinz, 2011). With this in mind it is unknown if families are providing less support as adolescents mature, or if adolescents are placing less value on support as they mature (Morrissey, Janz, Letuchy, Francis, & Levy, 2015).

Built Environment Influences

To additionally explore context and work towards an ecological perspective, environmental correlates are valuable to investigate. As early adolescents spend a large proportion of their time in school (Oberle, Schonert-Reichl, & Zumbo, 2011), the distance to

school from a child's main home will be explored within this thesis. A large distance to school can act as a potential barrier to children's likelihood to actively commute to school (Davison, Werder, & Lawson, 2008; Panter, Jones, & Van Sluijs, 2008; Pont, Ziviani, Wadley, Bennett, & Abbott, 2009). Actively commuting to school is a significant facet of PA behaviour and can provide convenient and meaningful contributions to overall PA levels and energy expenditure (Aibar et al., 2015; Slingerland et al., 2012). Distance to school from home is arguably the most important influence on the decision to use active transport (Oliver et al., 2014; Van Kann, Kremers, de Vries, de Vries, & Jansen, 2015). A large distance to school and a maximum threshold for an acceptable distance to actively commute to school has been suggested previously for 11 year olds as 5miles (8km) (Van Sluijs et al., 2009).

Summary

The main gaps concluded from the evidence above are that the relationship between biological maturation and PA, and the relationship between deprivation and PA ought to be observed alongside a wider context, exploring moderating factors. The first study of this thesis investigates whether the variables discussed above (gender, biological maturation, family support of PA and multiple deprivation) moderate the relationship between distance to school and the likelihood to use active transport. A moderation effect occurs when the relationship between two variables (distance to school and likelihood to actively travel) depends on a third variable (e.g., biological maturation). The examination of moderation effects within this first study provides a more complete analysis as disregarding the potential moderation effects may lead to oversimplified conclusions (Gubbels, Van Kann, de Vries, Thijs, & Kremers, 2014). For example, solely examining how the likelihood of actively commuting to school is affected by biological maturation may not reveal any significant results. However, the relationship between the likelihood of actively commuting to school and biological maturation may be moderated by distance to school. This first study is cross-sectional utilising UK early adolescents from secondary schools.

Conclusions from the first study displayed evidence of complexity among these variables; which led to move away from a variable-oriented approach and towards a person-oriented approach for the second study of this thesis. Utilising a person-oriented approach enables an examination of variables collectively and focuses on individuals rather than variables. This approach allowed for the identification of homogeneous groups of individuals who share similar characteristics. In addition, the second study expands the outcome focus to include overall PA, as well as active transport, to gain a greater insight into PA behaviour.

Although the use of active transport can significantly contribute to increasing PA levels and energy expenditure (Aibar, et al., 2015; Slingerland, Borghouts, & Hesselink, 2012), active travel is a specific form of PA that has distinct antecedents and individuals who engage in active transport may not engage within PA and vice versa (Carver, Timperio, Hesketh, Ridgers, Salmon, & Crawford, 2011; Jorgensen, 2012). This study uses the same variables as study one to act as predictors to classify distinct profiles of early adolescents, the study then investigates if PA behaviour was distinguishable across those distinct profiles. This second study also introduces an additional time point, time point 3 (12-18 months after baseline).

Across the first and second studies, there was mixed evidence for whether biological maturation has a role to play in the prediction of early adolescent PA behaviour. Therefore, the third study within this thesis investigates differences in biological maturation and gender and how these variables can predict subsequent PA levels. This study again has a longitudinal element and introduces an additional time point, time point 2 (6-9 months after baseline), as well as examining time point 3. The final chapter then expands the conceptualisation of PA behaviour to investigate school-time PA and leisure-time PA. The final study fully utilises the longitudinal data collected across the 18 month period using the same participant sample for baseline, time point 2 and 3. This thesis will aim to work towards gaining a more comprehensive understanding of how PA related variables across aspects of the ecological model can affect individuals and their PA behaviour throughout early adolescence. The data used within this thesis derived from a longitudinal project across 18 months involving three separate time points.

Chapter 2

General Methodology

The data collection within this thesis was approved by the Loughborough University ethics approvals (human participants) sub-committee following the submission of a research proposal and ethics checklist (Ref No: R13-P203) (see appendix 1).

School Recruitment

Twenty four secondary schools across the East Midlands, England, UK, were invited to participate in the study. Schools were selected on geographical proximity from the university. Each school was emailed initially with an invitation letter to participate using the email address provided on each school's website (see appendix 2) for the attention of the head of Physical Education (P.E) at the school. If schools did not respond via email they were followed up with phone calls a week after receiving the initial email and letter. Follow up phone calls continued until each school had provided a yes or no answer to participating within the research. Twelve schools did not respond to the initial invitation; however, these were not followed up by the lead investigator due to a satisfactory number of schools and children recruited into the research project. Five schools declined the invitation because a) they were already involved in a number of initiatives with the university, b) they did not have enough capacity or time; or c) the relevant department was going through a period of transition. One school did not provide any reason for declining to participate. Seven schools across three local authorities agreed to participate. Each school provided written informed consent which was obtained from the head teacher of each school. All children within each school in Year 7 (aged 11 - 12 years) were eligible to participate. All parents/guardians of eligible children were then supplied with an information letter and opt-out form (see appendix 3). If parents/guardians returned a signed opt-out form to the school, their child was prohibited from attending the data collection sessions. This process was facilitated by the class teacher and data on the number of parents/guardians who withheld their child from data collection was kept internally at the school. Primary school children within year 6 in the UK are aged 10-11 years, however these children were excluded and secondary schools were recruited solely due to the longitudinal element of the thesis.

School Characteristics

The schools that did participate fully into the research project varied in characteristics, five schools were state-funded schools and two were independent, fee-paying private schools. Tables 2.1, 2.2 and 2.3 below describe the Ofsted classification, rural-urban classification and

multiple deprivation indices for the schools who participated within the research, those who did not agree to partake and those who did not respond to the request. The Office for Standards in Education, Children's Services and Skills (Ofsted) is a department of the UK government responsible for inspecting a range of educational institutions, including state schools and some independent schools. The 2011 rural-urban classification of local authority districts and other higher level geographies was used, full descriptions of each classification, data and references are found within appendix 4. The Indices of Deprivation 2015 was used to gather information on school deprivation.

Table 2.1. School characteristics (Ofsted classification, rural-urban classification and multiple deprivation index) for schools who participated within the research.

School	Ofsted Grade as of January 2014	Deprivation	Local Authority and the Rural-Urban Classification
A	Good	Amongst the lowest 10% of most deprived areas in the country.	Urban with City and Town
B	Good	Amongst the lowest 30% most deprived areas in the country.	Largely Rural (rural including hub towns 50-79%)
C	Good	Amongst the lowest 30% most deprived areas in the country.	Urban with City and Town
D	Requires Improvement	Amongst the highest 50% least deprived areas in the country.	Largely Rural (rural including hub towns 50-79%)
E	Requires Improvement	Amongst the highest 30% least deprived areas in the country.	Urban with City and Town
F	Independent School - Exempt from Ofsted	Amongst the lowest 30% most deprived areas.	Urban with City and Town
G	Independent School - Exempt from Ofsted	Amongst the lowest 30% most deprived areas in the country.	Urban with City and Town

Table 2.2. School characteristics (Ofsted classification, rural-urban classification and multiple deprivation index) for schools who did not agree to participate within the research.

School	Ofsted Grade as of January 2014	Deprivation	Local Authority and the Rural-Urban Classification
H	Good	Amongst the lowest 40% most deprived areas in the country.	Urban with City and Town
I	Good	Amongst the highest 40% least deprived areas in the country.	Largely Rural (rural including hub towns 50-79%)
J	Requires Improvement	Amongst the highest 30% least deprived areas in the country.	Urban with City and Town
K	Good	Amongst the highest 10% least deprived areas in the country.	Urban with City and Town
L	Good	Amongst the lowest 20% most deprived areas in the country.	Urban with City and Town

Table 2.3. School characteristics (Ofsted classification, rural-urban classification and multiple deprivation index) for schools who did not respond to the request for research.

School	Ofsted Grade as of January 2014	Deprivation	Local Authority and the Rural-Urban Classification
M	Good	Amongst the highest 10% least deprived neighbourhoods in the country.	Urban with City and Town
N	Good	Amongst the highest 10% least deprived neighbourhoods in the country.	Urban with City and Town
O	Requires Improvement	Amongst the highest 30% least deprived neighbourhoods in the country.	Urban with City and Town
P	Outstanding	Amongst the lowest 40% most deprived neighbourhoods in the country.	Urban with City and Town

Q	Good	Amongst the lowest 40% most deprived neighbourhoods in the country.	Urban with City and Town
R	Requires Improvement	Amongst the highest 30% least deprived neighbourhoods in the country.	Urban with City and Town
S	Good	Amongst the 40% most deprived neighbourhoods in the country.	Urban with City and Town
T	Outstanding	Amongst the 50% most deprived neighbourhoods in the country.	Urban with City and Town
U	Requires improvement	Amongst the lowest 40% most deprived neighbourhoods in the country	Urban with City and Town
V	Good	Amongst the 40% most deprived neighbourhoods in the country.	Urban with City and Town
W	Good	Amongst the 10% most deprived neighbourhoods in the country.	Urban with City and Town
X	Outstanding	Amongst the 10% most deprived neighbourhoods in the country.	Urban with City and Town

Data Collection Process, Time Scale, Volunteer Recruitment and Training

Data collection sessions were conducted within school hours; primarily during timetabled P.E. classes in a classroom, sports hall or gym facility. Dates were arranged via email and telephone calls directly with each school's head of the P.E. department. Table 2.4 below displays the timescale of each data collection with each school. Each session targeted one class ranging from 14 – 36 children. Typically children wore their P.E. kit during data collection comprising a light polo top/t-shirt and shorts/tracksuit and removed their shoes for all measurements. Those who did not have their P.E. kit available were in school uniform, again a polo top/school shirt and light trousers/skirts.

In order to complete data collection effectively and efficiently, undergraduate and postgraduate university students were recruited as volunteers to assist in the project. To ensure standardised measurements, training for volunteers was mandatory and took place within a university room on campus and was delivered by the lead investigator. Correct

procedures to measure a child's stretch stature, stretch sitting height and weight, along with questionnaire training was received by each volunteer (measurement procedures are explained below). During each data collection session volunteers were also provided with guidance sheets (appendices 5-8) and training was recapped for the various measurement stations they were situated on. Typically for each session three volunteers accompanied the lead investigator, although some sessions had only two.

The lead investigator introduced the session to participants. Confidentiality of the data was explained, the children were reminded that there were no right or wrong answers and they had the right to withdraw from the research at any given time with no further explanation required. Every session was divided into three main 'stations' that each child was to complete. The first station involved participants completing the questionnaire, which took approximately 30-40 minutes to complete. This station was completed by the child alone in exam type conditions, which was monitored by the teacher, the lead investigator and the volunteers. If the child required assistance to comprehend or read aspects of the questionnaire they were told to raise their hand. Once a child had finished their questionnaire this was checked by the lead investigator and/or a volunteer. If the child had no incomplete sections of the questionnaire they were asked to wait and sit quietly. If any sections were incomplete the child was asked to complete those sections unless left incomplete intentionally by the child.

During the completion of the questionnaire each child was called separately to complete the other two stations; 2) height/sitting height and 3) weight. These were also run by the lead investigator or a volunteer. The physical measurements were taken in a separate room with the door open or a segregated area of the sports hall. Information on these measurement procedures are explained below. During some of the data collection sessions a fourth station was included which involved the provision of accelerometers. Similar to stations two and three, the child was called out by the lead investigator and/or a volunteer. They were then given an accelerometer (if verbally consented) to start wearing immediately. An information letter for themselves and their parents/guardians (see appendix 9), and verbal instructions on how to wear an accelerometer were provided.

Normally two volunteers were assigned onto the questionnaire station (1), one was assigned onto the weight station (3) and typically the lead investigator was situated on the height/sitting height station (2). In sessions where two volunteers were available, two volunteers were assigned onto the questionnaire station (1) and the weight and height/sitting height stations (2 & 3) were combined for the lead investigator to supervise. During sessions

where accelerometers were required, the lead investigator facilitated that process whilst assisting on the questionnaire station at the same time, an experienced volunteer ran the height/sitting height station and a further volunteer completed the weight station. If any station was completed before any of the others, that volunteer assisted where required.

Participants

Data included within study 1 (chapter 3) were from the baseline (first visit) data collection whereas study 2 (chapter 4) used data from baseline and time point 3 (last visit) and study 3 and study 4 (chapters 5 and 6) used data from baseline; time point 2 (second visit) and time point 3 (last visit). Further participants were included for time points 2 and 3 due to school trips and absences during baseline. Table 2.5 below demonstrates participant demographics, data time point and measures according to each study.

Table 2.4. Data collection timescale of school visits

Year	2014												2015					
Month	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	April	May	June
School A				X	X						O						Δ	
School B				X	X					O							Δ	
School C	X									O							Δ	
School D				X							O							Δ
School E	X	X	X								O	O						Δ
School F		X										O					Δ	
School G	X										O						Δ	

X – First Visit (Baseline) O – Second Visit (Time point 2) Δ – Last Visit (Time point 3)

Table 2.5. Participant and measures breakdown of each study.

Study	Participants	Baseline	Age (Years)	Time point 2	Age (Years)	Time point 3	Age (Years)
		Measures		Measures		Measures	
1	619 children Females, N = 334, 53.96% White, N = 498, 80.7% Asian, N = 94, 15.2% Black, N = 17, 2.8% Other, N = 8, 1.3%	Active Travel Biological Maturation Multiple Deprivation Family Support of PA Distance from Home to School	12.35 ± 0.29				
2	705 children Females, N = 387, 54.89%	Active travel Biological Maturation Multiple Deprivation Family Support of PA Distance from Home to School Self-report PA Accelerometer MVPA	12.35 ± 0.30			Self-report PA Accelerometer MVPA	13.4 ± 0.30
3	White, N = 569, 80.7% Asian, N = 108, 15.3% Black, N = 19, 2.7% Other, N = 9, 1.3%	Biological Maturation Self-report PA Accelerometer MVPA	12.35 ± 0.30	Self-report PA Accelerometer MVPA	12.85 ± 0.30	Self-report PA Accelerometer MVPA	13.4 ± 0.30
4		Biological Maturation Multiple Deprivation Family Support of PA School-time PA Leisure-time PA	12.35 ± 0.30	Family Support of PA School-time PA Leisure-time PA	12.85 ± 0.30	Family Support of PA School-time PA Leisure-time PA	13.4 ± 0.30

Measures

PA

Self-Report. PA was self-reported by participants using the PA Questionnaire for Older Children (PAQ-C) (Kowalski, Crocker, & Donen, 2004) (see appendix 10). The PAQ-C has been advocated to be appropriate for school-aged children (aged 8-14 years) who are currently in the school system and have recess or ‘break time’ as a regular part of their school week (Kowalski, Crocker, & Donen, 2004). This 7-day recall questionnaire measures general moderate-to-vigorous PA (MVPA). The PAQ-C has been shown to be valid measure of PA levels across early adolescence and has been used within similar samples to that of this thesis (Janz, Lutuchy, Wenthe, & Levy, 2008; Biddle, Gorely, Pearson, & Bull, 2011). However, limitations of self-report questionnaires to assess PA have to be acknowledged, such as social desirability bias leading to over-reporting of PA (Aggio et al., 2016) and the cognitive complexity of recalling PA (Baranowski, 1988), especially for children. Some specific limitations of the PAQ-C also exist. The PAQ-C was developed to measure general levels of PA, thus does not provide an estimate of caloric expenditure or specific frequency, time, and intensity information (Kowalski et al. 2004). Similarly, the PAQ-C provides a summary mean PA score which does not distinguish between specific intensities, unlike the Global Physical Activity Questionnaire and other PA questionnaires (Kowalski et al. 2004). On the other hand, self-report is inexpensive, relatively easy to administer to a large population and has a low participant burden (Dugdill & Stratton, 2007). The PAQ-C has been found to have moderate reliability and consistently high validity against a variety of direct measures of PA (Bervoets et al., 2014; Zaki et al., 2016); and has been deemed the best choice for collecting data in European nations by an expert group (Biddle et al., 2011). Additionally the PAQ-C is appropriate for individuals in the school system, during the school year; (Kowalski et al. 2004), thus suitable for the participants within this thesis.

Accelerometry. Accelerometers are monitors that objectively measure the frequency, intensity, and duration of PA (Freedson & Miller, 2000). Accelerometers consist of piezoelectric transmitters that are stressed by accelerative forces which lead to create an electrical signal that is converted by processing units to produce an indication of movement (Chen & Bassett, 2005; Welk, 2002). Actigraph™ GTM1 monitors were used within this thesis and these monitors measure acceleration between the magnitudes of 0.05 and two times the force of gravity (Gemmell, 2008). This accelerometer is specifically designed and programmed to detect normal human motion and reject motion from other sources

(Actigraph, 2007). The GT1M Actigraph is a small and lightweight (3.8 x 3.7 x 1.8 cm, 27g uniaxial accelerometer (Actigraph, 2007). For the purposes of the thesis, the accelerometers were programmed to record activity counts in 5-second epochs as previously recommended (McClain, 2007; McClain, Abraham, Brusseau, & Tudor-Locke, 2008) and to not obscure short bursts of vigorous PA and underestimate high intensity PA (Nilsson, Ekelund, Yngve, & Sjöström, 2002). Participants were asked to wear the monitor from first thing in the morning, when they woke, until they went to sleep at night for eight consecutive days (to capture 7 full days, including 2 weekend days), and only to be removed during water activities (i.e., showering, swimming). Each participant was provided with an information letter for themselves and to give to their parents/guardians (see appendix 9). ActiLife lite software was used to download data immediately upon retrieval of each accelerometer. The downloading process produced an AGD file. AGD files were processed using custom made data reduction software (KineSoft, Loughborough, UK, version 3.3.76) and batch reports were produced. Kinesoft is an accelerometer data reduction software package, which interprets and translates raw data to information that can be used for graphing, file inspection, manipulation and reporting. Non wear was considered as 60 minutes of consecutive zeros, allowing for 2 minutes of non-zero interruptions (Troiano, et al., 2008). A valid day criterion was set to at least 8 hours of valid wear time per day. The criterion has been used previously in this age group (Kolle et al., 2009; Anderson et al., 2017) and was chosen to maximise the data available. Previous research has advocated that five or more valid days are required to achieve strong reliability levels (Troost, Pate, Freedson, Sallis, & Taylor, 2000). However, as little as one day as a minimum criterion has been used (Troiano, et al., 2008; Webber et al., 2008; Treuth et al., 2009). To maximise the sample available in this thesis, files were retained if a participant had at least two valid days of data; previous researchers have employed this method (Keadle, Shiroma, Freedson, & Lee, 2014; Lima et al., 2014). Cut points are utilised to translate accelerometer counts into PA intensity categories. Trost, Loprinzi, Moore and Pfeiffer (2011) aimed to evaluate the classification accuracy of five sets of cut points; 1) Evenson et al. (2008); 2) Freedson et al. (2005); 3) Puyau et al. (2002); 4) Treuth et al. (2004); and 5) Mattocks et al. (2007); see table 2.6. The results by Trost and colleagues (2011) demonstrated that the Evenson et al. (2008) and Freedson et al (2005) cut points displayed significantly better classification accuracy than the other three examined (Puyau et al., 2002; Treuth et al., 2004; Mattocks et al., 2007). All the examined cut points presented lower classification accuracy for light-intensity PA, except for Evenson et al. (2008). Hence

the Evenson et al. (2008) cut points were used in the present thesis as they were shown to be the optimal choice for sedentary, light, moderate and vigorous intensity and perform well among children of all ages (Trost et al., 2011). Once excel reports were produced from Kinesoft, data was merged into a SPSS data set file.

Table 2.6. Cut points by intensity counts per minute.

Cut Points	Counts Per Minute (CPM)			
	Sedentary	Light	Moderate	Vigorous
1) Evenson et al. (2008)	0 – 100	101 – 2295	2296 – 4011	4012 +
2) Freedson et al. (2005)	0 – 149	150 – 499	500 – 3999	4000 +
3) Puyau et al. (2002)	0 – 799	800 – 3199	3200 – 8199	8200 +
4) Treuth et al. (2004)	0 – 99	100 – 2999	3000 – 5200	5201 +
5) Mattocks et al. (2007)	0 – 100	101 – 3580	3581 – 6129	6130 +

Active versus Inactive Travel. Following previous methods used by Van Sluijs and colleagues (2009) participants were asked “How do you get to school?” followed by eight responses: (a) Walk all the way (b) Walk part of the way (c) Public bus (d) School bus (e) Car/taxi (f) Bicycle (g) Train/metro (h) Skateboard or scooter (see appendix 11). Participants could mark as many responses that were appropriate to them. Children were classified into two groups (i) active travellers (children who walked all the way, or used a bicycle, skateboard, or scooter with no conjunction of an inactive mode of transport), (ii) inactive travellers (all other forms of transport, including those who travelled part-actively). Falconer and colleagues (2015) advocated the conservative classification to group part-active travellers and inactive travellers together as it is likely that the primary mode of transport for a child who reports part-active travel would be inactive (e.g., walking to the bus stop).

Biological Maturation

In this thesis biological age was estimated through predicting age at peak height velocity (APHV). Anthropometric measurements were taken at school for stretch stature, sitting height, and body mass using a portable stadiometer and electronic scales. Two measurements were recorded initially and the average of the nearest two measurements was calculated and recorded for each. A third measurement was taken if variation was more than 0.1 mm/kg. From these measurements, a prediction of years from age at APHV (maturity offset) was

calculated (Mirwald et al., 2002). International Standards for Anthropometric Assessment (ISKA) stretch stature method and sitting height measurement was applied (The International Society for the Advancement of Kinanthropometry, 2001). Heavy outer garments (e.g. jackets/coat) and shoes and socks were removed along with any objects within pockets and heavy jewellery if applicable. In brief, a gender-specific multiple regression equation that included stature, body mass, sitting height, leg length, chronological age, and their interactions was applied (see appendix 12).

There are a variety of anthropometric based methods available to predict biological maturity. Some of these tools are based on the premise of comparing a child's actual height to their estimated adult/final height to predict their biological maturity. The principle is that the closer an individual is to their adult height (in comparison to peers of the same chronological age), the more biologically advanced or mature they are (Malina et al., 2004). Methods include the Bayley-Pinneau method; this technique uses a series of tables that provides the child's predicted percentage of adult height (Bayley & Pinneau, 1952). Tables are displayed according to gender, chronological age, and skeletal age. This method may lead to overestimation of predicted height in those with advanced bone age and underestimation in those with an underdeveloped bone age (Tarimm, 2016). Another height prediction method is the Roche-Wainer-Thissen method, which estimates adult height directly from a linear combination of a child's horizontal length, weight, and bone age, along with mid-parental height by using gender and age-specific equations (Roche, Wainer, & Thissen, 1975). Bone age is measured with an x-ray, or x-rays, which require expensive, specialist equipment and administrators. Last, the Khamis-Roche method is similar to the Roche-Wainer-Thissen technique and calculates adult height prediction directly from a linear combination of child's height and weight, together with mid-parental height but does not require bone age. Mid-parental height is the adjusted mean height of both parents. Typically when these methods are applied, parental heights are self-reported and thus vulnerable to poor recall and social desirability bias (Danubio, Miranda, Vinciguerra, Vecchi, & Rufo, 2008). However, the inclusion of mid-parental height has been shown to reduce error (Susanne, 1975; Bielicki & Welon, 1976) yet heights of both (biological) parents are not always obtainable. The present longitudinal research study did not have the resources to determine skeletal/bone age and/or collect parental height and thus the optimal choice was predicting APHV using the technique developed by Mirward and colleagues (2002) (see appendix 12). The technique from

Mirward and colleagues has been shown to estimate maturity status to within an error of 1.18 years 95% of the time in boys and 1.14 years 95% of the time in girls (Mirwald et al., 2002).

Multiple Deprivation

The index of multiple deprivation (IMD) was calculated throughout the thesis based on the participant's home postcode. This measure has been used previously in PA based research (Pearson, Atkin, Biddle, Gorely, & Edwardson, 2009). It is calculated from a variety of data including average income, employment, health and disability, education, skills and training, housing and services, crime and living environment. The scale ranges from 0 (most deprived) to 9 (least deprived).

Distance from Home to School

Six/seven digit postcodes of the child's home and school were obtained and entered into Google Maps. Using the 'get directions' function, the walking distance between the two postcodes were recorded in kilometres. Google Maps as a GPS mapping resource is a recommended method to measure walking and cycling routes for research (Badland et al., 2010).

Family Support of PA

Adapted from the Amherst Health and Activity study (student survey), questions about children's perceived family support of PA were used (Sallis et al., 2002). The question stem, 'During a typical week how often has a member of your household (for example, your father, mother, brother, sister, grandparent, or other relatives)' was followed by five items (e.g. 'Encouraged you to do physical activities or play sports?'). All items were responded to on a 5-point scale ranging from 1 (none) to 5 (daily) and the option of 'Don't know' was offered and re-recorded as missing data. See appendix 13 for full questionnaire. The survey was designed to be appropriate to all children aged 6 – 17 years and all items have been shown to be reliable (Sallis et al., 2002).

