Acculturation and Physical Fitness of the Male Indigines of the Ok Tedi Region, Papua New Guinea

by

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Long olgeta manmeri i stap long
Ok Tedi, Papua Niugini

ABSTRACT

Data on body composition, resting metabolic rate (RMR) and physical fitness was obtained on a group of Papua New Guineans undergoing rapid acculturation between September 1985 and June 1986. The population comprised 233 males representing the Wopkaimin, Ningerum and Awin ethnic groups.

Young adults were significantly heavier, fatter and more muscular than the older cohorts but only slightly taller. Compared to previous studies an increase in weight, fat and muscle in all age groups was noted. Acculturated individuals although shorter were significantly heavier, fatter and had a greater amount of muscle, because of their improved diet. Cross-sectional ageing coefficients showed the more acculturated villagers exhibited a slower decline in all indices of body composition with age, the onset of this fall began later in these groups; and in this respect are beginning to resemble Europeans.

Mean lung capacities were small compared to other Papua New Guineans, probably because of the high incidence of respiratory infection previously noted. No significant differences were seen between any of the groups but larger volumes were observed the nearer one got to Tabubil and the more acculturated groups.

RMR was lower in the least acculturated villagers which was attributed to differences in body size. Mean RMR was high which was attributed to the hot environment, psychological factors or subjects failing to fast properly.

Predicted maximum oxygen uptake ($\dot{V}o_2max$) was significantly lower in villagers whose lifestyle had changed the least, but as with other studies of rural/urban comparisons and longitudinal changes, values approached those of the acculturated when related to body dimensions. Vo_2max decreased with age in all age groups, the cross-sectional ageing coefficients being lower in the more acculturated groups, whose figures approached those of Europeans.

Submaximal indices showed a clearer picture of physical fitness. In all cases the submaximal heart rate (fh) and ventilation rate at a fixed oxygen uptake ($\dot{V}o_2$) were lower, and physical work capacity at a fixed fh higher in the more acculturated groups. This was especially seen when comparing the ethnic groups and the village groups. The $\dot{V}o_2$ at a fixed workload and net mechanical efficiency were higher in the least acculturated, because they maintained a relatively active life.

Acculturation in the Ok Tedi is leading to an increase in size and improvement of nutritional status, and a slight increase in lung capacity and physical fitness. However a longitudinal study is required to examine further changes.

KEYWORDS: Acculturation; Physical Fitness; Lung Capacity; Body Composition; Papua New Guinea.

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1. INTRODUCTION

1. Introduction.

Until the advent of draught animals, modern tools and machines, the strength and endurance of the individual provided the principal energy resource for the cultivation of crops and/or the capture of game. One might therefore expect that an unacculturated primitive society would be marked by an evolutionary pressure favouring the survival, mating and successful rearing of children by the more resourceful males, i.e. those with a capacity for long and arduous physical work, able to perform the elemental tasks of agriculture, hunting and fishing in a particularly skilful and efficient manner.

The acculturation of a primitive population, in the present context, refers to the progressive erosion of a traditional culture by the social customs of 'western society'. The disappearance of a traditional way of life (hunter, gatherer, pastoralist or primitive agriculturalist) is often accompanied by changes in domestic equipment, language and thought, with profound consequences for physical activity, nutrition and health. Changes have been associated with the migration from rural areas to the city, and in other instances they have reflected the transition to a wage- or welfare-based economy within what was initially a traditional primitive community.

A number of human biological studies of the contrasting physical characteristics of groups at different stages of economic development have been carried out in the past 15 to 20 years (Hankin and Dickinson, 1972; Edginton, Hodkinson and Seftel, 1972; and Hornabrook, Crane and Stanhope, 1974). They have also included the variation between such groups in the incidence of so-called "western" diseases like obesity, diabetes and cardiovascular disorders. Populations have usually been compared whose differing levels of technology and socio-economic development are associated with separation in space or in time. Thus many factors other than 'degree of acculturation' often separate the groups, like climate and geography. A better situation would be one where a population were investigated as the environmental factors changed around them, over a short space of time.

Such an opportunity has arisen by the development of the Ok Tedi gold and copper mine in the Star Mountains of the Western Province of Papua New Guinea (5^{o} 12' S, 141^{o} 8' E). The people of this area had until the late 1960's, relatively little contact with the outside world. The Ok Tedi Health and Nutrition Project ('Ok' means 'river' or 'water'), of which this study was part, was therefore set up by the University of Papua New Guinea and Institute of Medical Research to study and record changes in the disease pattern, food intake, nutritional status and physical fitness in sample villages, both in the Star Mountains, and on the road between Tabubil and Kiunga (Figure 1.1).

The massive influx of western technology in the Ok Tedi region, associated with the construction and operation of the mine, has resulted in rapid and profound socio-economic and cultural changes affecting all aspects of the local inhabitant's lifestyle in a period of only four or five years. Prior to this, the local groups of hunters and shifting horticulturalists had lived for hundreds of generations in a precarious but finely tuned ecological balance with their natural environment.

1.1. Papua New Guinea: A Brief Description.

The main island of New Guinea, second largest in the world, sits astride the northern tip of Queensland, Australia. A jagged mountain spine, the central cordillera, extends from the west in Irian Jaya, Indonesia, south-eastwards, trailing off into a scattering of palm-fringed islands. More islands, larger and mountain dominated, are angled off the north-east coast. Mountains dominate the land and lives of the people of PNG, rising in places up to 5,000 m. The central cordillera is in the form of a roughly parallel series of massive ranges separated in the centre of the mainland by broad, grassed valleys, falling steeply to the Papuan plains to the south and to the Sepik-Ramu-Markham trough in the north. North again is another lesser mountain chain in the Huon Peninsula.

The Netherlands Government took possession of that part of the island which lies west of 141^{o}E in 1828 and is now part of Indonesia. The eastern half, in 1884, was shared between Germany and Great Britain, the latter later transferring her share, Papua, to Australia. After the First World War Australia also inherited the German share as a League of Nations mandate

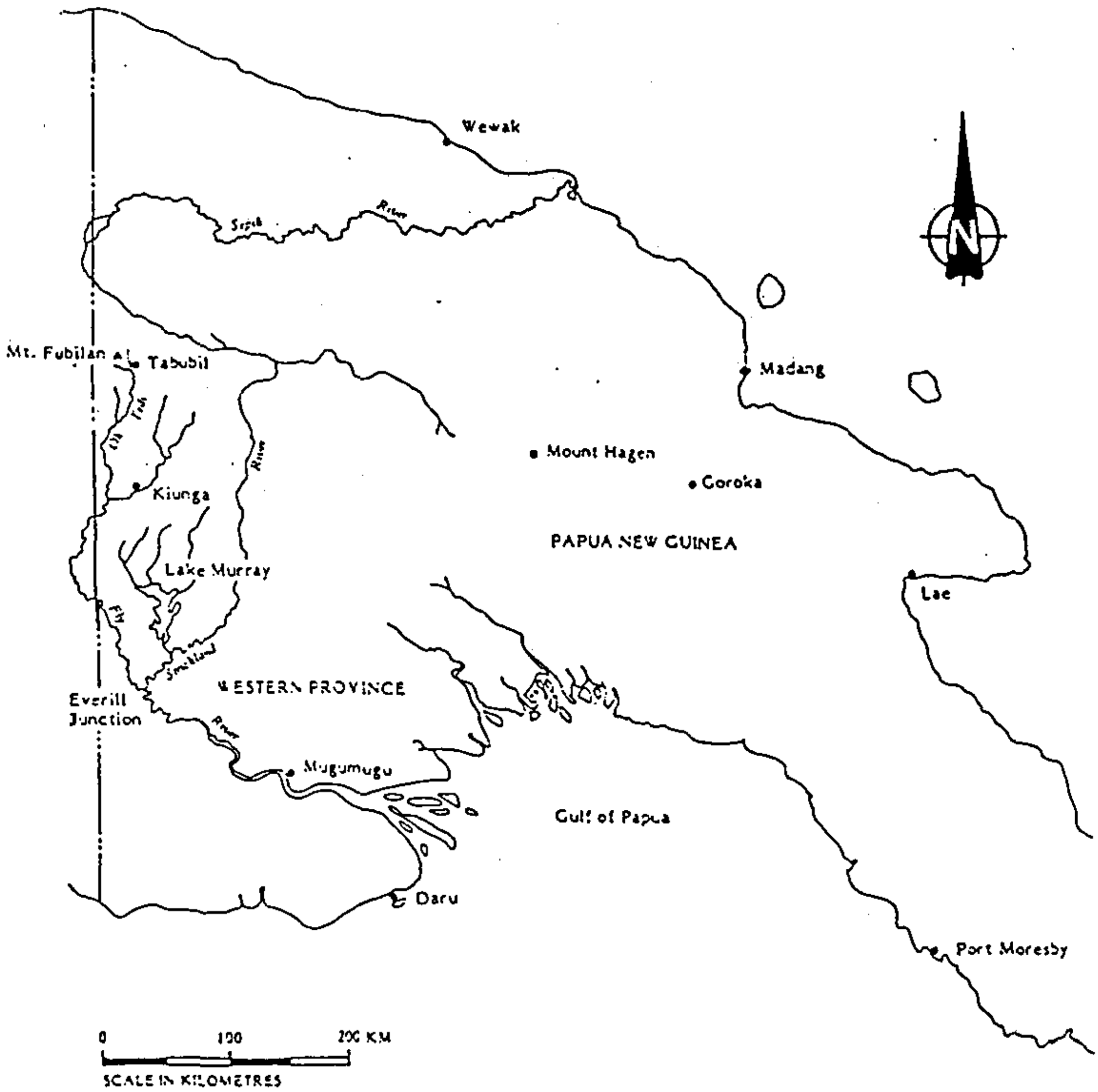

Figure 1.1 : Locality map of Papua New Guinea.

and up until 1975 the whole country was a United Nations Trust Territory, being administered as the Territory of Papua and New Guinea. The country became self-governed as the State of Papua New Guinea (PNG) on December 1, 1973, and was granted independence on September 16, 1975.

Early explorations into the interior of the island were individual excursions ending all too often in tragedy. This continued after the Second World War and until only recently large areas were still uncontrolled and patrols ventured into them at the risk of their lives.

The climate and terrain hindered the development of the country by preventing the easy movement from place to place. These same factors provided conditions of intense anthropological and physiological interest in the country. They divided the populations into discrete units, each restricted often to a single mountain ridge, having little or no dealings with its neighbours except perhaps as trade or warfare, interbreeding within itself. The aeroplane solved the problem of communication and made possible contact with the people, exploration of the country and its effective appeasement and administration. The building of roads is now increasing the mobility of the population, with the intermingling of the various groups.

The native inhabitants of the country are Melanesians, the predominantly dark-skinned, woolly-haired people who occupy the greater part of the south-western Pacific. Based on physical differences in stature, hair texture, nose form, and other characteristics, they are often divided into a Papuan type and a Melanesian type proper. The latter are the smaller and have the rounder, broader faces.

1.2. The Region and Climate.

The Ok Tedi region of the Star Mountains is situated in the north-western most part of the Western Province. This area of several thousand square kilometres is bounded to the west, 15 km away, by the Indonesian Province of Irian Jaya and to the north by the mountainous border with West Sepik Province. The region has traditionally been the most remote and least developed part of the country (Figure 1.2).

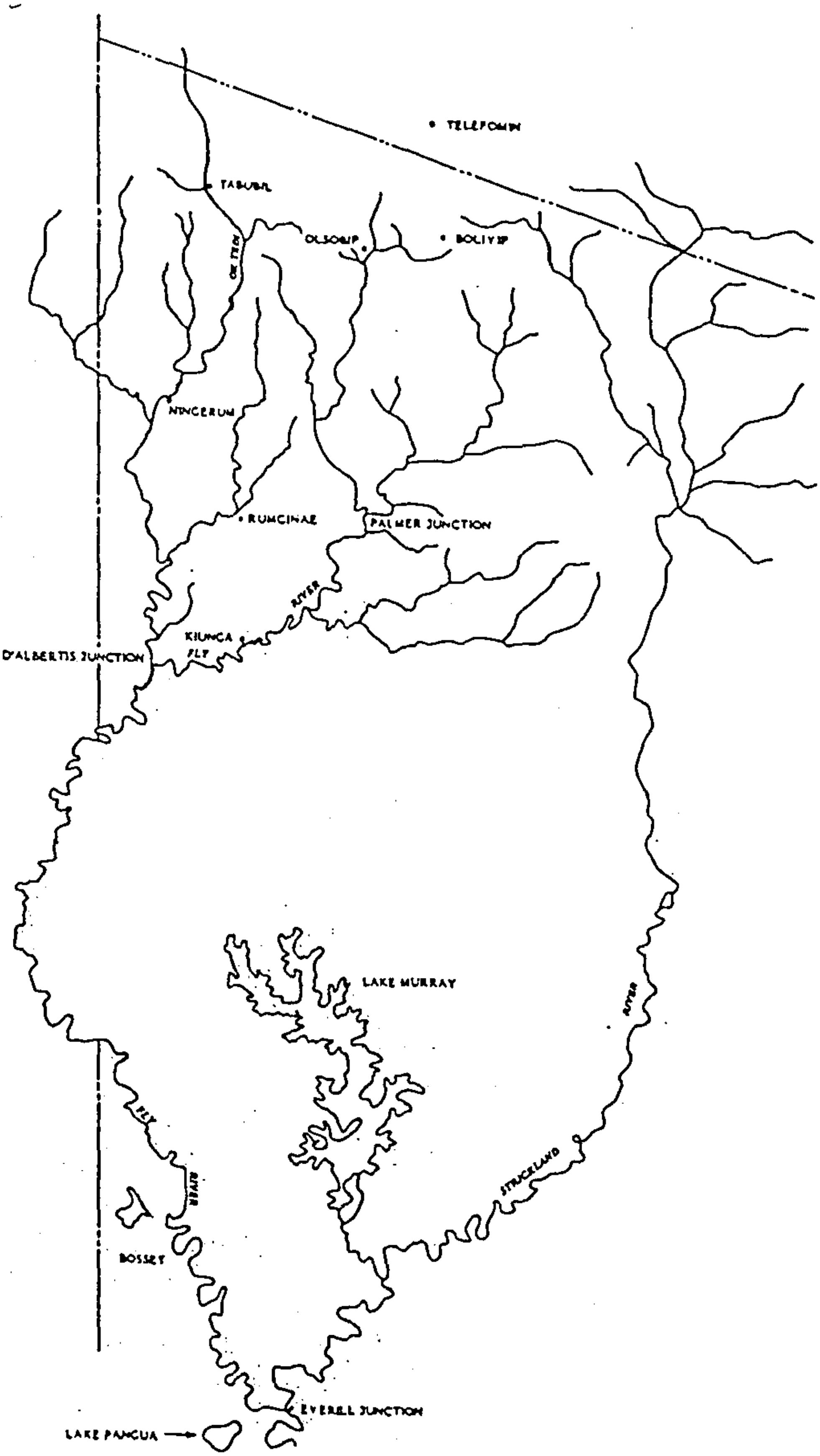

Figure 1.2 : The north-west of the Western Province of Papua New Guinea

The land around Tabubil is dominated by very dense, montane rainforest, except where it is kept clear by human activity, and has a closed canopy of 20-30m height. Tree density is very high, with a dense shrub layer and a very large number of plant species. The foothills of the Star Mountains, between Tabubil and Ningerum, are dominated by closed lowland hill rain-forest (Maunsell and Partners, 1982) with a canopy of 25-30m. Between Ningerum and Kiunga the land is characterised by a closed lowland rain-forest. Altitude in the region ranges from 20m at Kiunga to 650m at Tabubil, the altitude at Mount Fubilan (before mining had started) being 2095m. The lowest village is Miasomnai (20m) and highest Atemkit (980m).

A dominant characteristic of the whole region is its extremely high rainfall, the mean annual figure at Tabubil is 8000mm, with an average 339 rainy days per year. Rainfall is well distributed throughout the year, ranging from 568mm in October to 826mm in March (Maunsell and Partners, 1982). Mount Fubilan is one of the wettest places in the region with a mean annual rainfall of about 10,000mm. At the river port of Kiunga, on the other hand, the annual rainfall is only 4615mm, with distinct rainy and dry seasons.

Temperatures and humidity exhibit only slight seasonality. At Tabubil the mean maximum temperature ranges from 25°C to 29°C, and the mean minumum from 19°C to 21°C; although extremes of 39°C and 12°C have been recorded (OTML, 1982). At Kiunga the climate is more humid with mean monthly temperatures ranging from 23.5°C to 33.5°C.

1.3. Contact History of the Ok Tedi People.

Until 1963 the Ok Tedi area was 'a land time forgot', then the first Government patrol entered the territory. Before, the people of the area knew of no other world, no lifestyle other than their own which had survived thousands of years.

The first European contact with the lower Ok Tedi was that made by Luigi D'Albertis in 1876, who sailed up the Fly River and into the Ok Tedi in search of mountains of gold. Twenty years elapsed before Sir William MacGregor sailed up the Fly, bypassed the Ok Tedi and proceeded to the junction of the Palmer and Black rivers (Jackson, 1982). No substantial contact was then made until 1921/23 when Leo Austen, a Government officer, led expeditions to explore the lower and upper reaches of the Ok Tedi to see if this border area could be developed. He was pessimistic about the commercial possibilities of such an area and reported this to his superiors (Austen, 1923).

Austen's pessimism was reflected in the future administrative disinterest in the area for it was not until 1950 that a Government station was established at Kiunga. It was not a simple matter of neglect for the area is some 800 km from the sea along the meandering Fly River. This made the transportation of goods and services for development expensive. Kiunga is also remote from Government both Provincial in Daru and National in Port Moresby, which meant poor communication and decision making difficult. The land is also not too kind, consisting of wide swampy valleys, streams and creeks, all separated by sloping ridges which made movement difficult.

For the people of the upper reaches of the Ok Tedi their recent contact history began when the first Government patrol post was set up at Olsobip in 1963 by Hoad. In 1964, Des Fitzer led the first patrol into Wopkaimin territory and later reported "the Wopkaimin are so far removed and devoid of resources that they simply have no potential for development" (Hyndman, 1979). But in 1966, copper deposits were spotted in the streams by a patrol officer and by 1968 Kennecott Explorations of Australia had commenced a copper survey of the area. This brought intensive European contact for some of the Wopkaimin who were employed as Kennecott labourers and brought about the rapid spread of clothes, cigarettes, steel tools and New Guinea Pidgin English.

By 1970, Kennecott was in full operation drilling for copper and discovered it to originate from Mount Fubilan (2095m) where there was also a large amount of gold bearing ore present. They established and maintained the first medical aid post in the region and built a primary school in 1971. However, by 1972 exploration efforts began to grind to a halt; and in 1975 negotiations between the Government and Kennecott collapsed, and as a result the company pulled out.

The people were left with a mixture of rejection, resentment and longing for the good old mining days of sufficient cash. Many of the young able-bodied men bided their time in their villages and were ready to abandon their subsistence economy for the market economy of the mine if it went ahead.

In November, 1976, a consortium of Australian, American and West German companies commenced a major feasibility study which resulted in the submission of development proposals to the Government. Subsequently, in February 1981, Ok Tedi Mining Limited was formed and in June that same year construction of the mining infrastructure began. Mining of gold commenced in mid-1984 and copper in late 1986; the planned life of the mine is expected to be thirty years.

1.4. Historical Ethnography.

The people living in the vicinity of the Ok Tedi are representatives of the Wopkaimin, Ningerum and Awin populations (Figure 1.3). These names not only describe the people but also the language and land they live on. The Wopkaimin and Ningerum belong to the Ok family, the former to the Mountain Ok and latter the Lowland Ok. The Awin make up 80 percent of the Awin-Pa family. All three groups live in an area of about 5,000 square kilometres.

The territory of the Wopkaimin is rugged and mountainous, and extends along the southern escarpment of the Star and Hindenberg Mountains. They belong to the Min people, of which 5,000 (about one quarter) live on the southern slopes of the Star Mountains. The remainder live scattered amongst the valleys of the Upper Sepik and its tributaries across the ranges in West Sepik Province and some across the border in Irian Jaya.

Traditionally, the Wopkaimin live in scattered hamlets of no more than five or six houses, at altitudes between 600 and 1600 metres. They are mountain and foothill hunter-horticulturalists; 92 percent of their diet by weight is derived from plants and 8 percent from animals (Hyndman, 1979). The cultivated plant staple is taro (*Colocasia esculenta*), with kaukau (*Ipomoea batates*) taking over because of the presence of taro leaf blight; the leafy green vegetable aibeka (*Hibiscus manihot*) and edible grass pitpit (*Setaria*

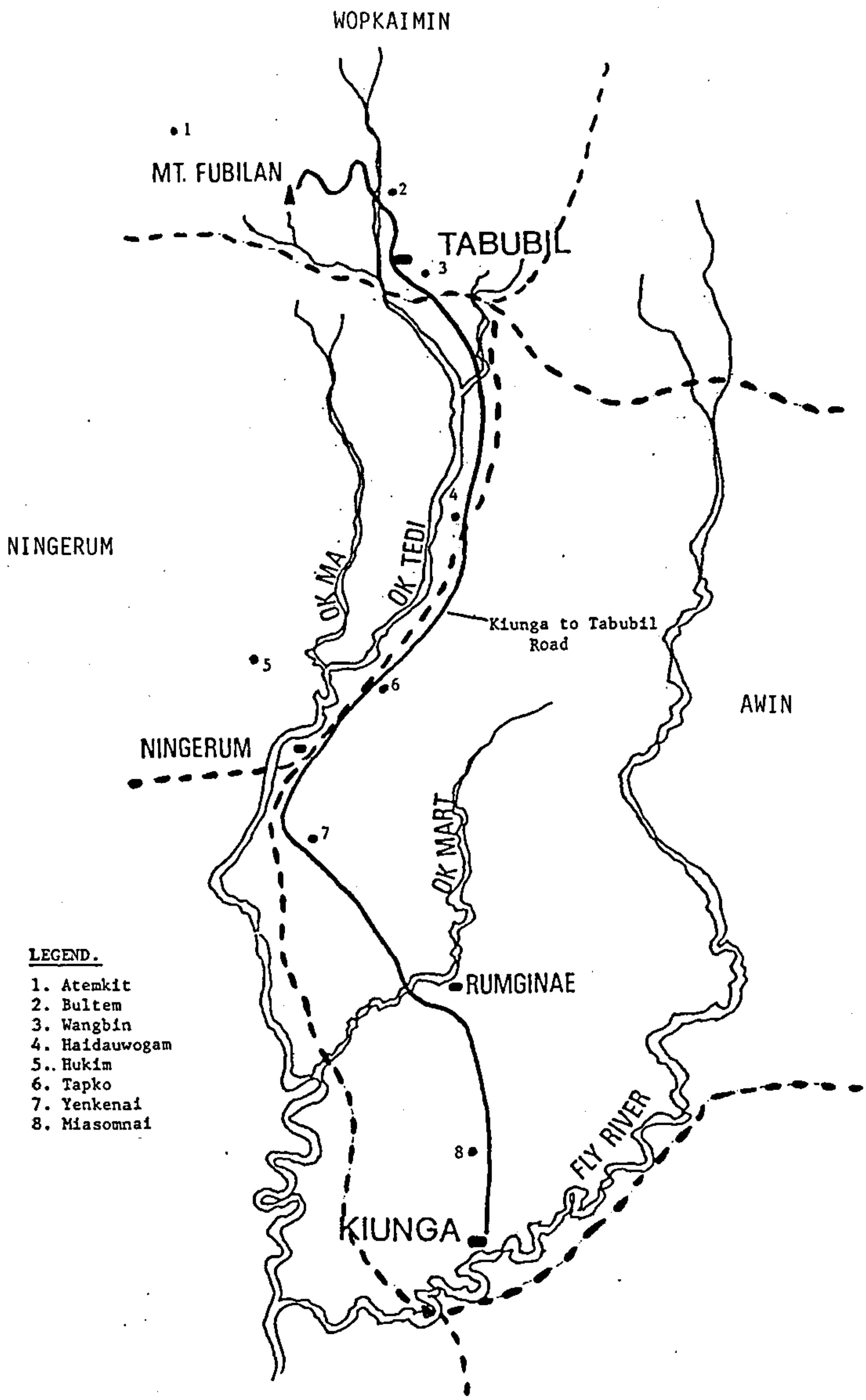

Figure 1.3 : Territories of Ethnic groups within the Ok Tedi Region

palmifolia) are also eaten. The most important game animals are possums, cassowary and feral pig.

The territory of the Ningerum lies between the Ok Mani to the north, the Ok Birim to the south and the Ok Tedi to the east; with about one quarter of the people living in Irian Jaya (Maunsell and Partners, 1982). They are primarily agriculturalists, and occupy an environment far less harsh but also far less varied than that of the Wopkaimin. Except in the extreme north of their area all the land is below 500 metres above sea level and the greater part of it is lower than 200 metres.

The Ningerum are fairly densely settled, particularly in the south, and as a consequence wild life is less common than in the mountains. However, the streams carry a large number of species of fish, large river frogs and crustaceans, etc. Traditionally they are settled in small scattered clusters of two or three houses, each surrounded by its mixed garden of yams (*Dioscorea sp.*), kaukau and taro, together with specialist gardens of banana (*Musa sp.*). However, European patrol officers have encouraged them to live in larger central villages, now situated on ridge tops.

The Awin live in an area bounded by the Ok Tedi, eastwards to an area north of the Elevala river and west of the Strickland river, and to the north share a common border with the Wopkaimin. They are hunter-horticulturalists of the lower foothills and riverine lowlands, and place more reliance on sago silviculture (*Metroxylon sp.*) than gardening for the staple plant food, but cultivation is still important. The major game animals are the bandicoot, crocodile and turtle (Hyndman, 1979).

1.5. Mining Effects on Subsistence and Populations.

In the comparative absence of western influence the traditional, intimate and diverse ecological links, characteristic of a subsistence way of life, have persisted between the indigenous peoples of the Ok Tedi region and their environment. However, there are great differences in the nature and strength of these relationships from one group to another, and the factors determine each one's susceptibility to the impacts and opportunities created by the Ok Tedi Mining Project.

At one extreme of susceptibility are the Wopkaimin. The actual area of their land to be destroyed is not large and is less than the total land take for the various leases required by OTML. A total of 6940 hectares within the Wopkaimin land is involved, which represents about 20 percent of their total area (Maunsell and Partners, 1982). For the use of their land every Wopkaimin receives royalties from OTML every year, as do the Ningerum and Awin for theirs, but not as much.

The Wopkaimin subsistence resources are the least abundant of the three ethnic groups. This means that their health and nutrition depends on a very wide diversity of plants and animals, from a large area to make ends meet, that important food items also acquire great cultural and ritual significance. The loss of a particular resource type from the diverse range used may be disproportionately serious, making the dietary attractions of the trade-store hard to resist.

Experience gained though from the coffee flush in the Highlands in the mid 1970's showed that economic advancement can lead to increased consumption of non-food items and food of low nutritional value, social problems and the neglect of food gardens and consequent food shortages (Lambert, 1977).

Hyndman (1979) undertook a three month resource and diet study of the Wopkaimin and found that only the collection and gathering of wild plant and animal foods would be affected by the land leases. Thus, 20 percent of these foods would be affected, which he found would result in the net dietary loss of 6.0% protein, 4.5% fat, 4.0% thiamine and 6.0% riboflavin, with other elements less than these (Table 1.1).

There has been a substantial population drift to Tabubil which could lower the resource base further. However, if there are sufficient jobs to go around everyone, including the women and children, should be able to purchase trade-store alternatives counterbalancing their loss of traditional resources. There would therefore be a better level of nutrition. With this change though, the cultural importance of many subsistence activities could be lost unless upheld by village elders.

Table 1.1: Percentage of nutrients normally supplied by wild plant and animal foods, and estimated percentage loss (in brackets) due to leased mining land in the Wopkaimin.

Food Getting Activity	Energy	Protein	Fat	Thiamine	Riboflavin	Vit.C
Gathering	0.8	3.2	0.3	2.5	5.0	9.2
	(0.2)	(0.6)	(0.1)	(0.5)	(1.0)	(1.8)
Hunting	6.2	23.6	21.5	16.7	23.1	
	(1.2)	(4.7)	(4.3)	(3.3)	(4.6)	
Fishing	0.2	1.5	0.2	0.1	0.8	
	(0.04)	(0.3)	(0.04)	(0.02)	(0.2)	
Collecting	0.1	1.2	0.1	0.1	0.4	
	(0.02)	(0.2)	(0.02)	(0.02)	(0.1)	
Total	7.3	29.5	22.1	19.4	29.3	9.2
	(1.46)	(5.8)	(4.46)	(3.84)	(5.9)	(1.8)
Percentage from plant foods	78	53	5	67	66	100
Percentage from animal foods	22	47	95	33	34	-

(Source: Hyndman, 1979)

In Ningerum territory the major area taken by the mine will be in the form of a tailings impoundment, the waste products of the gold and copper extraction processes emitted by the mine's processing plant at Folomian near Mount Fubilan. The area taken by new roads and powerline easements is small, but actual habitat destruction may be complicated by a barrier effect to the dispersal of small animals, with the subdivision of the populations concerned.

A richer resource base and greater distance from employment opportunities at Tabubil have for the Ningerum and Awin peoples seen only a small decline in the population of the closer villages and an increase in size of the more distant villages. However, for the Ningerum and Awin one major food source in their less diverse and more abundant diet is at risk, namely the aquatic species comprising an important source of protein.

Biologists have predicted major changes in the Ok Tedi (Maunsell and Partners, 1982), with toxicity from mine wastes to some aquatic organisms possibly extending as far as D'Albertis Junction, the confluence of the Ok Tedi and Fly River. In this case the large food species (catfish, river frogs, turtles, etc.) of this section of river could be depleted and unlike the Wopkaimin case, this would represent a significant loss of a high quality food resource that would be less easily forgone and less readily substituted by trade-store commodities.

Continuous monitoring of the river system for toxic tailings is being carried out by the Environment Department of OTML to ensure that levels remain within strict limits.

The terrestrial resources of the Ningerum and Awin comprise a more heterogenous biota than the diversity over a large altitudinal range of the Wopkaimin. Land will be cleared for roads and project facilities and squatting and gardening will follow, but the resources area close to the present villages are not expected to be significantly affected.

Most of the villagers grow vegetables to sell at the markets in Tabubil, Ningerum and Kiunga, providing them with money to buy tinned meat and rice. However, it also allows the men to purchase beer and the women and children cakes and soft drinks.

1.6. Nutritional and Health Status of the Ok Tedi People.

The influence of nutrition and health on physical fitness and lung capacity are well documented (Wyndham, Strydom, Morrison, Williams, Breddell and Heyms, 1963; Barac-Nieto, Spurr, Maksud and Lotero, 1978; Shephard, 1978 and 1980; and Cotes 1979). With the acculturation to a more 'western' way of life there is a rise in living standards and an improvement in the health and nutrition of the individual, and thus an improvement in general all round fitness. It would be helpful then to discuss the health and nutritional status of the Ok Tedi population prior to this study.