Chapter 3

Evidence of moderation effects in predicting active transport to school

Regular PA reduces risk of disease (Lee et al., 2012), improves mental health (Biddle & Asare, 2011) and extends life expectancy (Wen et al., 2011). Incorporating PA into everyday life is imperative especially for children to promote long-term active lifestyles lasting into adulthood (Telama et al., 2005) and offset the general decline in PA that occurs at approximately 12 years old (Duncan, Duncan, Strycker, & Chaumeton, 2007). However, only 24% of boys and 18% of girls aged 5 – 15 years in the United Kingdom (UK) are meeting guidelines for recommended PA levels (Health Survey for England, 2015). Actively commuting to school (i.e., primarily walking and cycling for the purpose of functional, rather than leisure travel; Saunders, Green, Petticrew, Steinbach, & Roberts, 2013) can provide a convenient and meaningful contribution to increasing PA levels and energy expenditure (Aibar, et al., 2015; Slingerland, Borghouts, & Hesselink, 2012). Further statistics from the Health Survey for England (2012) present that 64% of boys and 67% of girls aged 2 – 15 years walked to or from school on at least one occasion and a mere 6% of boys and 1% of girls cycled to or from school on at least one day in the week before participating within the survey. To increase the number of children actively commuting, understanding the underlying reasons for this behavioural choice are essential (Panter, Jones, & Van Sluijs, 2008).

Distance from home to school is integral to the decision to actively commute to school, specifically the likelihood of utilising inactive transport increases with distance (Dessing, de Vries, Graham, & Pierik, 2014; Chillón et al., 2014). A longitudinal study exploring 31 mostly socio-cultural and environmental factors found that distance to school (< 1km) was primarily associated with maintenance of active travel over a one year period (Panter, Corder, Griffin, Jones, & Van Sluijs, 2013). Very few UK 9 - 10 year old children were observed to actively commute when the distance between home and school was over 2km (Panter, Jones, Van Sluijs, & Griffin, 2011) however a maximum threshold for an acceptable distance to actively commute to school has been suggested previously for 11 year olds as 5miles (8km) (Van Sluijs et al., 2009).

Despite the importance of distance to school, behaviour is guided by multiple levels of influence (Bronfenbrenner, 1977; Sallis, Owen, & Fisher, 2008); at the core of which is individual psycho-biological factors. For example, boys are more likely than girls to actively commute to school (Leslie, Kremer, Toumbourou, & Williams, 2010). Similarly, biological

maturation may also be important when predicting active transport. Adolescents of the same chronological age can vary by up to five years in biological age (Malina, Bouchard, & Bar-Or, 2004). The timing and pace of biological maturation has important consequences for physical, psychological and behavioural development, some of which may impact involvement in PA (Cumming et al., 2012b). For instance, children's maturation status has been investigated with regards to self-reported (Bond et al., 2006) and objectively measured PA with equivocal findings reported (Sherar et al., 2010). Biological maturity has not been previously explored as a predictor of active school transport.

Interpersonal and socio-cultural influences must also be considered. The central interpersonal guidance on children's mode of transport decision is their parents/guardians. Children are more likely to actively commute if their parents did so when they were children and if they currently actively commute to work (Merom, Tudor-Locke, Bauman, & Rissel, 2006). Positive parental attitudes have been shown to be particularly important for children who lived a short distance from school (Panter, Jones, Van Sluijs, & Griffin, 2010). Despite active travel being a specific form of PA, that may have distinct antecedents, children are more likely to actively commute when their parents value the benefits of PA (Ziviani, Scott, & Wadley, 2004). Another socio-cultural influence on the decision to actively commute to school is multiple deprivation. A review of predominantly cross-sectional studies concluded that children from low multiple deprivation areas were more likely to actively commute to school (Davison, Werder, & Lawson, 2008); previous explanations included less access to cars (McDonald, 2008) and living in urban environments closer to schools (Fulton, Shisler, Yore, & Caspersen, 2005).

Despite the above knowledge, a key strength of ecological perspectives has generally been overlooked. With a few exceptions (Panter et al., 2013; Ziviani et al., 2004; Larouche et al., 2014) researchers haven't considered how the multiple levels of influence interact with each other. It is currently unknown whether the association between distance to school and active transport is moderated by the individual, interpersonal, and socio-environmental variables described above. Although many factors may influence the decision to active commute, the aim of the present study is to focus on variables that might intuitively moderate the relationship between distance to school and the likelihood to use active travel to school. Prior to considering these moderating effects it is expected that; boys, children who are biologically more mature, children with a supportive family for PA, children living in socio-economically deprived areas and those who live closer to school will all be more likely to actively commute to school (hypothesis 1). With regard to moderating effects, as the distance

from school increases, the likelihood of boys actively commuting may decrease less rapidly, compared to girls (e.g. because of decreased safety concerns of parents for boys compared to girls (McMillan, Day, Boarnet, Alfonzo, & Anderson, 2006) (hypothesis 2). The same can be said for biologically more mature children, independent of gender and age, in that their parents/guardians are more likely to allow them to actively commute to school independently or with peers, and therefore distance to school will be less impactful (hypothesis 3). Children whose parents encourage and provide support for PA and to actively commute will be less influenced by the distance to school, compared to those who don't receive family support towards PA (hypothesis 4). Finally, distance to school may be less of an important influence on the decision to actively commute in areas of multiple socio-economic deprivation (hypothesis 5). This may be because families in these deprived areas are less likely to own motorised transport and the child has less choice but to actively commute (McDonald, 2008).

Method

Participants

Twenty-four secondary schools across the East Midlands, England, were invited to participate. Seven schools across three local authorities (two independent private schools, five state-funded schools) agreed to participate. Two schools were rural and five schools urban (Rogerson, 2011). Using the 2014 index of multiple deprivation (IMD), which ranks areas from 0 (most deprived) to 9 (least deprived) based on their postcode, the sampled schools ranked 0 ($n = 1$), 2 ($n = 4$), 5 ($n = 1$) and 7 ($n = 1$). The Ofsted grades as of January 2014 awarded three schools 'Good', two school 'Requires Improvement' and the two independent schools were exempt from Ofsted. Within our sample (and across the UK), secondary school pupils who live further than 4.8km away from their nearest school are eligible for free transport (Department for Education, 2014).

Data were collected from 619 11-12 year old children (334 females; $M = 12.35$ years, $SD = 0.29$; ethnicity: White = 80.7%, Asian = 15.4%, Black = 2.7%, other = 1.3%). The study was approved by a university ethics committee and written informed consent was obtained from each schools head teacher, parent/guardians had an opportunity to withdraw their child from the study, and children provided their written assent.

Measures

Full descriptions of the measures used within this study (biological maturation, multiple deprivation, family support for PA, distance from home to school and active versus inactive travel) are found within the general methodology (chapter 2). The Cronbach's Alpha

coefficient for the family support of PA questionnaire in the present study was 0.79. Within the active versus inactive travel measure, a conservative classification was adopted in that those who travelled part of the route to school actively and part inactive were classified as inactive travellers, this was because it is likely that the primary mode of transport for a child who reports part-active travel would be inactive (e.g., walking to the bus stop) (Falconer, Leary, Page, & Cooper, 2015). To further justify this choice, we examined differences between part-active and inactive participants in the study variables. MANOVA and follow up univariate test revealed no significant differences across all the variables except from distance to school ($F(1, 333) = 9.682, p = .002$; part active = 2.9 ± 2.3 km versus inactive = 4.0 ± 3.0 km).

Statistical Analysis

Logistic regressions using SPSS (IBM version 21) were used to test the study hypotheses with active versus inactive travel as the binary coded outcome variable. In the main effects model (hypothesis 1), predictor variables were un-standardised to assist in interpreting odds ratios, however, they were standardised into Z scores (with the exception of the binary coded gender variable) in subsequent models to facilitate interpretation of the interaction terms.

Results

Descriptive statistics

Eight children failed to answer how they travelled to school and were removed from the analysis. Of the remaining 611 participants, 45.3% were classed as inactive travellers, 36% used active transport to school and 18.7% travelled via a combination of active and inactive travel methods (and were therefore classified as inactive). The majority (75.4%) were classified as having a 'normal' BMI according to Cole's BMI cut points (Cole, Flegal, Nicholls, & Jackson, 2007). In terms of the living distances from school, 39.2% lived within 2km, 59.0% lived within 4km, 76.9% lived within 6km and 82.9% lived within 8km. Descriptive statistics of the sample can be seen in table 3.1. Bivariate correlations among constructs are presented in table 3.2 for information only.

Primary analysis

The first logistic regression model (hypothesis 1) included all main effects (distance from school, gender, APHV, family support of PA, and multiple deprivation) as predictors of active versus inactive travel to school. The results can be seen in table 3 and the predictors explained 40.2% of the variance in mode of transport, however, only distance to school was a

significant predictor of active transport, after adjusting for other variables. There were no differences in relationships across gender (i.e., no gender \times predictor interactions).

Table 3.1. Descriptive statistics of study variables and relevant child characteristics

	All Children (<i>n</i> = 611)		Females (<i>n</i> = 334)		Males (<i>n</i> = 277)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Age (years)	12.35	.29	12.35	.29	12.36	.30
Height (cm)	152.12	7.80	152.95	7.83	151.13	7.66
Weight (kg)	45.69	11.07	46.87	11.57	44.29	10.30
BMI (kg/m ²)	19.63	3.77	19.92	3.97	19.28	3.51
% Overweight/Obese*	-	24.6%	-	25.8%	-	23.3%
Family support for PA	3.29	.93	3.21	.91	3.38	.95
Multiple deprivation	5.60	2.71	5.88	2.73	5.27	2.67
Years from age at peak height velocity	-.53	1.02	-.19	.91	-.92	1.00
Predicted age at peak height velocity	12.87	1.00	12.54	.89	13.28	.98
Distance from school (km)	4.51	5.01	5.31	6.06	3.55	3.13

Table 3.2. Pearson Correlations between Variables

	1	2	3	4	5
1 Gender	–	–	–	–	–
2 Age at peak height velocity	.37**	–	–	–	–
3 Multiple deprivation	-.12**	-.13**	–	–	–
4 Walking distance from home to school (km)	-.17**	.07	.31**	–	–
5 Family support of PA	.09*	.03	.11*	-.02	–
6 Active travel vs inactive travel	.07	.03	-.32**	-.47**	-.09*

Note. * $p < .05$, ** $p < .01$

Table 3.3. Logistic regression model including main effects predicting active travel (hypothesis 1) and interaction terms (hypothesis 2 - 5)

Predictor Variable	Hypothesis 1		Hypothesis 2		Hypothesis 3		Hypothesis 4		Hypothesis 5	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
		Lower - Higher		Lower - Higher		Lower - Higher		Lower - Higher		Lower - Higher
Constant	1.03	-	.09	-	.06	-	.07	-	.06	-
Gender	.99	.66 - 1.92	.69	.22 - 2.10	1.13	.67 - 1.93	1.02	.60 - 1.74	1.02	.60 - 1.73
Multiple Deprivation	.35*	.90 - 1.08	.94	.73 - 1.21	.92	.71 - 1.19	.93	.71 - 1.20	1.94	.97 - 3.86
Distance (km)	.94	.29* - .43*	.004*	.001* - .02*	.004*	.002* - .01*	.004*	.001* - .01*	.004*	0.001* - .01*
Family Support of PA	1.10	.71 - 1.24	.92	.70 - 1.20	.92	.70 - 1.19	.46	.28 - .76	.92	.70 - 1.20
Age at PHV	4.78	.81 - 1.39	1.03	.80 - 1.33	2.05	1.19 - 3.51	1.07	.83 - 1.38	1.04	.80 - 1.35
Gender × Distance from Home to School (km)			2.26	.32 - 16.06	-	-	-	-	-	-
Age at PHV × Distance from Home to School (km)					3.60*	1.45 - 8.96*	-	-	-	-
Family Support of PA × Distance from Home to School (km)					-	-	.26*	.11 - .61*	-	-
Index of Multiple Deprivation × Distance from Home to School (km)					-	-	-	-	3.54*	1.17 - 10.72*

Note. PA = PA; PHV = Peak height velocity; OR = Odds Ratio; CI = Confidence Interval; * $p < .05$. Predictor variables were unstandardized in the model testing hypothesis 1, and standardized in subsequent models.

To test subsequent hypotheses, each proposed interaction was independently added to the standardised version of the model described above. As shown in table 3.3, the interaction between gender and distance to school was not significant; however, APHV, family support for PA, and multiple deprivation significantly moderated the relationship between distance to school and mode of transport. Simple slopes analysis using data ± 1 standard deviation from the standardised mean scores revealed that distance to school had a relatively greater negative impact on the use of active travel in children who are biologically late-maturing (i.e., Girls with $APHV \geq 13.43$ years; Boys with $APHV \geq 14.26$ years), from less deprived backgrounds (i.e., 8.31 on a 0 – 9 index of multiple deprivation) and with low family support of PA (i.e., 2.36 on a 1 – 5 self-report scale), compared to children who are biologically early-maturing (i.e., Girls with $APHV \leq 11.65$ years; Boys with $APHV \leq 12.30$ years), from more deprived backgrounds (i.e., 2.89 on a 0 – 9 index of multiple deprivation) and with high family support of PA (i.e., 4.22 on a 1 – 5 self-report scale). See figure 3.1 for graphical representation of these moderation effects.

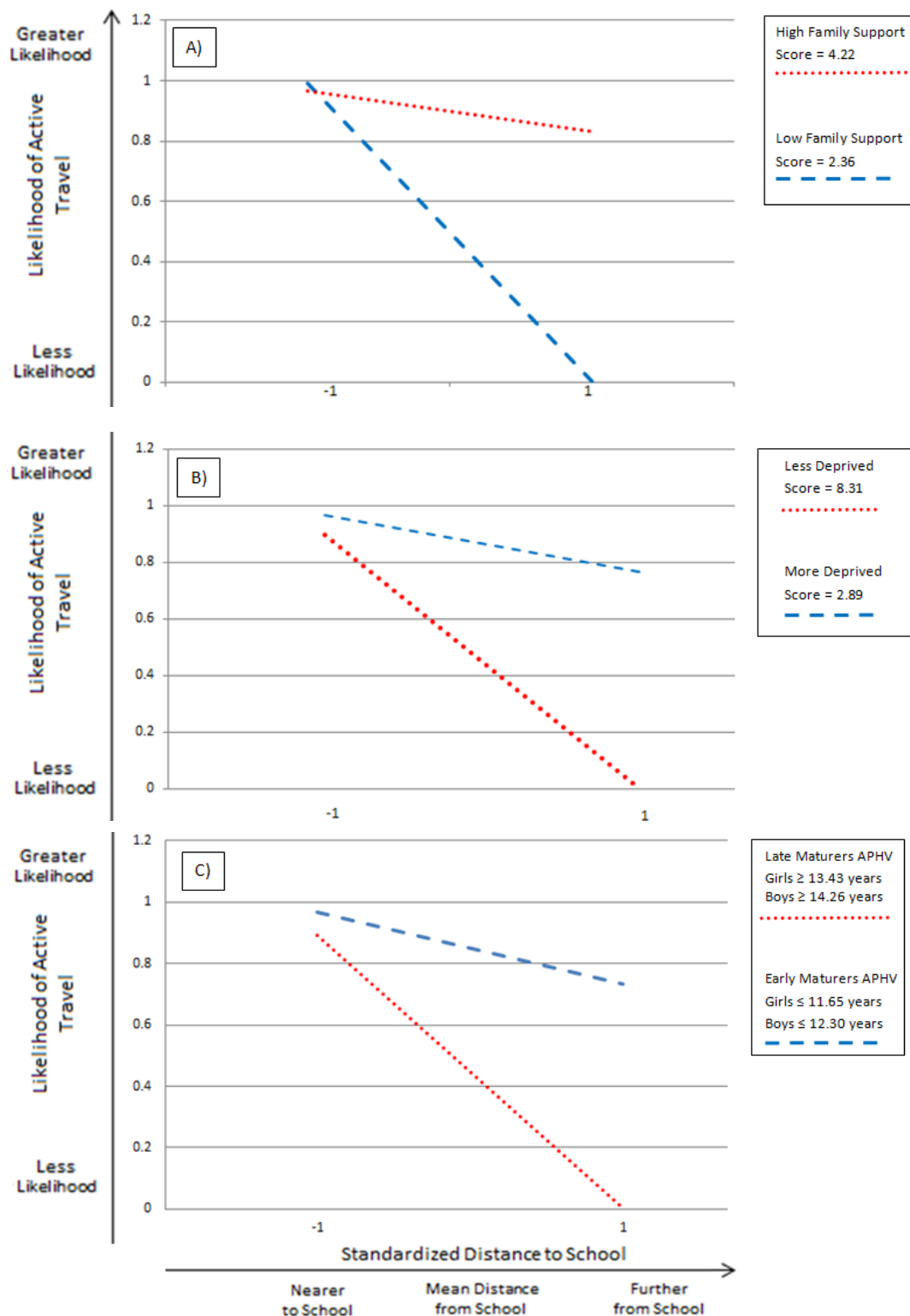


Figure 3.1. Simple slopes graphs to show interactions between distance to school and family support of PA (A); multiple deprivation (B); and biological maturation (C).

Note: Gender was binary coded as girls = 0 and boys = 1, therefore, the regression equations reflect relationships between predictor variables and active travel in girls. However there was no meaningful difference between boys and girls.

Note: The simple slopes analysis used data ± 1 standard deviation from the standardised mean scores to represent 'nearer' and 'further'. APHV = Age at Peak Height Velocity.

To account for potential school differences, regression models were ran again adjusting for school differences in student catchment area (i.e., school average distance travelled by students; coded as 0 = > 6km, 1 = 5.9 - 3km, 2 = < 3km). All significant relationships remained with the exception of the interaction between distance and deprivation (OR = 2.37, CI = .75 - 7.44, $p = .14$). No changes to the results were seen in further interactions when we adjusted for the fact that two of the sampled schools were privately funded (versus state schools) and that another two of the sampled schools were largely rural (versus urban).

Discussion

In accordance with previous research (Chillón et al., 2014; Panter et al., 2013; Panter et al., 2011; Van Sluijs et al., 2009), the closer to school participants lived; the more likely they were to actively commute. None of the remaining study variables (Gender, APHV, family support of PA, and multiple deprivation) were associated with active transport, when other variables were held constant. However, many of these constructs helped in providing new information demonstrating that the relationship between distance and active transport is moderated by a number of factors. In particular, distance had a greater negative impact on the use of active transport in a) late-maturing children, b) less socio-economically deprived children and c) children with low family support of PA.

Distance to school is arguably the most important influence on children's decision to use active transport (Oliver et al., 2014; Van Kann et al., 2015). Other studies have suggested that gender (Leslie et al., 2010), family support for PA (Ziviani et al., 2004) and multiple deprivation (Davison et al., 2008) are also contributing factors. The majority of prior research has failed to adopt an ecological perspective; however, this study suggests that behavioural choices are complex decisions based on the interplay between multiple levels of influence.

Biological maturity of children was not associated with active transport in our main effects model; however, our results demonstrated that the influence of distance to school on active travel was stronger in later maturing children. Graph C in Figure 1 illustrates the likelihood of actively commuting decreases considerably as distance to school increases for a later maturing child, to such an extent that a later maturing child (1 *SD* above the APHV mean) who lives relatively far away (1 *SD* further than the mean distance) has a probability of near zero of actively commuting to school. In contrast, the likelihood of actively commuting decreases to a much lesser extent in an earlier maturing child. No previous research has

examined the association between biological maturity and active transport. To speculate, this may be because there is less interest in active transport; as the behaviour of active transport may be harder to change. Individuals that take motorised transport to school typically do so for reasons of convenience and/or distance (Lu et al., 2014); thus the decision is heavily determined by the parent/guardian and not the child and consequently harder to manipulate. A low interest surrounding the association between biological maturation and active transport may be because of the burden of assessing biological maturity at a large scale. Biological maturation has been more characteristically investigated within a smaller population, across the sports performance environment and talent identification of athletes (i.e. Georgopoulos et al., 2001; Malina et al., 2013; Malina, Rogol, Cumming, e Silva, & Figueiredo, 2015) rather than in a context to encourage PA for all. The moderation effect found across biological maturation and active transport within this study is novel and the reasons why this may occur is unclear. To venture ideas, parents of physically and biologically mature children may be less concerned with safety and allow more independence to actively travel relatively long distances, compared to parents of physically/biologically immature children. Future research may wish to explore these potential mechanisms.

Different to previous research (Davison et al., 2008) multiple deprivation did not predict active transport. This is likely due to our focus on models adjusted for other variables, as the bivariate correlation between multiple deprivation and active travel was statistically significant and of moderate magnitude. Moreover, multiple deprivation or socio-economic status (SES) can be measured using methods other than that employed by the current research, for example; household income, parental highest educational qualification, and employment status and/or occupation (Shavers, 2007). The variation in techniques may explain the inconsistencies in the literature. Nonetheless, the results do suggest that in deprived areas the influence of distance to school has little impact upon the decision to walk to school, whereas the influence becomes much stronger in less deprived areas. This may be explained by the limited options available to those living in deprived areas, including less access to cars for commuting to school (Davison et al., 2008) and living in urban environments which are closer to schools (Oliver et al., 2014). Increased options of active transport for less socially deprived children means the likelihood of active travel decreases markedly as distance increases. When accounting for school differences in catchment areas the interaction between distance and deprivation was no longer significant. This may be because of the similarity and shared variance between catchment area and deprivation (i.e., urban, deprived areas tend to have schools with smaller catchment areas).

Despite literature evidencing a relationship (Ziviani et al., 2004; McDonald, 2008), the adjusted main effects model suggests that when distance to school is included as a predictor of active travel, family support for PA offers no additional explanatory utility. However, there was support found for the proposed interaction between distance to school and family support of PA. Specifically, distance to school was a less meaningful influence on the decision to actively commute when family support for PA was present. This means that, unlike findings reported by Panter and colleagues (2010), the likelihood of active travel when living near school (i.e., -1 *SD* below the standardised mean distance from school) was similar whether positive attitudes were conveyed or not. However, the chances of active travel decline much more rapidly as distance increases if positive attitudes are not conveyed. It should be noted, however, that the attitudes measured by Panter and colleagues (2010) differed to those in the present study (attitudes towards active travel versus PA).

Finally, in contrast to previous research (Leslie et al., 2010; Cumming et al., 2012a; Davison et al., 2008) the results displayed no significant main or interaction effects of gender. It is unlikely that this was attributable to the inclusion of other variables in the regression models as the bivariate correlation between gender and active travel was also non-significant. However, it should be noted that within this sample girls lived a mean distance of 5.31km from school whereas boys lived, on average, 3.55 km from school. It is unknown why the current sample and findings should differ from many others, although studies reviewed by Davison and colleagues (2008) were based in countries other than the UK. School systems differ between countries, for example, in the UK children tend to transition to their next school aged 11 years old, often located further afield compared to their previous school. It is also worth investigating whether the UK perspective on active travel for boys and girls may differ when compared to other countries.

The schools used within this study represent a range of multiple deprivation, included both urban and rural schools, and have a transport policy consistent with the rest of the UK. The results, therefore, have generalisable implications for increasing active transport behaviour in schoolchildren. For example, children (and their parents) from less deprived areas may be more likely to choose sedentary travel options, when the distance from school is relatively far. Therefore, enhanced cycling and walking routes from less deprived areas not near schools could be the target of environmental intervention. Instead of free bus provision, could supervised cycling, scooting or walking groups be an effective alternative? Finally, parents who do not value and support PA may be the focus of educational interventions,

especially those who do not live near their child's school. Future work exploring later maturing children and active travel should also be undertaken.

Limitations

This study did not objectively measure active travel and the sample is taken from a narrow age range, therefore, the findings do not reflect younger or older children whose active travel may be influenced by different variables. Many other factors have been shown to influence active travel that were not measured, such as weather conditions, neighbourhood characteristics and parental mode of travel to work (Panter et al., 2008; Schlossberg, Greene, Phillips, Johnson & Parker, 2006; Eyler et al., 2008; Henne, Tandon, Frank, & Saelens, 2014; Carlson et al., 2014). Furthermore the choice to identify specific moderators of the distance to school and active travel relationship was taken, rather than to maximise the amount of explained variance in the decision to actively travel to school. The IMD score is a comprehensive indicator of social deprivation; however, it is a normative ranking system used to compare areas, not a true measure of actual deprivation (Department for Communities and Local Government, 2015). In addition, using the IMD to make inferences about individual participants may introduce ecological fallacy and potential circularity, whereby the deprivation score is partly based on lack of access to facilities (for example), yet this deprivation leads to a lack of access to facilities (Macintyre, Macdonald, & Ellaway, 2008; Lamb, Ferguson, Wang, Ogilvie, & Ellaway, 2010). Also assessing biological maturation through predicted APHV with cross-sectional data is likely less accurate than when observed in a longitudinal study (Sherar, Esliger, Baxter-Jones, & Tremblay, 2007). Furthermore, the maturity offset equation may be particularly limited for early and late maturing individuals, when individuals are further away from their APHV (Baxter-Jones & Sherar, 2007). All predictions have accompanying errors and challenges around their application that require attention (Malina & Kozieł, 2014a; 2014b). The maturity offset has been shown to estimate APHV within 1.18yr, 95% of the time (Malina & Kozieł, 2014). The original protocol for the prediction equation was based on a sample of white populations, thus, there is a need for care in applying the protocol to other ethnic groups (i.e. 19.3% of present sample) (Malina, 2009). Finally the mechanisms which may explain some of the findings, including the underlying reasons why socially-deprived and late maturing children are less influenced by distance to school were not explicitly investigated. Speculation on these topics have simply been offered, such as less inactive options available and less safety concerns, however, these should be explicitly tested.

Conclusion

The present study provides evidence that distance to school is the strongest predictor of active transport. However, the study also displayed that this relationship is complex. Late-maturing children, those from socio-economically less deprived backgrounds, and children with low family support of PA should be targeted to help increase active transport uptake, particularly when living relatively far from school. The characteristics of the sampled schools (e.g., state and privately funded, urban and rural) and participants (distance to school, ethnicity, degree of social deprivation, overweight/obese rates) suggest that our sample may reflect UK school children in general.

Future Directions: Onto the next chapter

This first chapter looked at the relationship and moderating effects between active transport and multiple levels of influence. A broad conclusion from the findings was that it would be pertinent to examine the variables collectively, as each of the variables did not work in isolation. As such the following chapter aims to continue this exploration of the same variables by adopting a person-oriented approach rather than a variable-oriented approach. Utilising a person-oriented approach focuses on individuals rather than variables and can tolerate complexity among variables. This next study aims to identify and classify adolescents based on individual biological, interpersonal and social influences and then to estimate whether group classification was associated with different levels of PA. Overall PA will now be considered in addition to active transport which will help to generate a superior image of PA behaviour among early adolescence as active travel is a specific form of PA that has distinct antecedents. Individuals who engage in active transport may not engage within PA and vice versa (Carver et al., 2011; Jorgensen, 2012). The next chapter also looks at the data from a prospective view; again this will work towards generating a further insight of how individuals may differ in their PA behaviour across time.

Chapter 4

A latent class analysis of PA correlates in early adolescents

As described within the literature review, PA is a vital determinant of health and is associated with an array of physiological (Eijssvogels & Thompson, 2015) and psychological (Biddle & Asare, 2011) benefits. Current UK guidelines state that children and young people should accumulate at least 60 minutes of daily moderate to vigorous PA (MVPA) to gain these health benefits (Department of Health, 2011). Despite this recommendation, it is widely acknowledged that many children fail to achieve this minimum level of PA (Ekelund, Tomkinson, & Armstrong, 2011; Health and Social Care Information Centre, 2014). It is imperative for children and young people to establish physically active lifestyles to translate into adulthood (Telama et al., 2005); therefore the amount of children achieving the minimum level needs to increase.

Research that examines adolescent PA behaviour has been dominated by the variable-oriented approach (Raufelder, Jagenow, Hoferichter, & Drury, 2013). Despite important benefits of this approach, the variable-oriented approach expresses statements in terms of variables and not individuals; for example, “the presence of family support and/or the presence of friend support results in higher levels of total MVPA and weekday evening MVPA from ages 13–17 years” (Morrissey et al., 2015, p. 7) and “higher levels of temperature, rainfall, and the use of active school transport are significant predictors of MVPA levels in adolescents” (Aibar et al., 2015, p. 409). Criticisms of the variable-oriented approach suggest that inter-individual differences are often disregarded and the data analysis compares the sample means of specific variables and not the actual individuals (Von Eye, Bogat, & Rhodes, 2006). The present study navigates away from this variable-oriented approach and instead employs a person-oriented approach.

The person-oriented approach instead holds the individual central. This approach is typically studied by examining patterns of information, not separate variables, and by exploring characteristics and comparable patterns shared by a subgroup of the studied population (Collins & Lanza, 2010; Bergman & Wångby, 2014). The person-oriented approach and the identification of subtypes have become popular within health literature to study PA and health determinants (Heitzler et al., 2011; Jago, Fox, Page, Brockman, & Thompson, 2010). This research has focused on individuals rather than variables which allowed for the formation of homogeneous groups of individuals who share similarities. The person-oriented approach can foster a better understanding about what individualities need to

be changed or manipulated simultaneously so that behaviours can be improved. Identifying homogeneous sub-groups can also assist in the identification of children who should be prioritised when targeting health interventions.

For instance, Heitzler and colleagues (2011) found three separate sub-groups for boys and three for girls described by their PA and sedentary behaviours within their sample of 11 - 17 year olds. This analysis decided to separate girls and boys based on the known differences in PA and sedentary habits between both genders. Both genders included an ‘active’ sub-group who were more likely to participate in higher levels of MVPA compared to other children. They also reported the highest probability of participating in traditional sports and fitness activities on both weekdays and weekends. Across both genders a ‘sedentary’ sub-group emerged; children in these groups were characterised by their high participation in screen media activities and reading/homework. Additionally sedentary girls had the highest likelihood of texting or talking on the phone for an hour or more and reading or doing homework for two or more hours. Sedentary boys and girls had low tendencies to participate in 30 minutes or more of MVPA on both weekdays and weekends. The third sub-groups for each gender also shared similarities. For boys, this was the ‘low media/moderate activity’ group which tended to have relatively low to moderate probabilities of participating in almost all of the behaviours examined. The third girls sub-group, named ‘low media/functional activity’ had the lowest probability for participating in MVPA for 30 minutes or more on weekend days and had the lowest probability for participating within all screen media activities. However, girls from this sub-group had the highest likelihood of participating in functional activity such as chores and outside work.

Dissimilar to the above research, which utilises clusters of health behaviours to classify individuals, the present study aims to identify and classify adolescents based on predictors of PA. The PA behaviours discussed and tested in this study are; self-reported mean PA levels, mean MVPA levels objectively measured and levels of active transport for commuting to school. Actively commuting is primarily walking or cycling for the purpose of function, rather than leisure; in this case, for travelling to school (Saunders, Green, Petticrew, Steinbach, & Roberts, 2013). Using active transport can provide convenient and meaningful contributions to increasing PA levels and energy expenditure (Aibar et al., 2015; Slingerland, et al., 2012). The thesis so far has displayed that both PA and active transport are guided by multiple levels of influence. To investigate the variables collectively within a person-oriented approach will be a progressive next step to achieving a further comprehensive grasp of PA

behaviour across early adolescence. The next section describes each of the influences that will contribute to the sub-group classification.

(i) *Gender.* Boys are more physically active than girls (Wetton et al., 2013); however, overall PA declines rapidly during childhood and adolescence (Troost, Kerr, Ward, & Pate, 2001). Boys are also more likely to actively commute to school (Leslie, Kremer, Toumbourou, & Williams, 2010); however, this relationship has been attributed to boys having more opportunity to actively commute (McMillan et al., 2006).

(ii) *Biological maturation.* Adolescents of the same chronological age can vary by up to five years in biological age (Malina, Bouchard, & Bar-Or, 2004). Biological maturation has been shown to impact involvement in PA to some extent; however, findings are inconsistent (Sherar et al., 2010; Bacil et al., 2015). Gender differences in PA have been shown to disappear when biological maturity is controlled for (Sherar, et al., 2007), thus suggesting that biological maturity may have a role in PA behaviour. The present research adds to infrequent attention on active transport and biological maturation. During the first study (chapter 3) it was found that biologically late-maturing children are less likely to actively commute to school, particularly if they live relatively far from school. The reasons for this are unclear; however, parents of physically mature children may be less concerned with safety and allow more independence to actively travel relatively long distances, compared with parents of physically immature children (Garnham-Lee, Falconer, Sherar, & Taylor, 2016).

(iii) *Distance from home to school.* The distance from home to school is integral to the decision to actively commute to school, specifically the likelihood of utilising inactive transport increases with distance (Dessing et al., 2014; Chillón et al., 2014). In study 1 (chapter 3) it was found that the distance to school from a child's home is the strongest predictor of active transport but that this relationship is complex. Interaction analysis revealed that biological maturation, multiple deprivation and family support of PA moderate the relationship of active transport and distance to school. Thus distance to school is one of the influences that will be focused on during this study.

(iv) *Family support of PA.* Family support has consistently been associated with child PA and there is strong evidence that parental support, in particular, can enhance PA levels (Troost & Loprinz, 2011). Arguably the central guidance on children's mode of transport is their parents/guardians; children are more likely to actively commute when their parents value the benefits of PA (Ziviani, Scott, & Wadley, 2004). Study 1 (chapter 3) demonstrated the relationship between family support of PA and the likelihood to active transport is

moderated by distance from home to school. Those with higher reported levels of family support are less influenced by distance to school on the decision to actively commute to school, whereas the influence of distance to school is stronger in those who report less family support of PA (Garnham-Lee et al., 2016).

(v) *Multiple Indices of Deprivation.* Another social influence on PA and active transport is various aspects of socio-economic deprivation. A review found that adolescents from a more deprived background display lower levels of PA (Hanson & Chen, 2007). However, the relationship in PA and multiple deprivation has been shown to be influenced or mediated by BMI (Drenowatz et al., 2010), self-esteem (Veselska, Geckova, Reijneveld, & van Dijk, 2011) and educational attainment and neighbourhood deprivation (Cerin & Leslie, 2008). A review of predominantly cross-sectional studies concluded that children from low multiple deprivation areas were more likely to actively commute to school (Davison, Werder, & Lawson, 2008). Nonetheless, study 1 (chapter 3) demonstrated this relationship was moderated by distance to school; in more deprived areas the influence of distance to school has little impact upon the decision to actively commute to school, whereas the influence of distance to school is stronger in less deprived areas (Garnham-Lee et al., 2016).

The complexity and interaction among the above variables demonstrates that PA behaviour can be guided by many layers of influences and the relationships between them. These variables described above all act as predictors of the sub-groups of early adolescents within this study. Once sub-groups of early adolescents that share similar characteristics are formed this study aims to estimate whether group membership is associated with PA behaviour. This study proposes no hypotheses as it is exploratory; however, it investigates whether individuals from the identified groups, who share similar characteristics based on the predictor variables (gender, biological maturation, family support of PA, multiple deprivation, and distance from home to school), differ in PA behaviours and their likelihood to use active transport. This investigation is done prospectively over two time points so that identified subgroups at baseline can be used to predict outcomes in the future (12-18 months later).

Methods

Participants

Twenty-four secondary schools across the East Midlands, England, were invited to participate; seven schools across three local authorities (two independent private schools, five state-funded schools) agreed to participate. Data was collected from 705 children ($M = 12.4 \pm 0.3$ years (at baseline), 387 (54.89%) females); ethnicity: White = 80.7%, Asian = 15.3%,

Black = 2.7%, other = 1.3%). Due to accelerometers being in limited supply (total of 51), PA was objectively assessed within a sub-sample only ($n = 152$, 84 females at baseline and $n = 73$, 40 females at time point 3). For convenience, schools B, D and E (see general methodology for characteristics) were chosen as ‘accelerometer schools’. All the available accelerometers, at the time of data collection for those selected schools, were given out on a first come first serve basis as there were not enough monitors for each participant. This process started with the first classes seen by the lead investigator in each of the accelerometer schools until all monitors were given out. For follow up accelerometer measures, the same children were asked to wear the monitors again. If one child did not agree, a new participant was asked in an attempt to ensure optimal use of all accelerometers available. The new participant was the next participant available to the lead investigator who was not already a previous accelerometer wearer (i.e., the next child on the class list).

Procedures

The study was approved by a university ethics committee and written informed consent was obtained from each schools head teacher, parent/guardians had an opportunity to withdraw their child from the study, and children provided their written assent. Participants completed all measures at baseline and completed the PA measures (self-report and accelerometer) and the active transport measure again at time point 3 (12 -18 months later). All data collection was conducted at the participant’s school during school hours, typically within their P.E lesson.

Measures

Full descriptions of all measures used within this study (biological maturation, multiple deprivation, family support for PA, distance from home to school, self-reported PA, accelerometer measured PA and active versus inactive travel) are found within the general methodology (chapter 2). The Cronbach’s Alpha coefficient for the family support of PA questionnaire in the present study was 0.79 and the Cronbach’s Alpha coefficient for self-reported PA in the present study for baseline was 0.85 and 0.90 for time point 3.

Statistical Analysis

Latent Class Analysis (LCA). LCA looks to identify unobservable sub-classes within a population (Hagenaars & McCutcheon, 2002). Within a person-oriented framework, the aim of LCA is to use predictor variables to categorise individuals into homogenous sub-groups, named as classes; these classes should be distinct from each other (Marsh, Lüdtke, Trautwein, & Morin, 2009). The LCA was performed using Mplus v.6 (Muthen & Muthen, 1998-2012). Predictor variables were used to create distinct classes of based on a participants

individual profile. These predictor variables were (i) multiple deprivation (ii) gender (iii) APHV (iv) distance from school and (v) perceived family support for PA (all at baseline). To determine the participants' class, subsequent class probabilities were estimated and participants were placed into the class in which they had the highest probability for sharing characteristics with compared to the other classes (Nylund, Asparouhov, & Muthén, 2007). When compared to more traditional subgroup analysis, for example confirmatory and exploratory subgroup analysis, LCA can decrease Type I error rate and prevent issues of statistical power due to missing data or thinness of data (data sparseness) (Lanza & Rhoades, 2013). Moreover, traditional subgroup analysis may fail to reveal important subgroups defined by the higher-order interactions of subgroup variables whereas LCA analysis allows for the consideration of every possible combination (Lanza & Rhoades, 2013). To determine the best number of classes for the sample model comparisons were made; firstly the model was run with one class, then successive models with an increase in the number of classes, up to five. Sample-adjusted Bayesian Information Criteria (BIC) together with entropy was used to evaluate the goodness-of-fit and to help select the best fitted model and the optimum number of classes (Yang, 2006). For sample-size adjusted BIC lower values indicate a better model fit (Raftery, 1995) whilst for entropy values range from 0 to 1, a higher value indicates better precision (Berlin, Williams, & Parra, 2014). Bootstrap Likelihood Ratio Test (BLRT) was also used to evaluate goodness-of-fit. A statistically significant ($p < 0.05$) BLRT indicates a better model fit for k -class model compared with the $k-1$ class model (Nylund et al., 2007). In determining the appropriate number of classes, the numbers of cases within each class was also considered, as small numbers are considered less feasible (Marsh et al., 2009; Berlin et al., 2014).

Post LCA Analysis. The identified classes through LCA were then used as a categorical predictor variable and logistic regressions were ran to predict active transport status at baseline and time point 3. A one way ANOVA was ran with classes as a fixed factor to compare the differences between classes of both the PA outcome variables (self-reported PA and objectively measured mean MVPA levels) at baseline and at time point 3. Multiple comparisons were made to locate the significant differences indicated with ANOVA.

Results

Descriptive Results

All 705 participants provided information on their gender, 12 participants failed to provide their postcode or a valid postcode, therefore measures of multiple deprivation and

walking distance to school were not computed for those participants. Moreover 166 participants did not complete sufficient measures to calculate their biological maturity and 102 failed to respond to the family support of PA questionnaire. To deal with this missing data, the full information maximum likelihood (FIML) method was applied. The FIML technique is a direct estimation technique which directly analyses the incomplete data set to produce unbiased data estimates and accurate standard errors (Newman, 2014). Therefore applying FIML here allowed all available data to be included and used to create the class identification and LCA profiles (Newman, 2014). Full mean values and standard deviations for all study variables and class descriptive statistics are presented in tables 4.1 and 4.2 overleaf.

Table 4.1. Descriptive statistics of study variables and relevant child characteristics split by gender.

Note. *Values are percentages rather than mean (SD).

Variable	Full Sample (N = 705)					
	Males (N = 318, 45.11%)			Females (N = 387, 54.89%)		
	N	M	SD	N	M	SD
Chronological Age (years) (Baseline)	318	12.36	0.30	387	12.35	0.30
Multiple Deprivation	316	5.28	2.59	377	5.72	2.77
Years from PHV (Baseline)	242	-1.59	0.48	297	0.26	0.52
Predicted APHV (years) (Baseline)	242	13.95	0.50	297	12.10	0.48
Family Support of PA (Baseline)	275	3.39	0.93	328	3.20	0.93
Walking Distance to School (Km)	315	2.44	2.26	377	3.01	3.06
Self-Report PA (Baseline)	285	3.12	0.74	333	2.76	0.66
Self-Report PA (Time point 2)	308	2.29	0.65	362	2.09	0.56
MVPA (mins/day): Baseline	57	63.68	23.69	67	56.90	19.56
MVPA (mins/day): (Time point 2)	22	76.38	21.06	30	52.20	15.98
Active Transport (Baseline)*	281			330		
Inactive (including part-active)	171 (60.9%)			220 (66.7%)		
Active	110 (39.1%)			110 (33.3%)		
Active Transport (Time point 2)*	282			320		
Inactive (including part-active)	167 (59.2%)			212 (66.3%)		
Active	115 (40.8)			108 (33.8%)		
BMI (kg/m ²) (Baseline)	273	19.39	3.48	330	19.83	4.00
% Overweight/Obese*	84	30.8%		96	29.1%	
Ethnicity*	318			387		
White	266 (83.6%)			303 (78.3%)		
Asian	40 (12.6%)			68 (17.6)		
Black	9 (2.8%)			10 (2.6%)		
All Other	3 (0.9%)			6 (1.6%)		

Table 4.2. Descriptive statistics of study variables and relevant child characteristics split by class.

Variable	Full Sample			Classes (N = 705)											
	(N = 705)			Class 1 (N = 106)			Class 2 (N = 498)			Class 3 (N = 72)			Class 4 (N = 29)		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD
Chronological Age (years) (Baseline)	705	12.36	0.30	106	12.38	0.28	498	12.35	0.30	72	12.38	0.29	29	12.25	0.25
Multiple Deprivation	693	5.52	2.69	105	5.63	2.72	489	5.60	2.62	71	5.15	2.86	28	4.71	3.24
Predicted APHV (years) (Baseline)	539	12.93	1.04	89	13.00	1.00	369	12.94	1.06	64	12.88	1.04	17	12.66	0.81
Years from PHV (Baseline)	539	-0.57	1.05	89	-0.61	0.99	369	-0.58	1.06	64	-0.52	1.09	17	-0.39	0.79
Female	387	54.89%		63	59.43%		262	52.61%		40	55.56%		22	75.86%	
Male	318	45.11%		43	40.57%		236	47.39%		32	44.44%		7	24.14%	
Family Support of PA (Baseline)	603	3.29	0.93	106	2.79	0.63	407	3.66	0.74	72	1.94	0.67	18	3.26	0.88
Walking Distance to School (Km)	692	2.75	2.74	105	2.77	3.14	488	2.63	2.51	71	3.05	2.98	28	3.99	3.93
Ethnicity*	705	-	-	106	-	-	498	-	-	72	-	-	29	-	-
White	569	80.71%	-	80	75.47%	-	411	82.53%	-	58	80.56%	-	20	68.97%	-
Asian	108	15.32%	-	24	22.64%	-	68	13.65%	-	9	12.50%	-	7	24.14%	-
Black	19	2.70%	-	1	0.94%	-	15	3.01%	-	2	2.78%	-	1	3.45%	-
All Other	9	1.28%	-	1	0.94%	-	4	0.80%	-	3	4.17%	-	1	3.45%	-

Table 4.2. Continued

Self-Report PA (Baseline)	618	2.99	0.72	106	2.65	0.61	420	3.07	0.70	72	2.56	0.76	20	2.77	0.65
Self-Report PA (Time point 3)	670	2.18	0.61	100	2.00	0.53	477	2.24	0.62	67	2.03	0.68	26	2.25	0.46
MVPA (mins/day): Baseline	124 (17.59%)	60.02	21.73	16 (15.09%)	61.91	21.56	88 (17.67%)	59.58	21.01	16 (22.22%)	59.99	26.93	4 (13.79%)	62.13	24.14
MVPA (mins/day): (Time point 3)	52 (7.38%)	62.43	21.76	5 (4.76%)	51.50	15.54	39 (7.83%)	63.11	22.40	6 (8.33%)	63.02	22.63	2 (6.89%)	74.53	25.14
Active Transport (Baseline)*	611	-		104	-		415	-		72	-		20	-	
Inactive (including part-active)	391	64.00%		64	61.54%		265	63.86%		45	62.50%		17	85.00%	
Active	220	36.00%		40	38.46%		150	36.14%		27	37.50%		3	15.00%	
Active Transport (Time point 3)*	602	-		93	-		427	-		60	-		22	-	
Inactive (including part-active)	379	62.96%		61	65.59%		263	61.59%		39	65.00%		16	72.73%	
Active	223	37.04%		32	34.41%		164	38.41%		21	35.00%		6	27.27%	
BMI (kg/m ²) (Baseline)	603	19.63	3.78	106	19.44	3.56	410	19.61	3.75	67	19.57	3.67	20	21.37	5.30
% Overweight/Obese*	180	29.85%		31	29.25%		118	28.78%		23	34.33%		8	40.00%	

Table 4.3. LCA model results means and class contribution.

Latent Class	Variable	Estimate	S.E.	Est./S.E.	P-Value
Latent Class 1	Multiple Deprivation	5.615	0.250	22.441	0.000**
	APHV	0.180	0.108	1.660	0.097
	Family Support of PA	3.034	0.051	59.797	0.000**
	Distance to School	2.309	0.193	11.957	0.000**
	Gender ^Δ	0.419	0.195	2.153	0.031*
Latent Class 2	Multiple Deprivation	5.599	0.134	41.779	0.000**
	APHV	-0.089	0.057	-1.560	0.119
	Family Support of PA	4.694	0.026	178.951	0.000**
	Distance to School	2.330	0.109	21.276	0.000**
	Gender ^Δ	0.079	0.103	0.768	0.443
Latent Class 3	Multiple Deprivation	5.109	0.391	13.064	0.000**
	APHV	0.120	0.125	0.962	0.336
	Family Support of PA	1.430	0.088	16.289	0.000**
	Distance to School	2.602	0.302	8.611	0.000**
	Gender ^Δ	0.113	0.284	0.398	0.691
Latent Class 4	Multiple Deprivation	4.825	0.654	7.383	0.000**
	APHV	0.101	0.305	0.331	0.741
	Family Support of PA	4.128	0.307	13.425	0.000**
	Distance to School	12.002	0.847	14.167	0.000**
	Gender ^Δ	1.055	0.596	1.769	0.077

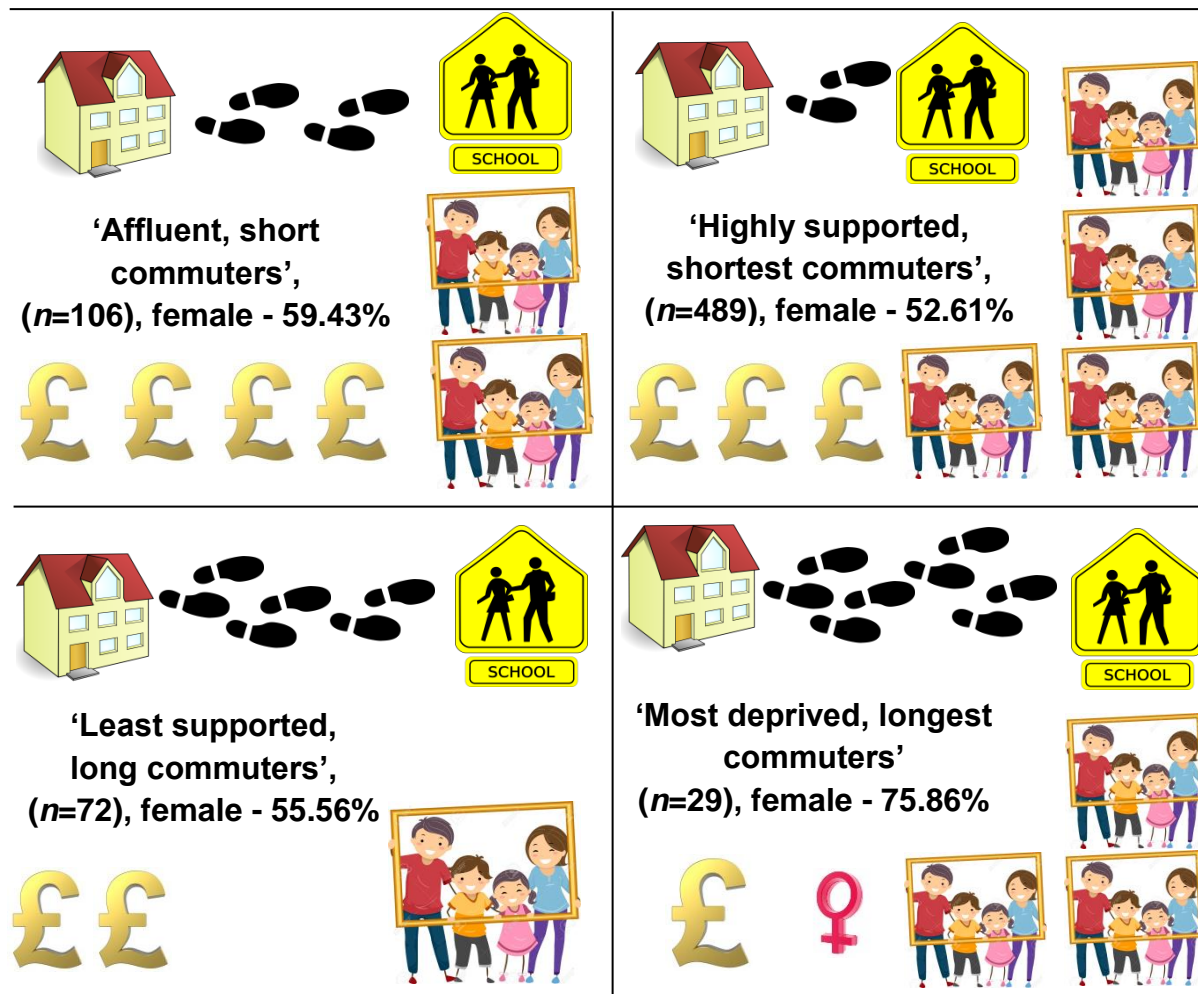
* $p < .05$, ** $p < .00$

^Δ Gender (binary variable) based on thresholds not means.