Hyndman (1979) observed that the diet of Wopkaimin women and children was nutritionally inferior to that of men (Table 1.2). Men were seen to receive adequate energy, protein, fats, vitamins and minerals. Women and children were observed to have a less adequate diet and said to be nutritionally deficient in protein and riboflavin. Women furthermore had only a marginally adequate energy intake.

Table 1.2: Daily intake of nutrients and estimated intake after land is taken up by mining leases in the Wopkaimin.

	Energy (KJ)	Protein (g)	Fat (g)	Thiamine (mg)	Riboflavin (mg)	Vit.C (mg)
Men:						
Daily Intake	9698	78	62.7	2.12	1.24	184
Intake after leased mining land	9551	73	59.7	2.12	1.24	181
Women:						
Daily Intake	7513	35	19.7	1.62	0.74	184
Intake after leased mining land	7403	33	18.7	1.62	0.74	181

(Source: Hyndman, 1979)

As the men are traditionally a privileged group they have created a system of food distribution that successfully channels in their direction the many large mammals which are nutritionally very significant. These mammals are denied to the women, especially those that are pregnant or lactating. The many and complex food taboos and prohibitions all further reinforce that women only receive marginally adequate nutritional returns to sustain their constant levels of energy expenditure. This may account for the low to moderate fertility and high mortality rate observed in the region (Lourie, 1985). The crude infant mortality rate among the Wopkaimin was found by

Lourie, Taufa, Cattani and Anderson (1986) to be about 230 per 1000 in 1982/83. This compares with a rate of 79/1000 for PNG as a whole, 125/1000 for India, and approximately 10-12/1000 for western countries.

Hipsley and Kirk (1965) concluded "the typical outcome of the New Guinea problem of continuous energy demand and quantitatively marginal nourishment is a system that produces women who experience gradually deteriorating energy storage as they grow older".

Ulijaszek and Pumuye (1985) have shown that only a small proportion of Wopkaimin men and women living close to the mining town of Tabubil have a diet sufficiently rich in energy to allow them to meet their daily requirements. They also observed that people in remote villages who relied totally on subsistence gardening and hunting ate a diet low in protein and were in energy and protein equilibrium at a smaller body size. This they said is achieved by consuming vast quantities of the staple root crops daily with important contributions from wild animals and vegetation.

Anthropometric studies have shown that the men are lean and muscular and the women range from delicate to sturdy and always have protruding abdomens (Nakikus and Lambert, 1978). According to Nakikus and Lambert (1978) weight-for-height results in children indicated a high rate of malnutrition that was long-term and not the result of seasonal food shortages. The populations have adapted to chronic malnourishment through nutritional stunting and having small stores of fat in the body (Lourie et al, 1986).

Weights and heights of the children of the region are well below British standards remaining at or about the tenth centile up to the age of 18 years (Lourie et al, 1986). In PNG an upper-arm circumference less than 14cm has been taken as an indicator of undernutrition in one- to five-year olds (Shann and Biddulph, 1983). According to Lourie et al (1986) 41.9 percent would be considered as undernourished by this standard, with a similar figure of 39.3% for the Awin (Nakikus and Lambert, 1978). However, by the more stringent standard of 12.5cm commonly applied elsewhere in developing countries (Ebrahim, 1984), 11.8 percent would be classified as undernourished. In a Ningerum village using the same standard, 18 percent were considered undernourished (Ulijaszek and Welsby, 1985).

With the availability of food from Tabubil, better management of gardens and advice given to villagers on how to get the best from their gardens, their nutritional status should improve.

Malaria is hyperendemic to the whole region, positivity rates ranging from 20 percent in adults to 60 percent in children with Plasmodium falciparum the predominant species (Cattani, Taufa, Anderson and Lourie, 1983). Repeated attacks have caused the spleen to become permanently enlarged in many people and associated with this there is a high incidence of hepatomegaly (Welsch, 1982; and Schuurkamp, 1983).

Respiratory diseases are common to the area and along with malaria against a background of chronic malnutrition are responsible for most of the morbidity and mortality amongst the adults in the region (Taukuro, 1980). It has been reasoned that repeated epidemics are responsible for the low number of elderly in the region (Lourie and Taufa, 1984).

Now many new health hazards will face the community because of the mine. Infectious diseases to which the locals have little or no immunity will be introduced into the area. Alcoholism is likely to increase with the greater availability of beer. In the long term cardiovascular disorders, appendicitis, diverticulitis, diabetes and other diseases associated with western societies are likely to increase (Reed, Labarthe and Stallones, 1970; Edginton et al, 1972; and Hankin and Dickinson, 1972). However with the advent of better health facilities provided by OTML and the Government and the initiation of vaccination programmes, the incidence of diseases like measles, whooping cough and polio can be drastically reduced. The prevalence of malaria is likely to decrease with the spraying of insecticides in the villages and surrounding areas. Other simple infections like those of the skin, ears and eyes, can also be cured.

1.7. Acculturation on Physical Fitness and Lung Capacity.

First we must answer the question why measure physical fitness and lung capacity in a primitive population? In many primitive societies physical fitness and an associated high level of working capacity have had survival value. It has often been reasoned that primitive man in his natural

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higher habitual activity because of the steeper terrain experienced and thus an associated higher level of fitness.

In some primitive communities diseases such as tuberculosis, pneumonia and bronchitis, which restrict the amount of functioning lung tissue have been rife until only recently and cause a reduction in lung volumes (Cotes, 1979) aswell as restricting physical fitness. Measurements of lung capacity therefore help decide the health of the subjects particularly if direct communication with the patient is difficult. Major epidemics could ultimately lead to gains of physical fitness and lung size through the selective elimination of the weaker members of the population. On an individual basis disease restricts physical activity and hence fitness. Anaemia for instance can reduce working capacity (Barac-Nieto et al, 1978). The improved medical care in the region could see a reduction in the incidence of diseases and an improvement in fitness, especially in those with easy access to the aid posts and health centres.

Cigarette smokers show a decreased forced expiratory volume (FEV) and forced vital capacity (FVC) and a sharper rate of fall of the FEV/FVC ratio than non-smokers (Cotes,1979). Pollution from house smoke also brings about the same losses, as seen in the Highlands of PNG (Anderson, 1979). Both of these irritants are present in the Ok Tedi and so could affect lung capacity.

Socio-economic status can have an important influence upon the working capacity of an individual and a population through its interaction with such factors as nutrition, prevalence of disease and habitual physical activity. Changes in these factors occur with acculturation which would in turn bring about alterations in physical fitness and lung capacity.

The acculturation of many primitive groups over the past few decades has seen a rapid secular trend to an increase of adult stature and other supposedly genetically-determined features (Friedlander and Rhoads, 1982; and Rode and Shephard, 1984a) and also an increase in the amount of body fat (Wyndham, 1973; and Shephard, 1980). These trends probably reflect a better overall nutritional balance. Within a given population the small individuals commonly have smaller lungs than the tall, but these differences disappear when volumes are adjusted to a standard age and

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surroundings needs to be active in order to survive and that this factor has probably conferred an advantage on him. The process of natural selection has therefore produced populations of differing physiological and physical characteristics depending upon the degree of climatic and ecological stress within a given environment.

The total power that can be produced by the human body depends upon its size which can be related to nutrition (Wyndham et al, 1963; Satyanarayana, Naidu, Chatterjee and Rao, 1977; and Buzina, Grgic, Jusic, Sapunar, Milanovic and Brubacher, 1982). A low energy intake and/or deficiency of protein can stunt growth and thus restrict working capacity. Anthropometric data are therefore of particular importance when comparing the working and lung capacities of populations that differ in body size. In addition to the traditional indices of stature, weight and skinfolds thicknesses, it is useful to include measurements that will characterise the relative lengths of the trunk and limbs, the shape of the chest and nutritional status.

Lung capacity is related to the pattern of growth and bodily physique of the individual. In healthy subjects age, sex and stature account for about 60% of the total variability about the regression lines in these indices (Cotes, 1979). Lung volumes increase with stature and decrease with age after about the mid-20's and are larger in men.

The lung and working capacities are also related to the habitual activity of the individual. An increase in habitual activity as seen in training brings about an improvement of physical fitness and also lung capacity. During exercise the symptom of breathlessness can induce a voluntary limitation of physical activity (Shephard, 1974), and unpleasant breathlessness of dyspnoea develops when the tidal volume is 50% or more of vital capacity. Racial differences of lung volumes and also changes in capacity due to acculturation are therefore of interest.

Lung capacity and thus fitness are influenced by environmental factors such as high altitude, air pollution, including smoking, and disease. At high altitudes the low level of atmospheric pollution and the lower density and viscosity of the respiratory gases may contribute to a low airway resistance and large lung volumes. High altitudes are usually linked with a

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The overall effect of acculturation on aerobic capacity has in the main been examined with cross-sectional urban/rural and inter-population comparisons. With urban migration aerobic capacity has been found to decrease in some instances (Aghemo, Limas and Sassi, 1971; Miller, Cotes, Hall, Salvosa and Ashcroft, 1972; and Shephard, 1978) and increase in others (Van Graan, Wyndham, Strydom and Greyson, 1972; Wyndham, 1973). Nevertheless, acculturation has usually been found to result in a deterioration in physical fitness, primarily as a consequence of a decrease in activity level (Greksa and Baker, 1982; and Rode and Shephard, 1984b).

In spite of many differences between groups in different levels of acculturation, anthropometry and nutritional state, there is a remarkable similarity in the aerobic capacity in relation to body weight, provided the groups are comparable in the amount of physical effort they perform daily (Davies, Barnes, Fox, Ojikutu and Samueloff, 1972).

The purpose of this thesis is to describe the aerobic and lung capacity and body composition of acculturating Papua New Guinean males who have had, until recently, little contact with the outside world and to examine the effects on aerobic capacity of changes in activity level and body composition as a result of acculturation.

1. MATERIALS AND METHODS

2. Materials And Methods.

2.1. Introduction.

The effects of acculturation are best examined longitudinally noting alterations in the average characteristics of a population as its life-style changes. Alternatively, cross-sectional comparisons can be carried out between individual members of a population who differ in their degree of acceptance of the new way of life. This work was a cross-sectional study of the Ok Tedi Region undertaken as part of the Ok Tedi Health and Nutrition Project (HNP) carried out between September 1985 and June 1986.

The Environmental Monitoring Programme of OTML included a commitment to monitor the effects of mine development on the health, diet and nutrition of the local populations. It was within the context of this Programme that the HNP had been mounted. It was coordinated by the Department of Human Biology (now Basic Medical Sciences) of the Medical Faculty in the University of Papua New Guinea (UPNG) at Port Moresby, with the assistance of the Department of Community Medicine at UPNG and the Institute of Medical Research in Madang.

The HNP was initiated in September 1983, and later that same year all villages to be included in the study were visited and explanations of the Project given to the inhabitants. During 1984 an intensive field study of food intake and nutritional status in two seasons was undertaken. In addition, regular supporting visits were made to villages by a medical team who performed clinical examinations and other specialised investigations.

The eight villages were selected to represent the Wopkaimin, Ningerum and Awin ethnic groups at different levels of acculturation. These villages were Atemkit, Bultem and Wangbin (Wopkaimin); Hukim and Haidauwogam (Ningerum); and Tapko, Yenkenai and Miasomnai (Awin; Figure 2.1). In this study men from these villages who worked in Tabubil as cooks, bakers,

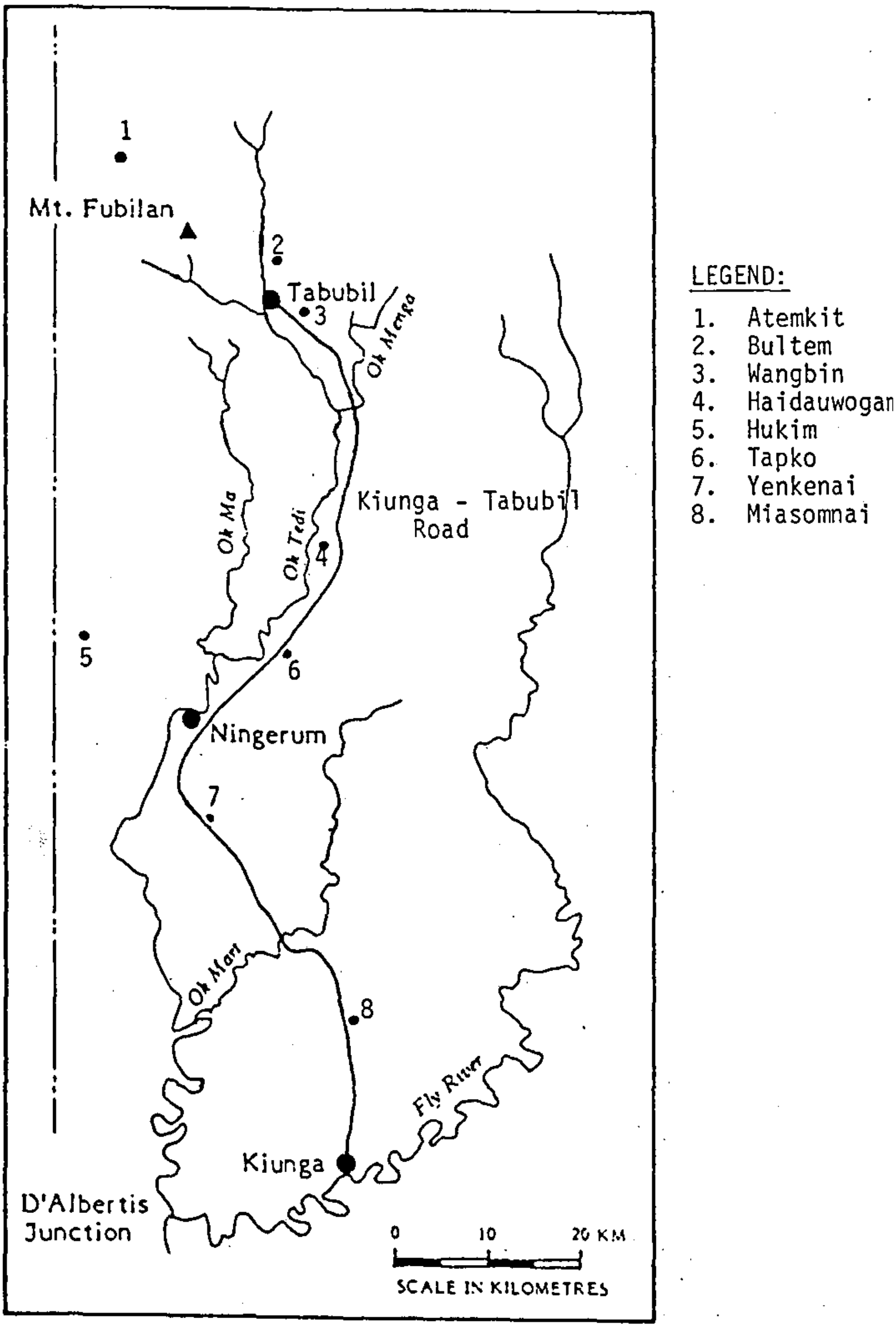


Figure 2.1: Location map of Ok Tedi region, indicating the the villages studied.

cleaners and janitors, and who lived and ate in the camps built by OTML were also included.

All villages were visited prior to the study to explain the nature and purpose of the survey and to get acquainted with the villagers. The Mamus (Chief) was first approached, aswell as some of the village Council. They were told about the work by my assistant in Pidgin English or Motu, and they then relayed the information to the rest of the villagers in their own language. Lists of men were used for each village so that the original names could be entered onto computer and references made to previous studies. This was helpful because the villagers had a habit of changing their name every year or so to fit a trend.

Participation by the villagers was purely voluntary, with no reward being offered as an incentive to take part. Most took part because they appeared interested, though some may have volunteered because they would be looked upon as inferior if they did not. However, a number who had anthropometric measurements taken refused to undergo the exercise test and were not persuaded to complete the study.

2.2. Subjects.

A total of 233 subjects were interviewed and had anthropometric measurements taken. The number in each ethnic group measured was 88 Wopkaimin, 69 Ningerum and 76 Awin. Of these, 95 had their lung capacity measured, and 166 their resting metabolic rate and response to exercise measured.

For each subject simple demographic information on father's and mother's name, birthplace, age, marital status, occupation and education was collected.

As there were no birth records ages were estimated by indirect methods. First by reference to local events, then by ranking each villager from oldest to youngest. Functional age-sets were then defined within the community. The age-groupings used and age distribution of the sample are given in table 2.1.

Table 2.1. Age groups and age distribution.

Age Group	Wopkaimin	Ningerum	Awin	Total
16 - 19	15	6	8	29
20 - 24	20	8	13	41
25 - 29	17	10	10	37
30 - 34	14	19	14	43
35 - 39	8	13	17	38
Over 40	14	13	14	41
Total	88	69	76	233

Each villager was as fit and healthy as could be expected in a primitive society. A large proportion exhibited signs of lung disease by the presence of loose coughs; some had arthritic joints and were allowed to take part except in the exercise test. A few had difficulty breathing with the mouthpiece and so did not take part in the exercise test. Three men were deaf but appeared to cope well with all the tests. When a subject was badly deformed he was measured because he wanted to be, but his record was not used in analyses. Smokers were asked to refrain from smoking at least two hours before the lung capacity, resting metabolic rate and exercise tests.

There follows a brief description of the size, location, housing and diet of each village:

A. Atemkit (Plate 2.1) is a small village of about seven houses, situated on the hillside above the Kauwol River north-west of Tabubil. It is approximately two days walk from Tabubil across very rugged country and through dense rain-forest, or a 20 minute helicopter ride. The houses are built of traditional materials found locally, which include forest saplings, split palms and trees, bark, leaves, palm fronds and vines. The diet is also traditional with trade-store foods being eaten now and again when the villagers travel to Bultem or Tabubil.

Plate 2.1: Atemkit

Plate 2.2: Bultem II

Plate 2.3:Wangbin

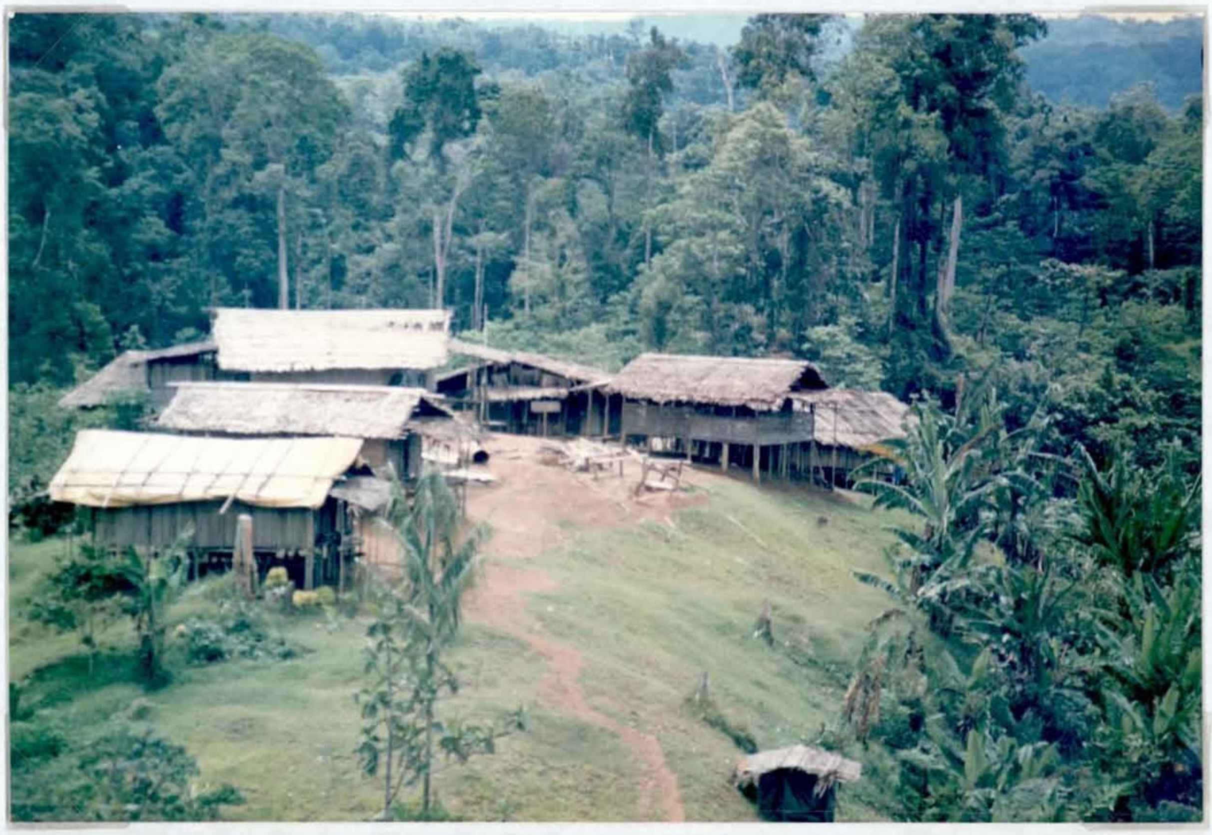


Plate 2.4: Haidauwogam

B. Bultem II (Plate 2.2) is a village of approximately a 100 houses, with many people from other villages living there either looking for employment or already employed in Tabubil. It is about 20 minutes by car from Tabubil. The majority of the houses are built from wood obtained from large packing cases with corrugated tin roofs. The villagers rely on the trade-store for most of their food, with the women and unemployed men growing their own food in their gardens.

C. Wangbin (Plate 2.3) is also a large village of about a 100 houses and only a short distance from Tabubil. Like Bultem it has many people from outside villages living there, and the houses are built of packing case material and tin roofs with some from pre-cut timber; the diet is based on trade-store foods supplemented by their own produce.

D. Haidauwogam (Plate 2.4) is a village of about 20 houses built of traditional materials (as are the rest of the village's described below), and approximately 45 minutes drive from Tabubil. The villagers eat a basically traditional diet which is supplemented by trade-store foods, bought with money they get from selling their own produce at the market.

E. Hukim (Plate 2.5) has approximately 30 houses and situated about 37 km south-west of Tabubil. It takes approximately 30 minutes by helicopter to get to, or an hour's drive to Ningerum and then an eight hour walk after first crossing the Ok Tedi. The diet is traditional.

F. Tapko (Plate 2.6) has about 20 houses, and about an hour's drive from Tabubil. The diet is traditional supplemented by trade-store foods.

G. Yenkenai (Plate 2.7) is another large village of about a 100 houses, an hour and a quarter's drive from Tabubil. The traditional diet is again supplemented with trade-store foods.

H. Miasomnai (Plate 2.8) has about 40 houses, two hour's drive from Tabubil, and about 20 minutes away from Kiunga. Diet is also traditional supplemented with trade-store foods. The villagers have their own cattle farm with about twenty head.

Plate 2.5: Hukim

Plate 2.6: Tapko

Plate 2.7: Yenkenai

Plate 2.8: Miasomnai

Plate 2.9: Aerial view of Tabubil

All villagers have to obtain water from streams, except those living in Bultem and Wangbin who have had standpipes erected. No electricity is available to villagers, although there is an agreement in the pipeline between OTML and Bultem and Wangbin villagers to supply them with lighting. Most villages are within access of an aid post, except Atemkit who have to go to Tabubil.

Plate 2.9 shows a picture of Tabubil where the workers for OTML and all associated sub-contractors live, some with their families. Approximately 4,000 people live there. In the town there is a supermarket, pharmacy, bank, post office, food take-away shop, tavern, and recreational facilities, all available for use by the workers and villagers. There are three schools, one for the young national children (Infants), and International Junior and Secondary.

The data were analysed in three ways. Firstly, according to what ethnic group the villager belonged to, each one being affected differently by the mine as discussed in section 1.5.

Secondly, villages were grouped into those 'close to Tabubil' (less than half a day's walk away), those 'remote from Tabubil' (one to three days' walk away), and those 'on the road' (those villages situated on the side of the Tabubil-Kiunga road). Bultem and Wangbin villagers plus workers in Tabubil belong to the first group, Atemkit and Hukim to the second, and the rest to the last.

Thirdly, the men were divided into workers and non-workers. The former ate a more Western diet in the OTML canteens, and their habitual activity would almost certainly be lower than that of the villagers. They had a steady cash flow and so were able to purchase alcohol and confectionary. Being away from home would also have affected their behaviour, especially as they were living in an environment with electricity and television and other people from different cultures.

2.3. Anthropometry.

All measurements were performed in the village church or aid post. For the workers in Tabubil they were performed close to their place of work or in a laboratory provided by OTML.

The anthropometric data taken were stature; body weight; sitting height; mid-upper-arm circumference (MUAC); biacromial and bi-iliocristal diameters; transverse and antero-posterior chest diameters; chest circumference; and skinfolds at the following sites, biceps, triceps, subscapular, supra-iliac, midaxillary, abdomen, medial and lateral calf, and anterior and posterior thigh. All measurements were taken in accordance with the methods established by the International Biological Programme (Weiner and Lourie, 1981), on the right-hand side where appropriate. Exceptions to this were the subscapular and supra-iliac skinfolds which were taken at the sites described by Durnin and Womersley (1974); the anterior and posterior thigh skinfolds which were taken at the level of a third subischial height measured up from the knee joint space (subischial height equals stature minus sitting height). The lateral calf skinfold was taken at the same level as the medial calf.

Stature was measured using a Harpenden anthropometer, to 0.1cm, given support by means of a metal rod which fixed into a wooden base. Sitting height was also measured using the anthropometer and a portable table into which the wooden base fitted. The anthropometer was regularly checked with a steel ruler kept in an air-conditioned room.

Body weight was taken to the nearest 0.1kg using a beam balance (CMS Weighing Equipment Limited, Model MPS 120), which was calibrated regularly with objects of known weights. The men wore shorts, the weight of which was subtracted before analysis. All circumferences were measured using a flexible fibreglass tape to 0.1cm, checked using the steel ruler. Skinfolds were measured with a Harpendon caliper (Holtain Limited, Bryberian, Crymmych, Pembrokeshire, Wales) to the nearest 0.1mm. This was calibrated before going to and returning from each village with blocks of known thickness.

From these measurements indices were calculated. Firstly, body density was estimated using the regression formulae derived by Durnin and Womersley (1974) using the biceps, triceps, subscapular and supra-iliac skinfolds.

Age Group	Equation
17 - 19	$y = 1.1620 - 0.0630\ x$
20 - 29	$y = 1.1631 - 0.0632\ x$
30 - 39	$y = 1.1422 - 0.0544\ x$
40 - 49	$y = 1.1620 - 0.0770\ x$
50 +	$y = 1.1715 - 0.0779\ x$

where y is body density (g/ml) and x is log of the sum of the four skinfolds (mm). The percentage of the body as fat was then estimated using Siri's (1956) formula,

$$\text{Percentage Body Fat} = \left[\frac{4.95}{y} - 4.5 \right] \times 100$$

MUAC and triceps skinfold (TSF) were used to estimate arm muscle area (AMA) using the equation described by Frisancho (1974),

$$\text{AMA (cm}^2\text{)} = \frac{(\text{MUAC} - (\text{Pi} \times \text{TSF}))^2}{(4 \times \text{Pi})}$$

Indices of body shape and nutritional status were calculated, to examine whether these would change, along with the alteration in lifestyle, and also to see if they had any influence on lung capacity, resting metabolic rate or physical fitness. They included weight-for-height; body mass index (weight/stature squared); biacromial:biiliocristal ratio; cormic index (sitting height/stature); antero-posterior:transverse chest index.

Body surface area (BSA) was estimated by the method described by Jones, Wilkinson and Davies (1985) using body weight and minimum circumference of the upper calf. This method was used and not the more commonly one of Dubois and Dubois (1916) because the latter was observed by Jones et al (1985) to be based on measurements taken from 12 subjects who were by any standards unrepresentative of the general population, e.g. a cretin, an emaciated diabetic, amputees, etc. The Dubois and Dubois formula was also seen to overestimate BSA of obese people and did not take into account the distortion observed in the thigh and trunk. The new formula used was,

$$BSA = 0.327 + 0.0071 \text{ Weight} + 0.0292 \text{ Upper Calf Circumference}$$

and was stated to account for a large percentage of the total variance (88.9%) and have a low standard error of estimate ($0.05m^2$).

Further anthropometric measurements were taken to estimate leg muscle-plus-bone volume (LMV) by the method described by Jones and Pearson (1969), which involved partitioning the leg into six truncated cones. The circumferences and heights above the floor of seven sites were taken on the right leg. The sites were the gluteal furrow fold; the one-third subischial height measured up from the knee joint space; the minimum circumference height of the lower thigh; the tibio-femoral joint space; the minimum circumference height of the upper calf; the maximum circumference of the calf; and the minimum circumference of the ankle above the malleolus.

The anterior and posterior thigh, and lateral and medial calf skinfolds were corrected to a single, uncompressed, rontgenogrammetric value, using the regression formulae derived by Jones (1970). The sums of the thigh and calf fat layers were then subtracted from their respective diameters and the volumes calculated. For a full description of the calculation of LMV see Appendix B.

Thigh muscle width (TMW) at the level of one-third subischial height up from the knee joint space was calculated from the inner cone diameter used to estimate the thigh muscle-plus-bone volume.

Table 2.2 gives a list of the abbreviations of measurements used, but not defined, in the tables and text.

Table 2.2: Abbreviations of measurements used in table and text.

Abbreviation	Parameter
Sit. Hght.	Sitting Height
MUAC	Mid-upper-arm circumference
Chest Circ.	Chest circumference
Trans. Chest	Transverse chest diameter
A.P. Chest	Antero-Posterior chest diameter
Biac & Biil Diams	Biacromial and Biiliocristal Diameters
Wt/Ht	Weight divided by Stature
Wt For Ht%	Weight-for-height as percentage of standards
MUAC%	MUAC as percentage of standards
TSF%	Triceps skinfold as % of standards
Cormic	Sitting Height/ Stature
BMI	Body mass index
BSA	Body surface area
Biac/Biil	Biac:Biil ratio
Chest Ind.	A.P. Chest:Trans. Chest ratio
AMA	Arm muscle area
FFM	Fat free mass
LMV	Leg muscle-plus-bone volume
TMW	Thigh Muscle Width
fh_{rest}	Resting heart rate
$\dot{V}_{e}rest$	" ventilation rate
$\dot{V}o_{2}rest$	" oxygen consumption
$fh_{1.5}$	Heart rate at a $\dot{V}o_2$ of 1.5 l/min
" adj	$fh_{1.5}$ adjusted to age 25 years, stature 1.7m and FFM 55kg
$\dot{V}e_{1.5}$	Ventilation at a $\dot{V}o_2$ of 1.5 l/min
" adj	$\dot{V}e_{1.5}$ adjusted to same figures as $fh_{1.5}$ adj
PWC_{170}	Physical work capacity at a heart rate of 170
$\dot{V}o_{2}150$	$\dot{V}o_2$ at a work rate of 150 W (- 900 kgm/min)
N.M.E.	Net mechanical efficiency

2.4. Repeatability of Anthropometric Measurements.

Repeated measurements were carried out for some of the anthropometric parameters on a number of men from Atemkit, Bultem and Wangbin, to test the accuracy. Measurements were taken at the beginning of a visit and repeated at the end. The average age was about 30, with a range of 18 to over 40 (See Appendix A). The standard error of measurement was chosen to calculate the accuracy, and the values obtained were,

Weight	1.1 kg
Stature	0.5 cm
MUAC	0.6 "
Skinfolds:	
Biceps	0.3 mm
Triceps	0.4 "
Subscapular	0.5 "
Suprailiac	1.0 "
All skinfolds	0.6 "

Paired t-tests on the raw data showed no significant differences between the means ($p>0.05$).