LCA

A series of LCA analyses, with varying numbers of classes, were performed in order to test for the optimal number of classes. Based on the model fit indices (described within the methods section previously), four latent classes of participants were identified (sample-size adjusted BIC = 10641.14, entropy = 0.81, numbers of cases within each class, class 1 $n = 106$, class 2 $n = 498$, class 3 $n = 72$, class 4 $n = 29$; BLRT p value = 0.000). Four classes were seen as a better fit than three latent classes (sample-size adjusted BIC = 10727.031; entropy = 0.88; numbers of cases within each class, class 1 $n = 225$, class 2 $n = 454$, class 3 $n = 26$; BLRT p value = 0.000). Although the entropy value for three classes was a slightly higher value, indicating better precision (Berlin et al., 2014), the sample-size adjusted BIC was higher, with lower values indicating a better model fit (Raftery, 1995) and the number of cases spread across classes were more even. When conducting a LCA for five classes, the output did not fully compute and resulted in convergence problems.

Model results (see table 4.3 above) displays that multiple deprivation, family support of PA and walking distance to school significantly contributed to the characteristics of each latent class. Gender meaningfully contributed to class 1 only and APHV did not meaningfully contribute to any of the class characteristics. Class 1 ($n = 106$) participants lived a relatively short distance to school in areas of the lowest deprivation and had relative moderate family support of PA, labelled ‘affluent, short commuters,’ Class 2 ($n = 498$) participants were characterised by the highest family support of PA and lived the shortest distance to school in areas of low deprivation, labelled ‘highly supported, shortest commuters’. Class 3 ($n = 72$) participants reported the lowest family support, lived relatively far from their school and lived in areas of relative moderate multiple deprivation, labelled ‘least supported, long commuters’. Class 4 ($n = 29$) participants lived the furthest distance to school in areas with the highest deprivation and reported relatively high family support of PA, labelled ‘most deprived, longest commuters’. See overleaf for an infographic, figure 4.1 to describe the four classes.



Infographic Key

Images from google images and Microsoft clip art.

Family Support of Physical Activity



The more images, the higher the mean family support.

Multiple Deprivation



The more pound signs, the higher the mean multiple deprivation.

Walking Distance to School from Home



The more footprints, the further the mean distance to school.

Figure 4.1. Infographic to describe the four latent classes.

Accelerometer PA (MVPA)

After data exclusion criteria was applied (see general methodology) to the sub-sample of participants which were asked to wear accelerometers ($n = 152$, 84 females at baseline and $n = 73$, 40 females at time point 3); valid accelerometer measures were completed by 124 participants at baseline and 52 participants at time point 3. However, there was an insufficient distribution in the valid accelerometer data across the four latent classes, thus this data was not included within the full analysis. The ‘affluent, short commuters’ (class 1) contained 16 participants at baseline and 5 participants at time point 3 that had valid accelerometer data. The ‘highly supported, shortest commuters’ (class 2) contained 88 participants at baseline and 39 at time point 3 that had valid accelerometer data. The ‘least supported, long commuters’ (class 3) contained 16 participants at baseline and 6 at time point 3 that had valid accelerometer data; and the ‘most deprived, longest commuters’ (class 4) contained 4 at baseline and 2 at time point 3 that had valid accelerometer data.

Despite being unable to use the LCA results to predict accelerometer measured MVPA, bivariate correlations were run between the study variables and MVPA to provide descriptive information. At baseline, APHV ($r = 0.230$, $p = 0.015$) and walking distance to school ($r = -0.216$, $p = 0.017$) were correlated with MVPA. Gender ($r = 0.156$, $p = 0.083$), multiple deprivation ($r = -0.112$, $p = 0.221$) and family support of PA ($r = 0.028$, $p = 0.762$) shown no association. Correlation results at time point 3 suggested that gender was correlated with MVPA ($r = 0.554$, $p = 0.000$); APHV ($r = 0.185$, $p = 0.218$); walking distance to school ($r = -0.115$, $p = 0.419$); multiple deprivation ($r = 0.216$, $p = 0.123$) and family support of PA ($r = 0.275$, $p = 0.056$) shown no association.

Self-Report PA

Eighty-seven participants at baseline and 35 participants at time point 3 failed to complete the PAQ-C and were excluded from further analysis. ANOVA results revealed significant differences between the four classes in self-report PA at baseline ($F(3,614) = 19.31$, $p < 0.001$) and time point 3 ($F(3,666) = 5.91$, $p < 0.001$). At both time points, the ‘highly supported, shortest commuters’ (class 2) significantly reported more PA than the ‘affluent, short commuters’ (class 1) and the ‘least supported, long commuters’ (class 3) participants. At both time points, there were no significant differences of self-reported levels of PA from the ‘affluent, short commuters’ (class 1) and the ‘least supported, long commuters’ (class 3); the ‘affluent, short commuters’ (class 1) and the ‘most deprived, longest commuters’ (class 4); the ‘highly supported, shortest commuters’ (class 2) and the ‘most deprived, longest commuters’ (class 4); and the ‘least supported, long commuters’

(class 3) and the ‘most deprived, longest commuters’ (class 4). Full results are displayed in table 4.4 and shown across figure 4.2.

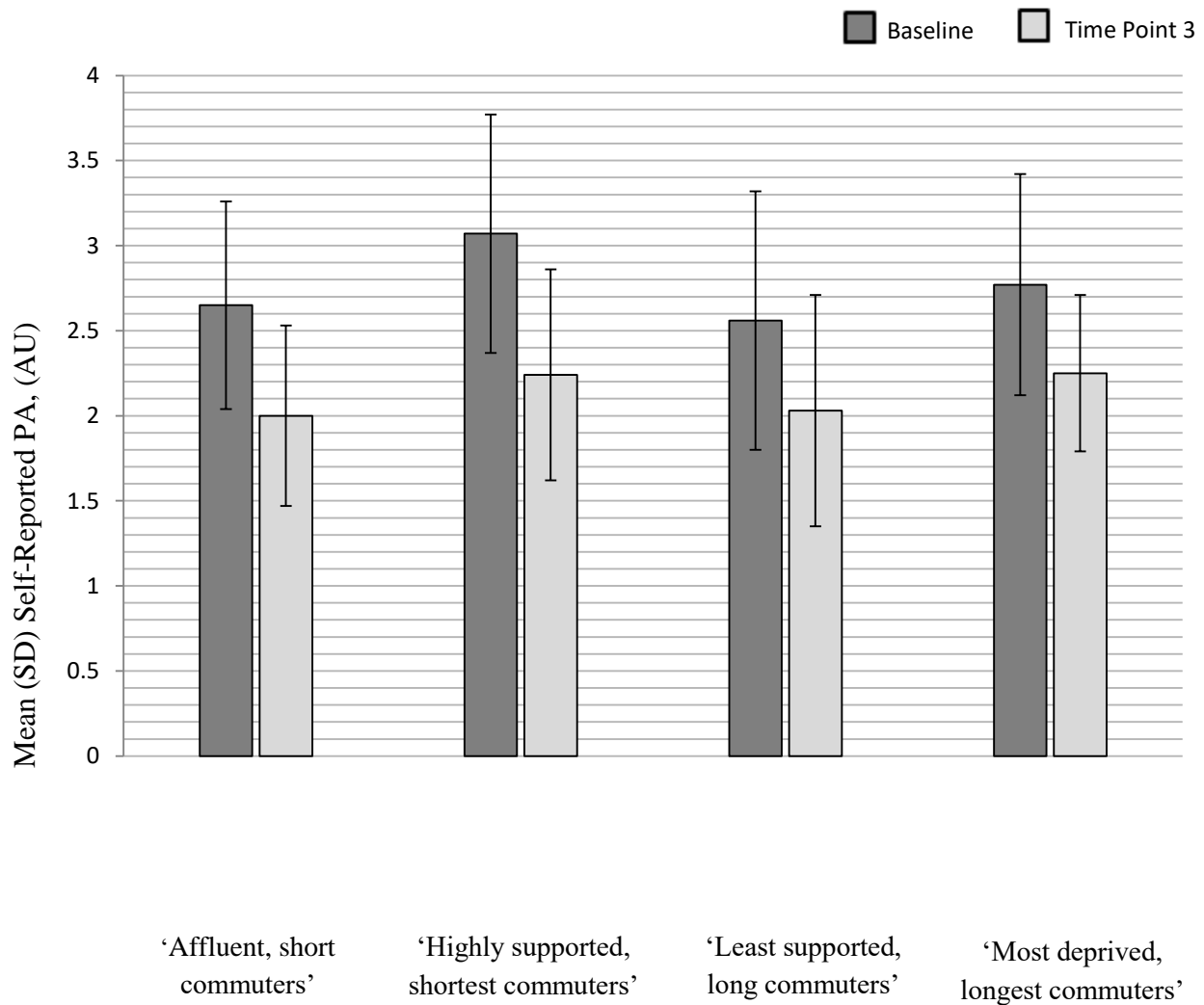


Figure 4.2. Self-reported PA mean and SD by latent class.

(Note; y-axis, arbitrary units on a scale from 0-5)

Table 4.4. Self-reported PA class comparisons displaying *p* values and effect sizes.

Baseline, means (SD)								
	<i>p</i>	Effect size	<i>p</i>	Effect size	<i>p</i>	Effect size	<i>p</i>	Effect size
	Class 1, 2.65 (0.61)		Class 2, 3.07 (0.70)		Class 3, 2.56 (0.76)		Class 4, 2.77 (0.65)	
	‘Affluent, short commuters’		‘Highly supported, shortest commuters’		‘Least supported, long commuters’		‘Most deprived, longest commuters’	
Class 1			0.001*	0.640	0.826	0.131	0.885	0.190
Class 2	0.001*	0.640			0.001*	0.698	0.222	0.444
Class 3	0.826	0.131	0.001*	0.698			0.612	0.297
Class 4	0.885	0.190	0.222	0.444	0.612	0.297		
Time point 3, means (SD)								
	Class 1, 2.00 (0.53)		Class 2, 2.24 (0.62)		Class 3, 2.03 (0.68)		Class 4, 2.25 (0.46)	
	‘Affluent, short commuters’		‘Highly supported, shortest commuters’		‘Least supported, long commuters’		‘Most deprived, longest commuters’	
Class 1			0.001*	0.416	0.987	0.049	0.248	0.504
Class 2	0.001*	0.416			0.001*	0.323	1.000	0.018
Class 3	0.987	0.049	0.001*	0.323			0.413	0.379
Class 4	0.248	0.504	1.000	0.018	0.413	0.379		

* $p < 0.001$; note: Effect Size = Cohen's $d = (M_2 - M_1) / SD_{\text{pooled}}$.

Active Transport

At baseline, 94 (13.33%) participants failed to report their mode of travel to school and were excluded from further analysis; of the remaining 611 participants, 64% travelled to school inactively or part-actively and 36% travelled to school actively. At time point 3 a further 9 participants failed to report their mode of travel to school and were excluded from further analysis; from the remaining 602 participants, 63% travelled to school inactively and part-actively and 37% travelled to school fully actively. The logistic regression model included the identified classes as a categorical variable to predict the likelihood of active versus inactive travel to school. The ‘affluent, short commuters’ (class 1) were entered as the reference category (no differences in the findings were observed if the reference category was changed). Class membership explained 11% of the variance in mode of transport. Results revealed that the ‘affluent, short commuters’ (class 1) were more likely to actively travel to school than the ‘highly supported, shortest commuters’ (class 2), the ‘least supported, long commuters’ (class 3), and the ‘most deprived, longest commuters’ (class 4) at baseline (OR: 3.54, CI: 0.98-12.86, $p = 0.055$; OR: 3.21, CI: 0.93-11.12, $p = 0.066$; OR: 3.40, CI: 0.91-12.69; $p = 0.069$, respectively). No differences in travel mode were found at time point 3. Full logistic regression results can be seen in table 4.5 overleaf.

Table 4.5. Logistic regression model including main effects predicting active travel at baseline and time point 3.

Predictor Variable	Constant (reference) Category					
	Class 1		Class 2		Class 3	
	‘Affluent, short commuters’		‘Highly supported, shortest commuters’		Least supported, long commuters’	
	OR	95% CI Lower - Higher	OR	95% CI Lower - Higher	OR	95% CI Lower - Higher
Baseline						
Class 1			0.28	0.07 - 1.03	0.31	0.09 - 1.08
Class 2	3.54	0.98 - 12.86			1.10	0.71 - 1.72
Class 3	3.21	0.92 - 11.12	0.91	0.58 - 1.41		0.94
Class 4	3.40	0.91 - 12.69	0.96	0.52 - 1.78	1.06	0.63 - 1.78
Time point 3						
Class 1			1.05	0.40 - 2.79	0.94	0.38 - 2.31
Class 2	0.95	0.36 - 2.53			0.89	0.56 - 1.42
Class 3	1.07	0.43 - 2.63	1.12	0.70 - 1.78		1.05
Class 4	1.01	0.36 - 2.81	1.06	0.54 - 2.07	0.95	0.54 - 1.65

Note. OR = Odds Ratio; CI = Confidence Interval; * $p < 0.05$.

Discussion

The purpose of this study was to classify distinct profiles of children based on correlates of PA which were; (i) gender, (ii) multiple deprivation, (iii) predicted APHV (biological maturity), (iv) walking distance from home to school, and (v) perceived family support for PA. Subsequently, self-reported PA and active transport were investigated to determine whether these PA behaviours were distinguishable across these distinct profiles. This research was conducted within a person-oriented paradigm, which identifies individuals who have collective variables and can complement a variable-oriented approach. This method of identifying homogeneous sub-groups can foster a better understanding about which individual adolescents should be prioritised when targeting health interventions.

The results displayed that the ‘highly supported, shortest commuters’, (class 2) self-reported significantly more PA at baseline and at time point 3 when compared to the ‘affluent, short commuters,’ (class 1) and the ‘least supported, long commuters’, (class 3). The ‘highly supported, shortest commuters’ (class 2) had the largest amount of participants (70.6% of full sample) and these children reported the highest perceived family support of PA, and lived in relatively affluent areas only a short distance to school. This finding agrees with previous literature in that family support of PA is central to the uptake and maintenance of PA for adolescents (Wenthe, Janz, & Levy, 2009; Morrissey, Janz, Letuchy, Francis, & Levy, 2015); and that those from less deprived backgrounds generally participate in higher PA levels (Starfield, Robertson, & Riley, 2002; Tandon et al., 2012), however, this finding also demonstrates a collective relationship between perceived family support of PA, multiple deprivation and distance to school. This class lived the shortest distance to school and typically children who live near schools are from more urban, densely populated, deprived areas (Pateman, 2011); thus this may suggest that the sample population was uncharacteristic.

Individuals from the ‘affluent, short commuters,’ (class 1) and the ‘least supported, long commuters’, (class 3) significantly reported less PA levels than individuals from the ‘highly supported, shortest commuters’ (class 2); therefore individuals from these two classes may well require intervention. The two classes contain different characteristics; therefore, implementing the same intervention for both may not necessarily suffice. Typically individuals of similar PA behaviour levels would be assigned similar interventions; the LCA demonstrates that each sub-group of individuals have distinct characteristics that require different interventions. The ‘affluent, short commuters,’ (class 1, 15.0% of full sample) lived in relatively affluent areas close to school, and were characterised by relatively moderate

family support of PA. In contrast, the ‘least supported, long commuters’, (class 3, 10.2% of full sample) reported the lowest family support and lived relatively far from their school in a relatively moderate area of deprivation. The ‘affluent, short commuters’, (class 1) were the least deprived of the sample, which opposes previous literature suggesting that adolescents from less deprived backgrounds display higher levels of PA (Hanson & Chen, 2007). However, this relationship may be influenced by BMI (Drenowatz et al., 2010), self-esteem (Veselska et al., 2011), educational attainment and neighbourhood deprivation (Cerin & Leslie, 2008) and can be dependent on how PA is measured. Thus future research may look to expand the exploration of moderating factors.

The ‘affluent, short commuters’ (class 1), a logical intervention may include promotion and maintenance support around active transport, as these individuals live a relatively close distance to school. However, the active transport results display the ‘affluent, short commuters’ are already the most likely to perform the highest levels of active transport. Thus a better intervention for these individuals may include targeted after-school sports and activity clubs; as these class individuals are relatively affluent with relatively moderate family support of PA it should be acceptable for their families to support them on a tangible and non-tangible basis. The ‘least supported, long commuters’ (class 3), reported the lowest average family support of PA and come from relatively deprived areas, might better suit an intervention around family and parental support of PA. Potential objectives of an intervention could include encouragement for family and parents/guardians to watch their child perform PA, encouraging the uptake of PA programmes, provide transportation to PA related facilities, and reinforce PA participation regularly (Trost & Loprinz, 2011).

The fact that the ‘affluent, short commuters’ (class 1) were the most likely to activity commute to school at baseline was surprising given that the ‘highly supported, shortest commuters’ (class 2), lived the shortest the distance from school. Class 1 still lived relatively close to school (compared to the ‘least supported, long commuters’ and the ‘most deprived, longest commuters’ - class 3 and 4), in affluent areas and had moderate family support of PA. It has been previously suggested that those living in less deprived areas, as the ‘affluent, short commuters’ (class 1) do, have more access to cars for commuting to school (Davison et al., 2008) and live in less urban environments which are typically further from schools (Oliver et al., 2014). Therefore, the ‘affluent, short commuters’ coming from the least deprived backgrounds are the most likely to actively commute to school, is again challenging to previous findings.

The ‘most deprived, longest commuters’ (class 4) contained the fewest participants, just 4% of the sample ($n = 29$) but also the highest proportion of females ($n = 22$, 75.86%) and the highest proportion of children from non-white backgrounds ($n = 9$, 31.04%). The ‘most deprived, longest commuters’ (class 4) also had the lowest multiple deprivation scores, thus were the most deprived, and had relatively high family support and lived the furthest distance to school. This class was not significantly different to any of the other three classes in terms of self-reported PA levels; however, individuals from this class were less likely to actively commute to school than individuals from the ‘affluent, short commuters’ (class 1). To increase PA for these ‘most deprived, longest commuters’ (class 4), an active travel intervention which is specifically tailored towards females could be a possible solution. For this age group, 5 miles (8km) has been previously suggested as a maximum threshold for an acceptable distance to actively commute (Van Sluijs et al., 2009). The mean distance from school for class 4 individuals was 2.48 miles (3.99km), therefore, a cycling intervention may be more practical, as opposed to walking. An effective cycling intervention ought to address both the rates of cycling and the teaching of safety skills and knowledge (Teyhan, Cornish, Boyd, Joshi, & Macleod, 2016).

Biological maturation was shown to not meaningfully contribute to any of the class characteristics. This particular finding shows that biological maturation may not be a strong predictor of PA behaviour, if a predictor at all. This contradicts with results from study 1 (chapter 3) and previous evidence suggesting that biological maturation does contribute to adolescent PA behaviour (Van Jaarsveld, Fidler, Simon, & Wardle, 2007; Drenowatz et al., 2009; Sherar, et al., 2010; Bacil et al., 2015). Further research is required here to attempt to unpick the actual role that biological maturation has on adolescent PA behaviour.

Strengths and Limitations

This research is the first to examine these particular predictor variables from a person-oriented perspective to investigate PA behaviours. This study is, however, not without its limitations, the first of which is the absence of objective measurement for PA. The sub-sample of accelerometer data collected could not be used within the analysis as there was not a sufficient distribution of participants across the four classes as the majority of the sub-sample was from the same one class. Although accelerometer based MVPA could not be included within the main analysis, correlational analysis at baseline displayed a significant positive association between gender specific APHV and MVPA; and a significant negative association between walking distance to school and MVPA. At baseline multiple deprivation, gender and family support of PA were not associated with MVPA. At time point 3, boys were

significantly positively associated with more MVPA and those with more perceived family support of PA were bordering on levels of a significance association to produce more MVPA ($p = 0.056$). The number of participants with valid accelerometer data dropped by 58.1% from baseline ($n = 124$) to time point 2 ($n = 52$). Reasons for this included a combination of less accelerometer's available for deployment during time point 3 (51 monitors during baseline, 47 during time point 3), children not present at school during follow up measures and children declining to wear the accelerometers again. The children commented about the responsibility of having to remember to wear and return the monitors and they also protested about the appearance of the monitors on top of or underneath their normal clothes on evenings and weekends. These reasons have also been reported in earlier research (Audrey, Bell, Hughes, & Campbell, 2012). Furthermore, as described above, if one child did not agree to re-wear the monitor for a second time a new participant was asked in an attempt to ensure optimal use of all accelerometers available. This may have caused some bias as the more active children may have been more inclined to agree to wear the monitor. To avoid an insufficient distribution of participants across latent classes in future research, studies should use accelerometry for all participants. However if not feasible accelerometers ought to be provided across a range of different groups, school classes and schools through complete random sampling. This also should be done without school teacher or researcher bias which may prevent providing accelerometers to some children due to the risk of not retaining them. A protocol to maximise the provision of adequate data in future accelerometer based research has been proposed and future research ought to look towards implementing this (McCann, Knowles, Fairclough, & Graves, 2016).

Additionally across the study, the varied sizes of the latent classes and small samples; i.e. class 4 in particular with twenty-nine participants; may have resulted to a lowered statistical power which in turn may have reduced the true effect. The analyses departed from the study design and the recruitment of participants was via schools that differed markedly in terms of characteristics (see table 2.1). These limitations ought to be considered when using these results in context of predicting PA behaviour across early adolescence.

Further measurement limitations include that, even though the PAQ-C is a well-established and validated self-reporting tool which has been recommended for youth PA research (Biddle et al., 2011; Saint-Maurice et al., 2014; Thomas & Upton, 2014), the use of this tool may have subjected participants to social desirability biases and in result over reporting (Aggio, Fairclough, Knowles, & Graves, 2016). Also, the measure of travel mode, though previously used, has not been previously validated and it does not allow for assessing

trip frequency which could provide further behavioural context for active transport (Van Sluijs et al., 2009). The use of the multiple deprivation score using the index of multiple deprivation (IMD) is a comprehensive indicator of social deprivation; however, it is a normative ranking system used to compare areas, not a true measure of the individual adolescent's deprivation (Macintyre et al., 2008). In addition, using the IMD to make conclusions about individual participants may introduce ecological fallacy and potential circularity, whereby the deprivation score is partly based on lack of access to facilities, yet this deprivation leads to a lack of access to facilities, a deprivation paradox (Lamb et al., 2010).

Conclusion

The identification of distinct profiles and differences in their PA behaviours are important and may assist in targeting interventions for early adolescents most at risk of inactivity. This study illustrates those children who perceived support of PA from their families, and lived in relatively affluent areas close to their school produced higher levels of self-reported PA and were more likely to use active transport to travel to school. More research is required that examines predictor variables from a person-oriented perspective to investigate PA behaviours, both self-reported and objective. This type of research will complement variable-oriented research and work towards a greater understanding about what individualities need to be changed or manipulated simultaneously so that behaviours can be improved. This nature of research will also assist in the development of health interventions.

Future Directions: Onto the next chapter

Study 1 examined biological maturation as a moderator for active transport and distance to school and the analysis was cross-sectional. Study 2 introduced a person-centred approach where biological maturation was used as an identifier for subgroups at baseline that were used to predict PA behaviour outcomes 12-18 months later. Study 1 (chapter 3) and study 2 (chapter 4) displayed that distance to school, multiple deprivation and family support of PA all have a role to play in the moderation and prediction of PA behaviour within early adolescence. Biological maturation moderated the relationship between distance to school and the likelihood to actively commute to school within study 1; but did not meaningfully contribute to any class membership in study 2. Thus, the effect of biological maturation on PA behaviour has been inconsistent during the first half of the thesis. This third study follows a similar concept to study 2 in that it uses individual level characteristics measured at baseline to predict subsequent PA behaviour successively. However, in a different way the focus will be solely on biological maturation. This third study will investigate whether

biological maturation predicts subsequent PA (6 - 9 months and 12 - 18 months later) and whether this relationship differed by gender. So far the thesis has not utilised time point 2 or the accelerometer MVPA data; study 3 will capitalise on both these elements.

Chapter 5

Physical activity behaviour, biological maturation and gender across early adolescence

As suggested previously, it is well documented that PA is an essential part of a healthy lifestyle and that insufficient PA is a key risk factor for non-communicable diseases such as cardiovascular diseases, cancer and diabetes (Lim et al., 2012; World Health Organisation, 2015). The majority of children and adolescents in the UK currently do not achieve the recommended amount of PA (Health and Social Care Information Centre, 2008; 2012; 2015). Early adolescence is a period of rapid change, growth and development and it is a crucial phase for developing good PA habits. Those that are active during the early adolescence stage are more likely to continue and maintain good PA habits into late adolescence and throughout adulthood (Telama et al., 2005; Alberga, Sigal, Goldfield, Prud'Homme, & Kenny, 2012). This phase is also the start of biological growth and development, indicated by the onset of puberty and often marked as the physical and biological transformation into adulthood (Stang & Story, 2005).