2.5. Lung Capacity.

Forced vital capacity (FVC) and forced expiratory volume in one second (FEV) were measured by the method described in Weiner and Lourie (1981), using a Mijnhardt spirometer (Gebr. Mijnhardt, N.V. Odijk, Holland). The spirometer was of the closed circuit bellows type with a built-in kymograph. As soon as the subject began the forced expiration the pressure sensitive record card began to move at a rate of 4 cm/sec and the fixed pen produced a line proportional to the volume of air expired.

The test procedure was first demonstrated to the subject. He practised the procedure and was then asked to perform the forced expiration, from total lung capacity, five times whilst in a standing position. There was at least a 30 second interval between each attempt to allow the subject to recover. A nose-clip was used to ensure that all the air was expired through the mouth. Encouragement was given to each subject to breathe in as much as possible and then expire fast and continue to do so until no more air was left in the lungs.

Of the five trials the highest values for FEV and FVC were taken and corrected to body temperature (37°C) and pressure, saturated with water vapour (BTPS). From the corrected FEV and FVC values the forced expiratory volume ratio (FEV% = FEV/FVC x 100) was calculated.

The volumes were adjusted to a stature of 1.7m and age 30 years, as they are known to vary with these (Cotes, 1979), so comparisons could be made between the different groups on an equal basis. Firstly, a rough factor for stature was calculated,

$$a = \frac{1.7^2}{\text{Stature}^2}$$

The volumes were then multiplied by this factor and regressed on age,

$$FEV = b - (c \times Age)$$

Uncorrected Volumes were then adjusted to 30 years and then regressed on stature,

$$FEV_{30} = FEV_{obs} - (c \times (30 - Age))$$

$$\text{and} \quad FEV_{30} = b + (d \times Stature)$$

Volumes were then adjusted to both 30 years and 1.7m,

$$FEV_{30,1.7} = FEV_{obs} - (c \times (30 - Age)) + (d \times (1.7 - Stature))$$

2.6. Resting Metabolic Rate.

Basal metabolic rate (BMR) is the energy required to maintain body temperature and the activity of the internal organs, and has been defined as the sum total of the minimal activity of all tissues of the body under steady state conditions (Schofield, 1985). BMR therefore depends on the relative proportion of active tissue to body mass and hence nutritional status. In this study the resting metabolic rate (RMR) was measured which is slightly greater than the BMR.

The RMR was determined whilst the subject was lying down at complete rest, between 6:00 and 8:00am, after a 12 hour fast. Measurements were usually undertaken in the village church after the subject had rested for at least 30 minutes. Workers in Tabubil were measured either in their rooms or as close to them as possible, again after they had rested from the short walk to the test place. RMR was measured on two consecutive mornings and the lowest of the two used for analysis because it would be nearer to basal conditions. This was so, unless obviously false figures were obtained, i.e. those that did not fall into the normal physiological limits given by Durnin and Passmore (1967). Then the measurement was repeated.

Expired air was collected by the standard Douglas bag method for 5 minutes after a 10 minute running-in period to allow the subject to get accustomed to the mouthpiece and nose clip. Heart rate was measured by taking the pulse at the wrist in the last 30 seconds of the collection period. Gas analysis and expired air volume measurement are described in the next section as is the calculation of oxygen consumption ($\dot{V}o_2$) and energy expenditure.

Resting metabolic rate (RMR) was standardised to age 30 years and body weight 65 kg.

1) RMR was regressed on age:

$$RMR = a + (b \times Age)$$

2) RMR adjusted to an age of 30 years:

$$RMR_{30} = RMR_{obs} + (b \times (30 - Age))$$

3) New RMR_{30} regressed on body weight:

$$RMR_{30} = a + (c \times Weight)$$

4) Adjusted RMR then calculated:

$$RMR_{30,65} = RMR_{obs} + (b \times (30 - Age)) + (c \times (65 - Weight))$$

2.7. Fitness Assessment.

2.7.1. Exercise Test:

Because all equipment had to be easily transportable and facilities like electricity were limited, a step test was chosen to provide the exercise stimulus. It was also chosen for its reliability, economy, safety and versatility. A height of 42cm was selected because the smaller individuals may have found it difficult to ascend a step that was any higher. A single-step was chosen over a double-step because of the greater safety at higher work rates.

The test was only carried out when the temperature was 25°C or below. This figure was taken as the cut-off point because higher temperatures are known to increase the heart rate (fh) at a fixed $\dot{V}o_2$ (Astrand and Rodahl, 1977). Thus, when in the villages no work was carried out in the extreme heat of mid-day.

The step test procedure consisted of four work loads, rhythm of ascent and descent being kept by a metronome and also by one measurer calling out "up" and "down" in the local language. In all cases the right leg led, i.e. always ascended and descended the step first. The continuous test procedure was as follows, Time (min)

0 - 5	Subject works at 15 ascents/min.
3 - 5	Expired air collected.
4.75 - 5	Measurement of fh taken
5 - 10	Work load increased to 17 or 18 ascents/min depending on the response of the subject to the previous load.
8 - 10	Expired air collected.
9.75 - 10	Measurement of fh taken.
10 - 15	Work load increased to 19 or 20 ascents/min.
13 - 15	Expired air collected.
14.75 - 15	Measurement of fh taken.
15 - 20	Work load increased to 21 or 24 ascents/min.
18 - 20	Expired air collected.
19.75 - 20	Measurement of fh taken.

Heart rate, because of the lack of electricity, was measured by taking the pulse rate at the wrist in the last 15 seconds of each work load. The accuracy of this method was tested in the laboratory by comparing the fh measured by a Gould electrocardiogram monitor with that by taking the pulse rate, over a range of work loads. No significant difference between the means was found ($p>0.05$). See Appendix C.

Because of the limited time and resources available to myself and the HNP, the exercise test was not repeated. However, as four measurements were made at different work loads, a small error at one load would be suppressed or eliminated by the others. If one measurement was obviously incorrect, i.e. if it deviated by two or more standard deviations from the regression line of the other three points, then it was rejected.

2.7.2. Gas Analysis and Calculations:

Collection of expired air was by the standard Douglas bag method, (Weiner and Lourie, 1981). A two litre sample of the air collected in the Douglas bag was taken via a flexible side-arm in a heavy duty plastic bag for analysis. The volume of air collected in the Douglas bag ($\dot{V}_e$) was then measured using a CIG Medishield dry gas respirometer and corrected to standard temperature (0^oC) and pressure (760mmHg), dry (STPD). The meter was checked by passing air of known volumes through it from bags of known capacity. At the beginning of the survey three strong plastic bags of various sizes were fully inflated and their volumes measured by the respirometer. Periodically these bags were again inflated and the air expelled through the meter, and if the readings differed significantly from the original values the meter was adjusted accordingly.

Each sample of air was analysed for its oxygen content (FeO_2) with a Beckman oxygen analyser (model OM-14). The manufacturers claimed the instrument was accurate over a temperature range of 4-43°C and humidity 0-85 percent, but this was never checked because of the lack of testing facilities. Standard gases were hard to obtain because of the remoteness of the region. Zero percent oxygen was usually available from the Chemistry Section of OTML, and occasionally 100% oxygen was obtained from the Tabubil Health Centre. But these were never allowed to be taken to the villages.The analyser was checked before going to, and after returning from a village. It was allowed to warm-up and then a sample of expired air was passed through it. The 0% oxygen was then sampled. This was repeated three or four times. There was only negligible difference (about 0.005) between the before and after readings. Whilst in the village the instrument was calibrated every morning and afternoon to the fraction of oxygen in the air (0.2094) when it was needed.

The analyser was used over an altitude range of 20-980m, but could always be spanned on atmospheric air without recourse to adjustment of the internal circuitry (See Appendix D).

Using the FeO_2 and corrected V_e, the Vo_2 and energy expenditure were calculated using the equations given in Lamb (1984), the fraction of nitrogen in the expired air being assumed to be 0.7904 (Appendix E). Montoye, Cunningham, Welch and Epstein (1970) compared Vo_2 calculated by this method with that calculated using the FeO_2 and the fraction of carbon dioxide expired measured by chemical analyser, and found no significant difference between the means of the two methods ($p>0.05$). Experiments carried out by myself in the laboratory also showed no significant difference between the means ($p>0.05$). See Appendix F.

2.7.3. Maximal Oxygen Consumption Estimation:

For each subject a regression equation was calculated from the four pairs of submaximal fhs and Vo_2s by the method of least squares, a modification of the method described by Maritz, Peter, Strydom and Wyndham (1961), who fitted a line through the points by inspection. The modified method was shown by Washburn and Montoye (1984) to consistently provide the smallest amount of variability between measured and predicted values for all ages (mean r=0.83), compared to the methods described by Astrand and Rhyming (1954) and Margaria, Aghemo and Rovelli (1965). They also found the method to be reasonably accurate for estimating the mean $\dot{V}o_2max$ a group, but large errors were made on an individual basis.

Vo_2max was estimated by an extrapolation to an estimated maximum fh (fh_{max}) using the following regression equation from Washburn and Montoye (1984), which was based on published fh_{max}s,

$$fh_{max} = 211 - (0.82 \times Age)$$

This equation was seen to overpredict fh_{max} by about 2% ($p<0.05$), but Washburn and Montoye (1984) observed that the modified method of Maritz et al (1961) had a tendency to underestimate $\dot{V}o_2max$ by up to 2%. So the two could counterbalance each other.

Because of the different age structures of each group and different body dimensions $\dot{V}o_2max$ was standardised to a reference age of 25 years, a FFM of 55 kg and stature 1.7m.

1) $\dot{V}o_2max$ regressed on age:

$$\dot{V}o_2max = a - (b \times Age)$$

2) $\dot{V}o_2max$ adjusted for age:

$$\dot{V}o_2max_{25} = \dot{V}o_2max_{obs} - (b \times (25 - Age))$$

3) $\dot{V}o_2max_{25}$ regressed on FFM:

$$\dot{V}o_2max_{25} = a + (c \times FFM)$$

4) $\dot{V}o_2max$ adjusted for FFM:

$$\dot{V}o_2max_{55} = \dot{V}o_2max_{obs} + (c \times (55 - FFM))$$

5) $\dot{V}o_2max_{55}$ regressed on stature:

$$\dot{V}o_2max_{55} = a + (d \times Stature)$$

6) $\dot{V}o_2max$ adjusted to age 25 years, FFM 55 kg and stature 1.7m:

$$\dot{V}o_2max_{adj} = \dot{V}o_2max_{obs} - (b \times (25 - Age)) + (c \times (55 - FFM)) + (d \times (1.7 - Stature))$$

2.7.4. Submaximal Indices of Fitness:

Submaximal indices of fitness were calculated. The physical work capacity at a fh of 170 (PWC_{170}), was estimated from regression equations of work performed and the corresponding fhs by either interpolating or extrapolating to the fh of 170. The fh at a $\dot{V}o_2$ of 1.5 l/min ($fh_{1.5}$) was estimated from the regression equation of submaximal fh on $\dot{V}o_2$. The minute ventilation at the same $\dot{V}o_2$ ($\dot{V}e_{1.5}$) was estimated from regression equation of submaximal $\dot{V}_e$ on $\dot{V}o_2$. The $\dot{V}o_2$ at a work load of 150W (900 kgm/min) was estimated from the $\dot{V}o_2$:work performed relationship ($\dot{V}o_2150$).

In addition the net mechanical efficiency (N.M.E.) of work, a measure of the relationship between the work performed and energy expended above that at rest (En.Exp.), was estimated at each work load.

$$N.M.E. = \frac{[Work\ Performed\ (kgm/min)] \times 0.0098\ (KJ/min)}{En.Exp.\ (KJ/min)} \times 100$$

The work performed was calculated as the product of body weight, step height (0.42m) and work load (number of ascents of the step per minute), and then converted to kilojoules/min (KJ/min) by multiplying by 0.0098. Thus for a 50kg subject working at a rate of 15 ascents per minute, the work performed is 3.087 KJ/min.

2.8. Statistics.

For analysing the data of the three ethnic groups and three village groups an analysis of variance was used to test for any differences between them, after taking account of the different age structures of the groups. If a difference was then found a t-test was carried out between two groups at a time, i.e. Wopkaimin versus Ningerum, Wopkaimin versus Awin and Ningerum versus Awin, to see which one differed the most from the other two. Thus in the tables of the results chapter a significance level is given and a mark put next to a figure of one of the groups indicating they were higher or lower than the others.

For the analysis of workers and non-workers a simple unrelated t-test was used and the one whose mean was significantly greater indicated with the significance level.

This is a cross-sectional study so the effects of ageing could not be fully examined, however regression analysis was carried out and ageing coefficients calculated to give some indication of ageing.

3. RESULTS

3. RESULTS.

The results are discussed under the headings: a) ethnic groups; b) the locality of the village in relation to Tabubil (village groups); and c) workers and non-workers (occupation groups).

3.1. Ethnic Groups.

The age structures for the three ethnic groups were given in table 2.1. There was a disproportionate number of young adult Wopkaimin in the sample, and a greater number of elderly Ningerum and Awin. Because of this, age was taken into account in the statistical analysis.

A. Anthropometry and Body Composition:

Differences were found between the three ethnic groups for most of the anthropometric measurements and indices of body composition (Tables 3.1 and 3.2). Generally the Awin were the taller group, which was associated with a slightly greater trunk (sitting height) and leg length (stature minus sitting height) as the cormic index did not appear to differ between the three (Table 3.2). The Wopkaimin were the heavier, fatter and had the greater amount of muscle in all age groups (Figures 3.1 to 3.3). The sum of the ten skinfolds in table 3.1 was significantly greater in the Wopkaimin ($p<0.01$; 57.7 ± 19.2) than the Ningerum (50.0 ± 12.1) and Awin (49.6 ± 11.4). Adjusting weight and stature to a standard age of 30 years did not significantly alter the means ($p>0.05$), and did not change the differences between the groups. Weights ranged from 35kg to 77kg, the heaviest Wopkaimin being some 9kg heavier than the largest Ningerum and Awin. The Ningerum generally, although not significantly, had narrower shoulders and transverse chest diameters.

Table 3.1: The anthropometry of males in the Ok Tedi region (mean(std. dev.)). For abbreviations see Table 2.2.

	ALL	ETHNIC GROUP		
		Wopkaimin	Ningerum	Awin
	[N=233]	[N=88]	[N=69]	[N=76]
Age	30.1(8.1)	28.2(8.6)	31.4(7.3)	31.0(7.9)
Weight (kg)	55.1(7.4)	57.5(7.5)*	52.7(6.2)	54.5(7.6)
Stature (cm)	157.1(5.9)	156.0(5.9)	155.6(4.7)	159.6(6.2)*
Sit. Hght.(cm)	79.9(3.3)	79.8(3.7)	78.8(2.6)	80.9(3.3)*
MUAC (cm)	27.5(2.5)	28.0(2.7)	26.9(2.4)	27.4(2.2)
Chest Circ.(cm)	90.1(4.8)	90.7(4.7)	88.9(4.0)	90.7(5.4)
Trans. Chest (cm)	25.0(2.1)	25.4(2.0)	24.3(1.9)	25.1(2.1)
A.P. Chest (cm)	17.4(1.1)	17.5(1.0)	17.4(1.1)	17.3(1.2)
Biac. Diam. (cm)	35.4(1.8)	35.8(1.7)	34.6(1.6)	35.8(1.9)
Biil. Diam. (cm)	26.1(2.2)	26.4(1.9)	26.1(2.7)	25.8(1.8)
Skinfolds (mm):				
Biceps	2.8(0.5)	3.0(0.6)*	2.6(0.5)	2.6(0.4)
Triceps	4.8(1.4)	5.3(1.7)*	4.6(1.3)	4.5(0.9)
Subscapular	7.6(2.0)	8.1(2.3)**	7.2(1.7)	7.5(1.9)
Suprailiac	6.5(3.1)	7.5(3.6)**	5.9(2.7)	5.9(2.5)
Abdomen	7.1(3.0)	7.7(3.8)	6.7(2.3)	6.9(2.7)
Midaxillary	5.2(1.7)	5.6(2.4)	4.9(1.0)	5.0(1.3)
Ant. Thigh	6.1(2.2)	6.8(2.3)	6.2(2.5)	5.5(1.3)*
Post. Thigh	5.6(1.9)	6.3(2.3)*	5.2(1.7)	5.3(1.4)
Med. Calf	3.3(1.1)	3.5(1.0)	3.3(1.4)	3.1(0.7)
Lat. Calf	3.6(1.1)	3.9(1.3)**	3.5(1.1)	3.3(0.7)
Sum of 10	52.8(14.2)	57.7(19.2)*	50.0(12.1)	49.6(11.4)

* p<0.01, **p<0.05

Table 3.2: Indices of body composition of ethnic groups and total population (mean(std. dev.)). For abbreviations see Table 2.2.

	ALL	ETHNIC GROUP		
		Wopkaimin	Ningerum	Awin
	[N=233]	[N=88]	[N=69]	[N=76]
Wt/Ht (kg/m)	35.0 (4.2)	36.8 (4.1)*	33.8 (3.7)	34.1 (4.1)
Wt-For-Ht (%)	90.4 (9.8)	94.8 (8.0)	88.6 (10.0)	87.3 (9.8)
MUAC%	90.3 (7.0)	91.8 (7.4)	89.0 (6.9)	89.9 (6.4)
TSF%	60.7 (4.3)	67.7 (6.6)	60.3 (2.4)	60.0 (---)
Cormic (%)	50.9 (1.4)	51.2 (1.7)	50.6 (1.2)	50.7 (1.2)
BMI (kg/m^2)	22.3 (2.6)	23.6 (2.4)*	21.7 (2.3)	21.3 (2.4)
BSA (m^2)	1.59(0.11)	1.62(0.11)**	1.57(0.10)	1.59(0.11)
Biac/Biil	1.36(0.10)	1.36(0.08)	1.34(0.12)	1.39(0.09)*
Chest Ind	0.70(0.06)	0.69(0.05)	0.72(0.05)	0.69(0.06)
AMA (cm^2)	54.1 (9.4)	55.7 (10.0)	52.0 (9.1)	54.1 (8.6)
% Body Fat	10.8 (3.2)	11.4 (3.4)*	10.5 (3.1)	10.4 (2.9)
FFM (kg)	49.1 (6.5)	51.0 (6.6)**	47.1 (5.6)	48.7 (6.5)
LMV (l)	12.7 (2.1)	13.4 (2.3)*	11.9 (1.8)	12.8 (1.9)
TMW (cm)	14.5 (1.4)	14.9 (1.6)**	14.3 (1.1)	14.4 (1.2)

* $p<0.01$, ** $p<0.05$

Weight and stature are given as a function of age in figures 3.1(a) and (b), respectively. Weight showed a decrease in all three groups over the age range studied, the decline was greatest in the Awin; correlation with age was highest in the Ningerum (r=-0.47). With the cross-sectional data the Awin appeared to get taller with age, whereas the Wopakimin became smaller and Ningerum showed no change. Stature was significantly but negatively correlated with age only in the Wopkaimin (r=-0.29). In the older cohorts there was a significant difference in stature between the groups ($p<0.01$), in contrast to the young.

Weight-for-height and Wt/Ht indicated slight wasting in the total population. Reserves of muscle protein were adequate from the MUAC% values observed. However, energy reserves stored in the form of fat were very low, as indicated by the low mean percentage triceps skinfold thickness (TSF%).

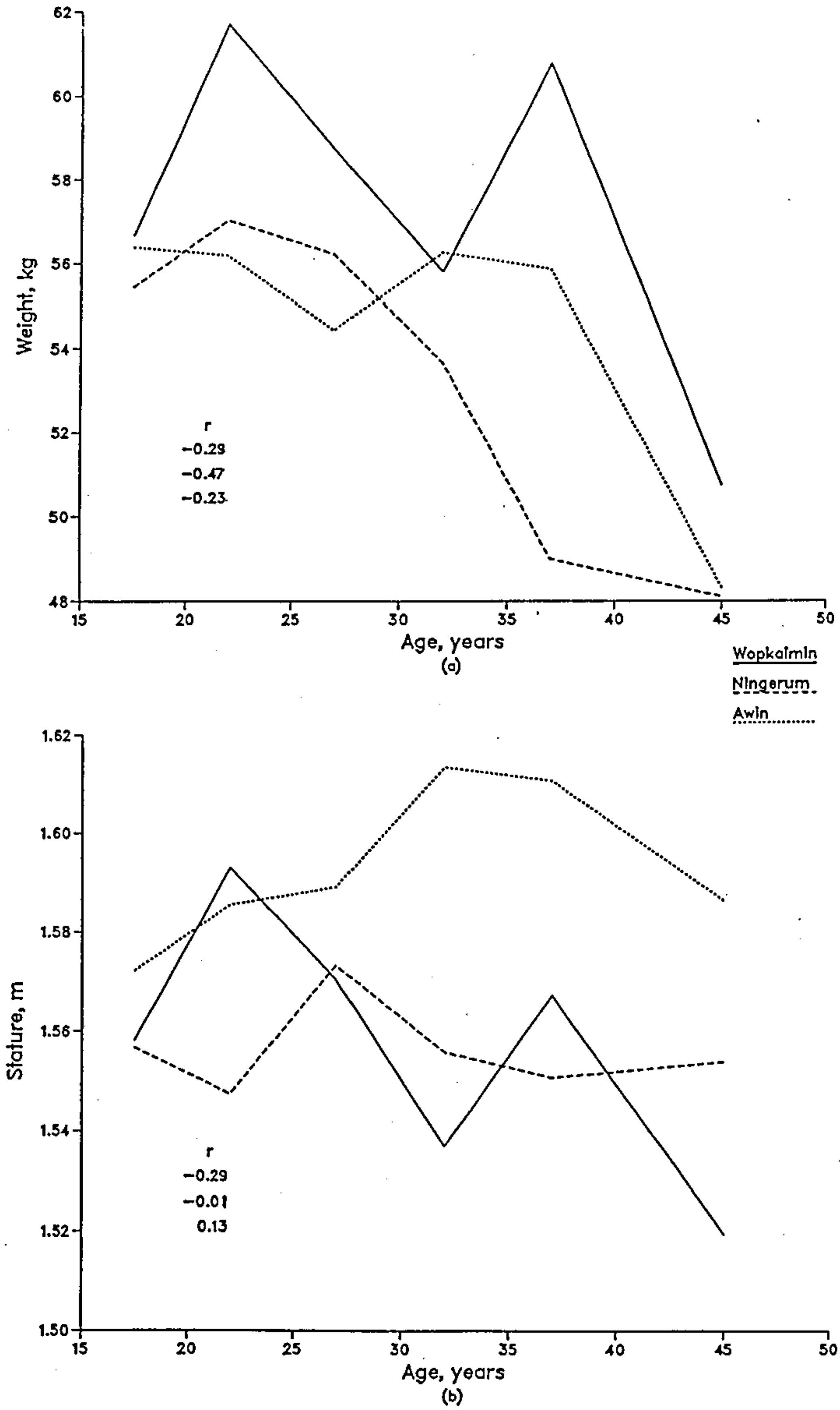


Figure 3.1: Age differences in (a) mean weight and (b) mean stature in the Ok Tedi.

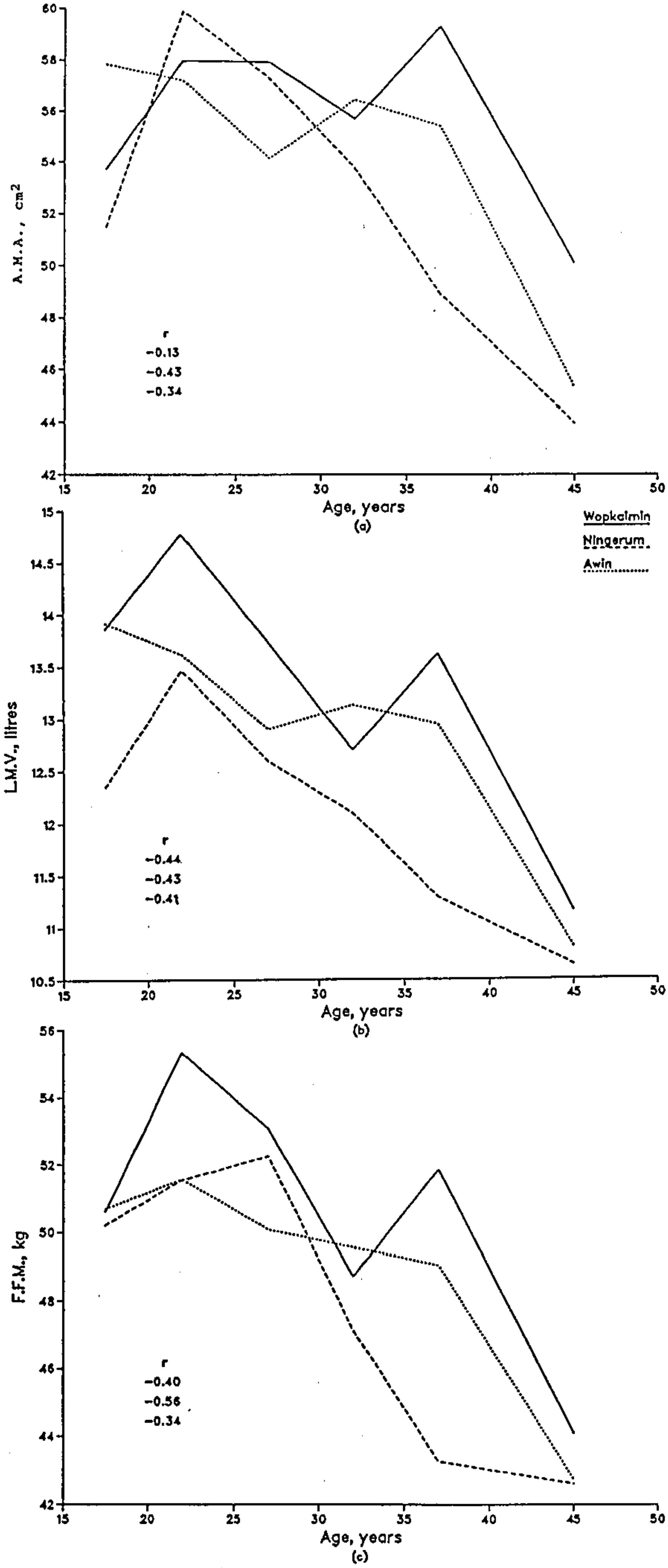


Figure 3.2: Age differences in (a) arm muscle area (AMA); (b) leg muscle volume (LMV); and (c) fat free mass (FFM).

These figures were obtained using standards published by Jelliffe (1966). If American standards are used (Frisancho, 1981) the MUAC and TSF lie between the 5th and 10th centiles, and AMA between the 10th and 25th centiles. Mean BMI figures were within the normal range defined by Garrow (1979) of 20-25 for average healthy Caucasians, the Wopkaimin having a significantly higher mean than the other two ($p<0.01$).

Figures 3.2(a) to (c) show a decrease in muscle area and volume and FFM with age. The loss of muscle appeared greater in the Ningerum and lowest in the Wopkaimin; the cross-sectional ageing coefficient for AMA being -0.53 and -0.16 cm^2/year for the Ningerum and Awin respectively (Figure 3.2(a)). However, the coefficients for LMV were comparable -0.10 and -0.11 l/year (Figure 3.2(b)). From figure 3.2(c) the onset of loss of FFM appeared to begin about 25 years in all three ethnic groups, the ageing coefficient for the Ningerum equalling -0.43, the Wopkaimin -0.31 and the Awin -0.29 kg/year.

Figure 3.3 shows a fall of Wt/Ht with age, decreasing greater in the Ningerum (-0.26 kg/m/year) and slowest in the Wopkaimin (- 0.12 kg/m/year). However BMI remained within normal limits for all age groups.

B. Lung Capacity:

FEV and FVC of the Wopkaimin were larger, but not significantly, than those of the Ningerum and Awin (Table 3.3). FEV and FVC were both significantly correlated with age and stature (FEV: $r=-0.18$ and 0.37; FVC: $r=-0.25$ and 0.47; Figure 3.8). When figures were adjusted to a stature of 1.7m and age 30 years (FEV_{adj} and FVC_{adj}) the differences were greatly reduced, but not totally. For a description of this adjustment procedure see section 2.5. Because of this insignificance and the small sample size, the three groups were combined and treated as one for comparing with other populations. The regression lines, from the mutiple regression equations on stature and age constructed, could thus be extrapolated beyond the ranges seen in the Ok Tedi to allow these comparisons to be made. The equations are given in figure 3.4, which also demonstrates the calculated change in volume with age and stature.

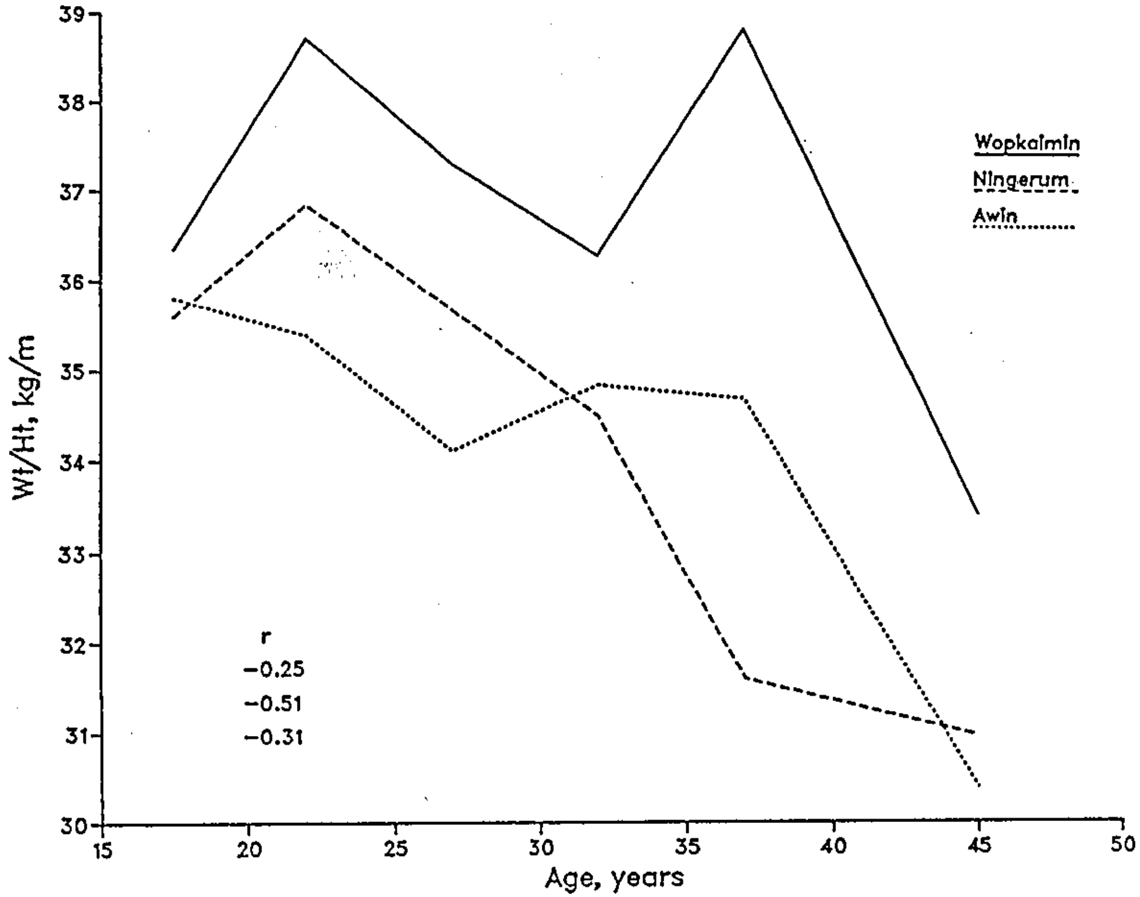


Figure 3.3: Change in weight/height with age of ethnic groups

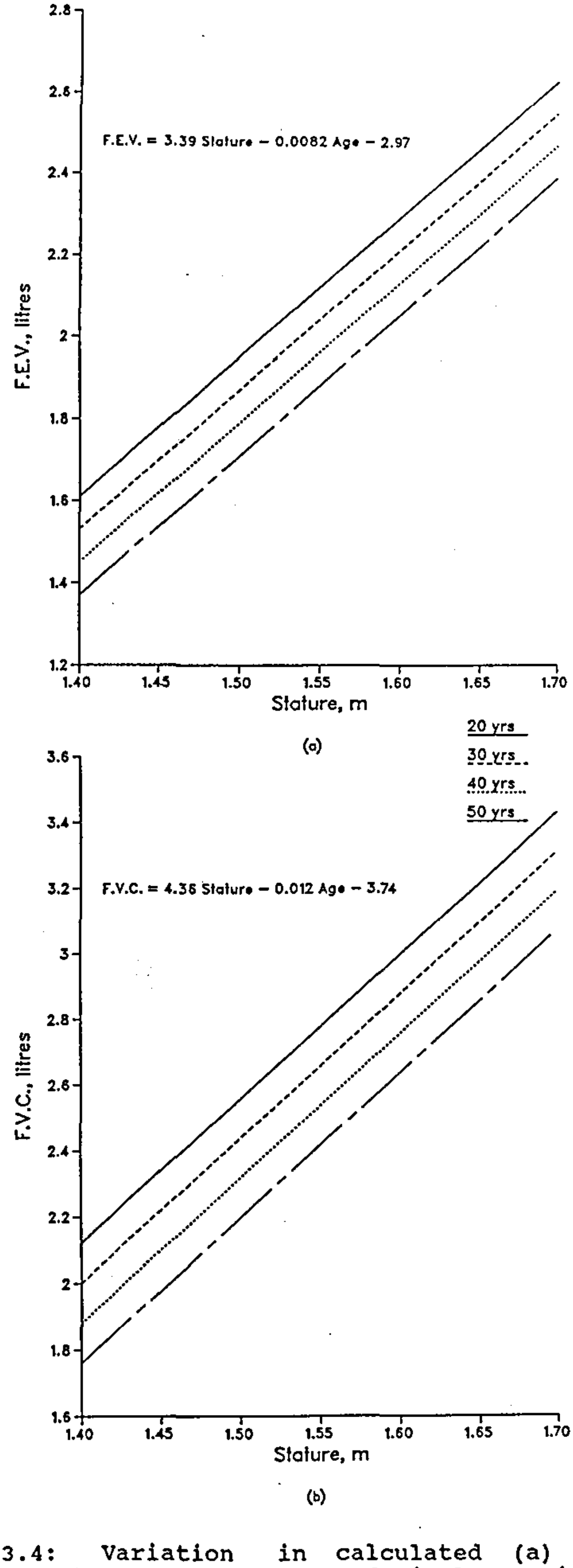


Figure 3.4: Variation in calculated (a) forced expiratory volume, and (b) forced vital capacity with age and stature in the Ok Tedi.

The mean FEV% and adjusted FEV% figures were the same in all three ethnic groups. The number of subjects with an FEV% less than 65 in this study was 20 (21%), a figure which gives an indication of the incidence of chronic obstructive lung disease.

Table 3.3: Lung volumes of the total population and individual ethnic groups (mean(std. dev.)). For abbreviations see Table 2.2.

	ALL	ETHNIC GROUP		
		Wopkaimin	Ningerum	Awin
	[N=95]	[N=51]	[N=22]	[N=22]
Age	28.0 (7.9)	26.1 (7.6)	33.1 (6.7)	27.7 (8.0)
Weight(kg)	56.5 (7.2)	58.5 (7.3)	53.2 (5.9)	54.4 (7.4)
Stature(cm)	155.8 (5.6)	156.0 (5.8)	154.0 (4.0)	157.0 (6.6)
FEV (l)	2.07(0.55)	2.13(0.57)	1.93(0.41)	2.08(0.60)
FVC (l)	2.71(0.56)	2.80(0.57)	2.53(0.43)	2.70(0.65)
FEV%	76.4 (13.7)	76.4 (14.7)	76.5 (9.1)	76.3 (15.5)
FEV_{adj} (l)	2.52(0.50)	2.55(0.56)	2.50(0.39)	2.48(0.50)
FVC_{adj} (l)	3.29(0.49)	3.34(0.52)	3.26(0.40)	3.22(0.51)
$FEV\%_{adj}$	76.3 (13.7)	76.2 (14.7)	76.6 (9.1)	76.2 (15.5)

Table 3.4: Correlation coefficients between lung volumes (litres) and indices of chest size (cm), and body surface area (cm^2).

	F.E.V.	F.V.C.	F.E.V. adj.	F.V.C. adj.
Stature	0.37*	0.47*		
Chest Circ.	0.53*	0.55*	0.38*	0.38*
AP. Chest	0.29*	0.24*	0.22**	0.16
Trans. Chest	0.15	0.24*	0.06	0.14
Biac. Diam.	0.43*	0.45*	0.22**	0.19*
BSA	0.53*	0.58*	0.32*	0.33*

* p<0.01, **p<0.05

Significantly positive correlations between lung volumes and the measurements of the chest were found (Table 3.4). FEV was highly correlated with chest circumference (r=0.53) and the antero-posterior diameter (r=0.29). FVC was also well correlated with these (r=0.55 and 0.24, respectively) and also with the transverse diameter (r=0.24). FEV% was only correlated with chest circumference (r=0.18).

C. Resting Metabolic Rate:

Mean $\dot{V}o_2$rest figures were greater than those given by Durnin and Passmore (1967) for men of equivalent %fat and weight of 0.21 l/min, and are at the upper limits of the range given by McArdle, Katch and Katch (1986) of 0.16-0.29 l/min for Caucasians in temperate climes. Fh_{rest} was about the same throughout the region, and lower than the average for a Caucasian of 72.

Table 3.5: Indices of resting metabolic rate of the Wopkaimin, Ningerum and Awin, and all three combined (mean(sd)). For abbreviations see Table 2.2.

	ALL	ETHNIC GROUP		
		Wopkaimin	Ningerum	Awin
	[N=166]	[N=46]	[N=57]	[N=63]
Age	30.0 (7.6)	27.4 (7.2)	31.7 (7.1)	31.5 (7.7)
Weight (kg)	54.2 (6.8)	57.4 (7.1)	52.2 (6.1)	53.6 (7.3)
Stature (cm)	157.4 (5.5)	156.1 (5.7)	155.8 (4.8)	159.7 (6.0)
fh_{rest} (bts/min)	68 (7)	65 (7)	68 (7)	69 (8)
$\dot{V}_e$rest (l/min)	13.3 (4.8)	12.1 (4.4)	14.7 (5.1)**	12.9 (4.5)
$\dot{V}o_2$rest (l/min)	0.27(0.11)	0.27(0.07)	0.29(0.13)	0.23(0.09)*
RMR,				
(MJ/24hrs)	8.19(3.76)	8.31(2.25)	9.27(5.03)	7.11(2.99)*
(MJ/m^2/24hrs)	5.15(2.29)	5.11(1.30)	5.91(3.06)*	4.50(1.83)
(MJ/kgFFM/24hrs)	0.17(0.08)	0.16(0.04)	0.20(0.11)*	0.15(0.06)
RMR adj$,				
(MJ/24hrs)	8.53(3.63)	8.12(2.16)	9.87(4.89)*	7.62(2.74)

* p<0.01, **p<0.05; $ Figures adjusted to age 30yrs, weight 65kg

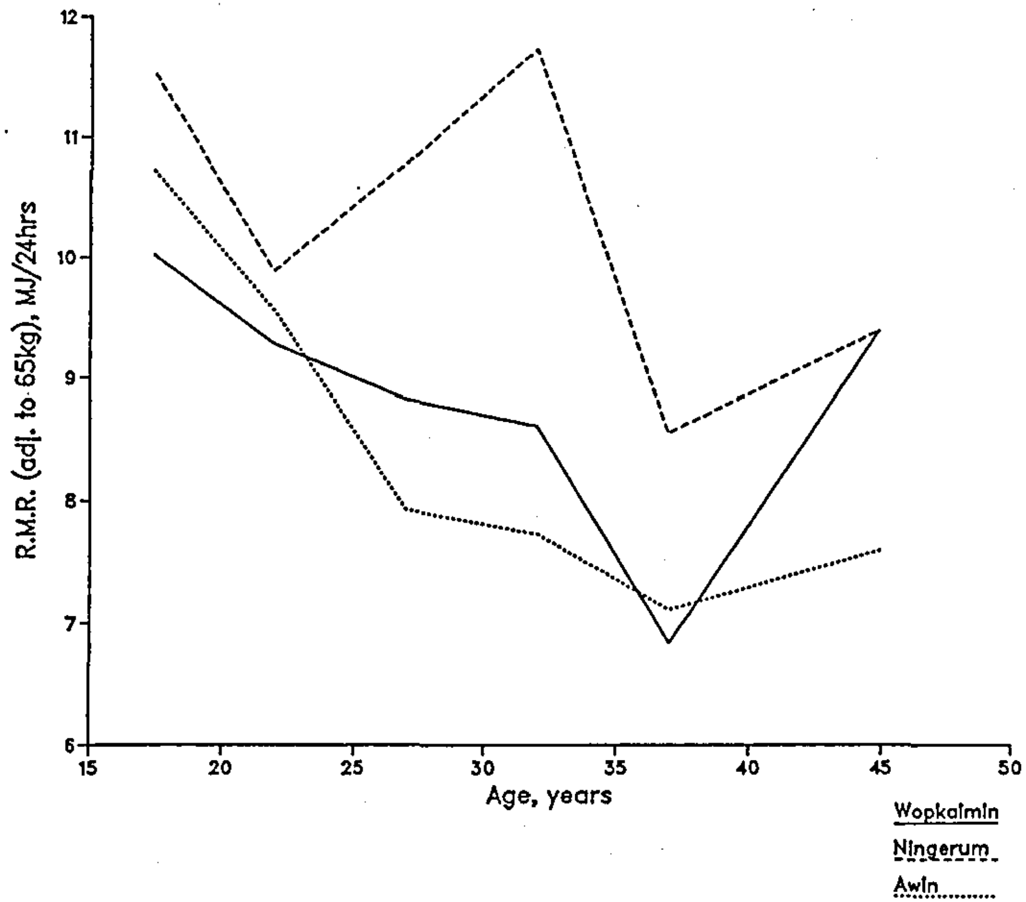


Figure 3.5: Change in resting metabolic rate adjusted to weight 65kg in the Ok Tedi with age.

RMR (Table 3.5) for the Wopkaimin was significantly larger than that of the Awin ($p<0.01$) but less than that of the Ningerum. Even when figures were expressed in relation to BSA and FFM, and adjusted to age 30 yrs and weight 65 kg, the Ningerum still had a significantly larger RMR. Figures were adjusted to the two standards because of the differences observed in weight and age between the groups. This also allows comparisons to be made with other populations where figures were also adjusted.

RMR was significantly correlated with weight, FFM and BSA in the Wopkaimin only (weight, $r=0.30$; FFM, $r=0.30$; BSA, $r=0.33$). It was though, highly negatively correlated with age in all three ethnic groups and was observed to decrease slowest in the Wopkaimin and at about the same rate in the Ningerum and Awin (Figure 3.5). Relating RMR to the body dimensions above and then to age did not affect the pattern significantly from that seen in figure 3.5.

Table 3.5 shows that the $\dot{V}_e$rest ($p<0.01$) and $\dot{V}o_2$rest ($p<0.05$) were both significantly different between the ethnic groups, the former being greater in the Ningerum and the latter lower in the Awin. Mean $\dot{V}_e$rest was high in all groups suggesting a degree of hyperventilation in villagers, probably because they were nervous and frightened of the equipment.

D. <u>Physical Fitness</u>:

Eight men refused to take the exercise test after they had anthropometric measurements taken, all from Hukim. The number who took the exercise test was lower than those who had anthropometric measurements because the latter were taken first on all men present on arrival in the village. Then because only a few could take the exercise test a day a rota was used, and those who were last became bored and went away to their gardens.

Table 3.6 illustrates the absolute Vo_2max of the Awin was approximately 0.2 litres lower, but not significantly, than that of the Wopkaimin and Ningerum. When figures were adjusted to age 25 years, stature 1.7m and F.F.M. 55kg the difference between the Awin and Wopkaimin almost disappeared, but that between these and the Ningerum increased ($p<0.05$). Although mean figures were generally low, few subjects had a high Vo_2max.

The highest was observed in a Ningerum subject of 4.14 l/min (80.4 ml/kg FFM/min), the highest for a Wopkaimin was 62.7 ml/kgFFM/min, and for an Awin 65.0 ml/kgFFM/min. In contrast the lowest of the low was seen in an Awin subject of only 1.09 l/min (22.5 ml/kgFFM/min).

Table 3.6: Predicted maximal oxygen uptake of the male population (mean(sd)). For abbreviations see Table 2.2.

	ALL	ETHNIC GROUP		
		Wopkaimin	Ningerum	Awin
	[N=166]	[N=46]	[N=57]	[N=63]
$\dot{V}o_2max$,				
(l/min)	2.17(0.63)	2.24(0.40)	2.27(0.81)	2.02(0.60)
(ml/kg/min)	39.8 (10.7)	39.2 (6.4)	43.0 (13.5)*	37.4 (10.2)
(ml/kgFFM/min)	44.4 (11.9)	43.8 (6.9)	48.1 (15.2)*	41.5 (11.1)
(ml/l LMV/min)	172.2 (47.4)	168.2 (32.4)	190.5 (57.8)*	158.4 (43.4)
$\dot{V}o_2max$ adj$				
(l/min)	2.62(0.56)	2.55(0.37)	2.83(0.72)*	2.48(0.47)

* p<0.01; $ Figures are adjusted to age 25yrs, stature 1.7m, FFM 55kg

The reliability of these estimates of $\dot{V}o_2max$ is questionable because the extrapolation procedure relies on estimating a maximum fh based upon age, and age in this study itself was estimated. Also because of the limited time and resources available no repeat measurements were carried out. However, by taking four submaximal measurements it was hoped to eliminate any errors, and if one measurement obviously deviated from the other three it was discarded and the regression equation based on three measurements.

Absolute $\dot{V}o_2max$ was significantly correlated with body weight, FFM and LMV in all 3 groups, r ranging from 0.30 to 0.52. In all, the relationship was that seen in figure 3.6, where the Ningerum had the greater slope (72 ml/kg/min) and the Wopkaimin and Awin similar ones (25.5 and 27.6 ml/kg/min)

Absolute $\dot{V}o_2max$ was negatively and significantly correlated with age in all three ethnic groups (Wopkaimin: -0.28; Ningerum: -0.34; Awin: -0.61). The

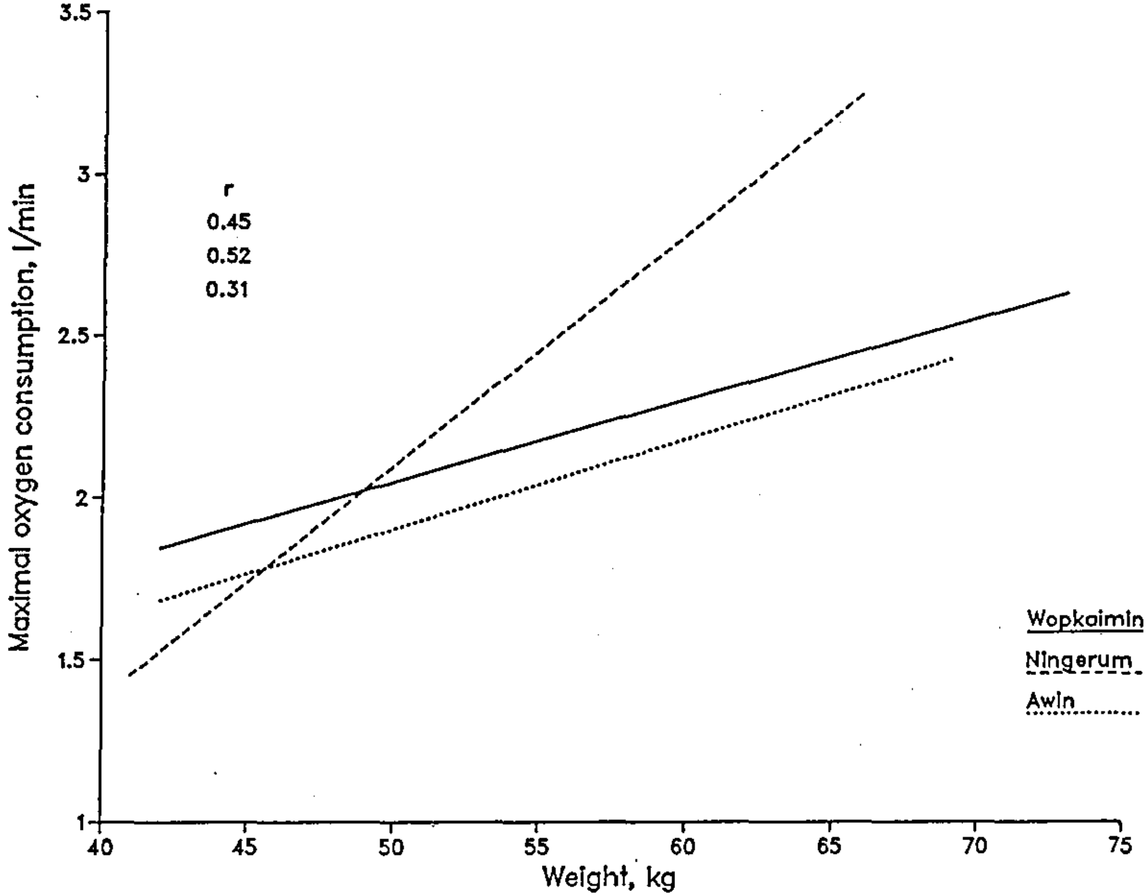


Figure 3.6: The relationship between absolute oxygen consumption (Vo_2max) and body weight.

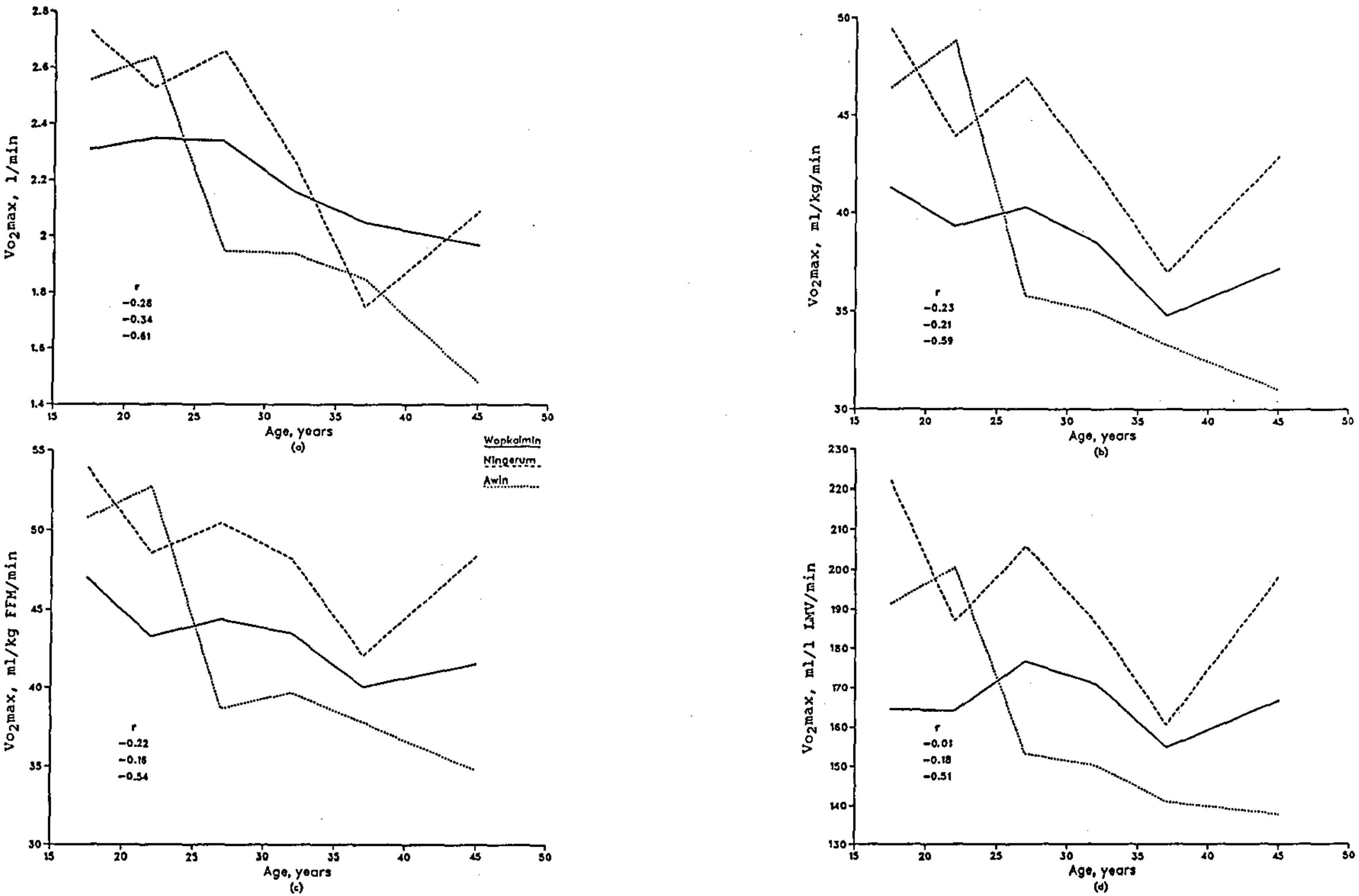


Figure 3.7: Variation of maximal aerobic capacity (Vo_2max) with age, in: (a) absolute terms; (b) relation to body weight; (c) relation to FFM; and (c) relation to LMV.

cross-sectional ageing coefficient was greatest in the Awin (-47.7 ml/year) and lowest in the Wopkaimin (-15.3 ml/year; Figure 3.7(a)). A similar picture was observed when $\dot{V}o_2max$ was related to weight, FFM and LMV (Figures 3.7(b) to (c)), however the changes with age were eliminated when Vo_2max was related to LMV in the Wopkaimin only.

The Ningerum appeared to be significantly fitter (p<0.01) no matter how the $\dot{V}o_2max$ was expressed, then the Wopkaimin and then the Awin.

The individual regression equations used to predict $\dot{V}o_2max$ varied greatly, the mean constant was -0.47 (range -2.6 to 1.15), and coefficient 0.0152 (range 0.0039 to 0.0386). R-squared values ranged from 63.1% to 97.4% with a mean of 89.9%.

No significant relationship was observed between adjusted $\dot{V}o_2max$ and adjusted lung volumes (Figure 3.8), in only the Wopkaimin does $\dot{V}o_2max$ increase with lung volumes. N.M.E. was observed to be significantly negatively correlated with $\dot{V}o_2max$ for the Ningerum (r=-0.66), Awin (r=-0.60) and Wopkaimin (r=-0.47).

Table 3.7: Response to submaximal exercise of the male Ok Tedi population (mean(sd)). For abbreviations see Table 2.2.

	ALL	ETHNIC GROUP		
		Wopkaimin	Ningerum	Awin
	[N=166]	[N=46]	[N=57]	[N=63]
$fh_{1.5}$ (beats/min)	140 (39)	130 (25)	139 (46)	150 (42)
$fh_{1.5}adj^{\$}$ (")	129 (35)	129 (25)	123 (42)	135 (34)
$\dot{V}_e1.5$ (l/min)	40.9(11.8)	37.9(5.2)	39.4(12.2)	45.2(14.6)**
$\dot{V}_e1.5adj^{\$}$ (l/min)	38.6(11.9)	35.1(6.5)	37.4(12.6)	43.0(13.7)*
PWC_{170} (watts)	90.7(17.6)	96.5(16.4)	86.0(16.5)	89.9(18.6)
$\dot{V}o_2150$ (l/min)	3.2(0.7)	3.0(0.5)	3.4(0.8)*	3.0(0.7)
N.M.E. (%)	19.6(6.9)	20.3(6.3)	17.8(4.9)**	20.7(8.6)

* p<0.01, ** p<0.05; $ Figures are adjusted to age 25yrs, stature 1.7m, FFM 55kg

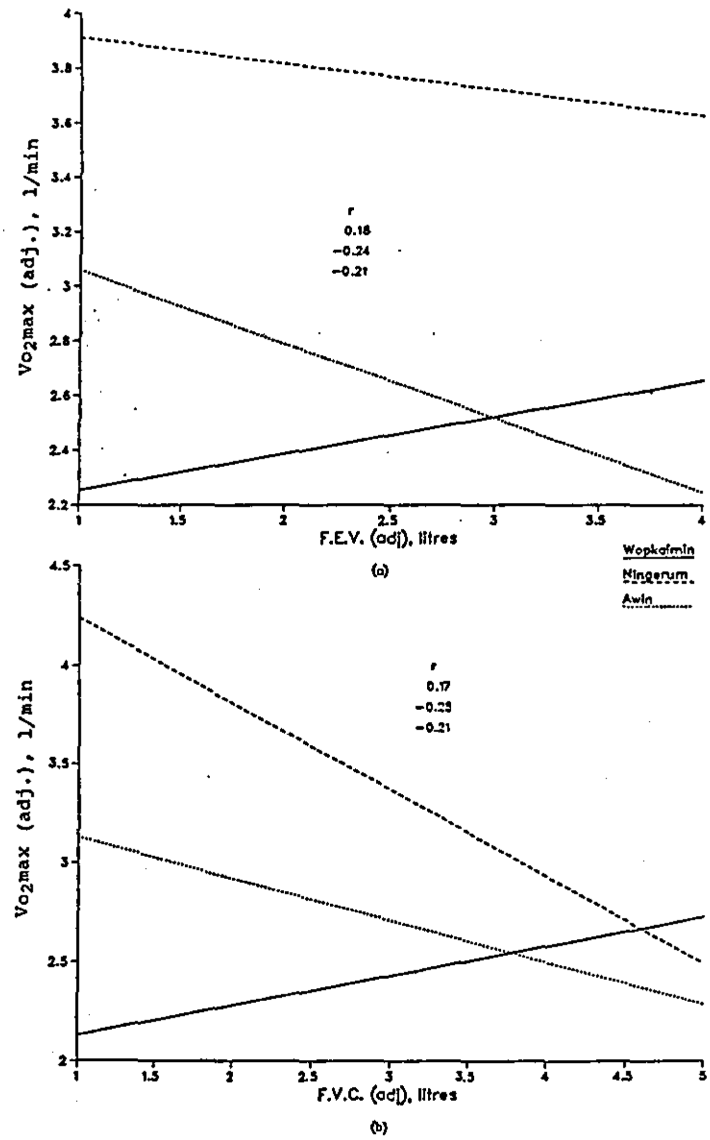


Figure 3.8: Relationship between adjusted (25 years, 1.7m, 55kg FFM) absolute aerobic capacity (Vo_2max), and adjusted (1.7m, 30 years) lung volumes.

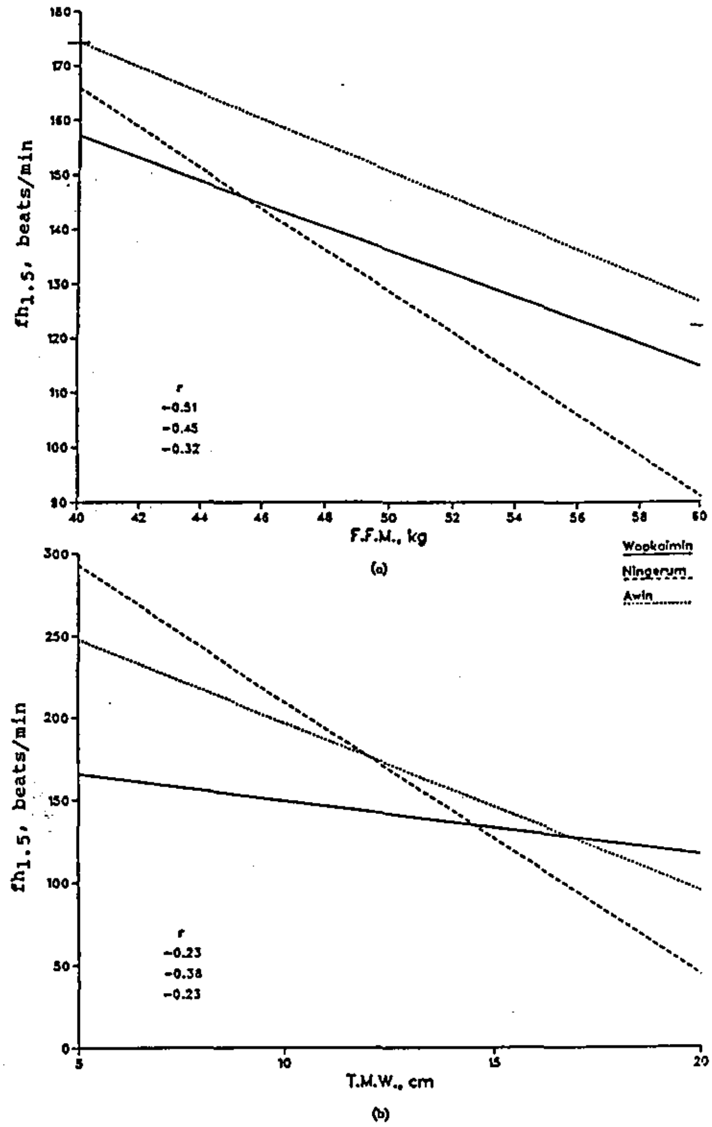
Submaximal indices of aerobic capacity are given in table 3.7. The $fh_{1.5}$ was lowest in the Wopkaimin (130 beats/min) and highest in the Awin (150 beats/min; $p>0.05$). Adjusting figures to the same standards as used for $\dot{V}o_2max$ decreased the mean figures. The lowest estimated $fh_{1.5}$ was about 68 beats/min for a Ningerum subject, which is very low; whereas the highest, for an Awin subject, appeared to be about 241 beats/min, which seems erroneously high. These two subjects also had very different $\dot{V}o_2max$ figures, the former was very fit with an absolute $\dot{V}o_2max$ of 4.14 l/min (67.6 ml/kg/min), in contrast to the Awin who had a $\dot{V}o_2max$ of only 1.09 l/min (42.1 ml/kg/min).