Biological maturation is the process of reaching a state of maturity and can be measured in terms of tempo and/or timing (Malina, Bouchard, & Bar-Or, 2004). Tempo refers to the speed at which the maturation process occurs and timing refers to the time of when certain maturity-related events occur (e.g., ages at menarche or age at peak height velocity) (Malina et al., 2004). There are gender differences in the timing of biological maturity with girl's typically entering puberty approximately two years earlier than boys (Malina et al., 2004; Cumming et al., 2012a). Adolescents of the same chronological age can vary substantially in biological age (up to 5 years) (Malina et al., 2004; Sherar et al., 2010; Cumming et al., 2012a).

There is reasonable evidence to suggest that timing of biological maturation may contribute to adolescent PA (Van Jaarsveld et al., 2007; Drenowatz et al., 2009; Sherar, et al., 2010; Bacil et al., 2015) and the influence may be different between girls and boys (Baker, Birch, Trost, & Davison, 2007; Drenowatz et al., 2010; Van Jaarsveld et al., 2007). Adolescent girls who mature earlier have significantly less pedometer steps per day (Drenowatz et al., 2009); self-report significantly lower PA levels and accumulate significantly lower levels of MVPA than average or late maturing girls (Baker et al., 2007). However, a study of over 5000 adolescents aged 11-16 years, showed that early-maturing males were found to have significantly higher rates of self-reported vigorous activity

compared with average- and late-developing boys; this effect became stable over time (Van Jaarsveld et al., 2007).

Reasons and explanations for these maturity based gender differences vary. Girls who mature early tend to display a decreased interest and enjoyment in PA (Davison, Werder, Trost, Baker, & Birch, 2007; Bacil et al., 2015). This may be as a result of the physical changes during adolescence that early maturing girls will experience (such as increased fat deposition, breast development and hip enlargement); these physical changes affect perceived physical capabilities and performance (Baker et al., 2007; Bacil et al., 2015) and elevate social anxiety (Blumenthal et al., 2011). Early maturing girls also tend to have an increased interest and attraction to the opposite sex which has been associated with lower self-esteem and enhanced consciousness of self-image (Davison et al., 2007; Bacil et al., 2015). These experiences may, in turn, cause a reduction in PA behaviour. In contrast, early maturing boys, experience different physical changes during adolescence (such as height increase, higher proportion of lean mass and the widening of shoulders), which are complementary for participation in PA (Rogol, Clark, & Roemmich, 2000; Bacil et al., 2015). Later maturing adolescent boys are associated with lower self-esteem and are typically more likely to disengage from PA (Sherar et al., 2010).

Key theoretical arguments applied to PA that explains the association between biological maturity and behaviours have been described with the literature review. The stage termination hypothesis suggests that early maturing children are more at risk of an acceptance of unhealthy behaviours, such as physical inactivity (Petersen & Taylor, 1980). In contrast, the maturational deviance hypothesis proposes that any adolescent that deviates from the relative average maturity status (i.e., earlier or later maturing adolescents) is at risk of negative health behaviours (Alsaker, 1995). Previous research has shown support of the stage termination hypothesis (Petersen & Taylor, 1980) and the maturational deviance hypothesis (Alsaker, 1995). For instance, early maturing girls are at heightened risk of depression and substance abuse (Stice, Presnell, & Bearman, 2001) as well as risk of sexual harassment and engaging in sexual activities (Skoog & Bayram-Özdemir, 2016). Increased levels of aggression have been displayed across earlier and later maturing boys (Susman et al., 2010); furthermore an emerging risk for depression in early maturing boys has been found (Rudolph, Troop-Gordon, Lambert, & Natsuaki, 2014). Early development for girls and late development for boys commonly present the greatest challenges to healthy body image (Siegel, Yancey, Aneshensel, & Schuler, 1999).

The evidence to date surrounding the association between PA and timing of biological maturity is equivocal (Cumming et al., 2008; Sherar et al., 2007; Sherar et al., 2010; Bacil et al., 2015). Within a sample of 161 9-14 year old girls and boys, no significant differences were found in MVPA across early, average, and late maturing girls or boys (Wickel, Eisenman, & Welk, 2009). Again, no differences were found across self-reported PA among 208 early, average and late maturing 11-year old girls (Niven, Fawcner, Knowles, & Stephenson, 2007). Likewise, no differences in PA were found to be associated with maturity status over a 12 month period between 150 11 - 12 year old girls (Knowles, Niven, Fawcner, & Henretty, 2009). Furthermore, maturity was found not to be a significant predictor of PA among 686 Portuguese children aged 10.5 years (± 0.3 years); however this was attributed to narrow age range of sample (Pereira et al., 2015). Reasons for the inconsistent findings can be attributed to cross-sectional design studies (Wickel et al., 2009; Drenowatz et al., 2009 Niven et al., 2007; Van Jaarsveld et al., 2007) and an inability to compare genders due to sampling and/or maturity indicator (Baker et al., 2007; Knowles et al., 2009).

Following from the evidence-based and theoretical literature review the aim of this study was to investigate whether biological maturation measured at baseline (11-12 years old) predicted PA 6 - 9 months and 12 - 18 months later and whether this relationship differed by gender. Based on prior knowledge and the stage termination hypothesis it was hypothesised that earlier maturing girls will participate in significantly less PA 12 - 18 months after baseline, compared to later maturing girls. However the opposite pattern is expected in boys and it is anticipated that earlier maturing boys will participate in greater PA at 12 - 18 months, compared with later maturing boys.

Methods

Participants

Twenty-four secondary schools across East Midlands, England, were invited to participate; seven schools across three local authorities (two independent private schools, five state-funded schools) agreed to participate. Data were collected from 705 children ($M = 12.35 \pm 0.3$ years (at baseline), 387 females); ethnicity: White = 80.7%, Asian = 15.3%, Black = 2.7%, other = 1.3%).

Procedures

The study was approved by a university ethics committee and written informed consent was obtained from each school's head teacher. Parent/guardians had the opportunity to withdraw their child from the study, and children provided their written assent. Participants

completed biological maturation and PA measures (both self-report and accelerometer) at three time points; baseline, time point 2 (6 – 9 months after baseline) and again at time point 3 (12 – 18 months after baseline). All data collection was conducted at the participant's school during school hours, typically within their Physical Education lesson.

Measures

Full descriptions of all measures used within this study (biological maturation, self-reported PA and accelerometer measured PA) are found within the general methodology (chapter 2). Cronbach's Alpha coefficient for self-reported PA in the present study for baseline was 0.85, for time point 2 0.89 and for time point 3 0.90. Due to accelerometers being in limited supply, PA was objectively assessed within a sub-sample ($n = 152$, 84 females at baseline; $n = 116$, 62 females at time point 2, and $n = 73$, 40 females at time point 3). Information on how this sub-sample was recruited is available within the methods section of chapter 4 (study 2).

Statistical Analysis

Linear regressions using SPSS (IBM version 23) were used to test the study hypotheses. Gender, APHV (standardised, gender specific) and the interaction between Gender and APHV (gender \times APHV) were used as independent variables. PA (self-reported and accelerometer measured) was used as the dependant variables in separate regressions. These regressions were repeated for time point 2 and time point 3.

Results

A breakdown of participants that had valid accelerometer MVPA and self-reported PA data is displayed within figure 5.1. Non-valid accelerometer files were removed by applying accelerometer valid wear criteria (see general methodology, chapter 2). Participants who failed to complete the PAQ-C were excluded from further analysis. Relevant descriptive statistics can be seen in table 5.1 overleaf.

<u>Baseline</u>	<u>Time Point 2</u> (6 – 9 months after Baseline)	<u>Time Point 3</u> (12 – 18 months after Baseline)
Age, M = 12.35 ± 0.3 years	Age, M = 12.85 ± 0.3 years	Age, M = 13.43 ± 0.3 years
Accelerometer MVPA Data		
124 54% female 96% white	81 56.8% female 95.1% white	52 57.7% female 94.2% white
Self-reported PA Data		
618 14.07% excluded 62.07% female 86.21% white	621 13.53% excluded 64.29% female 72.62% white	670 5.22% excluded 71.48% female 80% white

Figure 5.1. Valid accelerometer MVPA and self-reported PA data

After comparing gender, age, the % of overweight/obese, APHV and self-reported PA at each time point the non-response bias of the accelerometer sample is displayed across table 5.2. Full regression results can be seen in Table 5.3. At time point 2, APHV measured at baseline did not predict self-reported PA ($p = 0.930$) or objectively measured MVPA ($p = 0.878$); with no significant interaction effect of gender (self-report PA, $p = 0.982$; objectively measured MVPA, $p = 0.208$). Time point 3 results also displayed that APHV does not predict self-reported PA ($p = 0.611$), with no significant interaction effect of gender ($p = 0.675$). However time point 3 results reveal bordering on conventional levels of statistical significance for APHV to predict objectively measured MVPA ($p = 0.061$); nonetheless there was no significant interaction effect of gender ($p = 0.373$). At both time points gender significantly predicted both self-reported and objectively measured MVPA (time point 2, self-reported $p < 0.00$, objectively measured MVPA $p < 0.00$; time point 3, self-reported $p < 0.00$, objectively measured MVPA $p = 0.00$).

Table 5.1. Relevant descriptive statistics for each time point.

Variable	Baseline		Time Point 2 (6 – 9 months post Baseline)		Time Point 3 (12 – 18 months post Baseline)	
	M	SD	M	SD	M	SD
Chronological Age (years) (Baseline)	12.35	0.30	12.85	0.3	13.43	0.3
Predicted APHV (years) (Baseline)	12.93	1.04				
Years from PHV (Baseline)	-0.57	1.05				
Female	*387	54.89%				
Male	*318	45.11%				
Ethnicity:						
White	80.71%	-				
Asian	15.32%	-				
Black	2.70%	-				
All Other	1.28%	-				
Self-reported PA	2.93	0.72	2.22	0.55	2.18	0.61
Accelerometer MVPA	60.02	21.73	55.31	16.96	62.43	21.76

(Note; Gender and ethnicity are shown as %, *N =)

Table 5.2. Descriptive statistics for non-responsive vs responsive bias of the accelerometer sample.

	Baseline		Time Point 2		Time Point 3	
	Non-response	Valid Sample	Non-response bias	Valid Sample	Non-response bias	Valid Sample
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
N	28	124	39	81	20	52
Age (years)	12.26 (0.25)	12.33 (0.30)	12.82 (0.28)	12.80 (0.30)	13.39 (0.31)	13.39 (0.29)
% Female	50.00%	56.45%	48.72%	56.79%	50.00%	57.69%
% Overweight/Obese	17. 86%	28.23%	12.82%	28.40%	15.00%	17.31%
Self-reported PA (AU, on a scale of 0-5)	3.02 (0.84)	2.88 (0.68)	2.12 (0.57)	2.19 (0.53)	2.26 (0.54)	2.19 (0.52)
APHV (years)	12.90 (1.13)	12.88 (1.01)	13.19 (1.07)	12.87 (1.04)	13.12 (1.04)	12.91 (1.02)

Table 5.3. Linear regressions predicting PA from gender, biological maturation and gender \times biological maturation.

Measured at Baseline	Time Point 2				Time point 3			
	Self-Reported PA		Accelerometer MVPA		Self-Reported PA		Accelerometer MVPA	
	Beta	95% CI Lower ~ Higher	Beta	95% CI Lower ~ Higher	Beta	95% CI Lower ~ Higher	Beta	95% CI Lower ~ Higher
Gender	0.228*	0.154 ~ 0.345	0.550*	12.218 - 26.122	0.201*	0.142 ~ 0.350	0.592*	15.127 ~ 36.599
APHV	-0.005	-0.067 ~ 0.062	-0.019	-4.894 ~ 4.191	-0.030	-0.089 ~ 0.052	0.268	-0.296 ~ 12.308
Interaction: Gender \times APHV	0.001	-0.094 ~ 0.096	0.154	-2.916 ~ 13.133	0.025	-0.082 ~ 0.126	-0.126	-18.531 ~ 7.093

Note. * $p < 0.001$

Discussion

This study aimed to investigate whether biological maturation predicted subsequent PA across early adolescence and whether the relationship was moderated by gender. As expected boys displayed higher self-reported and objectively measured MVPA 6 – 9 months and 12 – 18 months after baseline (i.e., when biological maturity was measured). This is a well-established finding across PA literature and is in line with the most recent national statistics (Health and Social Care Information Centre, 2009, 2012). Further results from this study extend current knowledge and add to a growing evidence base that biological maturation does not predict subsequent PA across early adolescence, regardless of gender (Sherar et al., 2007; Sherar et al., 2009; Gebremariam et al., 2012; Cumming et al., 2014). However, contrary evidence exists to suggest that biological maturity does play a role (e.g., Sherar, et al., 2010; Bacil et al., 2015) and gender is an important moderator of this relationship (Baker et al., 2007; Drenowatz et al., 2009; Van Jaarsveld et al., 2007). However, not all of this previous research allowed for a comparison across both genders and was longitudinal in design. The previous inconsistent findings between biological maturation and PA have also been attributed to the different maturity indicators and the various methods of measuring PA (Sherar et al., 2010).

Past justifications for no associations between PA and biological maturation (i.e. a small sample size and limited PA measurement; Bacil et al., 2015) are not applicable to the present study. The average APHV at baseline for girls (12.35 ± 0.30 years) was 1.6 years younger than the boys within the sample (13.95 ± 0.50 years); this is consistent with previous research samples (Malina et al., 2004, Sherar et al., 2007). This study is one of few to examine the prospective relationship between biological and subsequent PA. However, Cumming and colleagues (2014) observed similar non-significant associations between biological maturation and prospective PA, with no differences observed across both genders. The results from this present study and that of Cumming and colleagues (2014) may suggest a weaker or more complex effect of maturation on PA than previously anticipated. Future research may wish to unpick and explore the potential reasoning behind biological maturation not predicting subsequent PA across early adolescents across both genders.

The results from this study did show that the relationship between biological maturation measured at baseline and time point 3 accelerometer MVPA was bordering on conventional levels of statistical significance ($p = 0.06$). This finding suggests that there may be a relationship between biological maturation predicting objectively measured MVPA 12-

18 months after baseline, and this relationship was consistent across gender. A justification for biological maturation predicting MVPA 12 - 18 months after baseline and not 6 – 9 months after baseline could be attributed to the advancement of maturity. Above-mentioned maturity-related factors concerning PA (physical changes, social anxiety and self-esteem) may not play a role across PA participation levels during earlier adolescence phases but as a child develops further into maturity these factors may become more salient.

The present study provides evidence to challenge the stage termination (Petersen & Taylor, 1980) and maturational deviance hypotheses (Alsaker, 1995). These theories suggest that adolescents classed as ‘early maturing’ are at greater risk for acceptance of unhealthy behaviours, such as, physical inactivity and that any adolescent that deviates from the relative average maturity status is at the risk of negative health behaviours (Petersen & Taylor, 1980; Alsaker, 1995). In contrast, the results from this study show that maturity status does not predict subsequent PA. This then implicates neither early, on-time nor late maturing adolescents are of a particular risk of low PA behaviour; however as this study measured PA and not physical inactivity the two cannot be easily compared. Future research should examine the association between adolescents who choose to participate in PA and whether this is affected by their maturation status; a qualitative design could potentially provide an insight into these choices.

As described in the general methodology section there are alternative non-intrusive/invasive techniques that are applicable for the age group used across this thesis (Roche & Sun, 2005). Previous literature (Cumming et al., 2014; Luz et al., 2016; Cumming et al., 2018) employed the Khamis-Roche method (Khamis & Roche, 1994) whereas the present study and others (Sherar et al., 2007; Lovell et al., 2015; Werneck et al., 2015) used the method by Mirward and colleagues (2002). The Khamis-Roche method, calculates peak height velocity directly from a linear combination of child’s height and weight, together with mid-parental height. There is no gold standard prediction technique that can be used in field testing therefore it is important to apply caution when comparing among previous research other than those that have utilised and applied the same methods and techniques.

The ‘Mediated Effects Model of Psychological and Behavioural Adaptation to Puberty’ (Petersen & Taylor, 1980), mentioned across the literature review, theorised that the relationship between biological maturation and PA is mediated by physical self-concept. Early maturing girls that have lower perceptions of body attractiveness, sport competence and physical conditioning (but not strength), led to overall lower levels of physical self-worth and predicted less PA involvement (Cumming et al., 2011; Hunter-Smart, et al., 2012). Research

surrounding the relationship between biological maturation, PA and physical self-concept in males has not yet been examined. Although late-maturing boys will likely hold lower perceptions of their sport competence and physical conditioning which may again lead to overall lower levels of physical self-worth and less PA involvement. Body attractiveness, sport competence and physical conditioning have not been included across this study and the thesis. Future research may wish to explore these concepts in association to biological maturation.

Strengths and limitations

The ethnicity and range of multiple deprivation reported is typical of the UK (Office for National Statistics, 2011); and both urban and rural schools were sampled; therefore, the findings seem generalisable across similar aged adolescents of the UK. Accelerometers were worn by only a relatively small sample of participants across the study and that small sample decreased by over 50% from baseline to time point 3. Also, the participants that did complete accelerometer MVPA measures were $\geq 94\%$ white for both of the two time points. Moreover, although the results can be generalised across the UK for this particular age group, further research would be required across further populations from other countries and age groups to fully validate the findings. Age, culture and ethnicity may have differing effects on maturation status and its relationship between PA behaviours, thus, these findings cannot be fully comprehensive. The biological maturation prediction used within this study has been previously validated; however, as with any prediction, errors are associated. An error of 1.18 years 95% of the time in boys and 1.14 years 95% of the time in girls has been previously suggested (Mirwald et al., 2002). The only other strong measure of biological maturation which is able to compare against males and females is skeletal age; however, this method is highly expensive and involves subjecting participants to radiation (Sherar, Baxter-Jones, & Mirwald, 2004). Although the proposed biocultural model of PA (Cumming et al., 2012b) identifies the potential of moderating factors across the relationship of biological maturation and PA, only gender was used as a moderating factor across the present study. Further work ought to look towards the inclusion of other moderating effects, such as body satisfaction and self-esteem, within an investigation of biological maturation, PA and gender.

Conclusion

This study investigated if biological maturation predicted subsequent PA across early adolescents and determined if this relationship is affected by gender. The study showed that

boys participated in greater self-reported and objectively measured PA at 6 – 9 months after baseline and 12 – 18 months after baseline. Biological maturation did not predict subsequent PA across early adolescence, regardless of gender. Further research across early adolescents is required to attempt to comprehend how biological maturation affects PA behaviour.

Future Directions: Onto the next chapter

The aforementioned thesis studies show that late-maturing children, those from less deprived backgrounds, and children with low family support of PA are less likely to actively commute to school as distance to school increases. Furthermore, the second empirical study (chapter 4) illustrated that those children who perceive PA support from their families, and lived in relatively affluent areas close to their school, self-reported more PA and were more likely to use active transport to school. The third study showed that maturity status did not predict PA behaviour at 6-8 months or 12-18 months after baseline with no distinction across gender. As yet the thesis has not fully capitalised on the longitudinal data that has been collected. The next chapter fully utilises the longitudinal data collected to look at describing the changes of PA behaviour across 12-18 months during early adolescence. The final chapter will also examine additional forms of PA behaviour. PA will be divided into school-time PA (during P.E. lessons, break and lunchtimes) and leisure-time PA (after school, during evenings and weekends). Schools have been identified as a key setting to for promotion of PA and there is a recognition that the current trend of low levels of PA behaviour is not likely to amend without schools' support (Centres for Disease Control and Prevention, 2011; Siedentop, 2009). The government published Childhood Obesity strategy also states that “long-term, sustainable change will only be achieved through the active engagement of schools, communities, families and individuals” (Department of Health and Social Care, 2016, p. 3). For children to develop healthy PA behaviour during their leisure-time, PA in school, particularly during P.E classes is significant (Owen, Smith, Lubans, Ng, & Lonsdale, 2014). Additionally, separating the two behaviours allows a separate examination as school-time PA and leisure-time PA may differ in the variables and predictors that affect them. This final study will also investigate if biological maturation, gender, family support of PA and multiple deprivation predict any observed changes in self-reported PA behaviour.

Chapter 6

The tracking and prediction of school-time and leisure-time physical activity behaviour across early adolescence

Physical activity is a crucial part of a healthy lifestyle. Individuals who do not meet sufficient levels of PA are increasing their risk of developing non-communicable diseases such as cardiovascular diseases, cancer and type 2 diabetes (Lim et al., 2012; World Health Organisation, 2015). Large percentages (85% of boys and 91% of girls aged 13-15 years) are not currently reaching the recommended amount of PA (Health and Social Care Information Centre, 2015). The volume of children achieving the recommended PA level needs to increase for children to translate good PA behaviours into adulthood (Telama et al., 2005). Regardless of the advantages of PA, it is well documented that PA levels decline across the lifetime, particularly during adolescence (Sallis, 2000; Cairney et al., 2014).

PA can be split into various domains, such as transportation; leisure time; occupational/school and household (Pratt et al., 2004). During break and lunchtimes children have a choice about their PA behaviour as opposed to during their P.E lessons (Guinhouya et al., 2009). Thus children can choose to be physically active or inactive. As expected, because of that choice, and in line with the age decline of PA behaviour, declines of MVPA have been reported during break and lunchtimes longitudinally across early adolescence (Ridgers, Timperio, Crawford, & Salmon, 2011). Furthermore, boys often engage in more PA and at higher intensities than girls during break and lunchtimes (Ridgers, Stratton, & Fairclough, 2005; Escalante, Backx, Saavedra, García-Hermoso, & Domínguez, 2011; Escalante, Backx, & Saavedra, 2014); although the opposite has also been found (Mota et al., 2005). The opposing result published by Mota and colleagues (2005) was attributed to the majority of boys spending their break-times in inactive play; for example, playing card games or talking, both of which are interrupted by occasional short bursts of PA (Mota et al., 2005). Variability has been previously found across these different time segments. For example, greater declines of PA were found during weekends, out-of-school and lunch-times, compared with the other periods measured (weekdays, in-school and during lesson-time) across a 4-year UK study of children aged 10-14 years (Brooke et al., 2016). Furthermore, in slight contrast, across a 10-year period for children aged 9-15 years, the typically structured school-time PA has been reported as not significantly different to leisure-time PA conducted out of school, which is typically unstructured (Metcalf, Hosking, Jeffery, Henley & Wilkin, 2015). Implications of this may display that children who are physically active will be physically active inside and

outside of school within a structured or non-unstructured setting and vice versa. School-time PA and P.E. classes in particular, are important for children to develop and translate healthy behaviour into leisure-time PA (Owen, Smith, Lubans, Ng, & Lonsdale, 2014). Thus, to inform intervention design and planning; investigating the differences in PA behaviour trends across school and leisure-time can provide a more complete view of PA behaviour.

Throughout this thesis, biological maturation, gender, family support of PA and multiple deprivation have all been shown to influence PA behaviours. Biological maturation, family support of PA and multiple deprivation all significantly moderated the relationship between distance to school and the likelihood to actively commute to school (study 1, chapter 3). Specifically, late maturing children, those from less deprived backgrounds and children with low family support of PA are less likely to actively commute to school when they live further away from school. Family support of PA and multiple deprivation were also both shown to contribute to the classification of distinct profiles of children that varied in their PA behaviour. The ‘highly supported, shortest commuters’ (class 2) significantly reported more PA than the ‘affluent, short commuters’ (class 1) and the ‘least supported, long commuters’ (class 3); full descriptions of classes can be found within chapter 4. The novel results evidence that these particular variables affect the PA behaviour of early adolescents when investigated and explored collectively. Gender; multiple deprivation; biological maturation and family support of PA are reviewed individually below in respect to PA behaviour.

Gender. Males with a low leisure time PA at the age of 13 have been identified as a particular risk group for low leisure-time PA at age 23; contrary to this, females with a low leisure-time PA at baseline increased their level of leisure-time PA over time (Kjønniksen, Torsheim, & Wold, 2008). Therefore, in this case, males with low adolescent PA behaviours are a potential target for intervention work (Kjønnikse et al., 2008). Furthermore, chapter 5 (study 3) showed that males displayed higher self-reported and objectively measured MVPA 6 – 9 months and 12 – 18 months after baseline. This is a well-established finding across PA literature and is reflected within most recent national statistics (Health and Social Care Information Centre, 2009, 2012, 2015), displaying that early adolescent females are of a particular risk of low levels of PA. Thus, across the present study it is expected that boys will produce more school-time and leisure-time PA than girls at baseline. The behaviour of both PA components is expected to decrease on average across the 18 months for both genders. This prospect is based upon previously established findings that displayed both genders are susceptible to a similar decrease of PA behaviour across adolescence (Dumith, Gigante, Domingues, & Kohl, 2011; Corder et al., 2013).