$\dot{V}e_{1.5}$ was again highest in the Awin ($p<0.05$) and adjusting these values only increased this significance. The lowest estimated figure was 22.0 l/min for a Ningerum subject, and the highest, 90.2 l/min for an Awin subject. This last figure may provide some evidence that a number of subjects were afraid of the test and hyperventilated, especially this subject who was one of the older men measured.

No difference was observed in mean PWC_{170} between the three groups although the mean figure for the Wopkaimin was some 6.5W greater than that for the Awin, and a further 3.3W than that for the Ningerum. The highest observed figure was about 129W for a Wopkaimin subject. The Ningerum had a significantly greater $\dot{V}o_2150$ ($p<0.01$) than the other two.

The $fh_{1.5}$ and $\dot{V}e_{1.5}$ showed a positive and significant correlation with age in all three ethnic groups, being greatest in the Awin (r-0.54 and 0.50 respectively). PWC_{170} was negatively correlated with age, but only significantly so in the Ningerum (r--0.42) and Awin (r--0.30). $\dot{V}o_2150$ only appeared to be correlated with age in the Awin (r--0.33).

For all ethnic groups at any specified sub-maximal $\dot{V}o_2$ the fh was negatively correlated with indices of body muscle. The submaximal heart rates at a low FFM and thigh muscle width (TMW) were least in the Wopkaimin, whereas at higher FFM's and TMW's, the Ningerum had the lower submaximal fh (Figure 3.9(a) and (b)).



Figures 3.9: Relationship between submaximal heart rate ($fh_{1.5}$), and fat free mass and thigh muscle width.

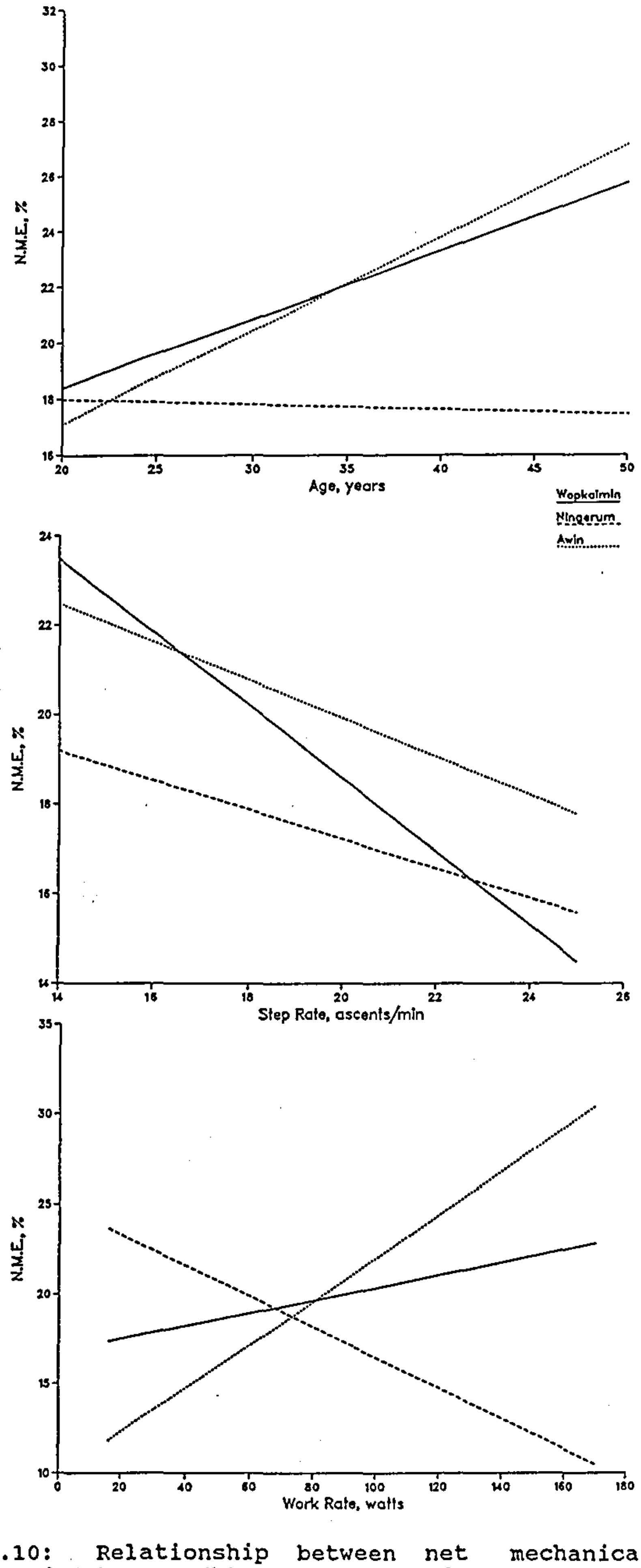


Figure 3.10: Relationship between net mechanical efficiency and (a) age; (b) step rate; and (c) work rate in ethnic groups.

The mean net mechanical efficiency (N.M.E.) was 19.6% (sd: 6.9), with the Ningerum not as efficient as the other two (mean: 17.8%; $p<0.05$). In the Awin and Wopkaimin N.M.E. improved with age whereas in the Ningerum it slightly decreased over 16 to 50 years (Figure 3.10(a)). N.M.E. decreased with increasing step rate in all groups, deteriorating greatest in the Wopkaimin (Figure 3.10(b)); overall from about 22% at 14 ascents/min to about 16% at 25. However, when related to work rate (Watts) the N.M.E. for the Awin and Wopkaimin increased with increasing work load, in contrast to the Ningerum. Thus, at high work rates the efficiency for the Awin was superior to the Wopkaimin and Ningerum (Figure 3.10(c)). N.M.E. was significantly and positively correlated with Wt/Ht in the Awin ($r=0.25$); but was not in the others, being slightly negative in the Ningerum ($r=-0.19$).

E. Summary:

The fittest group was the Ningerum according to maximal indices, whereas with the submaximal indices they were on a par with the Wopkaimin. The cross-sectional ageing coefficients indicated the Wopkaimin showed the smallest age changes. Lung volumes were greater in the Wopkaimin although the differences were not significant.

The Wopkaimin were also the fattest, heaviest and had more muscle, and again exhibited the smallest changes with age.

Table 3.8 gives a correlation matrix for the principal indices of body composition, lung capacity, resting metabolic rate, physical fitness and age, for the total population studied. All indices show a significant correlation with age, except for $\dot{V}o_2 150$ and stature, the latter because it was seen to change differently in the ethnic groups. Good correlations were seen between most indices, however no significant correlation was observed between indices of physical fitness and stature and lung volumes. N.M.E. was not correlated with any index of body composition, but significantly correlated with indices of physical fitness.

Table 3.8: Correlation matrix of principal indices of body composition, lung capacity, resting metabolic rate, physical fitness and age for the total population studied.

	Age	Weight	Stature	AMA	LMV	FFM	Wt/Ht	BSA	FEV	FVC	RMR	$\dot{V}o_2max$	$fh_{1.5}$	$\dot{V}e_{1.5}$	$\dot{V}o_2 150$	PWC_{170}
Weight	-.35															
Stature	-.06 *	.53														
AMA	-.29	.67	.12 *													
LMV	-.45	.86	.46	.70												
FFM	-.45	.96	.58	.64	.83											
Wt/Ht	-.37	.96	.29	.72	.83	.90										
BSA	-.41	.95	.49	.70	.86	.91	.92									
FEV	-.18	.59	.37	.18	.52	.54	.57	.53								
FVC	-.25	.58	.47	.21	.53	.55	.52	.58	.76							
RMR	-.25	.17	-.11*	.13 *	.21	.15 *	.23	.23	.15 *	.12 *						
$\dot{V}o_2max$	-.40	.39	.07 *	.31	.35	.41	.42	.40	.05 *	.03 *	49					
$fh_{1.5}$	.38	-.40	-.05 *	-.34	-.36	-.41	-.44	-.41	-.05*	-.02*	-.41	-.94				
$\dot{V}e_{1.5}$	.43	-.22	.09 *	-.21	-.22	-.24	-.28	-.24	-.02*	-.09*	-.45	-.70	.71			
$\dot{V}o_2 150$	-.13 *	-.18	-.22	-.05 *	-.09 *	-.18	-.13*	-.14*	-.37	-.36	.42	.70	-.68	-.63		
PWC_{170}	-.31	.74	.36	.50	.59	.76	.73	.70	.55	.47	.16 *	.62	-.60	-.27	-.10*	
NME	.18	.14 *	.12 *	.04*	.08*	.10*	.11*	.11*	.28	.26	-.08 *	.50	.51	.47	-.73	.13*

* $p > 0.01$, ie. not significant at the 99% level of significance.

3.2. Village Groups.

More young adults measured lived in the vicinity of Tabubil (61.4% of 16-24 year olds) compared to the remote areas (12.9%) and on the Tabubil-Kiunga road (25.7%). In the older cohorts numbers were comparable.

A. Anthropometry and Body Composition:

Villagers living in the vicinity of Tabubil were shorter, but appreciably heavier, fatter, and had greater muscle indices ($p<0.01$) than those living in remote areas and on the Tabubil-Kiunga road (Tables 3.9 and 3.10). Skinfolds were on average 25% greater in this group, the mean sum of all 10 skinfolds was approximately 20mm greater ($p<0.001$), and AMA about 14% greater. Weight decreased with age in all three groups (Figure 3.11(a)), declining greater in those living in remote areas (ageing coefficient: 0.45 kg/year). The change in stature with age is given in figure 3.11(b) and appeared not to alter in those living on the Tabubil-Kiunga road and those from the remote villages; whereas there was a fall in those living in the vicinity of Tabubil (0.15 cm/year).

The 'close to' group also had significantly larger LMV's and TMW's ($p<0.01$), and their chests were generally broader and deeper than the other two groups ($p<0.05$).

Figures 3.12(a) and (b) show a decrease in AMA and LMV after about 25 years of age. This is also confirmed from the change in FFM with age (Figure 3.12(c)), the cross-sectional ageing coefficient being greater in the 'remote' group (-0.46 kg/year).

Table 3.9: Means (sd) of anthropometric measurements of village groups within the Ok Tedi region. For abbreviations see Table 2.2.

	Close To Tabubil [N=92]	Remote From Tabubil [N=56]	On Tabubil-Kiunga Road [N=85]
Age	27.5(8.7)	31.4(6.5)	31.9(7.8)
Weight (kg)	58.3(7.2)*	52.6(6.8)	53.2(6.8)
Stature (cm)	155.8(5.8)	156.6(5.2)	158.8(6.1)*
Sit. Hght. (cm)	79.4(3.8)	79.4(2.5)	80.6(3.2)*
MUAC (cm)	28.6(2.6)*	26.5(2.3)	26.9(1.9)
Chest Circ. (cm)	91.2(4.6)	89.0(4.4)	89.7(5.0)
Trans. Chest (cm)	25.7(2.1)	24.0(1.4)*	24.9(2.1)
A.P. Chest (cm)	17.6(1.1)**	17.4(1.0)	17.2(1.1)
Biac. Diam. (cm)	35.9(1.6)**	35.0(1.6)	35.2(2.0)
Biil. Diam. (cm)	26.6(2.1)	25.9(2.2)	25.8(2.2)
Skinfolds (mm):			
Biceps	3.1(0.5)	3.0(0.4)	2.6(0.5)*
Triceps	5.6(1.7)*	4.3(1.2)	4.4(0.8)
Subscapular	8.7(2.4)*	6.7(1.7)	7.1(1.2)
Suprailiac	8.4(3.9)*	4.9(2.0)	5.5(1.2)
Abdomen	8.9(4.1)*	5.8(1.6)	6.3(1.4)
Midaxillary	5.9(2.4)*	4.7(0.9)	4.8(1.0)
Ant. Thigh	7.1(2.2)*	5.3(1.3)	5.8(2.3)
Post. Thigh	6.8(1.9)*	4.8(1.8)	5.0(1.3)
Med. Calf	3.7(0.9)*	2.9(0.6)	3.1(1.3)
Lat. Calf	4.0(1.2)*	3.2(0.8)	3.3(1.0)

* $p<0.01$, ** $p<0.05$

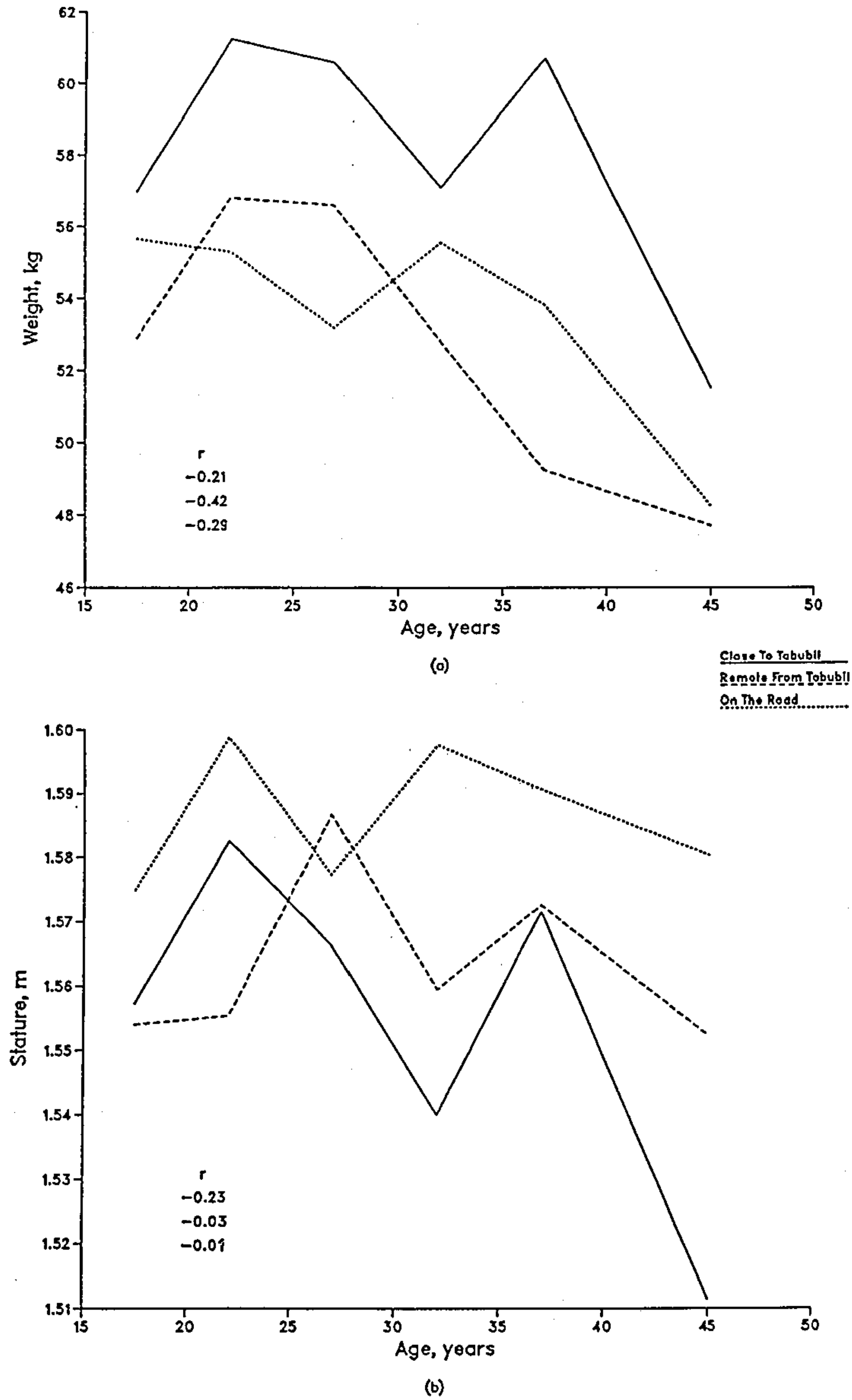


Figure 3.11: Age differences in (a) mean weight and (b) mean stature with age, in village groups.

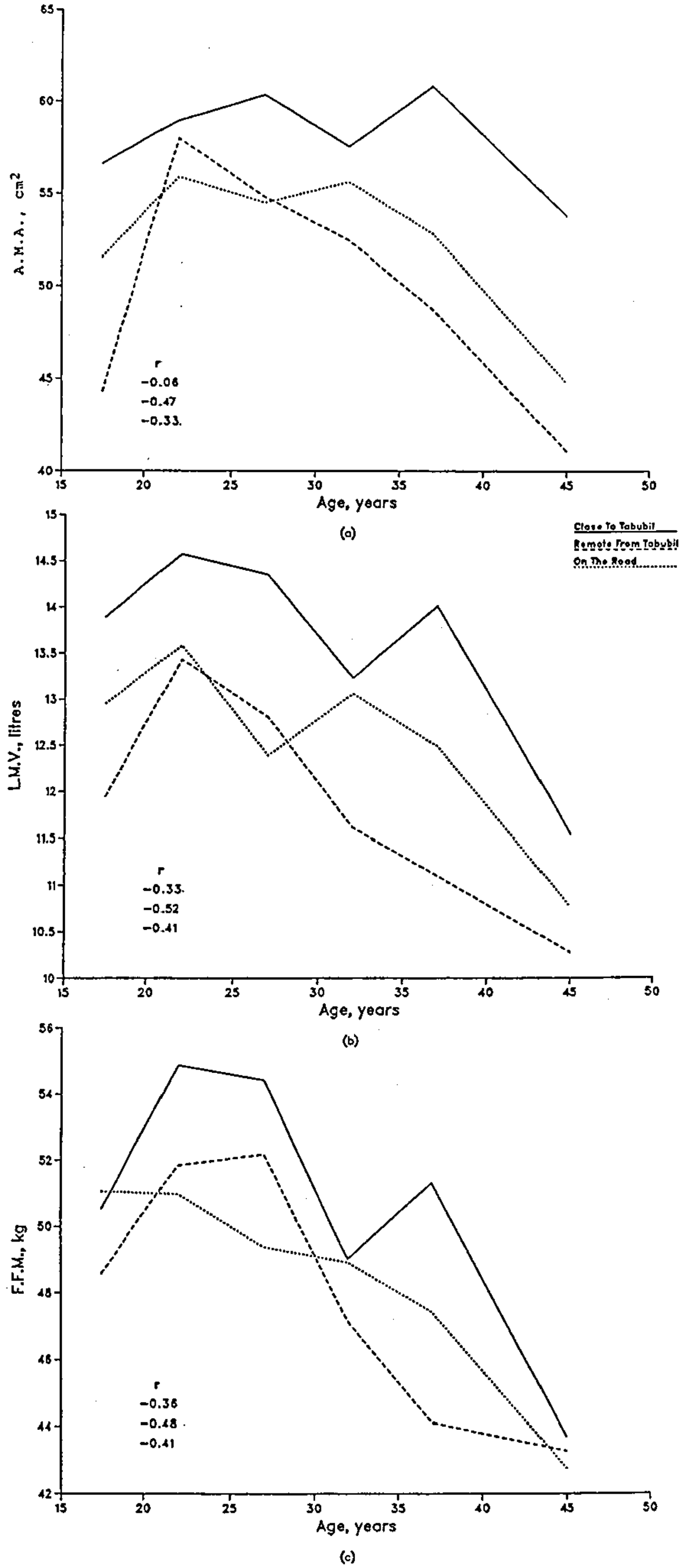


Figure 3.12: Change with age of (a) arm muscle area; (b) leg muscle volume; and (c) fat free mass, in village groups.

Table 3.10: Means (sd) of indices of body composition for village groups. For abbreviations see Table 2.2.

	Close To Tabubil [N=92]	Remote From Tabubil [N=56]	On Tabubil-Kiunga Road [N=85]
Wt/Ht (kg/m)	37.4 (3.9)*	33.6 (3.7)	33.5 (3.6)
Wt-For-Ht (%)	96.3 (7.4)	87.8 (9.9)	86.3 (8.8)
MUAC%	93.2 (7.1)	87.7 (6.6)	89.1 (6.1)
TSF%	61.4 (6.0)	60.5 (4.0)	60.0 (---)
BMI (kg/m^2)	24.0 (2.3)*	21.4 (2.2)	21.1 (2.1)
BSA (m^2)	1.64(0.11)*	1.56(0.09)	1.57(0.10)
AMA (cm^2)	58.0 (10.0)*	50.8 (8.6)	52.1 (7.7)
% Body Fat	12.2 (3.6)*	9.3 (2.4)	10.3 (2.5)
FFM (kg)	51.2 (6.4)**	47.7 (6.1)	47.7 (6.2)
LMV (l)	13.7 (2.2)*	11.8 (1.8)	12.4 (1.8)
TMW (cm)	16.3 (1.7)*	15.2 (1.2)	15.2 (1.2)

* $p<0.01$, ** $p<0.05$

Slight wasting was noted in the 'remote' and 'on the road' groups (low Wt-for-Ht), in comparison to the 'close to' group who approached normality. However energy reserves were low in all groups as observed from the low skinfolds and especially low TSF%. Figure 3.13 indicates a fall of Wt/Ht in those living in remote areas and on the Tabubil-Kiunga road across the age groups, but again mean BMI figures were not low.

B. <u>Lung Capacity</u>:

Only two villagers from the remote areas had their lung capacity measured, and although the mean figures are given in table 3.11 only the 'close to' and 'on the road' groups were statistically compared. The 'close to' group had larger lungs than the 'on the road' group, but not significant, even though there were differences of about 0.28 litres for both FEV and FVC. Adjusting volumes to a standardised age and stature reduced these differences to 0.16 litres.

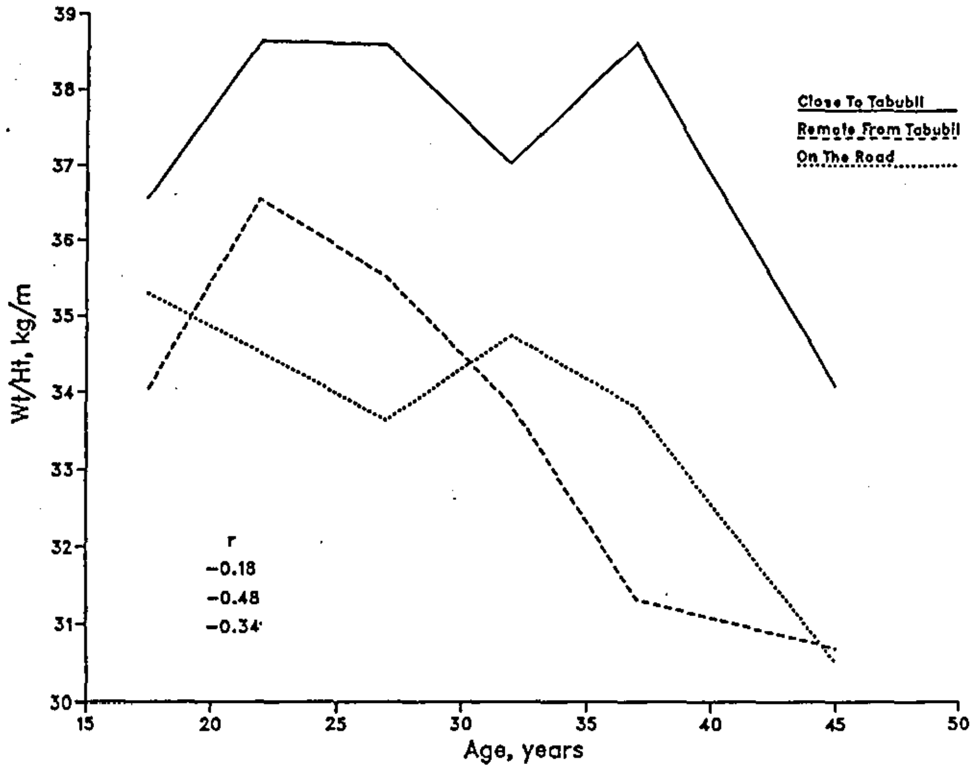


Figure 3.13: Variation in weight/height in different age groups for village groups.

Table 3.11: Lung volumes for the village groups in the Ok Tedi region (mean(sd)). For abbreviations see Table 2.2.

	Close To Tabubil [N=65]	Remote From Tabubil [N=2]	On Tabubil-Kiunga Road [N=28]
Age	26.2 (7.3)	20.0 (4.2)	33.0 (7.3)
Weight (kg)	58.1 (7.1)	58.4 (8.2)	52.1 (6.4)
Stature (cm)	155.9 (5.9)	154.9 (3.1)	155.6 (5.5)
FEV (l)	2.15(0.55)	2.13(1.08)	1.89(0.49)
FVC (l)	2.80(0.56)	2.85(0.52)	2.51(0.53)
FEV%	77.1 (13.8)	72.7 (24.6)	75.0 (13.2)
FEV_{adj} (l)	2.57(0.53)	2.52(1.03)	2.41(0.41)
FVC_{adj} (l)	3.34(0.51)	3.34(0.46)	3.18(0.45)
$FEV\%_{adj}$	76.9 (13.8)	72.1 (24.9)	75.2 (13.2)

C. Resting Metabolic Rate:

Resting fh and $\dot{V}_e$ of villagers living close to the Tabubil-Kiunga road were consistently higher than the other two groups (Table 3.12).

RMR for the 'remote' group was lower than the other two groups, but when adjusted for age and weight the difference between the 'remote' and 'close to' groups disappeared, and between these two and the 'on the road' group increased (Table 3.12). RMR decreased with age in all three groups (Figure 3.14), the cross-sectional ageing coefficients for the 'remote' and 'on the road' groups being the same (154 and 155 KJ/year, respectively), but much slower in the rest (41 KJ/year). Again, as with the ethnic groups, the pattern of change with age was not altered when RMR was related to body dimensions.

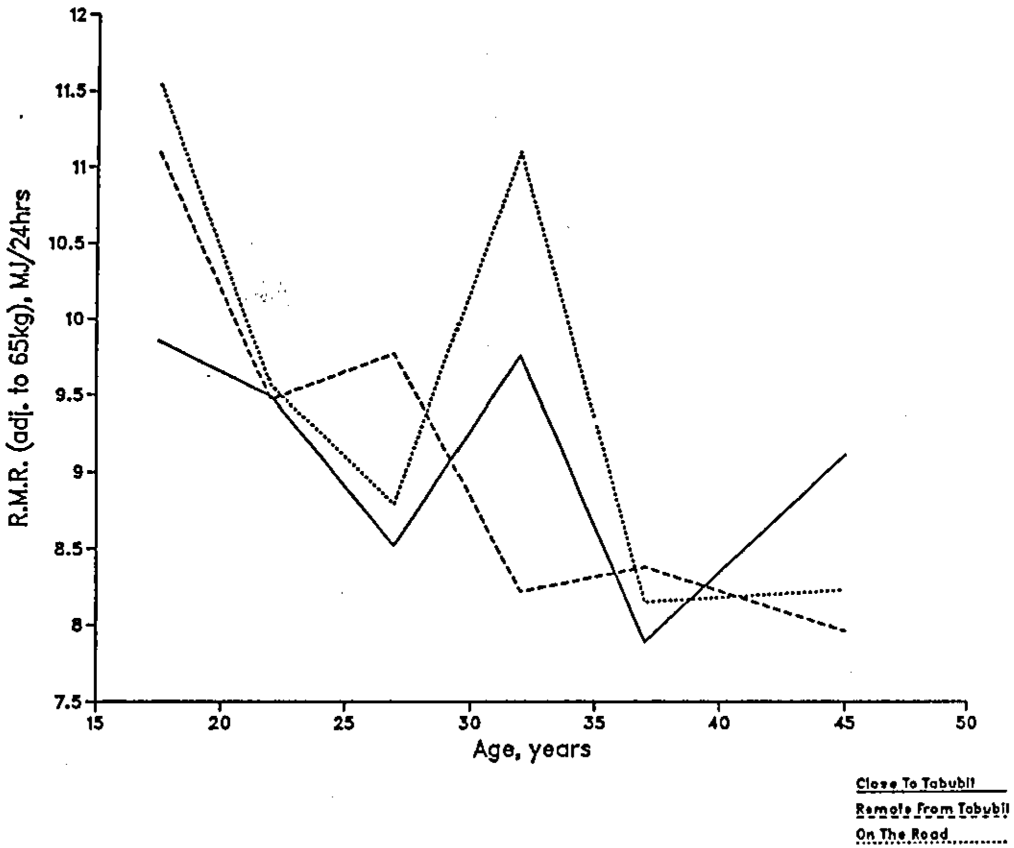


Figure 3.14: Change in resting metabolic rate adjusted to weight 65kg in village groups with age.

Table 3.12: Indices of resting metabolic rate within village groups (mean(sd)). For abbreviations see Table 2.2.

	Close To Tabubil [N=40]	Remote From Tabubil [N=49]	On Tabubil-Kiunga Road [N=77]
Age	26.1 (7.4)	31.6 (5.9)	31.9 (7.8)
Weight (kg)	58.0 (6.6)	52.9 (6.8)	53.0 (7.0)
Stature (cm)	155.6 (4.9)	156.8 (5.4)	158.7 (6.2)
fh_{rest} (beats/min)	67 (8)	66 (7)	69 (7)
$\dot{V}_e$rest (l/min)	12.4 (5.3)	12.5 (3.6)	14.3 (5.0)
$\dot{V}o_2$rest (")	0.29(0.08)	0.25(0.07)	0.26(0.13)
RMR (MJ/24hrs)	8.64(2.57)	7.65(2.27)*	8.29(4.88)
(MJ/m^2/24hrs)	5.25(1.50)	4.88(1.34)	5.27(3.01)
(MJ/kgFFM/24hrs)	0.17(0.05)	0.16(0.04)	0.18(0.10)
RMR adj$^{\$}$,			
(MJ/24hrs)	8.26(2.54)	8.21(2.02)	8.87(4.74)

* p<0.01; $ Figures adjusted to age 30yrs, weight 65kg

D. Physical Fitness:

Villagers in remote areas had a significantly lower absolute and adjusted $\dot{V}o_2$max and a lower $\dot{V}o_2$max when related to weight and FFM. When related to LMV those living on the Tabubil-Kiunga road were significantly fitter (Table 3.13). A decrease in $\dot{V}o_2$max with age was observed in all three groups, the decline in the 'close to' group being slowest and in the other two about equal (Figure 3.15).

Amongst the submaximal indices the $fh_{1.5}$ and $\dot{V}_e$1.5 were higher in the 'remote' group even after adjusting ($p<0.05$; Table 3.14). There was negligible difference between the three groups in PWC_{170}, however the $\dot{V}o_2$150 was significantly lower in the 'remote' group (2.86 litres; $p<0.01$).

Table 3.13: Means (sd) of indices of maximal aerobic capacity for village groups. For abbreviations see Table 2.2.

	Close To Tabubil [N=40]	Remote From Tabubil [N=49]	On Tabubil-Kiunga Road [N=77]
$\dot{V}o_2max$,			
(l/min)	2.27(0.41)	1.91(0.81)*	2.27(0.77)
(ml/kg/min)	39.4 (7.3)	35.8 (6.1)*	42.4 (13.5)
(ml/kgFFM/min)	44.5 (7.8)	39.8 (6.6)*	47.3 (15.1)
(ml/l LMV/min)	165.3 (37.4)	161.7 (26.1)	182.7 (59.5)**
$\dot{V}o_2max$ adj$			
(l/min)	2.54(0.41)	2.45(0.29)	2.77(0.71)**

* p<0.01, ** p<0.05; $ Figures adjusted to age 25yrs, stature 1.7m, FFM 55kg

Table 3.14: Means (sds) of submaximal indices of aerobic capacity for village groups. For abbreviations see Table 2.2.

	Close To Tabubil [N=40]	Remote From Tabubil [N=49]	On Tabubil-Kiunga Road [N=77]
$fh_{1.5}$ (beats/min)	129 (23)	157 (38)**	138 (45)
$fh_{1.5}adj^{\$}$ (")	130 (26)	141 (29)**	121 (40)
$\dot{V}_e1.5$ (l/min)	36.1(4.6)	46.1(8.5)**	40.9(15.0)
$\dot{V}_e1.5adj^{\$}$ (")	34.2(6.9)**	43.1(9.4)	41.2(12.7)
PWC_{170} (watts)	93.2(14.2)	88.8(19.0)	90.3(18.6)
$\dot{V}o_2150$ (l/min)	3.2(0.5)	2.8(0.3)*	3.3(0.9)
N.M.E. (%)	19.9(6.9)	19.7(3.1)	19.4(8.4)

* p<0.01, ** p<0.05; $ Figures adjusted to age 25yrs, stature 1.7m, FFM 55kg

The N.M.E. was not significantly different between the three groups and positively correlated with age ('close to' r=0.36; 'remote' r=0.15; 'on the

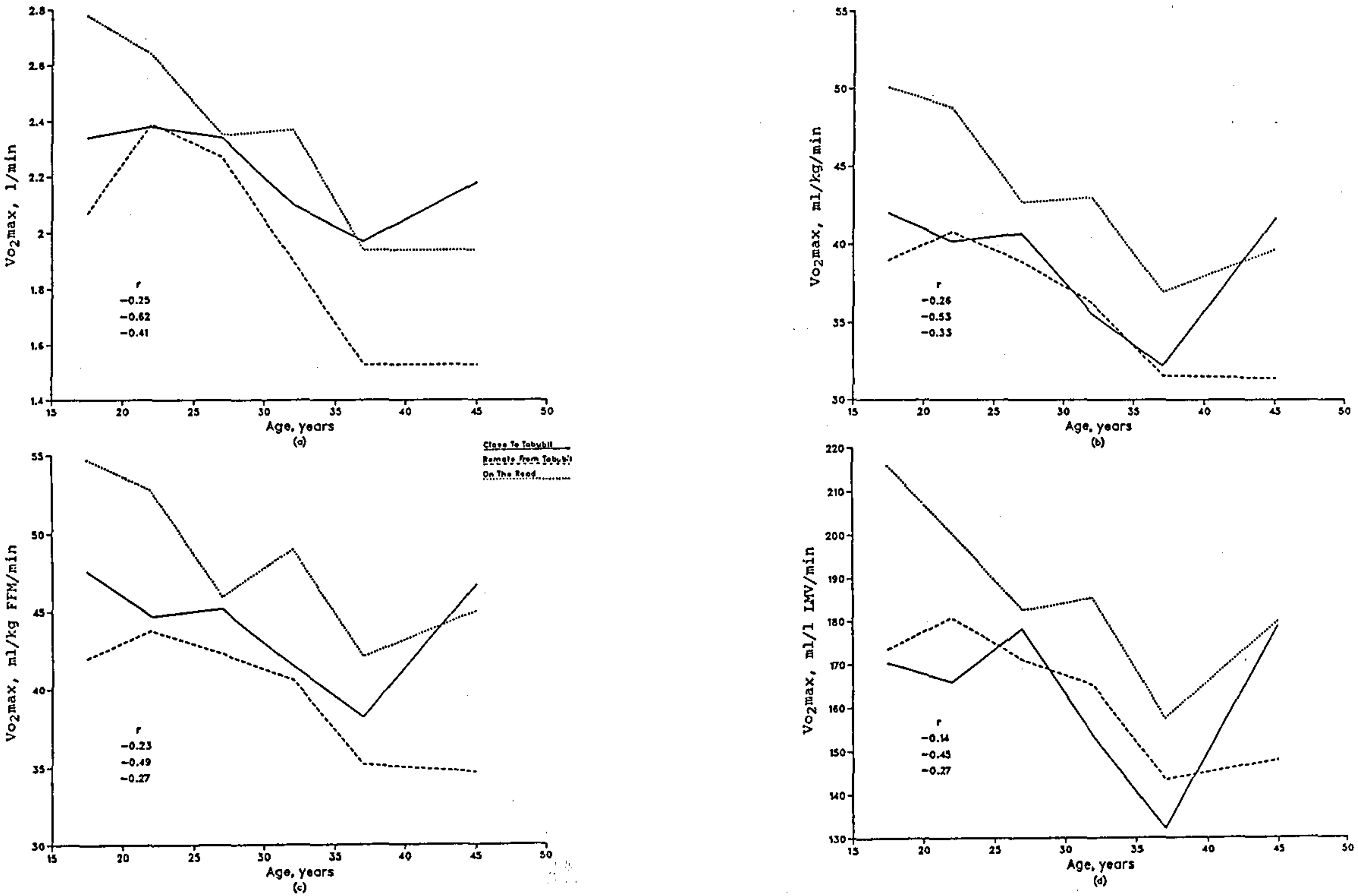


Figure 3.15: Variation in aerobic capacity (Vo_2max) with different age groups in village groups.

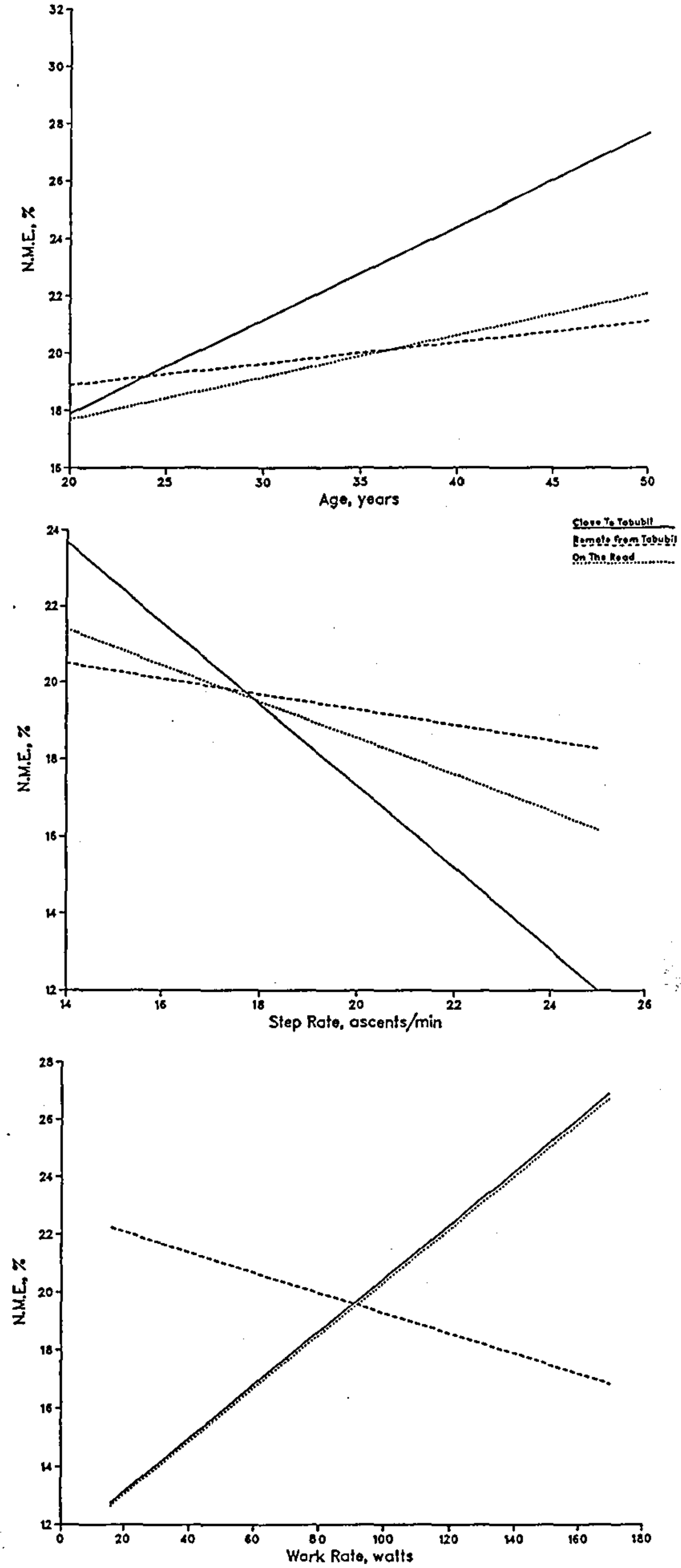


Figure 3.16: Relationship between net mechanical efficiency and (a) age; (b) step rate; and (c) work rate in village groups.

road' r=0.14; Figure 3.16(a)). With increasing step rate again there was a general decrease in N.M.E., deteriorating greatest in the 'close to' group (1.06% per ascent/min) and slowest in the 'remote' group (0.35% per ascent/min; Figure 3.16(b)). There was a concomitant increase in N.M.E. with work load in both the 'close to' and 'on the road' groups (Figure 3.16(c)), whereas in the 'remote' group there was a decrease, which suggest they are not very efficient at high work loads.

E. Summary:

Villagers living in remote areas were the least fit group for both maximal and submaximal indices, mean figures for those living in the vicinity of Tabubil and on the Tabubil-Kiunga road being comparable. However the latter exhibited a greater change with age than the other two. Lung capacity was greater in villagers living close to Tabubil compared to those living on the road.

Villagers living close to Tabubil were also significantly larger than the rest at all ages in all measurements except stature.

3.3. Occupation Groups.

In this study there was no difference in the number of young adults who were working and not working, however a greater percentage of those over 25 years were non-workers.

A. Anthropometry and Body Composition:

Workers were significantly heavier than non-workers ($p<0.01$) and also had a greater mean AMA and LMV, both being about 18% larger (Tables 3.15 and 3.16). They also had significantly larger skinfolds ($p<0.01$) which were on average 30% bigger, reflecting the larger fat mass (7.2kg cf 5.5kg). Weight and stature are related to age in figure 3.17, where it appears that both decreased in non-workers and but did not change in workers.

AMA appeared to increase in workers and decrease in non-workers with age (Figure 3.18(a)), cross-sectional ageing coefficients for both were approximately the same but with opposite signs (-0.29 and +0.23 cm^2/year). In contrast LMV was seen to decrease in both across the age groups (Figure 3.18(b)) but much slower in workers. This was also seen with FFM (Figure 3.18(c)).

Table 3.15: Anthropometry of non-workers and workers (mean(sd)). For abbreviations see Table 2.2.

	Non-workers [N=168]	Workers [N=65]
Age	31.8(7.9)	25.6(7.0)
Weight (kg)	53.5(7.4)	59.3(6.8)*
Stature (cm)	157.5(6.0)**	155.8(5.5)
Sit. Hght. (cm)	80.1(3.1)**	79.3(3.9)
MUAC (cm)	26.7(2.2)	29.5(2.1)*
Chest Circ. (cm)	89.3(4.7)	92.4(4.3)*
Trans. Chest (cm)	24.7(2.0)	25.8(2.1)*
A.P. Chest (cm)	17.4(1.1)	17.4(1.1)
Biac. Diam. (cm)	35.2(1.9)	36.1(1.5)**
Biil. Diam. (cm)	26.0(2.2)	26.6(2.0)
Skinfolds (mm):		
Biceps	2.7(0.6)	3.0(0.4)**
Triceps	4.5(1.0)	5.8(1.8)*
Subscapular	7.1(1.5)	9.1(2.5)*
Suprailiac	5.5(1.9)	9.0(4.1)*
Abdomen	6.3(2.0)	9.1(4.0)*
Midaxillary	4.8(1.2)	6.0(2.4)*
Ant. Thigh	5.7(1.9)	7.3(2.3)*
Post. Thigh	5.0(1.5)	7.1(1.8)*
Med. Calf	3.1(1.1)	3.8(0.9)*
Lat. Calf	3.3(0.9)	4.1(1.3)*

* $p<0.01$, ** $p<0.05$

Wt-for-Ht and MUAC% approached normal standard values in workers, but despite this there were low fat scores (low TSF%) for both. Wt/Ht figures

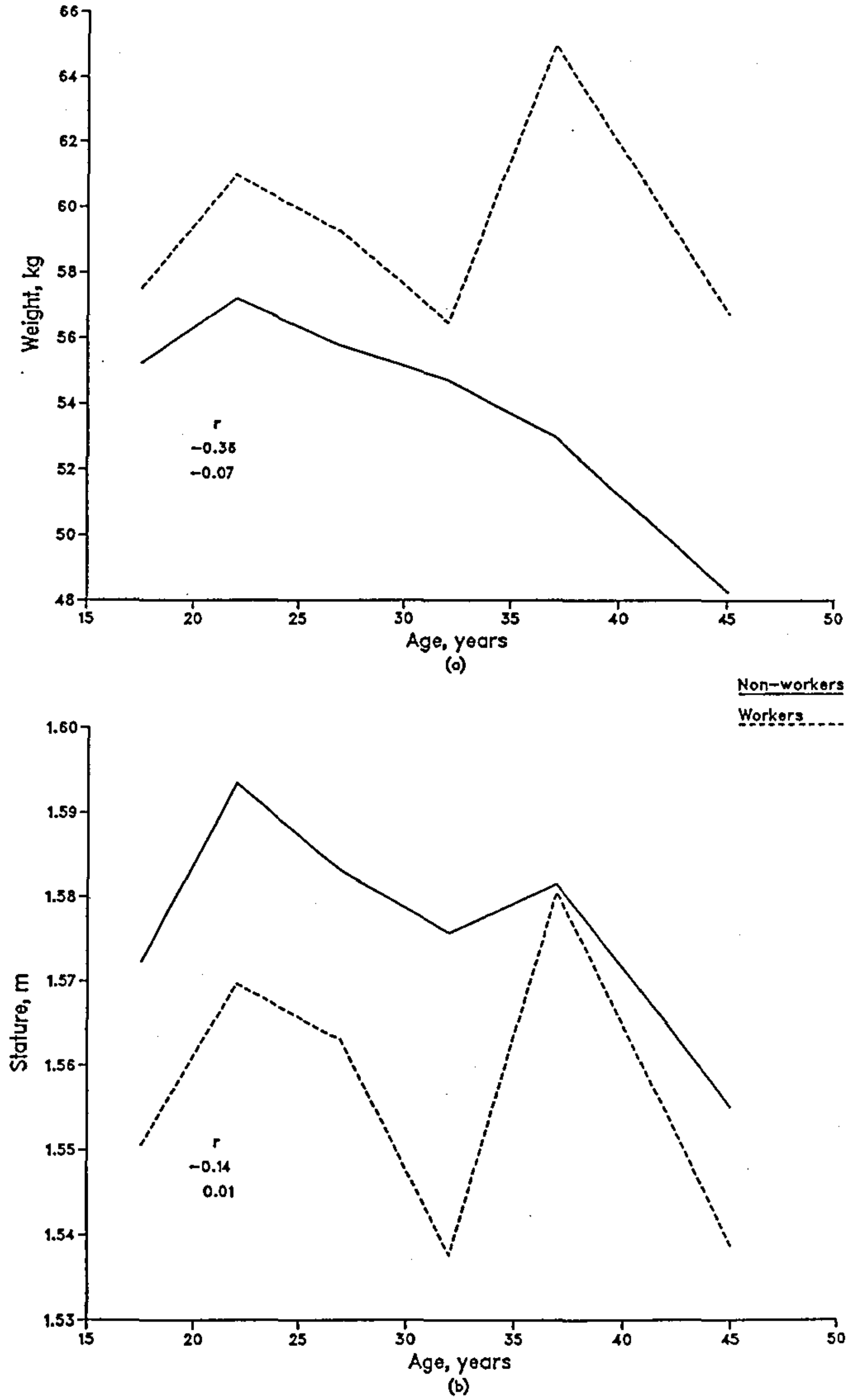


Figure 3.17: Comparison between workers and non-workers of change in (a) mean weight and (b) mean stature, in different age groups.

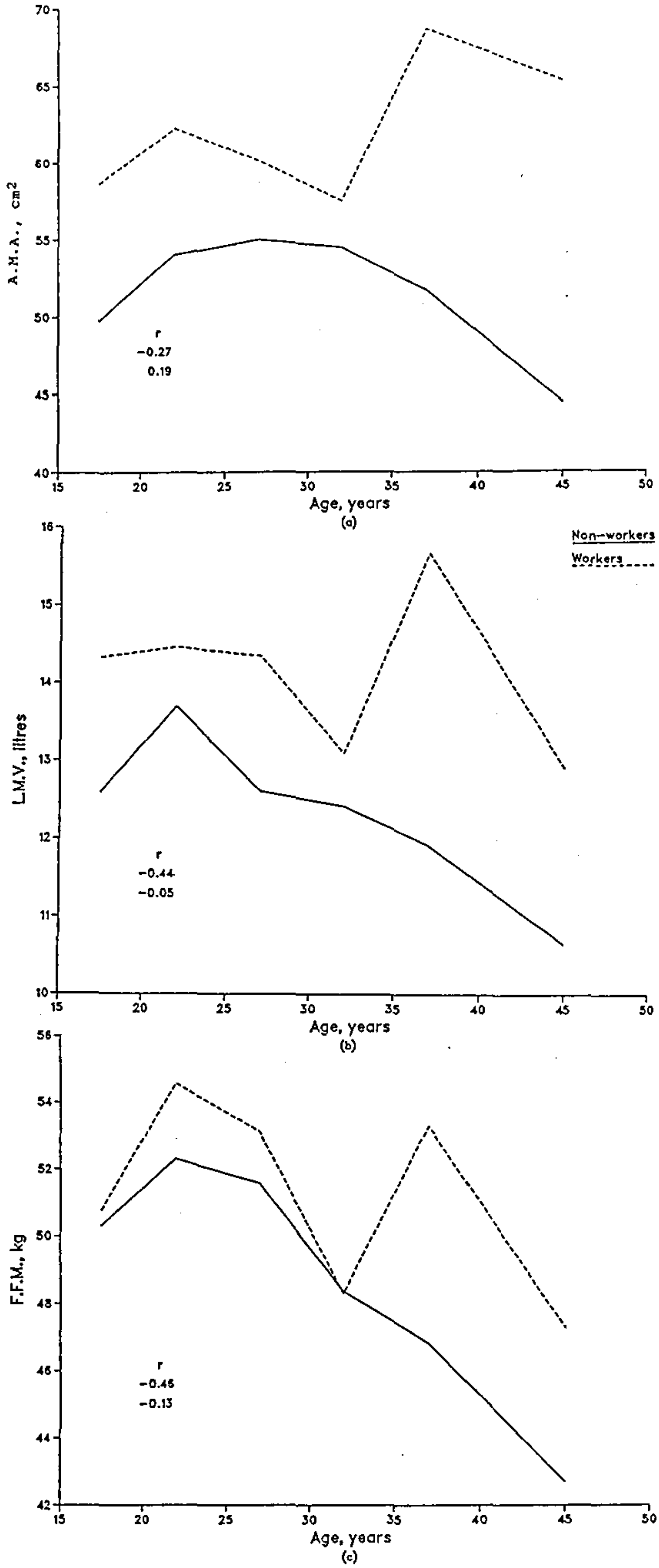


Figure 3.18: Alteration in (a) arm muscle area; (b) leg muscle volume; and (c) fat free mass in different age groups for workers and non-workers.

were significantly lower in non-workers ($p<0.01$), and decreased with age, whereas it appeared constant for all ages in workers (Figure 3.19).

Table 3.16: Indices of body composition of workers and non-workers (mean(sd)). For abbreviations see Table 2.2.

	Non-workers [N=168]	Workers [N=65]
Wt/Ht (kg/m)	33.9 (3.8)	38.0 (3.7)*
Wt-For-Ht (%)	87.9 (9.3)	97.6 (7.3)
MUAC%	88.4 (6.7)	95.4 (5.0)
TSF%	60.2 (2.3)	62.0 (7.1)
BMI (kg/m^2)	21.5 (2.2)	24.4 (2.3)*
BSA (m^2)	1.57(0.10)	1.66(0.10)*
AMA (cm^2)	51.4 (8.3)	61.2 (8.4)*
% Body Fat	10.3 (2.7)	12.2 (3.8)*
FFM (kg)	48.0 (6.4)	52.0 (5.7)**
LMV (l)	12.1 (1.8)	14.2 (2.0)*
TMW (cm)	14.2 (1.1)	15.3 (1.5)*

* $p<0.01$, ** $p<0.05$

B. Lung Capacity:

Lung volumes were larger although not statistically in workers, the difference being reduced after adjusting for age and stature (Table 3.17).

C. Resting Metabolic Rate:

RMR for workers was higher, although not statistically, than non-workers, however when figures were adjusted for age and weight the picture was reversed (Table 3.18). RMR in non-workers decreased with age whereas in workers it increased (Figure 3.20), the cross-sectional ageing factor for the former (165 KJ/24hrs/year) was approximately four times that of the latter and positive.

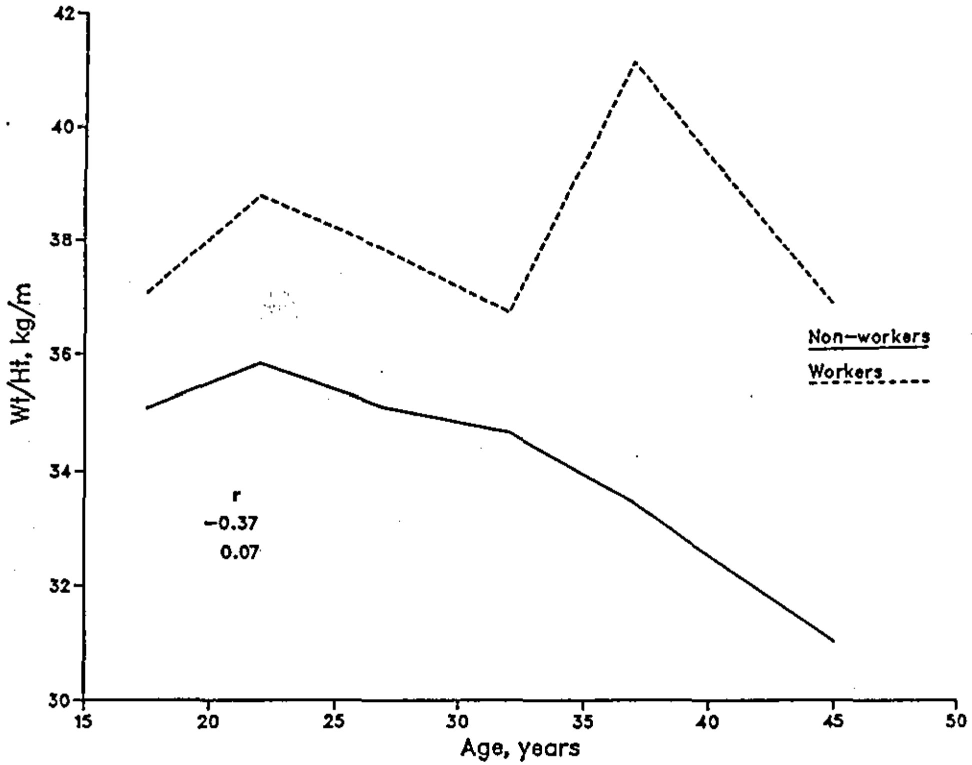


Figure 3.19: Change in weight/height in non-workers and workers in different age groups.

Table 3.17 Means (sd) of lung volumes for occupation groups. For abbreviations see Table 2.2.

	Non-workers [N=49]	Workers [N=46]
Age	31.3 (8.2)	24.7 (6.1)
Weight (kg)	54.9 (7.7)	57.9 (6.7)
Stature (cm)	145.9 (5.8)	155.2 (5.6)
FEV (l)	2.03(0.48)	2.12(0.57)
FVC (l)	2.66(0.57)	2.77(0.56)
FEV%	76.1 (12.8)	76.7 (14.7)
FEV_{adj} (l)	2.50(0.47)	2.55(0.54)
FVC_{adj} (l)	3.27(0.49)	3.32(0.50)
$FEV\%_{adj}$	76.1 (12.8)	76.4 (14.7)

Table 3.18: Means (sd) of indices of resting metabolic rate for non-workers and workers. For abbreviations see Table 2.2.

	Non-workers [N=136]	Workers [N=30]
Age	31.9 (7.1)	25.1 (6.7)
Weight (kg)	53.1 (7.0)	57.9 (6.3)
Stature (cm)	157.9 (5.9)	155.2 (4.9)
fh_{rest} (beats/min)	68 (7)	67 (8)
$\dot{V}_{e}$rest (l/min)	13.6 (4.7)	12.4 (5.0)
$\dot{V}o_{2}$rest (l/min)	0.26(0.11)	0.29(0.07)
RMR (MJ/24hrs)	8.03(4.09)	8.76(2.16)
(MJ/m^2/24hrs)	5.11(2.50)	5.32(1.27)
(MJ/kgFFM/24hrs)	0.17(0.09)	0.17(0.04)
RMR adj$ (MJ/24hrs)	8.60(3.92)	8.26(2.30)

$ Figures are adjusted to age 30yrs, weight 65kg

D. Physical Fitness:

Absolute $\dot{V}o_2max$ was higher in workers but not significantly, but when figures were related to body weight and FFM or adjusted for age, stature and FFM, non-workers had slightly higher mean values (Table 3.19). When related to LMV though, non-workers had a significantly higher $\dot{V}o_2max$ ($p<0.05$).

Table 3.19: Maximal indices of aerobic capacity for workers and non-workers (mean(sd)). For abbreviations see Table 2.2.

	Non-workers [N=136]	Workers [N=30]
$\dot{V}o_2max$,		
(1/min)	2.15(0.69)	2.25(0.42)
(ml/kg/min)	40.0 (11.5)	39.2 (7.7)
(ml/kgFFM/min)	44.5 (12.9)	44.3 (8.4)
(ml/l LMV/min)	175.0 (49.6)**	164.0 (39.8)
$\dot{V}o_2max$ adj.$		
(1/min)	2.66(0.60)	2.49(0.42)

** p<0.05; $ Figures adjusted to age 25yrs, stature 1.7m, FFM 55kg

$\dot{V}o_2max$ in both groups deteriorated with age (Figures 3.21(a) to (d)), the ageing coefficient in all cases being greater in non-workers.

Sub-maximal indices showed no significant difference between the two groups (Table 3.20), although workers had the slightly better mean $fh_{1.5}$, $\dot{V}_e1.5$ and PWC_{170}, the non-workers had the better $\dot{V}o_2150$ and N.M.E.

E. Summary:

Workers were significantly heavier, fatter and had more muscle than non-workers, but were shorter. They also showed the smallest changes of

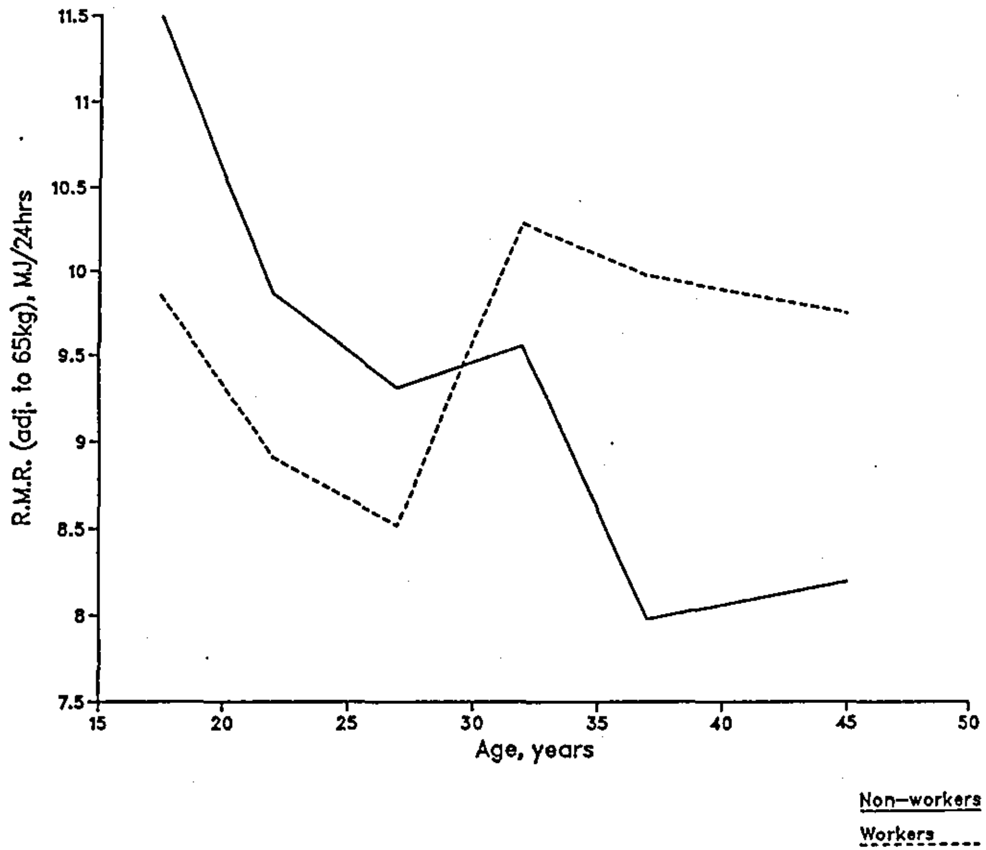


Figure 3.20: Variation of resting metabolic rate in occupation groups with age.