Multiple deprivation. Multiple deprivation is technically a time-variant measure of socio-economic status, as scores can fluctuate. Within the present chapter there was minimal variance of deprivation scores across the 18 months. Consequently multiple deprivation will be treated as a time-invariant variable. Predominantly cross-sectional studies concluded that children from low multiple deprivation areas were more likely to do less PA (Hanson & Chen, 2007; Noonan, Boddy, Knowles, & Fairclough, 2016). Reasons for this have been attributed to adolescents living in urban, unsafe neighbourhoods with a lack of green spaces (Estabrooks, Lee, & Gyurcsik, 2003; Weir, Etelson, & Brand, 2006, Bennett et al., 2007). Furthermore, early adolescents from more deprived households may spend their after-school time within part-time employment (Van Matre, Valentine, & Cooper, 2000; Bélanger et al., 2011) and are less likely to be involved in organised club sports, which can be costly (Kantomaa, Tammelin, Näyhä, & Taanila, 2007; Vandermeerschen, Vos, & Scheerder, 2015). Both these aspects may well contribute and impact leisure-time PA behaviour more significantly. Though the relationship between deprivation and PA is multifaceted and inconsistent with studies reporting atypical relationships (those with a higher socioeconomic status produced less PA) (Nelson, Gordon-Larsen, Adair & Popkin, 2005; Stalsberg & Pedersen, 2010) or no relationship (Patrick et al., 2004; Whitt-Glover et al., 2009). Few studies have examined a measure of socioeconomic status in regard to tracking PA longitudinally across adolescence (Cleland, Ball, Magnussen, Dwyer & Venn, 2009; Rauner, Jekauc, Mess, Schmidt, & Woll, 2015; Metcalf et al., 2015). Along with the typical decline of PA, there were no differences found between PA behaviour and socioeconomic status across children aged 9 to 15 over a 10-year period (Metcalf et al., 2015). A large Australian longitudinal study spanning 19 years found in contrast, that an enhancement in socioeconomic position indicated by educational level was associated with an increase in PA behaviour from childhood to adulthood (Cleland et al., 2009).

Biological Maturation. Biological maturation may also be important when predicting and tracking PA behaviours. APHV should not change through adolescence; however, when predicted changes are seen, they are most likely due to measurement errors and limitation with the prediction itself (Malina, Choh, Czerwinski, & Chumlea, 2016). Thus APHV is treated as a time invariant variable for the present study. The timing and pace of biological maturation has important consequences for physical, psychological and behavioural development, some of which may impact involvement in PA (Cumming et al., 2012b). PA tends to decrease with an increase in biological age, even after controlling for chronological age (Cumming, et al., 2008; Smart et al., 2012), although the evidence around maturity

timing and PA behaviour is mixed (Sherar et al, 2010; Bacil et al., 2015). The previous chapter, study 3, for example found that biological maturation does not predict subsequent PA across early adolescence, regardless of gender.

Family Support of PA. In previous literature family support of PA has consistently been associated with child and adolescent PA and there is strong evidence that family support is both a positive correlate and determinant for PA behaviour (Sallis, 2000; Trost & Loprinz, 2011). During the early adolescent years, parents and families that are active themselves are essential to creating a social model of good PA behaviours (Gustafson & Rhodes, 2006). Yet as the child matures and becomes more independent from their parents and family system, that support can become less impactful (Yao & Rhodes, 2015). In contrast, longitudinal evidence has displayed that a positive improvement in family support across adolescence was associated with a positive improvement in PA behaviour, relative to that individual (Morrissey et al., 2015). This was particularly apparent across adolescent girls, suggesting that support is a central determinant of PA behaviour in adolescence, and in particular in girls (Dowda, Dishman, Pfeiffer, & Pate, 2007; Bradley, McRitchie, Houts, Nader, & O'brien, 2011; Laird, Fawkner, Kelly, McNamee, & Niven, 2016). Across the current study there is an expectation that children with higher family support of PA at baseline will report higher levels of PA across both school and leisure-time at baseline. It is also predicted that this trend will continue throughout the study. In other words, those with higher family support will continue to report higher levels of PA and vice versa. This is expected to be particularly apparent across leisure-time PA where family support is more influential (Morrissey, Wenthe, Letuchy, Levy, & Janz, 2012).

Based on the literature presented above, the aims of the current study were to describe and identify the variation of PA across 18 months of early adolescence and to determine if these patterns can be predicted. This particular study examines adolescent PA across school-time PA (during P.E. lessons, break and lunchtimes) and leisure-time PA (after school, during evenings and weekends). The present study, however, aims to examine gender; multiple deprivation; biological maturation and family support of PA in isolation to predict the PA behaviour of during early adolescence. Research, such as this which aims to identify patterns of behaviour, can ultimately assist with identifying 'at risk' groups and/or variables that can lead to physical inactivity. A further aim of the present study is to investigate how variables that change over time (time variant variables) and variables that do not change over time (time invariant variables) can predict these potential changes in PA across early adolescence.

From the above literature review, it is expected that both school-time and leisure-time PA behaviour will decline in general over the course of the study. Also that males; those from less deprived backgrounds and children with higher family support of PA will all have higher levels of PA behaviour at baseline across both components. It is expected that those individuals mentioned will also maintain higher levels of PA than their counterparts throughout the study. School-time and leisure-time PA are expected to have similar results across genders yet for leisure-time PA it is expected that multiple deprivation and family support will be more impactful on behaviour. Due to the conflicting evidence surrounding biological maturation and PA behaviour there is not enough evidence to form a hypothesis for the current study. These results may be used to inform the timing, targeting and content of future interventions to increase and maintain good levels of PA behaviour.

Methods

Participants

Twenty-four secondary schools across East Midlands, England, were invited to participate. Seven schools across three local authorities (two independent private schools, five state-funded schools) agreed to participate. Data was collected from 705 children (Mean = 12.35 ± 0.3 years (at baseline), 387 females); ethnicity: White = 80.7%, Asian = 15.3%, Black = 2.7%, other = 1.3%).

Procedures

The study was approved by a university ethics committee and written informed consent was obtained from each school's head teacher. Parents/guardians had an opportunity to withdraw their child from the study and children provided their written assent. Participants completed biological maturation, multiple deprivation, family support of PA and self-reported PA measures at baseline. Family support of PA, school-time and leisure-time PA were also measured again at time point 2 (6 – 9 months after baseline) and time point 3 (12 – 18 months after baseline). All data collection was conducted at the participant's school during school hours, typically within their Physical Education lesson.

Measures

Full descriptions of all measures used within this study (biological maturation; multiple deprivation; family support of PA; gender and self-reported PA) are found within the general methodology (chapter 2). Gender is time invariant and was coded as followed; 0 – female, 1 – male. Multiple deprivation was coded (0 - 9, 0 = more deprived, 9 = less

deprived). Postcodes data did not change for 674/ 693 children from baseline - time point 3 thus confirming multiple deprivation was relatively time invariant for 97.3% of the sample. This chapter uses only six items from the PAQ-C to measure children's physical activity. All items from the original PAQ-C were not used because some did not allow for differentiation of school and leisure-time, which was a purpose of the study (Taylor, 2017). Cronbach's Alpha coefficient for self-reported PA in the present study for baseline was 0.85; for time point 2 was 0.89 and for time point 3 was 0.90. Three items were used to measure school-time PA (during PE, break time and lunch time) and three items for leisure-time PA (after school hours, in the evenings and weekends). Table 6.1 displays the items in respect of school-time or leisure-time PA measurement.

Table 6.1. School-time and leisure-time PA items from PAQ-C.

	PAQ-C item	PA time segment
1	In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)?	School-time PA
2	In the last 7 days, what did you do most of the time at recess (break time)?	
3	In the last 7 days, what did you normally do at lunch (besides eating lunch)?	
4	In the last 7 days, on how many days, right after school, did you do sport, dance, or play games in which you were very active?	Leisure-time PA
5	In the last 7 days, on how many evenings did you do sports, dance, or play games in which you were very active?	
6	On the last weekend, how many times did you do sports, dance, or play games in which you were very active?	

Statistical Analysis

The statistical analysis utilised longitudinal growth models within MLwiN 3.00 software (Rasbash, Steele, Browne, & Goldstein, 2012). Two levels of analysis were specified and estimated simultaneously: level 1 (i.e., within-person) and level 2 (i.e., between-person). Multilevel analysis is different to traditional analysis of variance as it allows for missing data points; unequally spaced time points; time-varying covariates and non-normally distributed repeated measures (Curran et al., 2010). Initially, intercept only

models were ran and the intraclass correlation (ICC) was calculated for school-time PA and leisure-time PA. The ICC displays the amount of variance in PA that lies within or between the study individuals (Hox, Moerbeek, & van de Schoot, 2010). Second, to examine changes in school and leisure-time PA over time, unconditional growth models were run with time as a fixed effect predictor. The unconditional growth models were then repeated with time as a random effect to explore whether changes were variable across participants. Third, predictor variables were added to these models to create conditional growth models. Gender, multiple deprivation and biological maturation were all time invariant and were added un-centred in addition to the interaction term (time \times variable). Family support of PA was the only time variant variable as scores can change over time and are dependent on situations and experiences. Family support was measured three times over the 18 months. Therefore, the variable was group-mean centred before being added into the conditional growth model to capture the within-person variation across family support through the study (Paccagnella, 2006).

Results

Descriptive Results

All 705 children provided information on their gender, age and ethnicity. Twelve participants failed to provide their postcode or a valid postcode; therefore, measures of multiple deprivation were missing for those participants. Moreover, 166 participants did not complete sufficient measures to calculate their biological maturity at baseline. Additionally, 102 children at baseline; 85 at time point 2 and 86 at time point 3 failed to respond to the family support of PA questionnaire. Full descriptive statistics are displayed within table 6.2.

Preliminary Analysis Results

Table 6.3 shows correlations between school-time PA and leisure-time PA across the time points and suggests the presence of two related, yet distinct types of PA behaviour.

Table 6.2. Descriptive statistics of study variables and relevant child characteristics.

	Baseline			Time Point 2			Time Point 3		
	N	M	SD	N	M	SD	N	M	SD
Gender*	705	-	-						
Males	318	45.11%		Same as Baseline					
Females	387	54.89%							
Chronological Age (years)	705	12.36	0.30	705	12.85	0.30	705	13.43	0.30
Ethnicity*	705	-	-						
White	569	80.71%		Same as Baseline					
Asian	108	15.32%							
Black	19	2.70%							
All Other	9	1.28%							
School-Time PA (AU, on a scale of 0-5)	617	3.30	0.86	620	3.17	0.83	622	3.18	0.88
Leisure-Time PA (AU, on a scale of 0-5)	617	2.95	0.98	619	2.89	0.98	621	2.89	1.03
Predicted APHV (years)	539	12.93	1.04	-	-	-	-	-	-
Years from PHV	539	-0.57	1.05	-	-	-	-	-	-
Multiple Deprivation	693	5.52	2.69	-	-	-	-	-	-
Family Support of PA	603	3.29	0.93	620	3.18	0.99	619	3.11	1.01

Note. *Values are percentages rather than mean (SD).

Table 6.3. Pearson Correlations between School-time and Leisure-time PA across time points

	N	Pearson Correlation (<i>r</i>)
Baseline	616	.399*
Time point 2	619	.516*
Time point 3	620	.450*

Note. * $p < .01$

Intercept Only and Unconditional Growth Models

The intercept only models displayed significant variance at both levels (within-person and between-person) for both school-time and leisure-time PA, see table 6.4. The results show that 57% of the variance across school-time PA was between-person and 43% of variance was within-person over time. Then for leisure-time PA, 60% of the variance was between-persons and 40% of variance was within-person over time. Unconditional growth models displayed that school-time PA decreased over time on average, however PA during leisure-time showed no change on average over time. When explored as random effects, changes in school-time and leisure-time PA displayed significant variability across children over the course of the study. In other words, changes in PA are not homogenous across the sample.

Table 6.4. Intercept-only and unconditional growth model results.

Intercept-only Model		
	School-Time PA	Leisure-Time PA
	Regression Coefficient (Standard Error), <i>p</i> value	
Intercept	3.213 (0.028)*, 0.00*	2.907 (0.032)*, 0.00*
Level 2 variance (between-persons)	0.420 (0.030)*, 0.00*	0.561 (0.040)*, 0.00*
Level 1 variance (within-persons)	0.316 (0.013)*, 0.00*	0.432 (0.018)*, 0.00*
Intraclass coefficient (ICC)	0.571	0.601
Unconditional Growth Model (fixed effect)		
Regression Coefficient (Standard Error)	-0.055 (0.016)*, 0.00*	-0.031 (0.019), 0.10
Unconditional Growth Model (random effect)		
Regression Coefficient (Standard Error)	0.080 (0.014)*, 0.00*	0.069 (0.019)*, 0.00*

* Significance (> 1.96), * $p < .00$

Conditional Growth Models

Full results are displayed within table 6.5.

Gender. Results exhibited that males reported more school-time PA than females at baseline. On average, both genders decreased and there was no significant difference in the rate of change between genders over 18 months. For leisure-time PA, males reported more leisure-time PA than females at baseline, and, on average, there was no change over time and there was no significant difference in the rate of change between the genders over 18 months.

Multiple Deprivation. Results displayed that the children from higher deprivation backgrounds reported less school-time PA at baseline. On average, there was no change over time and there was no significant difference in rate of change across different levels of multiple deprivation over 18 months. For leisure-time PA no differences at baseline were observed between multiple deprivation levels in leisure-time PA. Again there was no significant change over time and across the rate of change between multiple deprivation and leisure-time PA over 18 months.

Biological Maturation. Results showed that there was no significant relationship between biological maturation and both components of PA measured at baseline. In other words regardless of whether a child was biologically more or less mature they reported the same school-time and leisure-time PA at baseline. On average school-time PA decreased over the course of 18 months and there was no significant difference in the rate of change between individuals based on their maturity status. On average for leisure-time PA, there was no change over time and there was no significant difference in the rate of change between the individuals and their maturity status over 18 months.

Family Support of PA. Results of family support showed that those individuals with higher family support of PA significantly completed more school-time PA at baseline. On average school-time PA decreased over time but results showed no significant difference in the rate of change between individuals with lower or higher levels of family support of PA over the 18 months. For leisure-time PA, again those individuals with higher family support significantly produced more leisure-time PA at baseline. On average, there was no change over time for leisure-time PA and there was a significant difference in the rate of change between individuals and their family support of PA over 18 months. After further analysis it was demonstrated that those with higher family support tended to maintain their leisure-time PA, with a very slight increase over the 18 months; whereas those with lower family support decreased their leisure-time PA more rapidly on a constant rate, see figure 6.1. To then test for the within-person changes for family support and leisure-time PA, family support was group mean centred by subject. Again the main effect was significant, meaning if an individual experiences a relative change in family support, their leisure-time PA changes. In

other words, if an individual's family support increases, so does their leisure-time PA and vice versa.

Table 6.5. Conditional growth model results for Gender (1), Multiple Deprivation (2), Biological Maturation (3) and Family Support of PA (4).

		School-Time PA	Leisure-Time PA
		Regression Coefficient (Standard Error)	
Between Person (Time Invariant)			
1.	Main Effect of Gender	0.511 (0.086)*	0.271 (0.099)*
	On average over time (β_{1j})	0.083 (0.025)*	-0.029 (0.028)
	Time point x Gender	0.055 (0.036)	-0.004 (0.041)
2.	Main Effect of Multiple Deprivation	-0.035 (0.016)*	0.002 (0.018)
	On average over time (β_{1j})	-0.050 (0.041)	-0.039 (0.047)
	Time point x Multiple Deprivation	-0.001 (0.007)	0.001 (0.008)
3.	Main Effect of Biological Maturation	0.046 (0.048)	0.072 (0.053)
	On average over time (β_{1j})	-0.063 (0.020)*	-0.029 (0.020)
	Time point x Biological Maturation	-0.009 (0.020)	-0.027 (0.023)
4.	Main Effect of Family Support of PA	0.360 (0.051)*	0.464 (0.056)*
	On average over time (β_{1j})	-0.055 (0.018)*	-0.029 (0.020)
	Time point x Family Support of PA	-0.002 (0.021)	0.064 (0.024)*
Within Person (Time Variant)			
4.	Main Effect of Family Support of PA		0.330 (0.029)*

* Significance (> 1.96)

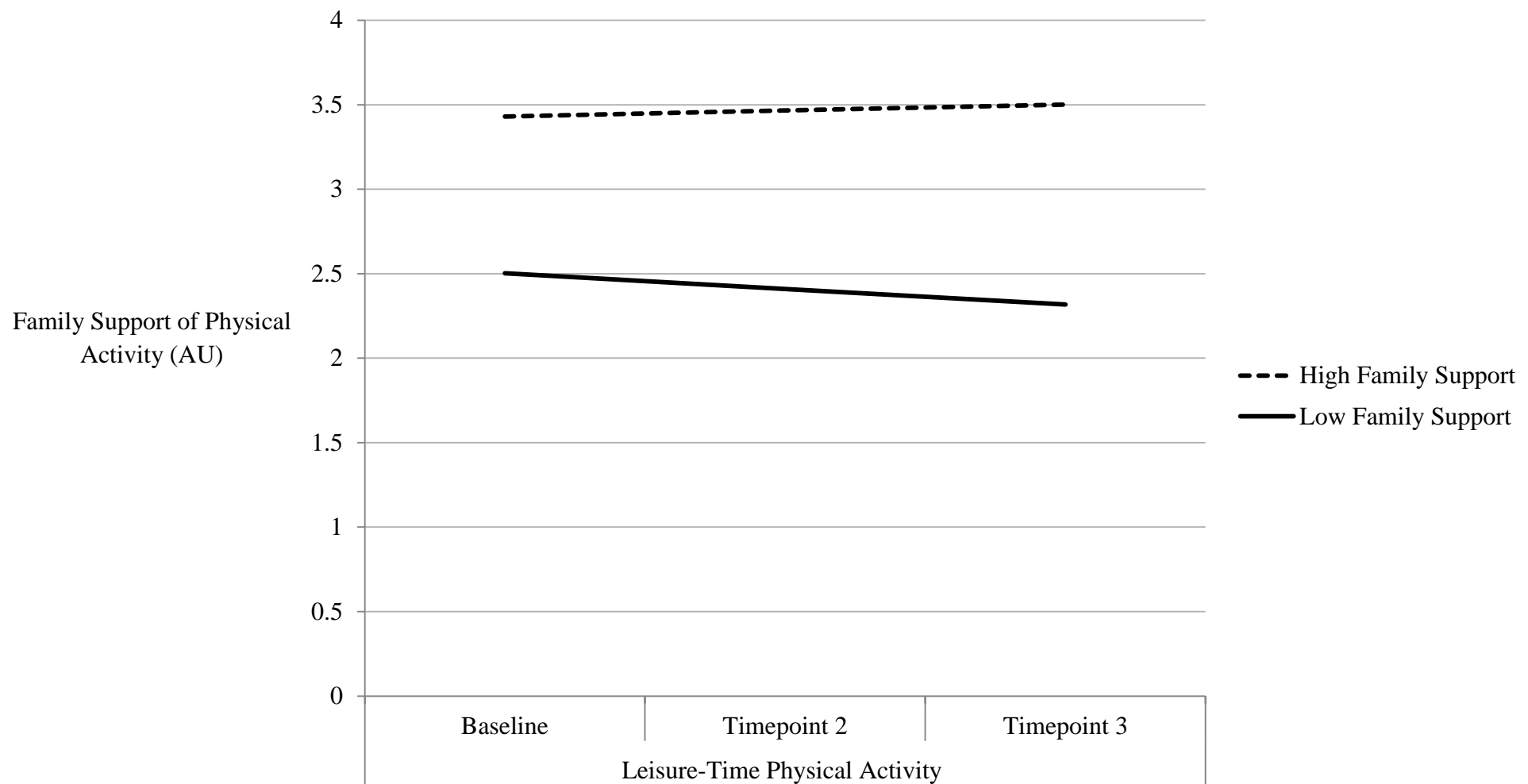


Figure 6.1. Average levels of family support of PA and leisure-time PA. (Note; y-axis, arbitrary units on a scale from 0-5).

Discussion

This chapter aimed to investigate the changes of self-reported school-time and leisure-time PA across 18 months during early adolescence. Moreover, the study examined how biological maturation; gender; family support of PA and multiple deprivation can predict these potential changes in PA. On average, school-time PA decreased over the course of the 18 months over early adolescence, which agrees with previous research (Gordon-Larsen, McMurray, & Popkin, 2000; Harding, Page, Falconer, & Cooper, 2015). Explanations for this finding could be attributed to a shift of responsibilities during break and lunchtimes with more emphasis on academic achievement (Eime, Payne, Casey, & Harvey, 2010) and attending physically inactive extra circular activities such as homework club; peer mentoring; choir and subject-specific activities (e.g. Maths club to benefit academic performance). Furthermore, many schools withhold a child's break time and/or segments of their lunchtime as a form of punishment or discipline for poor classroom behaviour or for not returning homework on time etc. The reasons described above may be particularly apparent after the transition from primary to secondary school, which many of participants of the study experienced 5 months prior to baseline testing. Additionally, this age group may spend more time socialising with peers of both sexes in an inactive manor rather than active play, e.g. just talking, listening to music or playing with technology. Many of the above reasons have been speculated. Research directly observing the behaviour of how early adolescents use their break and lunchtimes to engage in physical activity and/or sedentary behaviours is needed to gain a more complete insight (Ridgers, Timperio, Crawford, & Salmon, 2013). The on-average decline of school-time PA may also be associated with a negative perception of the participant's competence of PA and sport during P.E lessons (Bélanger et al., 2011). This may include comparing themselves to peers and negatively evaluating their own skill levels (Bélanger et al., 2011). PA, P.E and sport may also start to become more serious and competitive than in the past and those with lower perceived competency may opt to remove themselves from situations where their performance risked being judged unfavourably (Bélanger et al., 2011).

Furthermore, explanations of the on-average decline of school-time PA may be embedded within the school culture, across both staff and students. Following a recent report, P.E. has fundamentally been regarded as the 'Cinderella subject' of the school curriculum (All-Party Parliamentary Group, 2016). This means that the subject is seen as less significant; P.E is exempt from National Curriculum core subject status and typically receives minor

coverage by school inspections and league tables (All-Party Parliamentary Group, 2016). Thus, naturally senior school leaders have priorities and targets influenced by the degree of external scrutiny made of curricular subjects whereas P.E has less in comparison to the core subjects such as Maths, English and Science (All-Party Parliamentary Group, 2016). The age group from this study were first tested within the second or third term of their first year within secondary school. At the beginning of this study the culture of P.E being less significant may not have been immediately apparent but developed over the course of 18 months, thus attributing to the on-average decline of school-time PA.

The present study also displayed there was no significant mean change across leisure-time PA over the of 18 month period. This contradicts earlier research which displays leisure-time PA decreases across adolescence (Kjønniksen et al., 2008; Jose, Blizzard, Dwyer, McKercher, & Venn, 2011). Justifications for this non-significant change could be down to the age of the participants, the previous studies mentioned looked at older adolescents (13 years+), the participants of the present study may be too young to view a decline in leisure-time PA (mean age time point 3, 13.43 years \pm 0.30). A further perceived barrier to leisure-time PA has been reported for males and females as a lack of company from friends (Dias, Loch, & Ronque, 2015). The adolescence phase brings more independence from the family and as a result friends can have a greater influence on leisure-time activities (Viner et al., 2012). The participants of the present study are on the cusp of adolescence the transition from ‘doing as their parents say’ to ‘doing as their friends do’ may not be apparent yet.

Significant variability across children in regard to their school-time and leisure-time PA was displayed over the course of the study, thus it was justified to complete further analysis on the predictor variables. As anticipated, males reported more school-time and leisure-time PA than females at the start of the study (baseline); this is in line with the most recent national statistics (Health and Social Care Information Centre, 2009, 2012). However, there were no significant differences in the rate of change between genders over 18 months for both school-time and leisure-time PA; in other words girls continued to report less PA than boys across the time measured. This follows literature and recent statistics; for boys aged 11-15 years, 7% met the recommended guidelines whereas no girls aged 11-15 years met the guidelines (Health and Social Care Information Centre, 2009). Additionally European youth data reported that across children between the ages of 4–18 girls perform on average around 17% less total PA than boys (Ekelund et al., 2012). Females reporting less school-time and leisure-time PA at adolescence is likely to translate into adulthood, as PA generally decreases from adolescence to adulthood (Corder et al., 2017). In an attempt to combat the

lower levels of participation within PA, targeting and tailoring interventions especially for females has been shown to be successful with the results of female oriented campaign ‘This Girl Can’, motivating 1.6million women to start to exercise (Kemp, 2016).

Children with higher deprivation undertake less school-time PA, this is consistent with previous studies (Gordon-Larsen et al., 2000; Starfield, Robertson, & Riley, 2002; Tandon et al., 2012), yet this previous research measured overall PA. Across leisure-time PA there was no significant difference found between participants from backgrounds of higher or lower multiple deprivation. This difference between multiple deprivation and the two components of PA adds to the contradictory evidence between socio-economic status and PA behaviour (Stalsberg & Pedersen, 2010). For instance, multiple deprivation is shown here to affect the behaviour of school-time PA but not leisure-time PA. Our results also differed from a previous longitudinal study that examined in-school and out-of-school PA and concluded PA behaviour declined at the same rate across both PA components for children from areas of high and low deprivation (Metcalf et al., 2015). The present results demonstrate that regardless of deprivation status, the population of early adolescents measured, will produce the same amounts of leisure-time PA, making deprivation less impactful for leisure-time PA than school-time PA. This was unforeseen as typically children from more deprived backgrounds have less opportunity for leisure-time PA as they are thought to live in more urban and unsafe neighbourhoods with a lack of green spaces (Estabrooks, Lee, & Gyurcsik, 2003; Weir, Etelson, & Brand, 2006; Bennett et al., 2007; Timperio, Crawford, Telford, & Salmon, 2004). Naturally these types of neighbourhoods may discourage parents to allow the use of active transport and participating with PA outside. Furthermore, early adolescents from less deprived backgrounds with a higher family annual income are more likely to be involved in organised club sports, which can provide additional opportunities to be active during leisure-time but can also be costly (Kantomaa, Tammelin, Näyhä, & Taanila, 2007; Vandermeersch, Vos, & Scheerder, 2015).