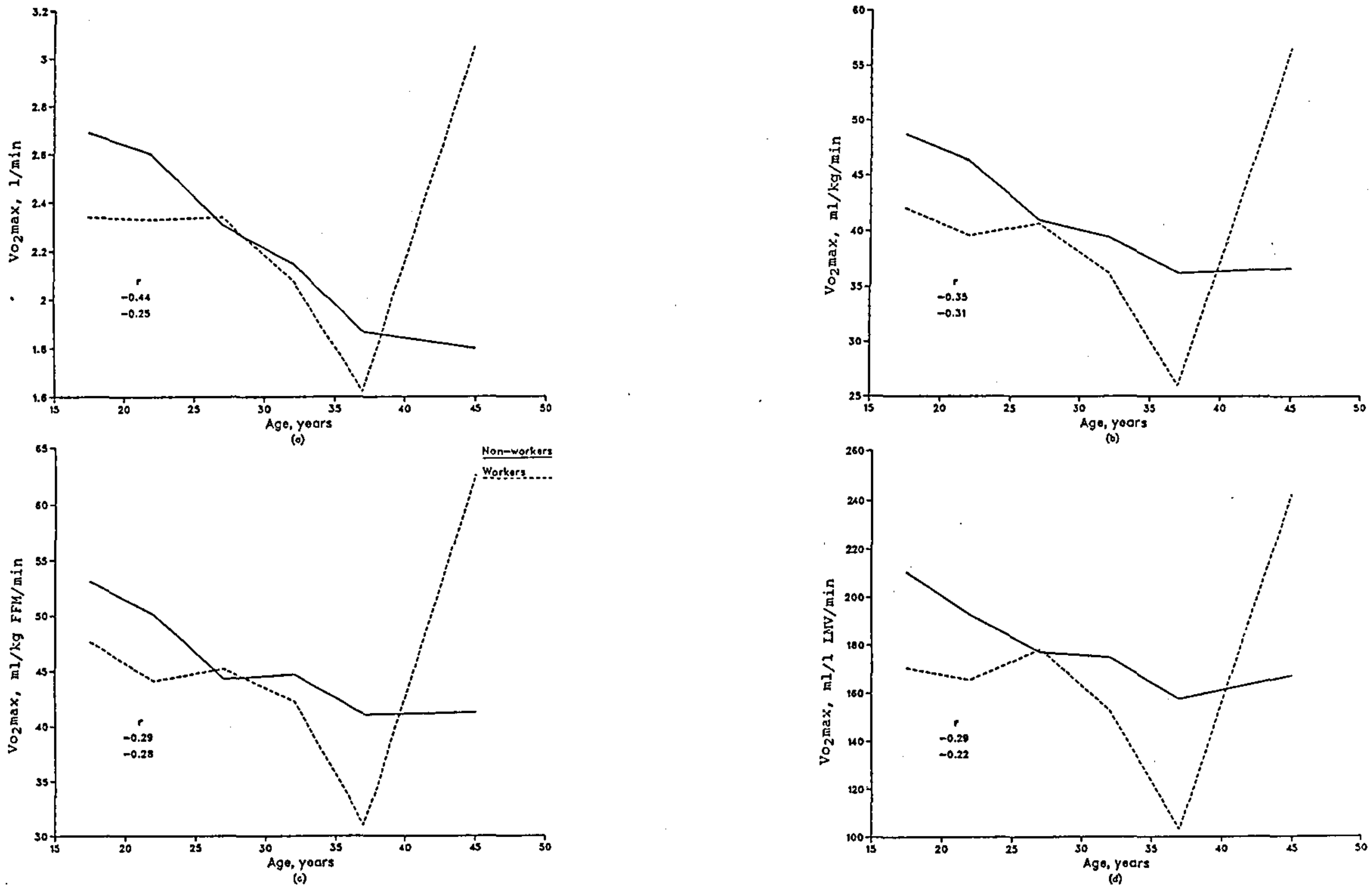


Figure 3.21: Alteration of aerobic capacity with age in occupation groups.

indices of body composition with age. However relatively few aged over 30 were employed, 19 compared to 107, so these age changes are questionable.

It was surprising that the workers did not have a significantly larger absolute $\dot{V}o_2max$, but the mean was 100ml greater. Also the larger body weight and FFM did not appear to affect the workers in anyway as relative $\dot{V}o_2max$ was similar to that of non-workers. Nevertheless $\dot{V}o_2max$ related to LMV was significantly greater in non-workers. Submaximal indices did not show any difference between the groups.

Table 3.20: Submaximal indices of aerobic capacity for workers and non-workers (mean(sd)). For abbreviations see Table 2.2.

	Non-workers [N-136]	Workers [N-30]
$fh_{1.5}$ (beats/min)	144 (43)	130 (24)
$fh_{1.5}adj^{\$}$ (")	127 (37)	134 (25)
$\dot{V}_e1.5$ (l/min)	42.6(13.0)	35.9(4.4)
$\dot{V}_e1.5adj^{\$}$ (l/min)	39.9(12.9)	34.6(6.7)
PWC_{170} (watts)	90.6(19.0)	91.2(12.7)
$\dot{V}o_2150$ (l/min)	3.1(0.7)	3.2(0.5)
N.M.E. (%)	19.8(7.4)	19.1(4.7)

$ Figures adjusted to age 25 yrs, stature 1.7m, FFM 55kg

Lung volumes were greater in workers but the difference was reduced when adjusted for age and stature.

It is noteworthy that the standard deviations were larger for the non-working sample. This suggests that in their indices of aerobic fitness, maximal and submaximal, non-workers were a more heterogeneous group. This is probably due to the fact that the group includes Awin, Ningerum and Wopkaimin, and also those living in remote areas, which have been shown to be different from each other.

4. DISCUSSION AND CONCLUSIONS

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4.1. Introduction.

The transformation from a primitive existence to the complex mode of life of an urbanised society must be accompanied by considerable sociological, psychological and physiological changes and these in turn can be expected to affect patterns of health and disease. The purposes of this thesis are to describe a group of Papua New Guineans who, until recently, have had little contact with the outside world and are now undergoing rapid acculturation and to examine the changes of aerobic and lung capacity as a result of acculturation.

The arrival of the Ok Tedi Mining project has completely removed the natural supports for maintaining subsistence life. The fine balance between the culture and environment which has successfully maintained the people has now been under severe pressure to change.

Of the three ethnic groups the most acculturated are the Wopkaimin for it is on their land that the mine and all supporting facilities has been built. This has been predicted to have profound effects upon the gathering of wild plant and animal foods (Hyndman, 1979; and Maunsell and Partners, 1982). They receive royalties, lease and mining tenement payments and different forms of compensation from OTML, with which they have been encouraged to develop local businesses. They also have a greater opportunity to gain employment.

With the inflow of cash the Wopkaimin are able to purchase trade-store foods which supplement the loss of traditional food items. However it also allows the men to obtain beer which has given rise to drunkenness and created social problems and conflicts within village life. The money allows the men to buy kerosene lamps and stoves, radio/cassettes and other consumer goods, purchase factory-made cigarettes which is not good for their health; bush knives and axes enable gardens to be cleared more easily. Ultimately they buy their own car; one Bultem man has purchased a truck which he uses to transport villagers to and from Tabubil, habitual activity is therefore reduced.

A major bonus for the Wopkaimin is health care. Previous studies commented on the poor state of health within the community (Taukuro, 1980; and Lourie et al, 1986). Now Bultem and Wangbin villages are within easy access of two staffed aid posts where simple treatment can be administered; and the Tabubil Health Centre, run by OTML for the mine employees and their families, where more serious illnesses can be treated.

The better medical care has been noticed in the villages by the decrease in the incidence of skin, ear and eye infections (Lourie, personal communication). In addition, with the advent of vaccination programmes and spraying of insecticides the infection rate, especially from malaria, has dropped with a concomitant decrease in the average size of the liver and spleen (Schuurkamp, personal communication).

The Ningerum and Awin have the opportunity to earn a little cash, and also receive some compensation from OTML but not as much as the Wopkaimin, however few have bought consumer goods. They have been encouraged to grow cash crops to sell in Tabubil, but not every villager has taken up this opportunity. Health care is adequate for both groups with most villages in easy access of an aid post, or the Health Centres at Ningerum and Rumginae (see Figure 1.3) which are not as well equipped as the one in Tabubil.

Within the village groups, proximity to Tabubil itself leads to accessibility to dietary supplementation, through the distribution of surplus food from the camp and from the use of the trade-store. An improvement of the diet of these villagers has been observed by Ulijaszek and Pumuye (1985). Most of the villagers are Wopkaimin from Bultem and Wangbin, and so are affected as described above, the rest are workers who live and eat in Tabubil.

Villages situated near the Tabubil-Kiunga road have the advantage of greater mobility and better access to Government services, and are also able to dispose of their cash crops much more easily than those in the bush. Bouchard (1972) concluded "Roads are not that necessary for the introduction of western practices but they are essential for the continuing intensification of commercialisation and westernisation".

For villagers over a day's walk away from a road cash-cropping has become a non-viable proposition for earning money. A number of the younger men have therefore become disenchanted at their more prosperous neighbours and packed their belongings to move closer to Tabubil. This migration could eventually have bad effects on village life if the women and children are left to fend for themselves.

The workers ate and slept in the camps built by OTML, and their diet was of a more 'western' type. Non-workers have to tend to their gardens, some of which were a good hour's walk away from the village. Their habitual activity thus appears to be higher than workers, who were employed in jobs which did not require the expenditure of large amounts of energy.

Workers are psychologically affected because they are living away from their family in a foreign environment with all its modern conveniences. Alcohol is available to them and they have to meet many people from totally different cultures. They are able to buy more consumer goods, nevertheless a few do send money back to their families for them to buy food and clothing. Non-workers, on the other hand, rely on their gardens and hunting to supply them with food and the sale of their produce for money, on top of royalties.

4.2. Anthropometry and Body Composition.

In the majority of studies concerning acculturation, there is a tendency for the body dimensions to increase (Wyndham, 1973; Weitz and Lahiri, 1977; and Shephard, 1978), this probably reflects a better overall nutritional balance. The most acculturated groups within the Ok Tedi region were significantly the heaviest and fattest, and had the greater muscle areas and volumes. However stature did not agree with this.

The cross-sectional data in this study showed a decrease with age in stature (Figures 3.1(b), 3.11(b) and 3.16(b)), and most other indices. This decrease in mean values of skeletal measurements with increasing age in groups studied cross-sectionally has frequently been ascribed to the effects of secular trend (Harvey, 1974), and the presence or absence of this change has been considered as one index of the effects of acculturation (Tobias, 1962).

The reason why stature increased with age in the Awin is not clear (Figure 3.1(b)), but may be because they were previously employed by the Australian Petroleum Company or on rubber plantations and were thus able to buy foods (Argyll-Robinson, 1982). Now though jobs are very limited for them and they have to rely on growing their own food. Thus the young adults may not have had enough protein and other foods to grow to their potential height as the older cohorts had.

All groups show significant decreases in body weight with age, which is the reverse of the situation pertaining in developed countries (Figures 3.1, 3.11 and 3.16). The negative regression of body mass on age for cross-sectional samples of adults appears to be a well-established feature of New Guinea anthropometry (Sinnett, 1972; and Harvey, 1974). It has been suggested this may, in part, be due to the unsatisfactory nutritional status of the older cohorts, at least as far as protein is concerned. The decrease in body mass with age, is strongly associated with a reduction in FFM, seen in figure 3.2(c).

Parizkova and Eiselt (1966) reported a decline in MUAC and calf circumference, and of the absolute amount of FFM among men over 65 years who practised physical training, compared to no change in those not in training. Harvey (1974) showed in active New Guineans there appear to be similar decreases in MUAC, calf circumference, AMA and weight, although the onset of these changes was earlier than in Western populations. In the present study the decrease in FFM was seen to begin after 25 years (Figure 3.2(c)), as did MUAC, except in the Wopkaimin in whom it began later (about 35-40). Similarly in the 'close to' (Figure 3.12(c)) and working (Figure 3.16(c)) groups the decline began later. Therefore, in this respect, these groups are beginning to resemble western populations.

However the interpretation of cross-sectional data is complicated by the difficulties of partitioning the effects of secular changes, degenerative age changes and changes due to continuing growth in certain parts of the body.

Compared to 1982/83 (Lourie et al, 1986) the Wopkaimin are no taller (Table 4.1), probably because more men were assessed to be over 40 in this study. Adjusting figures for age did not have a significant effect on the means ($p>0.05$). However, they are some 4kg heavier, and the amount of fat present from the skinfolds has increased. AMA calculated from the mean MUAC and triceps skinfold has increased from $48.2cm^2$ to $55.2cm^2$.

Mean figures for the Awin have also changed since 1978 (Nakikus and Lambert, 1978), mean weight has increased from 52.6 to 54.5kg, and mean stature from 157.9 to 159.6cm. The increase in stature is seen in young and old, both being taller than their respective groups in 1978 indicating a secular trend (the age structure of the populations in the previous and present studies being similar). However, longitudinal comparisons can be made between successive surveys if figures are standardised, although doubts often arise about the comparability of techniques and inter-observer variability.

Table 4.1: Change in anthropometric measurements for the Wopkaimin, from 1978 to present day.

	1978*	1982/83**	Present Study 1984/85
Stature (cm)	156.4	155.6	156.0
Weight (kg)	53.2	53.9	57.3
Sit. Hght. (cm)		80.0	79.8
Muac (cm)		26.0	28.0
Biceps Sk/f (mm)		2.8	3.0
Triceps Sk/f (mm)	4.7	4.5	5.3
AMA, cm^2		48.2	55.2

* Nakikus and Lambert (1978) ** Lourie, Taufa, Cattani and Anderson (1986)

The reason why the 'close to' groups are the heaviest, fattest, etc. could be due to the fact that this group included workers. Removing these did not have any statistical effect in reducing the differences between this and the other groups. However, the workers within the group were heavier by about 3kg, and had about 20% more muscle, as measured from AMA and LMV (AMA: $61.1cm^2$ cf $50.9cm^2$; LMV: 14.21 cf 11.81). Differences have also been observed in the same direction amongst women who were not working (Lourie et al, 1986). The most likely factor to account for these trends amongst adults is the improved nutrition of those living in close proximity to Tabubil (Ulijaszek and Pumuye, 1985).

Even though the 'remote' group have an inferior diet compared to the 'close to' group (Ulijaszek and Pumuye, 1985), only a few showed signs of undernutrition, i.e. low Wt-for-Ht and Wt/Ht. The amount of body fat present was very small, and thus they appear to have developed lean muscular bodies confirming previous findings.

Lourie et al (1986) also compared Wopkaimin living near Tabubil with those living in remote areas and found similar results to those in this study. Comparing their results with the present ones, we see no real change in stature and weight in the 'close to' group (Table 4.2), but a slight increase in the 'remote' group; with all the other measurements increasing in both. But these changes are questionable because of the different age structure of the two samples.

Table 4.2: Change in anthropometric measurements for the Wopkaimin living in remote areas and close to Tabubil, from 1982/83 (Lourie et al, 1986) to present study.

	Close To Tabubil		Remote From Tabubil	
	1982/83	Present 1984/85	1982/83	Present 1984/85
Weight (kg)	58.2	58.3	51.5	52.6
Stature (cm)	157.8	157.1	155.4	156.6
MUAC (cm)	27.3	28.6	25.4	26.5
Triceps Sk/f (mm)	5.1	5.6	4.0	4.3
AMA (cm^2)	52.6	57.3	46.4	50.3

The differences observed between the workers and non-workers were obvious (Tables 3.15 and 3.16). Although shorter ($p<0.05$), workers were significantly heavier, fatter and had a greater amount of muscle. Wt-for-Ht and MUAC% approached standard figures for the workers, but TSF% was still below norm (62.0%).

The reason why they are larger is due to the fact that they are able eat a well-balanced diet, and eat large quantities of it, probably because they are used to having the satisfaction of a full stomach due to their previous bulky, starchy diet.

Another explanation why workers are generally larger could be that they were chosen because they looked the healthiest when employers were selecting men for work. It has been stated elsewhere (Lourie et al, 1986) this did occur in the early days, but since about 1980 physical size had not been a criterion of employment. Applicants were only rejected on the basis of gross hepatomegaly or splenomegaly, or cardiomegaly assessed by chest X-ray. Selection therefore does not appear likely to be responsible for the observed differences between the workers and non-workers.

Cross-sectional data showed a secular increase in size for non-workers only (Figure 3.17(b)). No trend was seen in the workers, probably because very few men assessed to be over 35 were in the group, so a clear picture was not seen.

Table 4.3: Change in anthropometric measurements of working and non-working Wopkaimin, from 1982/83 (Lourie et al, 1986) to present study.

	Workers		Non-workers	
	1982/83	Present 1984/85	1982/83	Present 1985/86
Weight (kg)	58.5	59.3	51.8	53.5
Stature (cm)	158.0	155.8	155.4	157.5
MUAC (cm)	27.4	29.5	25.4	26.7
Triceps Sk/f (mm)	5.2	5.8	4.0	4.5
AMA (cm^2)	52.8	61.0	46.4	50.9

Compared to 1982/83 (Lourie et al, 1986) workers are now heavier and fatter and have a greater AMA (Table 4.3). However they are shorter, again because fewer elderly were measured by Lourie et al (1986). Mean figures for all measurements for non-workers appear to have increased, especially stature.

A definite secular trend in stature in all groups is not observed in the Ok Tedi because of the age composition differences of the samples, even if figures were standardised for age. Other longitudinal studies though have shown this secular increase when changing to a more western lifestyle. Friedlaender and Rhoads (1982) observed an increase in stature in a number of groups of Solomon Islanders, where the younger and older cohorts were significantly taller than those of similar ages eight years earlier. Rode and Shephard (1984a) also noted this change in Canadian Inuit Eskimos.

Twenty-five subjects were classed as overweight, i.e. had a BMI over 25, according to Garrow's (1969) figures. Of these, only one was classed as grade II, with a BMI of 30.3 kg/m^2. Good muscular development was the norm in all adults. Bindon and Baker (1985) observed an overall trend for increasing adiposity with increasing modernity in Samoans, and was also noticed in South African Bantu (Wyndham, 1973) and Eskimos (Rode and Shephard, 1984a). From skinfolds the more acculturated groups were indeed getting fatter compared to villagers living in more remoter areas.

In the Ok Tedi acculturation is leading to an increase in size of fat and muscle, and there appears to be a secular trend to an increase in size throughout the region as a whole.

4.2.1. Anthropometric Comparisons with other Populations:

Table 4.4 gives mean values for a number of anthropometric measurements and indices of body composition of other populations compared with the men in the Ok Tedi. Stature is similar to that of Wajana and Trio Indians of Surinam (Glanville and Geerdink, 1970); chronically malnourished Columbians (Barac-Nieto et al, 1978); Twa Pygmoids of North-western Zaire (Austin, Ghesquire and Azama, 1979); and South African Bushmen (Tobias, 1972). But they are smaller than other Papua New Guineans (Harvey, 1974); Kenyan roadworkers (Latham, Stephenson, Hall, Wolgemuth, Elliot and Crompton, 1982); and Ntomba Bantu (Austin et al, 1979).

Table 4.4.: Mean figures of anthropometric and body composition data for the Ok Tedi people in comparison with other primitive populations*.

	Papua New Guinea			Surinam	Kenyan	Columbian	Ntomba	Twa	S.African
	Ok Tedi	Karkar	Lufa	Indians	Roadworkers	Indians	Bantu	Pygmoids	Bushmen
Weight	55.1	56.4	58.5	59.8	54.3	47.0	58.2	47.5	
Stature	157.1	161.0	160.3	157.2	167.5	156.4	168.5	159.5	156.6
Sitting Ht.	79.9	84.1	84.4	79.9			83.2	80.4	79.4
MUAC	27.5	25.5	25.1	26.1	25.4				
Triceps Skf	4.8	5.1	5.1	4.1	5.5	4.8	4.9	4.9	
Subscap Skf	7.6	8.9	8.9	7.4		6.9	9.6	8.0	
Sup.Ilc. Skf	6.5	4.0	3.8	3.9					
Cormic	50.9	52.2	52.6	50.8			49.8	50.4	50.7
%Fat	10.8	9.3	10.0						
FFM	49.1	50.8	52.8						
Wt/Ht	35.0	35.0	36.5	38.0	32.4	30.1	34.5	29.8	
BMI	22.3	21.8	22.8	24.2	19.4	19.3	20.5	18.7	
AMA (calc'd from means)	54.1	45.5	43.9	49.0	44.6				

* For references, see text.

There is some variation between the populations in the average contribution of trunk-length to stature. In many Negro peoples of Africa and Australian Aborigines the trunk is relatively short (Barnicott, 1977), the cormic index lying between 45 and 50 percent; whereas in some Chinese, Eskimo and American Indian samples the value may be as high as 53 or 54 percent (Black, Hierholzer, Black, Lamn and Lucas, 1977).

The Ok Tedi people are lighter than most of the other populations in table 4.4, but despite this Wt/Ht and BMI are comparable to most, and much greater than the Columbian Indians and Twa Pygmoids. Wt-for-Ht results for Brazilian Kayapo Indians (Black et al, 1977), who were studied at a time when they were little affected by exogenous cultures, exceeded Jelliffe's (1966) norms compared to a mean of about 90% for the Ok Tedi (Table 3.2). Some people in the Ok Tedi also showed the presence of undernutrition, the lowest Wt/Ht observed was 24.9 kg/m which compares with figures for well-fed European adult males of between 39 and 53 kg/m (Ferro-Luzzi, 1985).

Mean skinfold thicknesses in the Ok Tedi are below those of typical modern Europeans (Durnin and Womersley, 1974), and in this they resemble other groups living under primitive conditions, including other PNG groups (Norgan, Ferro-Luzzi and Durnin, 1982). In contrast muscle area (AMA) is much larger, as is LMV (12.71) compared to Ntombu Bantu (8.51) and Twa Pygmoids (7.11), and also East Africans (10.01; Davies, Mbelwa, Crockford and Weiner, 1973).

4.3. Lung Capacity.

Lung volumes in adults are directly related to body dimensions such as stature (Cotes, 1979), and thus if the latter increase with acculturation so should the former. Although no significant differences were seen in lung size there was a slight improvement in FEV and FVC the nearer one got to Tabubil, even when adjustments were made for stature and age differences.

No significant differences were observed because of the small numbers measured in each group especially in remote areas, and so a proper statistical analysis could not be undertaken. Also the population as a whole have only been affected by exogenous cultures for 4 to 5 years at the time of the study, and thus the benefits of the mine have not yet given rise to a significant improvement in lung capacity. Also this was a base-line study of the population and it would be a good idea to follow-up the villagers at a further date to obtain a much clearer picture.

Few follow-up studies on lung capacity have been carried out on populations undergoing acculturation, the best being that of Rode and Shephard (1984a and 1985). Their study of Canadian Eskimos after ten-years exposure to "white civilisation" showed a significant difference in lung volumes despite very little change in stature. The most noteworthy change they observed in FVC, and FEV, was a substantial increase of the cross-sectional ageing coefficient reflecting a significant improvement in lung size in the young adults (1980/81: 5.361 cf 1970/71: 4.931), with a worsening of scores in the oldest age groups (1980/81: 4.111 cf 1970/71: 4.601). The ageing coefficient for the Ok Tedi population is similar to that of the Eskimos before acculturation began and much better than those for other PNG populations (Table 4.5).

Table 4.5: Regression equation ageing coefficients of lung volumes for the Ok Tedi compared to Canadian Eskimos and other PNG populations.

	Regression Ageing Coefficient	
	FEV	FVC
Ok Tedi	-0.008	-0.012
Eskimos: 1970/71	-0.019	-0.008
1980/81	-0.035	-0.031
Baiyer River	-0.030	-0.024
Lufa	-0.038	-0.035
Trobriand Isles	-0.013	-0.008
Karkar Island	-0.029	-0.020

In the Ok Tedi the difference between young adults and the old was only 0.2 litres, less than 10% (Figure 3.4), which is about the same as that seen in the pre-acculturated Eskimos.

Rode and Shephard's (1984a) longitudinal data indicated over the ten-year period an accelerating loss of function in the older cohorts, which was unchanged by excluding individuals with a history of specific respiratory disease.

Miller et al (1972) measured the lung capacities of Caribbean men and women of African ethnic origin. Although this was not a study of acculturation it indicates what could happen after a few generations. They found Jamaicans and Trinidadians had similar FEV and FVC values which resembled closely those found for Guyanese people of the same ethnic origin (Miller, Ashcroft, Swan and Beadwell, 1970). Comparisons with Africans and Europeans showed that volumes were larger in the latter and smaller in the former, than those in the Caribbean.

Mean adjusted lung volumes for men in the Ok Tedi (Table 4.6) are much smaller than those of other groups in Africa (Patrick amd Femi-Pearse, 1970) and the Caribbean (Miller et al, 1972), and well below those of Europeans and other Papua New Guineans (Cotes, Saunders, Adam, Anderson and Hall, 1973).

The reasons why the volumes were low are numerous. Firstly, the subjects may not have been trying hard enough despite encouragement. However it was hoped to overcome this by taking the maximum FEV and FVC values of the five trials.

Secondly, differences in body size may play a role in determining the low lung volumes. Compared to Lufa and Karkar the Ok Tedi are about 3cm shorter, but this should be accounted for by adjusting the volumes to the common stature and age (Table 4.6). However stature equals leg-length plus sitting height, and Aborigines and Negroes have small lungs relative to stature (Cotes et al, 1973) and larger legs and shorter torsos than Indians and Europeans (Barnicott, 1977). Cotes (1979) states that using sitting height as a reference variable to lung size reduces dispersion between groups but does not eliminate it. In this study FEV ($r=0.33$) and FVC ($r=0.30$) were both significantly correlated with sitting height. However no correlations were given for the other populations.

Chest circumference was some 7cm larger in the present sample than in those from Karkar and Lufa, and so lung size should be bigger. But this measurement is less reliable than the two thoracic diameters for assessing the size of the rib cage as its magnitude depends not only on skeletal dimensions but also thoracic adiposity and pectoral musculature. Using these parameters men from Lufa and Karkar have the larger rib cages (Harvey, 1974), which could account for their greater lung capacity.

Table 4.6: Adjusted lung volumes (adjusted to stature 1.7m and age 30 years)of various populations* compared to those seen in the Ok Tedi.

	FEV (litres)	FVC (litres)	FEV%
Ok Tedi	2.52	3.29	76.4
PACIFIC:			
PNG: Karkar Island	3.26	4.10	80.1
Trobriand Isles	3.36	3.87	86.8
Lufa	3.74	4.66	81.5
Baiyer River	3.53	4.13	85.5
AFRICA:			
Nigeria: Yoruba	3.24	3.92	81.9
CARIBBEAN:			
Jamaica	3.27	3.98	82.6
Trinidad	3.45	3.90	87.0
EUROPEAN	4.06	4.83	83.8

* For references see text

Lung disease, as caused by pollution in houses from fire smoke or smoking cigarettes, reduces lung size through a reduction in functioning lung tissue. Melanesians have been reported to be susceptible to lower respiratory infections (LRI; Riley, 1973), because of pollution and also poor nutrition. In the Ok Tedi LRI, both acute and chronic, were often seen (Taukuro, 1980). Lourie, Taufa, Cattani and Anderson (1985) found evidence of LRI in 5% of adults and a clinical impression of widespread upper respiratory infection. However Highland houses are also polluted by domestic wood smoke and villagers here have larger lungs (Anderson, 1979) and as yet, increased lung has not been reported as an adaptation to pollution.

An indication of chronic obstructive lung disease (COLD) may be obtained by examining the proportion of subjects with an FEV%<65. In the present study this figure approached 21%, which compares with 7.4% for Lufa (Anderson, 1979) and 7.6% for Karkar (Anderson, 1976). Figures are not available for the Trobriand Isles and Baiyer River District but the high mean values in table 4.5 suggest the incidence is small (Woolcock, Colman and Blackburn, 1972). Thus COLD may be the cause of the small lung volumes.

Smoking has been shown to have an aetiologic role in COLD in coastal PNG (Anderson, 1976), but there is no evidence for an effect of smoking on lung size in Highland men (Anderson, 1979). Smokers though, show a rapid deterioration in FVC and FEV with age than non-smokers and was given as a probable cause for the rapid decline in lung volumes in Lufa (Anderson, 1979). Even though the majority of men in the Ok Tedi smoked a rapid deterioration of FVC and FEV with age was not observed.

Lung disease is a probable reason why lung volumes are low in the Ok Tedi. I observed a large number of subjects with a loose cough which has been associated with excessive bronchial secretion (Anderson, 1979) as a result of lung disease, or the physiological response to inhaled irritants.

Altitude plays a role in modifying lung capacity (Boyce, Haight, Rimmer and Harrison, 1974), but the highest point where measurements were taken, 650m at Bultem, is known not to have any significant effect (Cotes, 1979).

An increase in habitual activity as seen in people undergoing athletic training causes a relative increase in lung size (Cotes, 1979). Cotes (1979) also pointed out a 5-8% difference in FVC between individuals with a high habitual activity and sedentes. Daily energy expenditure was not measured in this case and so cannot be implicated as a cause of the low lung volumes.

Acculturation therefore appears to lead to an increase in lung capacity. In the Ok Tedi region the people who live in or around Tabubil have slightly larger lung volumes than those living further away. The differences also occur in the same direction for the workers compared to non-workers. It appears that the beginings of acculturation of lung capacity have started for a number of the Ok Tedi inhabitnts, but the figures are not conclusive, and so a longitudinal study needs to be implicated.

4.4. Resting Metabolic Rate.

The effects of acculturation on resting metabolic rate (RMR) have not been studied and in the majority of cases differences between populations have been accounted for by differences in body size and environmental conditions.

In the ethnic groups the Awin had a significantly lower RMR, but when figures were related to body dimensions and adjusted to age 30 years and weight 65kg the difference between the Awin and Wopkaimin was reduced, and between these two and the Ningerum increased. In the village groups men living in remote areas had a significantly lower RMR, however this was because of differences in body size, relative RMR being about the same. No difference was seen between workers and non-workers.

Environmental conditions exert the main influence on RMR, natives of the tropics usually have an RMR about 10% below British standards (Edholm, 1978). Also, most, but not all, immigrants to the tropics from Europe and North America show a similar 10% fall (Vallery-Mason, Bouliere and Poitrenaud, 1980). This fact is so if data are collected in a thermoneutral environment in both locations. The ethnic group differences therefore could be due to the temperature difference between Atemkit in the mountains (mean temperature 19°C) and Miasomnai near Kiunga (mean temperature 29°C). It has been claimed that above a mean temperature of 10°C there is a 5% decrease in RMR for every 10°C rise in temperature (Malhotra, Ramaswamy and Ray, 1960). But the region in which the Ningerum live is not cooler that the mountains, so the reason why they have the highest RMR is not clear.

RMR is related to the proportion of active tissue to body mass, and in this study it is this that accounts for most of the differences between the groups, except the Ningerum. In undernutrition there is a decrease in RMR of up to about 15% (Ferro-Luzzi, 1985) probably no more that the reduction in cell mass. Such a decrease has been estimated to account in a small-sized adult male typical of third world populations for the sparing of about 840KJ/day, less than 10% of his total energy expenditure.

Nevertheless, even taking these things into account mean values are a significantly higher ($p<0.05$) than the calculated BMR (4.88 MJ/24hrs) obtained using the equation in Hipsley and Kirk (1965) for Papua New Guineans, and that obtained using Schofield's (1985) equation (6.33 MJ/24hrs), even if the 10% or so difference between BMR and RMR is taken into account. These differences may be because the subjects did not properly fast. Eating just before the test has been found to increase RMR by about 10% (Bray, Whipp and Koyal, 1974). Alternatively the subjects' may have been apprehensive and nervous towards the test having never seen the apparatus before, which may have been the cause of the hyperventilation.