Biological maturation within this study did not predict school-time or leisure-time PA at baseline, regardless of their biological maturity. There were also no significant differences in the rate of change between individuals who are more or less biologically mature and their school-time PA across the 18 month study period. Similarly, for leisure-time PA there was no difference across time and no significant difference in the rate of change between individuals who are more or less biologically mature. These results extend current knowledge and add to a growing evidence base that biological maturation does not predict PA across early adolescence (Sherar et al., 2007; Sherar et al., 2009; Gebremariam et al., 2012; Cumming et

al., 2014). This finding was anticipated as the evidence around maturity timing and PA behaviour is mixed (Sherar et al, 2010; Bacil et al., 2015). Study 3 of this thesis also found that biological maturation does not predict subsequent PA across early adolescence, regardless of gender.

As expected; individuals with higher family support reported more school-time and leisure-time PA than those with less family support at baseline. This was hypothesised and is in agreement with previous work suggesting that family support is a positive correlate and determinant for PA behaviour (Trost & Loprinz, 2011; Morrissey, Janz, Letuchy, Francis, & Levy, 2015). This result also strengthens results from study 1, in that family support is a positive moderator for active transport, and study 2 in that individuals from the class with the highest family support of PA undertook more PA. In terms of school-time PA, the behaviour decreased over time on average and there was no difference over time across those with higher levels of family support of PA in comparison with those with lower levels of support. This finding implied that family support of PA does not seem to affect levels of school-time PA longitudinally but does determine the behaviour initially, i.e. at baseline. This finding agrees with previous research using adolescent girls that suggests other factors, such as peer support and influence and/or the school infrastructure may have more influence in predicting school-based PA (Laird et al., 2016).

Results regarding leisure-time PA displayed there was a significant difference in the rate of change between those with higher family support over 18 months. After further analysis it was demonstrated that those with higher family support tended to maintain their leisure-time PA, with a very slight increase over the 18 months; whereas those with lower family support decreased their leisure-time PA; demonstrating social cognitive theory in action (Bandura, 1986). In order to ingrain and maintain positive health behaviours, in this case higher levels of PA, a supportive environment is essential. Parents can enhance their child's PA behaviour through actively playing with their child, watching them perform PA, encouraging the uptake of PA programmes, providing transportation to PA related facilities, reinforcing PA participation, and teaching them how to play active games and sports (Trost & Loprinz, 2011).

Individual changes were examined in this study and results showed that if an individual experiences a relative change in family support, their leisure-time PA also changes; if family support increases, so will leisure-time PA. This displays that if an intervention can increase family support of PA, a child's leisure-time PA may increase. Engaging family is central when designing and planning interventions to increase levels of leisure-time PA across early

adolescence. Previous evidence around family support and PA behaviour of adolescents has suggested that as the child matures and becomes more independent from their parents and family system, the support provided can become less impactful (Yao & Rhodes, 2015). Despite this, the present study demonstrates that family support continues to influence PA levels across early adolescence; perhaps the participants were too young for this to be evidenced, as this was also found across previous literature utilising adolescents of the same age (Morrissey et al., 2012).

Strengths and Limitations

A key strength of this study was the use of longitudinal data which is continually being advocated (Evenson & Mota, 2011; Bauman et al., 2012). In addition, the variables used were across aspects of the ecological model and form a multidisciplinary approach. The analysis also included investigating both within-person changes and between-person differences of family support. The disentanglement of the two levels, within-person changes and between-person differences is valuable as the two levels of relationships are conceptually and statistically distinct (Taylor & Stebbings, 2012). Utilising both levels improves illustration of the data and not considering these separate sources of variation can lead to biased results and potentially incorrect conclusions (Hoffman & Stawski, 2009). An example of a practical advantage of applying this technique is apparent within the present results; those with lower family support decreased their leisure-time PA over time and further analysis displayed that individual leisure-time PA behaviour can be improved by positively modifying family support of PA.

To acknowledge the limitations of the study, there was no objective measurement for PA. The self-reported methods used may have led to over-reporting due to social desirability bias (Warnecke et al., 1997), and data may also be inaccurate due to the recall element required (Baranowski, 1988). The use of the multiple deprivation score using the index of multiple deprivation (IMD) is a comprehensive indicator of social deprivation; however, it is a normative ranking system used to compare areas and not a true measure of the individual adolescent's deprivation (Macintyre et al., 2008). In addition, using the IMD to make conclusions about individual participants may introduce ecological fallacy and potential circularity; whereby the deprivation score is partly based on lack of access to facilities, yet this deprivation leads to a lack of access to facilities, a deprivation paradox (Lamb et al., 2010). The biological maturation prediction used within this study has been previously validated; however, as with any prediction, errors are associated. An error of 1.18 years 95% of the time in boys and 1.14 years 95% of the time in girls has been previously suggested

(Mirwald et al., 2002). However, the only other strong measure of biological maturation which is able to compare males and females is skeletal age; yet this method is highly expensive and involves subjecting participants to radiation (Sherar, Baxter-Jones, & Mirwald, 2004). Additionally, levels of parental PA were not measured during this study which has formerly been found influential across previous research (Marques, Martins, Sarmiento, Deniz, & Carreiro da Costa, 2014; Christofaro et al., 2017).

Conclusion

To conclude, this chapter provides evidence that school-time PA is distinct from leisure-time PA. School-time PA declined on average throughout the 18 months of early adolescence whereas no changes were observed across leisure-time PA behaviour. Males and those with higher levels of family support all reported more school-time and leisure-time PA behaviours at baseline and throughout the 18 months than their counterparts. Whereas those with lower levels of deprivation reported more school-time PA there were no differences found between deprivation and leisure-time PA along with biological maturation and both the components of PA behaviour measured. Within-person changes for family support and leisure-time PA were found, and results displayed those with higher family support maintained their leisure-time PA, with a very slight increase over the 18 months. Those with lower family support decreased their leisure-time PA more rapidly on a constant rate. The full results display that PA during P.E. lessons, break and lunchtimes are critical periods for early adolescence to potentially decrease their overall PA and should thus be targeted for intervention. The results also evidenced that family support plays a central role in the maintenance of leisure-time PA; parents and close family members ought to be encouraged to provide tangible and emotional support towards their child's PA behaviour.

Chapter 7

General Discussion

Within this thesis four research studies are presented that, in combination, aim to work towards gaining a more comprehensive understanding of how variables across aspects of the ecological model can affect PA behaviour across early adolescence. The thesis began with a focus on a central element of child PA behaviour actively commuting to school. Distance from home to school is significant in the decision to actively commute to school; specifically, the likelihood of utilising inactive transport increases with distance (Dessing et al., 2014; Chillón et al., 2014). To investigate active transport further, study 1 examined how gender, biological maturation, family support of PA, and multiple deprivation moderated the relationship between distance to school and the likelihood of active travel to school. Based on the findings from the first study, the second study continued the exploration of the same variables. However, to achieve further insight, this second study navigated away from a typical variable-oriented approach and made the individuals central through a person-oriented-research approach. This approach classified adolescents, based on the same individual influences from the first study, into distinct profiles. Profiles of individuals that shared comparative characteristics were then investigated to determine whether they were associated with different levels of self-reported PA and likelihood to use active transport. Previously literature has demonstrated biological maturation and the influence it may have on PA behaviour is equivocal and this has also been echoed across the first two thesis chapters. The third study, therefore, looked at both biological maturation and gender and the impact on PA behaviour across early adolescence. Study 3 was able to use both objectively measured and self-reported PA as well as two time points for PA to gain a further understanding of the prediction of subsequent PA behaviours. Study 4 utilised longitudinal data, which is continually being advocated across PA research (Evenson & Mota, 2011; Bauman et al., 2012). The results from study 4 supported evidence that family support plays a central role in the maintenance of leisure-time PA. This following chapter will now summarise the main findings reported within this thesis and discuss implications of these findings for future research.

Key finding 1: ‘Likelihood to actively commute is not just about distance’.

Study 1 (chapter 3) displayed that distance to school was the only significant variable associated with active transport, when other variables were held constant. The closer to school participants lived; the more likely they were to actively commute. Although this may

suggest that distance is the key factor in predicting the use of active transport, biological maturation, socio-economic status and family support of PA all significantly moderated this relationship. In particular, later-maturing children, those from socio-economically less deprived backgrounds, and children with low family support of PA are likely to be more influenced in their decision to use active transport by how far they live from school.

Within the UK, all secondary school pupils who live further than 3 miles (4.8km) from their nearest school are eligible for free transport to and from school in the form of a school bus (Department for Education, 2014). This provision therefore leads to inactive transport becoming an easy, cheap and convenient solution. A resolution to this could be for those who live between the 3 - 5 mile area from their school to be offered supervised cycling provision instead; 5 miles (8km) has been previously suggested as a maximum threshold for an acceptable distance to actively commute for this age group (Van Sluijs et al., 2009). This suggests cycling provision ought to be particularly targeted at later-maturing children who live relatively far from school that are less likely to use active transport. The use of supervised walks and/or a cycle to school scheme could help encourage these less biologically mature early adolescents to actively commute. These individuals may not be permitted to independently actively commute by their parents/guardians due to their less biologically mature status, but supervision may solve this issue.

Within studies 1 and 2 (chapters 3 and 4), an association between areas of low deprivation, distance to school and likelihood to actively commute to school was revealed. In study 2, a homogenous sub-group of participants lived a relatively short distance to school in areas of the least deprived in comparison to the other class participants ('affluent, short commuters', class 1 in study 2). This group was the most likely to actively commute to school. The data supports the finding that children from areas of low deprivation are more influenced in their decision to use active transport by how far they live from school. Based on this data and the previous research, children from less deprived backgrounds who live far from school should be targeted and encouraged to use active transport. Individuals from these higher socio-economic backgrounds tend to have high health literacy (McCray, 2005), and therefore are able to obtain and understand basic health information better to make suitable health decisions (Stewart et al., 2014). Hence, the PA guidelines for children and young people in the UK should be reinforced to the child and their parents/guardians. They should be provided with the knowledge of how beneficial it would be for their child's health to actively commute to school rather than use motorised, inactive transport.

Lastly, as early adolescents with low family support who live relatively far from school are less likely to use active transport; parents/guardians and all immediate family members should be targeted and encouraged to provide support of PA, particularly to those who live relatively far from school. Based on the social cognitive theory (Bandura, 1986), to engrain and sustain positive health behaviours, a supportive environment is essential and that learning is directly associated with the observation of models. This modelling can include the observation of family members' attitudes towards and their practice of PA. Children's likelihood to use active transport is strongly associated with their parents' use of active transport (Merom et al., 2006; Wen et al., 2008; Henne et al., 2014). A systematic review of interventions conducted to promote active transport to school displayed that the most effective interventions shared a key parental element; the parents received specific materials about promoting active transport and were encouraged to walk themselves (Chillón, Evenson, Vaughn, & Ward, 2011). Families should reinforce actively commuting to school and, where possible, actively commute themselves to work and/or their daily activities to lead by example. The data presented here and previous research suggests interventions to engage children with active transport and increase participation should look at implementing a whole family based approach.

Key finding 2: 'Don't forget about the interplay of individual characteristics'.

The second key finding illustrates that individuals characterised by high family support of PA, living the shortest distance to school and from relatively affluent backgrounds ('highly supported, shortest commuters', class 2 in study 2) significantly self-reported more PA than two other distinct groups of individuals. Those who live a relatively short distance to school from the most affluent backgrounds with moderate family support of PA ('affluent, short commuters', class 1); and those who reported the lowest family support, lived relatively far from school from relatively deprived backgrounds ('least supported, long commuters', class 3) both self-reported significantly less PA, compared to the 'highly supported, shortest commuters', (class 2). Study 1 (chapter 3) results also support that PA behaviour, in the form of active travel, is moderated by family support, multiple deprivation and distance to school. This key finding illustrates the complex interplay of variables and characteristics that can affect PA behaviour.

Higher PA levels cannot be accredited to a single characteristic or variable but may be influenced by, and interact with, further characteristics. Even though the most active individuals had the highest family support for PA, for example, these individuals were also

from less deprived backgrounds and lived close to school. In contrast, significantly less active individuals who had the lowest family support also lived further from school and were more deprived. This finding corroborates previous literature in that individuals are more active when they have high family support of PA (Trost & Loprinz, 2011; Morrissey, Janz, Letuchy, Francis, & Levy, 2015) and are from less deprived backgrounds (Hanson & Chen, 2007). However the findings of studies 1 and 2 also demonstrate that this interplay can defy relatively established conclusions contained in previous literature. The individuals who were the most likely to actively commute to school at baseline (‘affluent, short commuters’, class 1) did not live the shortest the distance to school, which contrasts with previous literature (Dessing et al., 2014; Chillón et al., 2014). These individuals were also the least deprived, which enhances findings from study 1 (chapter 3) that demonstrated children from less deprived backgrounds were more influenced in their decision to use active transport by their distance to school (Garnham-Lee et al., 2016). It has been previously suggested that those living in less deprived areas have more access to cars for commuting to school (Davison et al., 2008) and live in less urban environments which are typically further from schools (Oliver et al., 2014) and, therefore, are less likely to actively commute.

In considering future interventions that aim to increase PA levels and the uptake of active transport, researchers and practitioners should not dismiss this interplay of individual characteristics that affect PA behaviour. Instead they should attempt to better understand individuals and characteristics they have that need to be changed or manipulated simultaneously so that these behaviours can be improved.

Key finding 3: ‘Biological maturation: does it really influence PA behaviour?’

Across the thesis biological maturation in relation to adolescent PA has been discussed and investigated. Study 1 evidenced that later-maturing children who live relatively far from school are less likely to use active transport. Nevertheless within study 2, maturity did not meaningfully contribute to distinguishing the sub-groups. Study 3, which was a more focused investigation of biological maturity, displayed that biological maturation does not predict subsequent PA, with no distinction across gender. Both study 2 and study 3 results suggest that biological maturation may not actually be related to PA behaviour, or the relationship is perhaps weaker or more complex than previously assumed. However, findings from study 3 did display that biological maturation measured at baseline bordered on conventional levels of statistical significance ($p = 0.06$) for the prediction of objectively measured MVPA 12-18 months after baseline.

This third discussion point deliberates why these inconsistent conclusions occur, concerning the relationship between biological maturation and adolescent PA behaviour. The results of this thesis demonstrate and complement the consistently mixed findings found within the literature (Sherar et al., 2010; Bacil et al., 2015). Biological maturation moderated the relationship between distance to school and the likelihood to actively commute to school within study 1; yet across studies 2, 3 and 4, biological maturation did not contribute to any significant results. Results from study 2 showed that maturation did not meaningfully contribute to the class membership and did not predict subsequent PA across early adolescence, regardless of gender, across study 3. Similarly, study 4 results showed that biological maturation did not predict school-time or leisure-time PA at baseline illustrating that regardless of a child's biological maturity their school and leisure-time PA behaviour was unaffected. There was also no significant difference in the rate of change between individuals who are more or less biologically mature and their school-time PA across 18 months. Similarly for leisure-time PA, there was no difference over time and no significant difference in the rate of change between individuals who are more or less biologically mature.

The inconsistent findings between biological maturation and PA previously in literature and across this thesis could be methodological and derive from the techniques used to measure biological maturity (Sherar et al., 2010). A skeletal age assessment involving an x-ray to determine bone age is considered the gold standard assessment of biological maturity (Malina, Bouchard, & Bar-Or, 2004). Yet this technique is expensive, requires specialist equipment and training, and raises ethical and recruitment issues around exposing children and adolescents to repeated radiation (Baxter-Jones & Sherar, 2007). Instead, predicting maturity from anthropometric measurements is increasingly being used (Malina et al., 2016). Validation studies have displayed that predicted maturity offset and predicted age at PHV is dependent upon the chronological age at prediction and the age-associated variation in body size (Malina et al., 2016). Mean predicted ages at PHV have been found to be later than actual age at PHV within early maturing girls and boys, and were earlier than actual age at PHV for later maturing children across most age groups (Malina & Koziel, 2014a; 2014b; Malina et al., 2016). From this it is reasonable to suggest that PA may differ across maturity indicators and that they are not comparable; some may be more closely linked to disengagement from PA than others. Actual and perceived indicators are distinct measures of

biological maturation; although they may correspond, they either measure biological or psychosocial differences which affect PA differently (Sherar et al, 2010).

To further speculate on the justifications of inconsistent findings between biological maturation and PA within this thesis, a closer inspection of the outcome variables is important. Study 1 found that late-maturing children were less likely to actively commute to school as distance to school increases. In this situation, parents likely make the ultimate decision about transport to school (McMillan, 2005). Whereas across studies 2 and 3, when the main outcome measure was self-reported PA, there were no significant direct effects of biological maturation on PA behaviour. Thus the child's maturity status may be a more distinct, indirect determinant when activity is profoundly influenced by parents/guardians. Parental concerns often affect the decision to allow their child to actively commute to school. These concerns originate from various road hazards, for instance street crossings and traffic (Oluyomi et al., 2014); and/or negative perceptions of neighbourhood safety, fear of neighbourhood violence, traffic volume and speed (Ahlport, Linnan, Vaughn, Evenson, & Ward, 2008). Likewise parents fear for children's safety due to stranger abductions, and distrust of neighbours (Greves et al., 2007). Mothers of less biologically mature adolescents have been found to perceive their adolescents to be less mature socioemotionally than did mothers of biologically more mature adolescents (Galambos, Barker, & Tilton-Weaver, 2003). Thus, parents (particularly mothers) of biologically mature adolescents may perceive their child to be more socioemotionally mature and be less concerned about the fears described above. Therefore these biologically more mature adolescences may be encouraged to actively commute to school by their parents/guardians.

The results from study 2 and 3, when the main outcome measure was self-reported child's PA participation, evidenced no direct effect of biological maturation on PA behaviour. This may suggest that the sample used may have been too young, with biological maturation being measured too early to show the full effects of biological maturation on children's PA. As previously stated boys, on average, enter puberty two years later than girls (Malina et al., 2004). At baseline the participants had a mean age of 12.35 years (± 0.3) and of the 539 who completed sufficient measures to calculate their maturity offset, 204 (100% female) were post-PHV and 335 (72.2 % males) were pre-PHV. Thus, 62% of the sample were pre-PHV including all the males tested and 93 females. Peak growth rate occurs in boys commonly between 14–15 years when testosterone levels are rapidly rising during mid-puberty (Tanner Stages 3–4) (Pinyerd & Zipf, 2005). This peak growth spurt in males lends itself to increased

PA (Kohl & Cook, 2013). Likewise females are likely to experience negative self-image at mid-puberty (e.g. Tanner Stage 3), which characteristically occurs after the age of 12 in an average maturing girl (Pinyerd & Zipf, 2005). Negative self-image and physical self-worth is likely to lead to decreased PA and/or PA avoidance (Cumming et al, 2011; Harriger & Thompson, 2012; Voelker, Reel, & Greenleaf, 2015). Therefore, as all the males within this sample were tested before their peak growth spurt; over half of the participants used within the thesis may have not truly reached PHV and a number of the females may not have reached mid-puberty yet this may explain the non-significant findings between biological maturation and PA behaviour.

Key Finding 4: ‘Just how influential is the family network towards PA behaviour?’

Family support has been shown to be a positive correlate and a determinant for PA behaviour (Trost & Loprinz, 2011; Morrissey, Janz, Letuchy, Francis, & Levy, 2015). Study 4 demonstrated that individuals with higher family support engaged in more school-time and leisure-time PA than those with less family support at baseline. In particular, an increase in participants’ perceived family support of PA corresponded with increased self-reported leisure-time PA levels. Distance to school was a less meaningful influence on the decision to actively commute when levels of family support for PA were higher (Study 1). In addition, in study 2 (chapter 4) the ‘highly supported, shortest commuters’ (class 2) reported significantly more PA than the ‘affluent, short commuters’ (class 1) and the ‘least supported, long commuters’ (class 3) participants. There were no significant differences displayed between the ‘highly supported, shortest commuters’ (class 2) and the ‘most deprived, longest commuters’ (class 4) however individuals from class 4 had the second highest levels of perceived family support of PA. The results from this thesis implicate that family support of PA is significant and can influence the PA behaviour of early adolescences.

This thesis measured perceived family support of PA, in particular a) encouragement towards PA provided by the family, b) active and passive (watching) participation within PA by the family with the participant, c) tangible support (providing transportation) towards PA and d) reinforcement of the health messages around PA. Although the different elements of support were measured, they were not examined separately thus the present thesis does not explain what type of support early adolescences desire more of and whether the support required may be gender-specific. Females have been shown to value praise given by family members towards their PA behaviour, whereas males have displayed having a family member watch them or (more effectively) participate with them more effective to support their PA

behaviour (Morrissey et al., 2012). Determining the most effective type of family support will help to tailor family-based interventions and can optimise the time utilised by the family to support their child towards PA.

Strengths of Thesis

A central strength of this thesis includes the use of a multidisciplinary perspective, which allowed for the examination of variables that are not typically observed together (e.g., biological maturation and multiple deprivation). As this thesis used data across three time points over an 18 month period, longitudinal perspectives were able to be gathered for studies 2, 3 and 4; this has been espoused as a necessary research undertaking (Evenson & Mota, 2011). To further strengthen this thesis all of the research approaches within the thesis used continuous variables where applicable rather than stratified analysis and/or a categorisation of variables. Stratifying and categorising variables is a common approach across health promotion literature, for example, categorising maturity levels (Cumming et al., 2012a) and PA levels (Bauman et al., 2009). Yet the use of continuous variables has been encouraged within the literature as there is no risk of falsely categorising variables (MacCallum, Zhang, Preacher, & Rucker, 2002), and will also improve the effect size, sample size and statistical power, producing a more accurate and reliable analysis (Cohen, 1983; Bissonnette, Ickes, Bernstein, & Knowles, 1990; Aiken & West, 1991; Maxwell & Delaney, 1993; Royston, Altman, & Sauerbrei, 2006). Further strengths included measuring different aspects of PA behaviour, such as active transport, MVPA levels and overall self-reported PA. Furthermore, there was no evidence for recruitment bias. The schools that agreed to participant within the study had similar characterises to those who did not agree to participate and those schools that did not respond to the research request; see tables 2.1, 2.2 and 2.3.

A further strength of the thesis was utilising the ecological model as a framework. The ecological approach was used to frame and structure the levels of influence examined across the thesis; however, the model has not been fully applied. The ecological model when applied to human behaviour, such as PA behaviour, advocates that no particular one factor can completely explain that behaviour and instead varied layers of influence need to be considered (Bronfenbrenner, 1977); this way of thinking can also broaden opportunities available for intervention (Sallis & Owen, 2015). Within this thesis the association between adolescence PA behaviour has been observed across gender, age, biological maturity, family support, multiple deprivation levels and distance from school. Certain environments can restrict the range of behaviour by endorsing certain actions and by discouraging or

prohibiting others (Green, Richard, & Potvin, 1996). The term ‘obesogenic environment’ has been coined and is defined as ‘the sum of influences that the surroundings, opportunities, or conditions of life have on promoting obesity in individuals or populations’ (Swinburn, Egger, & Raza, 1999, p. 564). To fully understand PA behaviour across an ecological approach these types of environments need to be considered. Concentrating on altering the obesogenic environment at the community and policy level can impact the local community and population. These changes could include access to healthy food and access to places to be physically active; e.g. accessible cycle routes. Moreover, policy and governance is the outer layer of ecological model and has the capacity to influence both the environmental and individual influences (Spence & Lee, 2003). An excellent example implemented by policy was the London bicycle sharing system (Boris Bikes) that showed overall positive health impacts (Woodcock, Tainio, Cheshire, O’Brien, & Goodman, 2014).

General Limitations

To fully comprehend behaviour across the ecological model all aspects need to be considered, which is a limitation of the thesis. Variables on an individual level, not measured across the present thesis, may include psychological variables, such as self-efficacy (Lu et al., 2014), basic needs satisfaction (Schneider & Kwan, 2013) and peer and teacher support (Park & Kim, 2008). A criticism of the use of ecological models for health behaviour is that typically ecological models demonstrate there is not one over-arching influence and this can lead to ambiguity and is challenging for health professionals when designing interventions (Sallis & Owen, 2015). Although the present thesis has attempted to dismantle the levels of influences, research should be aware of the potential ambiguity.

Overall across the thesis the analyses departed from the study design, the recruitment of participants was via schools that differed markedly in terms of characteristics (see table 2.1). For example, two out of seven were independent, fee-paying schools and the schools varied in terms of deprivation and rural-urban classification. This is a limitation that may have resulted to a lowered statistical power which in turn may reduce the true effect. This limitation should be considered when using these results in a context of predicting PA behaviour across early adolescence.

Further general limitations are primarily methodological. Firstly, the measure of biological maturation, although the most commonly used indicator of maturity across adolescence (Malina, Bouchard, & Bar-Or, 2004), is not the gold standard. The maturity offset equation may be particularly limited for early and late maturing individuals, when

individuals are further away from their APHV (Baxter-Jones & Sherar, 2007). This method is ultimately a prediction; all predictions have accompanying errors and applications to individuals and require attention (Malina & Kozieł, 2014a; 2014b). Also, as the prediction equation was based on a sample population from a white background, when applying to other ethnic groups there is a need for caution as proportions of sitting height and leg length differ (Malina, 2009). While the majority of the sample participants were white, 19.3% were not; thus the application of the prediction equation may not have been fully accurate for the non-white sample.

Another methodological limitation is apparent with the use of the measure for multiple deprivation. The index of multiple deprivation is a comprehensive indicator of social deprivation and is frequently used (Department for Communities and Local Government, 2015). Yet this tool can lead to implications about individual participants that may introduce ecological fallacy and potential circularity, whereby the deprivation score is partly based on a lack of access to facilities (for example), however this deprivation leads to a lack of access to facilities (Macintyre et al., 2008; Lamb et al., 2010). Again for the measure of multiple deprivation and additionally the measure of walking distance to school, the participants self-reported their own postcode. This may have led to error in recall or misunderstanding around which postcode to use if a child has more than one household due to separated parents.

The final methodological limitation to acknowledge was the substantial use of self-reported measures for PA and active transport behaviours throughout the entire thesis. Self-reporting behaviours may lead to the possibility of over- or under- reporting as well as issues around recall and social desirability (Aggio et al., 2016). Objective measures were successfully used in a sub-sample within study 3. However an unsuccessful attempt to use the sub-sample occurred within study 2. Ideally objective measures ought to be used for all participants to complement self-reported measures, however due to expenses and feasibility that is not always achievable.

Due to the longitudinal element of the thesis, particularly studies 2, 3 and 4, it is important to acknowledge that PA behaviour may have varied due to other factors not measured within this thesis such as the weather (Chan & Ryan, 2009) and daylight hours (Hillman, 2010). Adolescents have been evidenced to participate in less PA on days when it rains and during colder months (Bélanger, Gray-Donald, O'loughlin, Paradis, & Hanley, 2009; O'Neill, Lee, Yan, & Voorhees, 2013). Furthermore, small increases in daily PA are associated with longer evening daylight hours after adjusting for weather conditions across a

large international study of 23,000 5–16 year olds (Goodman, Page, & Cooper, 2014). The data collected for this thesis spans across all seasons thus requires consideration of some of the factors described above.

Further Directions

Findings presented within this thesis have implications for future research and practice relevant to PA behaviour across early adolescence. Generally, further research should look to continue the use of an ecological and inter-disciplinary perspective as well exploring potential mediators and moderators that affect PA behaviour of early adolescents (Biddle & Mutrie, 2008; Craggs et al., 2011). Good examples of this can be seen across current literature. Kantomaa and colleagues (2013) examined whether childhood motor function predicted later academic achievement and if that relationship was mediated by PA, fitness and obesity. Furthermore, Ghekiere and colleagues (2016) assessed the relationship between neighbourhood environmental features and the frequency of children's active trips per week and if any associations were moderated by the frequency of parental accompaniment when walking/cycling. Across science and policy contexts an inter-disciplinary approach to health and obesity has been espoused (Robertson, Martin, & Singer, 2003; Public Health England, 2014; Butland et al., 2007). These approaches are essential for the development and improvement of interventions as well gaining further insight into PA behaviour.

To further this, directions for future work should implement both variable-oriented approaches *and* person-oriented approaches that hold the individual central. Again, strong examples of studies such as these can be seen across current literature (Evenson, Wen, Hales, & Herring, 2016; Heitzler, et al., 2011; Huh et al., 2011). All these example studies used a latent class analysis approach which was adopted within study 2 (chapter 4). In order to successfully develop effective interventions across any behaviour change field, practitioners need to begin with a clear definition of who their audience is and what characteristics they hold (Heitzler et al., 2011). Additionally research ought to examine varied activity behaviour; this thesis explored both active transport and PA (self-reported and objectively measured) and school-time and leisure-time PA. Further research should continue this and additionally examine other elements of PA behaviour as well as associated behaviour, such as sedentary behaviour (Hallal et al., 2012); examples of research using varied activity behaviour can be seen across current literature (Biddle, Gorely, Marshall, & Cameron, 2009; Tandon et al., 2012).

This thesis was unable to present any causal effects due to the lack of experimental design (Bauman et al., 2002). However, future work can explore the temporal ordering investigated within this thesis to identify true determinants that have causal associations with PA behaviour. For example, is biological maturation a determinant of PA behaviour? Does family support of PA determine PA behaviour? The evidence presented within the thesis can be a basis for this further exploration into true determinants of PA behaviour across early adolescence.

In relation to biological maturation, this thesis begins to bridge gaps in terms of how it correlates to and predicts PA behaviour. However, much more can be done. To build on limited research, additional work that implements the bio-cultural model is required. This work ought to consider the relationship of the timing of biological maturity in psychological and social contexts; then investigate those relationships across adolescent PA behaviour (Sherar et al., 2010). Further work should also attempt to determine the discrepancy around subjective, self-reported and objective assessments of maturity status and their particular association with PA behaviour (Sherar et al., 2010). The present thesis was able to use longitudinal research study designs, yet this needs to be further promoted and attempts made to investigate how maturity can affect prospective PA and whether gender can affect that relationship. This could be done by tracking individuals from early adolescence through late adolescence and into young adulthood which would add to understanding of the variation of PA behaviour among this age group.

Overall Conclusion

This thesis has worked towards identifying correlations in PA behaviours of early adolescents. The thesis displays that early adolescents that live far from their school are less likely to actively commute to school, which can provide a useful contribution to their daily PA amount. This is particularly apparent for early adolescents who are either late-maturing and/or from socio-economically less deprived backgrounds and/or report low family support of PA. Findings also demonstrate that the interplay of individual characteristics can affect PA behaviour differently to previous conclusions. The examination of distinct profiles of individual characteristics must not be dismissed and is needed to attempt to unpick the complexity of PA behaviour across early adolescents. Findings displayed inconsistent evidence that biological maturation does actually have a role to play across the relationship of

adolescent PA behaviour. The third study of the thesis displayed no significant relationships between biological maturation, gender and subsequent PA. This and findings from study 2 illustrate biological maturation may not be a strong predictor of PA behaviour. The final study evidenced that school-time PA and leisure-time PA are distinct. School-time PA declined on average throughout the 18 months of early adolescence, whereas no changes were observed across leisure-time PA behaviour. The thesis exemplifies the complexity of PA behaviours for early adolescents and demonstrates that there is no one model that fits-all when it comes to designing and tailoring interventions.

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Appendix 1 – Ethical Approval

Ref No: R13-P203

LOUGHBOROUGH UNIVERSITY ETHICS APPROVALS (HUMAN PARTICIPANTS) SUB-COMMITTEE

RESEARCH PROPOSAL INVOLVING HUMAN PARTICIPANTS

Title: A longitudinal study to explore typologies of children who differ in their physical activity levels in early adolescence

Applicant: Dr I Taylor, K Garnham-Lee

Department: School of Sport, Exercise and Health sciences

Date of clearance: 22 November 2013

Comments of the Sub-Committee:

The Sub-Committee agreed to issue conditional approval, subject to the following conditions:

- That, when available, written confirmation was provided that the Headteacher of the school was happy for the study to proceed.
- That the Information letters were amended to replace 'Criminal Records Bureau' with the 'Disclosure and Barring Service'.

Appendix 2

School of Sport, Exercise & Health Sciences
Loughborough University,
Loughborough LE11 3TU



A Longitudinal Study to Explore Typologies of Children Who Differ in Their Physical Activity Levels in Early Adolescence

We are researchers in the School of Sport, Exercise & Health Sciences at Loughborough University and would like to take this opportunity to invite your school to participate in a study investigating the variables that affect physical activity levels within adolescents. We acknowledge that there are many competing demands upon the time of teachers and pupils but feel a study such as this, which explores a topic of public health and academic interest, would be a valuable and rewarding experience.

The study aims to identify different multidisciplinary typologies of children to determine whether early adolescents who differ in physical activity trends over adolescence can be identified and profiled prior to the onset of such patterns. We aim to collect data from Year 7 pupils during March/April 2014, and then measure their physical activity levels on 4 further occasions until July 2015; (specific dates will be arranged at your convenience). In the first session, pupils will be required to complete a questionnaire, which takes about 25 minutes to answer fully; we will gather some body measurements; height, weight, leg length and trunk length. We will also ask a sample of children to wear activity monitors. We would seek to minimise disruption to the school's lesson programme.

What you can expect from us:

1. All staff working on the project have a Disclosure and Barring Service (DBS) clearance. The study has been approved by the Loughborough University Ethical Advisory Committee.
2. All staff have been trained in the measurements involved and have previous experience working in schools with young people.
3. All information will be stored anonymously. No individual pupil or school will be identifiable in any subsequent report or research publication.
4. All visits will be by prior arrangement, and conducted in a professional manner with minimal disruption to the school and in close co-operation with school staff.

If you require any additional information, please do not hesitate to contact a member of the research team. We will follow up this email with a phone call to you in one week to gauge interest if we have not received a reply from you in the meantime. If you are willing for your school to take part, it would be helpful if you could nominate a member of staff with whom we can make further arrangements.

Many thanks for giving this request your consideration.

Yours sincerely,

Katy Garnham-Lee (K.Garnham-Lee@lboro.ac.uk)

Dr Ian Taylor (I.M.Taylor@lboro.ac.uk)

Appendix 3

School of Sport, Exercise & Health Sciences
Loughborough University
Loughborough, LE11 3TU



Dear Parent/Carer

I am a doctoral candidate at Loughborough University within the School of Sport, Exercise, and Health Sciences. I am currently undertaking a study which explores what different variables affect physical activity levels within adolescents. The findings could provide important insights into what interventions may be necessary to halt the decline in young people's participation in physical activity in school and during their leisure time.

The school which your child attends has agreed to participate in the research project. However, in line with Loughborough University procedures, we are also required to ask for your permission for your child to participate in the project. With your consent, your child will complete a questionnaire about themselves, their lifestyle and their friends and family. We will then gather a few body measurements from them including height, sitting height and weight. The data will be collected by trained researchers, who have a disclosure and Barring Service certificate. The class teacher will always be present during data collection.

All information will be confidential and no child will be identifiable in any publication arising from the project. The project aims to survey the opinions of approximately 600 school pupils in total. Children are not under any obligation to take part, and they can withdraw from the study at any time with no requirements of an explanation for their reasons.

If you **DO NOT** want your child to participate in this research, please read and complete the section overleaf and return it to the school via your son/daughter. **DO NOT RETURN THE FORM IF YOU GIVE YOUR PERMISSION FOR YOUR CHILD TO PARTICIPATE.** If you have any queries, please do not hesitate to contact the research team.

Many thanks for giving this request your consideration.

Yours sincerely,

Katy Garnham-Lee (K.Garnham-Lee@lboro.ac.uk) Mobile - 07807331320
Dr Ian Taylor (I.M.Taylor@lboro.ac.uk)

Appendix 3

PARENT INFORMATION SHEET

Your child is being invited to participate in this research study conducted by Loughborough University. Please take time to read the following information carefully.

Who is doing this research?

This research is being conducted by Katy Garnham-Lee, Sport and Exercise PhD student, under the supervision of Dr Ian Taylor of the School of Sport, Exercise and Health Sciences.

What is the purpose of the study?

To explore what different variables affect physical activity levels within adolescents.

Does my child have to take part? Can he/she change their mind once they have started?

They may decide whether or not to take part in this study. They are free to withdraw from the study at any time and do not have to give a reason.

What will happen if they choose to take part?

They will complete a questionnaire about themselves, their lifestyle and their friends and family. We will then gather a few body measurements from your child; these include your height, weight, leg length and trunk length. Afterwards they will be shown how to use an accelerometer and be asked to wear it at different times. Please see sheet overleaf titled 'physical activity Monitor Information' for further information on the accelerometers.

Will their taking part in this study be kept confidential?

Yes. This research is anonymous and confidential. All hard copy data (questionnaires and measurements) will be stored in locked filing cabinets in accordance with University guidelines.

What will happen to the results of the study?

The results will be published in a student project. Names or any other identifying feature of individual participants will not be revealed.

Are there any risks in participating?

There are no risks to physical or psychological health with taking part in this study.

What if I am not happy with how the research was conducted?

Loughborough University has a policy relating to Research Misconduct and Whistle Blowing which is available at

[http://www.lboro.ac.uk/admin/committees/ethical/Whistleblowing\(2\).htm](http://www.lboro.ac.uk/admin/committees/ethical/Whistleblowing(2).htm).

Appendix 3

PARENTAL OPT-OUT FORM (To be completed after Information Sheet has been read)

THIS FORM IS FOR THE PARENT/CARER OF A CHILD BEING REQUESTED TO TAKE PART IN A RESEARCH STUDY

The purpose and details of this study have been explained to me.

I understand that this project is designed to further knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my child's participation in this project.

I understand that my child is under no obligation to take part in the project.

I understand that my child can withdraw from this project at any stage and that they are not required to explain their reasons for withdrawing.

I understand that all the information provided by my child will be treated in strict confidence.

If you agree for your child to participate in the study then **DO NOT** return this form.

However, if you would **NOT** like your child to take part in this study, then please sign below. Your child will not be negatively affected in any way.

Your name: _____

Your child's name: _____

Your signature: _____

Date: _____

Appendix 4

Table Appendix A.1 Descriptions of each Rural-Urban classification

Category	Description	Broader category
Urban with Major Conurbation	Less than 26% living in rural settlements and hub towns	Predominantly Urban
Urban with Minor Conurbation	Less than 26% living in rural settlements and hub towns	
Urban with City and Town	Less than 26% living in rural settlements and hub towns	
Urban with Significant Rural	At least 26% but less than 50% living in rural settlements and hub towns	Urban with Significant Rural
Largely Rural	At least 50% but less than 80% living in rural settlements and hub towns	Predominantly Rural
Mainly Rural	At least 80% living in rural settlements and hub towns	

Table Appendix A.2 Local authority population and rural-urban classification.

LAD11CD	LAD11NM	RUC11CD	RUC11	Total Population
E06000016	Leicester	4	Urban with City and Town	329,839
E06000018	Nottingham	5	Urban with Minor Conurbation	305,680
E07000130	Charnwood	4	Urban with City and Town	166,100
E07000134	North West Leicestershire	2	Largely Rural (rural including hub towns 50-79%)	93,468
E07000176	Rushcliffe	2	Largely Rural (rural including hub towns 50-79%)	111,129

Reference

Department for Environment, Food & Rural Affairs., & Rogerson D. (2014). Rural-Urban Classification of Local Authority Districts and other higher level geographies - Lookup for 2011 Rural Urban Classification of Local Authorities. Retrieved from Department for Environment, Food & Rural Affairs GOV.UK website: <https://www.gov.uk/government/statistics/2011-rural-urban-classification-of-local-authority-and-other-higher-level-geographies-for-statistical-purposes>.

Appendix 5

Weight Measurement

**** Remind the child all results will be private ****

Ask the participants remove their heavy outer garments if applicable (e.g. jacket, coat) and shoes and socks.

Ask them to empty their pockets and remove any heavy jewellery if applicable.

Prepare the scales for measurement

Ask the participant to stand in the centre of the platform, weight distributed evenly to both feet (standing off-centre may affect measurement).

Record measurement.

Repeat twice and if variation, a third time.



Appendix 6

Height Measurement

Ask participant to remove their shoes, heavy outer garments, and hair ornaments (pony tails, clips etc.)

Ask the participant to step onto height measurer, with their feet on the diagram.

They should stand:

- Heels together and in a natural stance
- Hands by their sides
- Their heels, bum, back and head should all be touching the measure.
- Head should be straight, eye line should be in line with ears.

Once happy with position (take care) bring the blue measure down almost all the way and tell participant to take a nice deep breath in.

Then fully bring down the blue measure all the way so the hair is pressed flat.

Tell participant to breathe out, relax and step from the measure whilst ducking.

Record the measurement.

Do over twice, if variation do a third time.



Appendix 7

Sitting Height Measurement

Move stall onto height measurer base and push right up against the stand.

Ask participants to sit on stall.

Feet should be together, and completely flat on floor. Bum, back, and head again should be against the stand. Check eye line again.

Once happy with position (take care) bring the blue measure down almost all the way and tell participant to take a nice deep breath in.

Then fully bring down the blue measure all the way so the hair is pressed flat.

Record the measurement.

Tell participant to breathe out, relax, crouch and stand up.

Do over twice, if variation do a third time.



Appendix 8

Questionnaire

Make sure the children are completing the questionnaire in exam conditions.

They should work on their own.

There should be no talking.

If they raise their hand, help them.

When they have finished, check the questionnaire fully.

Make sure they have completed all the questions fully.

Create a finish pile.



Appendix 9

Physical activity Monitor Information for Parents

What is an activity monitor?

- A small device that records information about physical activity patterns. It uses a watch battery to power the monitor.
- It records body movements during everyday activities such as walking, running, skipping and jumping.
- Many studies with children and adolescents have successfully used activity monitors.



What is your child supposed to do with the activity monitor?

- We ask that your child wear the activity monitor every day for **8 days** (as shown in picture).
- They should put the monitor on **as soon as they get up** in the morning and take it off **just before they fall asleep**.
- Your child should **not** take the monitor off during the day **apart from when doing water sports (e.g. swimming) or having a shower/bath**.



Your child may find it difficult to remember to put the activity monitor back on in the morning. In the past children have found it useful to place the activity monitor by an alarm clock or place a reminder note on a bathroom mirror. It will be helpful if you and your child determine a strategy to help them remember to put the monitor back on in the mornings.

It is important that your child does not alter their normal physical activity behaviour while wearing the activity monitor – we are interested in their normal level of activity.

These monitors are very valuable pieces of research equipment, although they have no street value. PLEASE DO NOT LOSE THEM.

When does your child return the activity monitor?

We will collect the monitor from your child **during school hours** on:

If you have questions about the monitor please contact Katy Garnham-Lee:

Tel – 07807331320

Email – K.Garnham-Lee@Lboro.ac.uk

Appendix 10

ABOUT YOUR LIFESTYLE

Now we are trying to find out about your level of physical activity from the last 7 days (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

- Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Circle only one box per row.)

Number of Times	None	1-2 times	3-4 times	5-6 times	7 times or more
1. Skipping	1	2	3	4	5
2. Rowing/canoeing	1	2	3	4	5
3. Rugby	1	2	3	4	5
4. Gymnastics	1	2	3	4	5
5. Walking for exercise	1	2	3	4	5
6. Cycling	1	2	3	4	5
7. Jogging or running	1	2	3	4	5
8. Aerobics	1	2	3	4	5
9. Swimming	1	2	3	4	5
10. Rounder's	1	2	3	4	5
11. Dance	1	2	3	4	5
12. Football	1	2	3	4	5
13. Badminton	1	2	3	4	5
14. Skateboarding	1	2	3	4	5
15. Hockey	1	2	3	4	5
16. Volleyball	1	2	3	4	5
17. Basketball	1	2	3	4	5
18. Cricket	1	2	3	4	5
19. Martial Arts	1	2	3	4	5
20. Tennis	1	2	3	4	5
21. Other (write in)	1	2	3	4	5
22. Other (write in)	1	2	3	4	5

- In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Mark one only)

I don't do PE
Hardly ever
Sometimes
Quite often
Always

Appendix 10

3. In the last 7 days, what did you do most of the time at recess (break time)?
(Mark one only)

Sat down (talking, reading, doing schoolwork)	<input type="checkbox"/>
Stood around or walked around	<input type="checkbox"/>
Ran or played a little bit	<input type="checkbox"/>
Ran around and played quite a bit	<input type="checkbox"/>
Ran and played hard most of the time	<input type="checkbox"/>

4. In the last 7 days, what did you normally do at lunch (besides eating lunch)?
(Check one only)

Sat down (talking, reading, doing schoolwork)	<input type="checkbox"/>
Stood around or walked around	<input type="checkbox"/>
Ran or played a little bit	<input type="checkbox"/>
Ran around and played quite a bit	<input type="checkbox"/>
Ran and played hard most of the time	<input type="checkbox"/>

5. In the last 7 days, on how many days, right after school, did you do sport, dance, or play games in which you were very active? (Check one only)

None	<input type="checkbox"/>
1 time last week	<input type="checkbox"/>
2 or 3 times last week	<input type="checkbox"/>
4 times last week	<input type="checkbox"/>
5 times last week	<input type="checkbox"/>

6. In the last 7 days, on how many evenings did you do sports, dance, or play games in which you were very active? (Check one only)

None	<input type="checkbox"/>
1 time last week	<input type="checkbox"/>
2 or 3 times last week	<input type="checkbox"/>
4 or 5 last week	<input type="checkbox"/>
6 or 7 times last week	<input type="checkbox"/>

7. On the last weekend, how many times did you do sports, dance, or play games in which you were very active? (Check one only)

None	<input type="checkbox"/>
1 time last weekend	<input type="checkbox"/>
2 or 3 times last weekend	<input type="checkbox"/>
4 or 5 last weekend	<input type="checkbox"/>
6 or more times last weekend	<input type="checkbox"/>

Appendix 10

8. Which one of the following describes you best for the last 7 days? Read all five statements before deciding on the one answer that describes you. (Mark one only)

- All or most of my free time was spent doing things that involve little or no physical effort: ☐
- I sometimes (1 - 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics): ☐
- I often (3 - 4 times last week) did physical things in my free time: ☐
- I quite often (5 - 6 times last week) did physical things in my free time: ☐
- I very often (7 or more times last week) did physical things in my free time: ☐

9. How often did you do physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week. (Only mark one for each day)

	None	Little bit	Medium	Often	Very Often
Monday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tuesday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wednesday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Thursday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Friday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Saturday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sunday	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Appendix 11

How do you get to and from school?

(You **can** tick **more** than one answer in **each** column)

	(i) To school	(ii) From school
a) Walk all the way	<input type="checkbox"/>	<input type="checkbox"/>
b) Walk part of the way	<input type="checkbox"/>	<input type="checkbox"/>
c) By public bus	<input type="checkbox"/>	<input type="checkbox"/>
d) By school bus	<input type="checkbox"/>	<input type="checkbox"/>
e) By car/taxi	<input type="checkbox"/>	<input type="checkbox"/>
f) By bicycle	<input type="checkbox"/>	<input type="checkbox"/>
g) By train/metro	<input type="checkbox"/>	<input type="checkbox"/>
h) Skateboard or scooter	<input type="checkbox"/>	<input type="checkbox"/>

Appendix 12

Worked examples for calculating Age at Peak Height Velocity
(Mirwald *et al.*, 2002)

For Boys:

Age: 12.6
Weight: 49.30kg
Height: 153cm
Sitting Height: 79.5cm
Leg Length: 73.50cm

Interaction One - $\text{Leg Length} * \text{Sitting Height} =$
 $73.5 * 79.5 = 5843.25$

Interaction Two - $\text{Age} * \text{Leg Length} =$
 $12.6 * 73.5 = 926.10$

Interaction Three - $\text{Age} * \text{Sitting Height} =$
 $12.6 * 79.5 = 1001.70$

Weight by Height Ratio - $\text{Weight/Height} * 100 =$
 $49.3/153 * 100 = 32.22$

Maturity Offset Calculation =

$-9.236 + (0.0002708 * \text{Interaction One}) + (-0.001663 * \text{Interaction Two}) + (0.007216 * \text{Interaction Three}) + (0.02292 * \text{Weight by Height Ratio}) =$

$-9.236 + (0.0002708 * 5843.25) + (-0.001663 * 926.10) + (0.007216 * 1001.70) + (0.02292 * 32.22) = -1.23$

Age @ PHV = $\text{Age} - \text{Maturity Offset} =$
 $12.6 - -1.23 = 13.83$

Appendix 12

For Girls:

Age: 12.1
 Weight: 32.5kg
 Height: 137cm
 Sitting Height: 70.5cm
 Leg Length: 66.5cm

Interaction One - Leg Length * Sitting Height =
 $66.5 * 70.5 = 4688.25$

Interaction Two - Age * Leg Length =
 $12.1 * 66.5 = 804.65$

Interaction Three - Age * Sitting Height =
 $12.1 * 70.5 = 853.05$

Interaction Four - Age * Weight =
 $12.1 * 32.5 = 393.25$

Weight by Height Ratio - Weight/Height * 100=
 $32.5/137 * 100 = 23.72$

Maturity Offset Calculation =

$-9.376 + (0.0001882 * \text{Interaction One}) + (0.0022 * \text{Interaction Two}) + (0.005841 * \text{Interaction Three}) - (0.002658 * \text{Interaction Four}) + (0.07693 * \text{Weight by Height Ratio}) =$

$-9.376 + (0.0001882 * 4688.25) + (0.0022 * 804.65) + (0.005841 * 853.05) - (0.002658 * 393.25) + (0.07693 * 23.72) = -0.96$

Age @ PHV = Age – Maturity Offset =
 $12.1 - -0.96 = -13.06$

Appendix 13

During a typical week how often has a member of your household:
(for example, your father, mother, brother, sister, grandparent, or other relatives).

Mark only ONE.

	None	Once	Sometimes	Almost Daily	Daily	Don't know
Q1. Encouraged you to do physical activities or play sports?	1	2	3	4	5	6
Q2. Done a physical activity or played sports with you?	1	2	3	4	5	6
Q3. Provided transportation so you can go to a place where you can do physical activities or play sports?	1	2	3	4	5	6
Q4. Watched you participate in physical activities or sports?	1	2	3	4	5	6
Q5. Told you that physical activity is good for your health?	1	2	3	4	5	6

Participants who marked the response 6 (Don't know) were later recoded to missing data (999).