Table 4.7: Resting metabolic rate of the male Ok Tedi population compared to other groups living in the tropics*.

	Resting Metabolic Rate			
		Adj.**		
	MJ/24hrs	MJ/24hrs	MJ/m^2/24hrs	MJ/kg/24hrs
Ok Tedi	8.19	8.53	5.15	0.15
PACIFIC:				
PNG: Baiyer River	6.28	6.08	3.90	0.10
Port Moresby	6.20	5.94	3.79	0.12
Karkar Island		7.95		0.12
Lufa		8.55		0.13
ASIA:				
India: Natives			3.26	
Europeans			3.27	
AFRICA:				
West Africa: Natives	8.30			0.11
French	8.32			0.11

* For references see text; ** Adjusted to weight 65kg and age 30 years

Comparing figures with other populations in the tropics (Table 4.7) the RMR is substantially higher than Indians and European immigrants (Mason and

Jacob, 1972) and also Papua New Guineans from Port Moresby and Baiyer River (Hipsley, 1966). The differences remain even when body size is taken into account. However figures are comparable with those for Karkar and Lufa (Norgan, Ferro-Luzzi and Durnin, 1974) and West Africans and French immigrants (Dieng, Lemonnier, Bleiberg and Brun, 1980). But when adjusted, or related to BSA and weight, values are higher.

Although slight differences do exist between the groups in the Ok Tedi these can be put down to differences in body size and environmental conditions. The accuracy of the measurement though is uncertain because mean figures are high, which may suggest an underlying physiological adaptation or be due to psychological effects or subjects not properly fasting.

4.5. Physical Fitness.

Physical fitness is affected by many factors including age, sex, nutrition, disease, habitual physical activity, and environmental factors like climate and altitude. Of these nutrition, disease and habitual activity are modified during the process of acculturation (Shephard, 1980). In general acculturation is negatively correlated with measures of fitness (Shephard, 1978; 1980).

4.5.1. Maximal Aerobic Capacity.

Mean figures of aerobic capacity ($\dot{V}o_2max$) for the Ok Tedi men are comparable with those found in sedentary white communities (Davies et al, 1972). Absolute $\dot{V}o_2max$ was much lower in the least acculturated groups, and significantly lower ($p<0.01$) in those villagers living in remote areas (Table 3.13).

Differences in body dimensions and the relative contribution of fat and muscle to the total body mass between populations can have a significant effect. It is estimated that approximately 69% of differences in $\dot{V}o_2max$ among individuals can be explained simply by differences in body weight, 4% by differences in stature and 1% by variations in FFM (McArdle et al, 1986). Shephard (1978) says there is as yet little unequivocal evidence on how the secular trend to an increase of adult stature is affecting working capacity. Within a given population the short individuals commonly have a small absolute aerobic power, but a good $\dot{V}o_2max$ relative to body weight. One might thus anticipate that the secular trend would lead to an increase of absolute and a decrease of relative working capacity.

Relating $\dot{V}o_2max$ to body weight and FFM did not affect the differences between the village groups, mean figures for those in remote areas were still significantly lower than the rest although the differences were reduced (Table 3.13). With the ethnic groups figures for the least acculturated, the Awin, approached those of the Wopkaimin (Table 3.6). However, the Ningerum were significantly the fitter group ($p<0.01$).

The $\dot{V}o_2max$ of Ok Tedi subjects was closely correlated to their effective working muscle mass, which during stepping is essentially that of the legs. Davies (1974) stated that in healthy subjects who are normally active but not in training differences in LMV account, in part, for the large inter-subject variability of $\dot{V}o_2max$ in an otherwise homogeneous population of adults and explain the sex and racial differences of aerobic power output in subjects of European and African descent.

Expressing $\dot{V}o_2max$ in relation to LMV though did not have much effect in reducing the differences in the Ok Tedi. In the ethnic groups the Ningerum were still significantly fitter than the other two, who were comparable. In the village groups, figures for the 'remote' group approached those of the 'close to' group, but those for the 'on the road' group were far superior.

Adjusting figures to an age of 25 years, a stature of 1.7m and a FFM of 55kg did not have any significant effect in reducing the differences between the groups.

The men who work in Tabubil represent those who have been most affected by the mine. Other studies have shown that workers have a higher absolute $\dot{V}o_2max$ when compared with non-workers (Miller et al, 1972; Davies et al, 1973; and Wyndham, 1973). But when figures are related to body dimensions the two groups are comparable. Shephard (1978) also stated that the same differences occur between the more acculturated groups and those not. Workers in Tabubil had only a slightly greater absolute $\dot{V}o_2max$, but when figures were related to body size this difference disappeared. In Nigeria, Davies (personal communication in Shephard, 1978) noted that rural villagers and workers in light industry had a similar aerobic power, but that factory workers in heavy industry had a higher physical capacity. This may suggest why no differences were observed between the workers and non-workers, because the former were employed in occupations that did not require a high energy expenditure. However when expressed per litre of LMV the $\dot{V}o_2max$ of non-workers was signifcantly larger, which suggests they are more efficient in performing exercise with less LMV, which is about two litres lower (Table 3.15). This higher efficiency is also shown by the lower mean $\dot{V}o_2150$ and higher mean N.M.E. (Table 3.20). Also, when figures were adjusted to the standard figures as before they were the fitter group by about 200 ml/min.

The reasons why the mean predicted $\dot{V}o_2max$ figures are low are numerous. Firstly there is the use of age in the Vo_2max prediction procedure; which requires extending the $\dot{V}o_2$:fh regression line to a predicted maximum fh based on age. In most primitive societies it is difficult to ascertain age because of the lack of birth records. Therefore other ways of determining age have to be used like reference to local events, ranking villagers and the definition of functional age sets within the community. These methods will involve some error and there is the possibility of someone not telling the truth, e.g. a sample of supposed 'young' subjects may be diluted by the inclusion of older individuals. Consequently if age is overestimated the predicted maximum fh would be underestimated, and as a result so will the $\dot{V}o_2max$.

The prediction method also assumes a constant $\dot{V}o_2$:fh relationship up to and including maximal levels of work (Davies, 1968). However in some cases at maximal levels $\dot{V}o_2$ continues increasing while fh remains constant because of an efficient redistribution of blood (Astrand and Rodahl, 1977). Thus, $\dot{V}o_2max$ is nearly always underestimated. The only real way therefore of obtaining a true $\dot{V}o_2max$ is to measure it directly, which introduces ethical problems. Davies (1968) proposed correcting predicted values to give a more realistic estimate and using his equation gives a mean of 2.73 l/min (50.3 ml/kg/min).

If submaximal work is performed in a hot climate, fh tends to be higher at a given $\dot{V}o_2$ than would be expected in temperate regions, reflecting a greater skin blood flow. Predictions of $\dot{V}o_2max$ based on the fh response to submaximal effort will be erroneously low if data is collected in an over-heated test facility. It was hoped to eliminate this factor by not undertaking the exercise test around mid-day when the temperature was at its hottest. If the fh at a fixed $\dot{V}o_2$ was high though introducing the resting fh and $\dot{V}o_2$ values into the prediction equation could counterbalance this effect. Doing this significantly increased the overall mean $\dot{V}o_2max$ ($p<0.01$) from 2.17 to 2.44 l/min, just over 12%.

Climate may therefore have caused the differences seen amongst the ethnic groups, especially the lower predicted $\dot{V}o_2max$ for the Awin. But the reason why the Ningerum are significantly fitter is not down to a lower temperature/humidity, because the two groups live under similar conditions.

Smoking a single cigarette also increases the fh at a fixed $\dot{V}o_2$ by as much as 10 to 20 beats/min (Juurup and Muido, 1946), which would decrease the $\dot{V}o_2$:fh slope and lead to an underestimation of $\dot{V}o_2max$. It also causes a two- to threefold rise in the airway resistance (Da Silva and Hamosh, 1973) as a reflex response to the deposition of dust particles upon the epithelial lining of the lungs, and is not specific to tobacco smoke. This is not noticeable at rest, but when the demand on respiration is raised the increased respiratory resistance becomes evident. Thus a large majority of the men who smoked were asked to refrain from doing so at least two hours before the exercise test, and also the RMR and lung function tests.

As discussed in section 4.2 smoking or the inhalation of any irritant may give rise to lung disease, which could then affect $\dot{V}o_2max$. An epidemic of a lethal disease like pneumonia could theoretically improve the working capacity of an isolated community through the selective elimination of the weaker members. In the more immediate sense, disease usually has a negative effect on the effort tolerance of the individual. Restrictions of habitual activity may be imposed by the disease itself, systemic effects may restrict growth and development, and acute impairments of cardio-respiratory function may reduce the potential for oxygen transport.

Davies (1974) observed anaemic Tanzanians had a $\dot{V}o_2max$ of only 1.98 l/min (46.6 ml/kgFFM/min). Previously anaemia was very common in the Ok Tedi region, mainly due to malarial infections (Taukuro, 1980; and Lourie et al, 1985). However since then the incidence of malaria has decreased drastically (Schuurkamp, personal communication), but whether haemoglobin concentrations have concomitantly increased is not known as no estimations have been made recently.

Many populations suffer from poor nutrition and anaemia due to malaria and parasitic infections. Studies have shown that better nourished workers were more productive than less well-nourished workers (Wolgemuth, Latham, Hall, Chesher and Crompton, 1982), and that a nutritional situation which leads to a low adult body weight and FFM may be associated with reduced adult work output (Satyanarayana et al, 1977). Measurements in Columbians (Barac-Nieto et al, 1978) have shown that $\dot{V}o_2max$ was lower by 21% and 52% in subjects with moderate and severe undernutrition respectively when compared to men with mild nutritional compromise (see Table 4.8).

It can be seen from table 4.8 that the Ok Tedi have a higher mean Wt/Ht and an absolute $\dot{V}o_2max$ equivalent to the mild group. However relative $\dot{V}o_2max$ is not much different from the intermediate group. It therefore appears that the nutritional status is not limiting $\dot{V}o_2max$ in the Ok Tedi. However in many other indigines of tropical regions malnutrition limits the working capacity which makes the activities necessary for subsistence hard to perform.

Table 4.8: Maximal oxygen consumption of Columbian Indians*, in various states of nutritional compromise compared to the Ok Tedi.

	Ok Tedi	Nutritional Compromise		
		Severe	Intermediate	Mild
Weight/height (kg/m)	35.0	27.4	30.8	33.3
$\dot{V}o_2max$ (l/min)	2.17	1.05	1.71	2.17
(ml/kg/min)	39.8	24.5	35.4	41.7
(ml/kgFFM/min)	44.4	29.0	44.2	51.0

* from Barac-Nieto, Spurr, Maksud and Lotero (1978)

Edmundson (1980) claimed Indonesians on a low energy intake used 18% less energy when working at a low load (cycling at 50W), and 30% less at a medium load (100W), than those on a high intake. Spurr, Barac-Nieto and Maksud (1979) found no significant difference in gross mechanical efficiency of treadmill walking in groups of Columbians classified as normal, mild, intermediate and severely nutritionally compromised on the basis of anthropometric and biochemical indices. However the evidence for increases in N.M.E. of subjects on a low energy intake, and hence malnourished, is not conclusive, for there is no evidence in the literature for increased N.M.E.'s in various populations (including those on low intakes) compared to European values (Norgan, 1981).

N.M.E. in this study was observed to be about 3% greater than that for the average Caucasian (Shephard, Allen, Benade, Davies, Di Prampero, Hedman, Merriman, Myhre and Simmons, 1968), but this could be due to the high RMR.

Dietary intake was not measured in this study but nutritional status (which can be related to intake) was assessed anthropometrically, however a consistent relationship between N.M.E. and Wt/Ht was not seen. So as before the hypothesis for an improved N.M.E. with a decrease in nutritional status is not definite.

The N.M.E. is influenced by the limb length in relation to step height, which could then have affected oxygen uptake. The mean limb length, taken as the gluteal furrow height, was 72.7cm (sd: 3.2) and the step height 42cm. According to Shahnawaz (1978) a step of 42cm would be appropriate for subjects with a limb length of about 85cm; in his work limb length was taken as the height of the top of the greater trochanter from the floor. In this study this is probably the case as the gluteal furrow height is approximately 10-15cm below the greater trochanter. However a number of the subjects were small and may have found the step difficult to ascend.

This difficulty could have made these individuals, aswell as others, anxious and afraid of falling off the step. These factors may then have falsely increased the fh at a fixed $\dot{V}o_2$ which would lead to an underestimation of $\dot{V}o_2max$. Practise on the step may have reduced the anxiety and fear.

The level of habitual activity plays a role in determining $\dot{V}o_2max$ as Aghemo et al (1971) showed with Tarahumaras Indians. Runners, who were accustomed to running several kilometres every day for religious habits as well as for hunting and migrating purposes, had a significantly higher $\dot{V}o_2max$ (63.0 ml/kg/min) than non-runners (38.9 ml/kg/min), with former runners intermediate of the two (50.0 ml/kg/min). However the premise that a primitive population must have a high level of fitness in order to survive is not always true. The Kalahari Bushmen (reputed to be one of the most primitive groups in the world at the time they were studied, who were nomadic hunters and renowned for their feats of endurance) had only a slightly higher mean $\dot{V}o_2max$ than the average sedentary Caucasian male (Wyndham et al, 1963); and considerably less than Swedish cross-country skiers (47.1 ml/kg/min cf 68.0 ml/kg/min). But habitual activity was not quantified in this study and so cannot be examined thoroughly here. If we were to assume though that a steeper terrain is associated with a higher habitual activity we would have expected the Wopkaimin to have the highest $\dot{V}o_2max$ and the Awin the lowest.

In the village groups we would expect those individuals living in remote areas to have a high habitual activity as they have to produce their own vegetables and go hunting. Nutritional status from weight, skinfolds, Wt/Ht and Wt-for-Ht of these villagers was much lower than the rest, which is important because functional body mass has been shown to affect work output (Satyanarayana et al, 1977) and could then affect their ability to produce food.

Van Graan et al (1972) suggested that for an individual to be able to perform at a moderate work rate he must have a $\dot{V}o_2max$ of at least 30 ml/kg/min, and to perform hard work a $\dot{V}o_2max$ of 45 ml/kg/min. Within the ethnic groups a significantly lower percentage of the Wopkaimin (4.4%) had a $\dot{V}o_2max$ less than 30, compared to the Ningerum (17.0%) and Awin (29.2%). But only a small number of Wopkaimin (13.4%) were able to perform hard work, whereas a greater number of Ningerum (38.3%) and Awin (25.0%) could. Within the people living close to Tabubil only 5.1% were incapable of performing moderate work compared to about 22% of the rest. It is interesting to note that only 5.4% of villagers living in remote areas were classed as capable of performing hard work. These figures compare with urban and rural Venda, of which about 7% were not capable of performing moderate work; and 27% of the rural and 36% of the urban who were able to perform hard work (Van Graan et al, 1972).

However the usefulness of these figures is questionable because of differences in body weight. Van Graan et al (1972) said moderate work corresponds to a $\dot{V}o_2$ of 1.00 l/min. For a 50kg man a $\dot{V}o_2$max of 30 ml/kg/min is equivalent to an absolute $\dot{V}o_2$max of 1.5 l/min and for a 75kg man of 2.25 l/min. Thus working at a moderate rate requires the 50kg man to work at about 67% of his $\dot{V}o_2$max and the 75kg man at about 44% his. These standards therefore penalise lighter individuals.

There is likely to have been a difference in daily energy expenditure between the workers and non-workers, because the former were in occupations which did not require extensive physical exertion. On the other hand we would expect non-workers to be more active as they would have to tend to their gardens and also go hunting. However, no differences were seen in Vo_2max until it was related to LMV.

Predicted $\dot{V}o_2$max declined with age in the Ok Tedi as is to be expected with the extrapolation procedure. The cross-sectional ageing coefficients ranged from 0.2 ml/kg/year in the Wopkaimin to 0.8 ml/kg/year in the Awin (overall mean: 0.42 ml/kg/year). This decline is questionable because of the age estimation procedure, but comparisons with other primitive populations show similar rates. Cross-sectional studies of an Easter Island population (Ekblom and Gjessing, 1968), Nilo-Hamitics and Bantu (Di Prampero and Cerretelli, 1969), Tanzanians (Davies and Van Haaren, 1973) and Samoans (Greksa and Baker, 1982) have shown the Tanzanians to exhibit the slowest decline of the Africans, 0.17 ml/kg/year, compared to 0.18 ml/kg/year for Nilo-Hamitics and 0.28 ml/kg/year for Bantu. Compared to the other Pacific groups the Ok Tedi men exhibit a slower rate of decline than that for the Easter Islanders (0.48 ml/kg/year) and Samoans (0.76 ml/kg/year).

In cold regions the $\dot{V}o_2$max of the Eskimo is well maintained until about the age of 40 when there is a sudden drop in physical activity and a parallel deterioration of aerobic power. Rode and Shephard (1984b) in their follow-up study of Canadian Inuit illustrated that compared to 1970/71, men in 1980/81 exhibited a decline of predicted Vo_2max at all ages. The absolute prediction (l/min) was reduced by about 15%, the effect most marked in young adults. Relative $\dot{V}o_2max$ (ml/kg/min) showed a similar tendency, but the loss of aerobic power appeared larger because of the simultaneous increase in body mass. The cross-sectional ageing factor was observed to have decreased from 0.61 ml/kg/min to 0.45 ml/kg/min. It appears, in Eskimos at least, civilisation brings about a decrease in aerobic power and also slows down the ageing process. However their longitudinal data showed a decline of about 1.22 ml/kg/year which is more than double the usual rate of ageing in a white community.

From figures 3.7, 3.15 and 3.21 the most acculturated groups showed a slower decrease of $\dot{V}o_2max$ with age. Figures for the younger adults also endorse Rode and Shephard's (1984b) work where the most westernised have a lower aerobic capacity. But as yet, this is not shown in the older cohorts, probably because they have not fully accepted the new way of life, and continue a relatively active existence in maintaining their gardens. In contrast the young were often seen to hang around the villages or Tabubil on the look out for jobs, relying on their fellow villagers to provide them with food.

The lower rate of deterioration with age seen in warmer regions, is probably because habitual activity is at a lower level at all ages, and individuals maintain this level well into old age.

4.5.2. Aerobic Capacity Comparisons with other Populations:

Table 4.9 gives a list of reported mean $\dot{V}o_2max$ values for male populations compared to the Ok Tedi. Absolute $\dot{V}o_2max$ for the Ok Tedi men is comparable to Ethiopians (Areskog, Selinus and Vahlquist, 1969); rural Venda and Pedi (Wyndham, 1973); and Twa Pygmoids (Austin et al, 1979). However they were inferior to those who maintained an active lifestyle including Tanzanians (Davies and Van Haaren, 1973), Nigerian Yoruba (Davies et al, 1972), Tarahumaras Indians (Aghemo et al, 1971), and the Kaul lowlanders and Lufa highlanders of PNG (Patrick and Cotes, 1973).

Relative $\dot{V}o_2max$ is not much better and this mean $\dot{V}o_2max$ is now similar to that of Samoans (Greksa and Baker, 1982), urban Venda and Pedi (Wyndham, 1973), Ntomba Bantu (Austin et al, 1979), and Tarahumaras non-runners (Aghemo et al, 1971).

Table 4.9: Observed and predicted maximal oxygen consumption ($\dot{V}o_2max$) of various populations*, compared to the men of the Ok Tedi.

Population	Aerobic Power l/min	Aerobic Power ml/kg/min	Aerobic Power ml/kg FFM/min
Ok Tedi	2.17	39.8	44.4
PACIFIC:			
PNG: Kaul	3.10**		62.5
Lufa	4.00**		77.6
Enga	2.63	45.1	
Samoa: Office employee	3.09	40.8	
Labourers	2.78	35.8	
Agriculturalists	3.14	41.2	
AFRICA:			
Ethiopia: Workers	2.04	37.7	
Air Force Cadets	2.34	40.0	
Nigeria: Yoruba- Active	3.40	55.5	66.3
Inactive	2.81	45.9	56.2
Villager	2.99	48.5	61.2
S. Africa: Kalahari	2.39	47.1	
Venda - rural	2.26	39.9	
urban	2.60	40.5	
Pedi - rural	2.10	37.6	
urban	2.53	41.9	
Tanzania: Active	3.51	57.2	
Zaire: Ntomba Bantu	2.54	43.8	53.5
Twa Pygmoids	2.01	40.4	
S. AMERICA:			
Tarahumaras			
Indians: Runners	3.48	63.0	70.8
Non-runners	2.45	38.9	47.0
Former runners	3.01	50.0	58.6

* For references see text; ** Figures are $\dot{V}o_2$ at fh of 200

4.5.3. Submaximal Indices.

As stated previously, a number of factors could have affected the prediction of $\dot{V}o_2max$ making it unreliable. It may therefore be more useful to use submaximal indices which do not rely on extrapolating to a predicted maximal figure, to get a better picture of the response to exercise within the Ok Tedi region.

The $fh_{1.5}$ for the three ethnic groups resembled each other and were within the normal range for sedentary men. But when figures were adjusted for differences in age, stature and FFM, the Wopkaimin had a significantly lower submaximal fh. The Awin had a slightly (but significantly) raised $\dot{V}e_{1.5}$ which may suggest a degree of hyperventilation, but the figures are comparable with other populations in table 4.10. The Ningerum had a slightly higher $\dot{V}o_2150$ implying they climb a step with a lower N.M.E. than the Awin or Wopkaimin which is confirmed by the lower mean N.M.E. figure.

In all cases with increasing FFM and TMW, sub-maximal fh (Figure 3.9), and also V_e, decreased accordingly. Cotes, Berry, Burkinshaw, Davies, Hall, Jones and Knibbs (1973) observed that the submaximal fh/body muscle relationship was displaced upwards for sedentary subjects, and downwards for those who were fitter and whose level of habitual activity was greater. From figure 3.9 we see that there is no distinct trend, although it appears the Wopkaimin have a lower line, and would thus be fitter and have a higher habitual activity.

Villagers living in remote areas have a higher, but not significant, $fh_{1.5}$, being some 18 beats greater than that for those living on the Tabubil-Kiunga road, and a further 8 greater than for those living in the vicinity of Tabubil. They also have a significantly higher $\dot{V}e_{1.5}$ even after adjustments were made for age, stature and FFM. The increased $\dot{V}e_{1.5}$ had a negligible effect on $\dot{V}o_2$ in the remote villagers because of the lower $\dot{V}o_2150$. This implies that they work at a higher N.M.E. than the others, but it is not supported by the mean N.M.E. figures. The raised $\dot{V}_e$ of the remote villagers in response to work could be a genuine reflection of some basic underlying physiological mechanism, but it is more likely that the hyperventilation of effort is associated more with psychological factors, and was effected by residual anxiety and apprehension.

In this study no differences were observed between workers and non-workers in submaximal indices, probably because the workers were employed in occupations that did not require the expenditure of large amounts of energy. Other studies have also found no differences between villagers and workers of the same ethnic origin, in light industry (Ojikutu, Fox, Davies and Davies, 1972); whereas when compared to workers in heavy industry, villagers had a higher $fh_{1.5}$ and $\dot{V}e_{1.5}$ and a superior $\dot{V}o_2150$. A similar picture was seen in the Ok Tedi, although the differences were very small and not significant.

Submaximal indices show a clearer picture of physical fitness. In all cases the submaximal fh and $\dot{V}_e$ at a fixed $\dot{V}o_2$ were much lower in the more acculturated groups. This was especially seen when comparing figures between ethnic groups and between village groups. The more acculturated groups also show a greater PWC_{170}.

The oxygen consumption at a fixed work load was lower in the least acculturated villagers. The N.M.E. was also higher in these villagers which could be related to their poorer nutritional status, but the figures were not conclusive, because the Wopkaimin were just as efficient in performing the step test as the Awin. This may be because a large number were still active maintaining their gardens. Also men from Bultem II, Wangbin and other local Wopkaimin villages regularly took part in the Tabubil soccer league.

4.5.4. Comparison of Submaximal Indices of Fitness.

Table 4.10 lists the submaximal indices of other populations compared to those in the Ok Tedi. In the present study the fh response to submaximal exercise is similar to that of inactive Tanzanians (Davies and Van Haaren, 1973); Nigerians in light industry (Ojikutu et al, 1972), but much higher than most. The fh at a $\dot{V}o_2$ of 1.0 l/min for the Ok Tedi (95 beats/min) is comparable with that for Kaul (101 beats/min) and Lufa (95 beats/min), in PNG (Cotes, Anderson and Patrick, 1974).

The $\dot{V}o_2$:fh slope (oxygen pulse) for the Ok Tedi is lower (10.4 mlO_2/ heart beat) than in other groups (23.8 mlO_2/ heart beat; Cotes et al, 1973). This may be caused by the high environmental temperature in the Ok Tedi having an affect at the heavier work loads, or the psychological factors spoken of earlier. Adjusting figures to a standard age, stature and FFM did not alter the relationship between the Ok Tedi and other PNG populations; the mean figure for the Ok Tedi was reduced to 129, which was still larger than the figures given for Kaul and Lufa in table 4.10.

$\dot{V}e_{1.5}$ is comparable with most of the other groups in table 4.10 and lower than Nigerians (Ojikutu et al, 1972; and Davies et al, 1972). The figures are also not much greater than those for Europeans.

Table 4.10: Submaximal indices of aerobic power of various populations*.

	$fh_{1.5}$ (beats/min)	$\dot{V}e_{1.5}$ (l/min)	$\dot{V}o_2150$ (l/min)	PWC_{170} (watts)
Ok Tedi	140	40.9	3.15	90.7
PACIFIC:				
PNG: Kaul	119	42.7		
Lufa	113	38.7		
AFRICA:				
Nigeria: Villagers	132	59.9	2.06	
Heavy ind.	129	50.8	2.23	
Light ind.	143	53.9	2.16	
Inactive	137	51.9	2.18	
Active	129	51.4	2.22	
Ethiopia: Factory				117.7
Air force cadets				134.9
Tanzania: Active	120	46.4	2.08	
Inactive	148	41.7	2.14	
EUROPEAN:				
Swedes **	128	36.2	2.09	168.9

* For references, see text; ** Quoted by Areskog, Selinus and Vahlquist (1969).

The high oxygen consumption at a work load of 150 watts ($\dot{V}o_2150$) suggests that the men in the Ok Tedi work with a lower N.M.E. However, the majority of the other studies, from which the figures in table 4.10 were obtained, used a bicycle ergometer and not a step. The mean N.M.E. though, is about 3% greater than that for the average Caucasian (Shephard et al, 1968). Thus there appears to be a mismatch between the two indices, probably because $\dot{V}o_2150$ is an extrapolation in most cases in this study, whereas in the others it is an interpolation, and also because of the high RMR used to calculate N.M.E.

Figures for the physical work capacity at a fh of 170 (PWC_{170}), are lower in the Ok Tedi than the Ethiopians (Areskog et al, 1969) and much less than the figures for Swedes, quoted in the same paper. Relating figures to body weight only slightly reduces the differences. Again the reason for the differences may be because in this study most of the PWC_{170} figures were extrapolations rather than interpolations.

4.6. Conclusions.

The differences between the acculturated villagers and those less affected by the Ok Tedi mine can be seen in a number of measurements even after only a short period of time of contact with exogenous cultures. The greater availability of protein and other foods from the trade-stores to villagers living in the vicinity of Tabubil has seen an improvement in their diet (Ulijaszek and Pumuye, 1985), and greater access to medical care an improvement in their health status.

These changes for the better have brought about a distinctive alteration in the physical and physiological attributes of the villagers. Their size was significantly greater than those less affected by the mine. The cross-sectional ageing data indicated the onset of loss of body mass occurred earlier in life than in Europeans. However the more acculturated groups appeared to be moving towards these populations because they began to lose weight and fat free mass approximately five to ten years later than those less affected by the mine.

There was an increase in size of the Wopkaimin and Awin compared to about five or ten years ago because of the greater availability of foods of all kinds, with the exception of stature. Figures for the Ningerum are not available at the present.

Acculturation is giving rise to an increase in lung size, with those villagers living nearer Tabubil having slightly greater FEV's and FVC's. However volumes were significantly lower than expected, and worse than those of other populations, which is probably due to a high incidence of respiratory infection previously noted in the region.

The RMR was much higher than expected and greater than most other populations living under similar conditions. This may have been due to underlying anxiety towards the experiment, because hyperventilation was indicated by the high mean resting $\dot{V}_e$ for all groups. The hot environmental conditions may have played a significant role in shifting the blood to the skin for cooling purposes raising the fh at a fixed $\dot{V}o_2$. It may therefore have been more profitable to have measured RMR in an air-conditioned room rather than the village church or aid post. Within the Ok Tedi the differences observed between the groups were mainly due to disparities in body dimensions.

Predicted $\dot{V}o_2max$ was lower than expected for an active primitive community, figures comparing with those for Caucasian sedentes. This was probably because the prediction method depends upon the estimation of a maximal fh based upon age, which itself in this study was also estimated because there were no birth records. Nevertheless if the same subjects are followed-up at a future date a much clearer picture can be obtained; because at the time of this study the villagers had only been affected by the mine for a short period of time and also this was the first time physical fitness had been measured.

Absolute $\dot{V}o_2max$ was significantly inferior in the least acculturated groups. But despite this, as with other studies of rural/urban comparisons and of longitudinal changes, differences were reduced when $\dot{V}o_2max$ was related to body dimensions. The reasons the more acculturated groups had a higher $\dot{V}o_2max$ and also a greater percentage of these who were capable of hard work can be attributed to their better diets.

Cross-sectional ageing coefficients were much lower in the more acculturated groups, whose figures approach those of Europeans.

Submaximal indices showed a clearer picture of physical fitness in the region. In all cases the submaximal fh and $\dot{V}_e$ at a fixed $\dot{V}o_2$, and physical work capacity at a fixed fh were better in the more acculturated groups. This is especially seen when comparing figures between the different ethnic groups and also the different village groups.

The $\dot{V}o_2$ at a fixed workload and N.M.E. were better in those villagers least affected by the mine. This is not related to a poorer nutritional status as in other studies, but maybe because they maintain an active life compared to those living in the vicinity of Tabubil.

However the presence of the Ok Tedi mine, the attractions of employment and availability of consumer goods has led to a migration from villages deep in the bush to those surrounding Tabubil. This may lead to a decrease in the general nutritional and health status of the surrounding community if there are not enough jobs to go around, the land is over-gardened and animals overhunted. There also may be a loss of traditions and initiation rites which would be sad.

With the greater availability of food from the trade-stores there is likely to be an increase in obesity, which is not helped by the increase in the number of cars owned by the villagers which would decrease their habitual activity and thus bring about a decline in fitness. Diseases that are common in Western countries like cardiovascular disorders, diabetes, etc., may also be seen because of the change in lifestyle.

Psychological factors may be a problem of the future especially now everyone appears to be accepting the mine. The eventual problem will be one of readjustment when the mine closes down. Unless there is further investment in the region, or the country as a whole gets richer, the facilities already present may deteriorate and the villagers would have to revert back to their old way of life. Youngsters being born now, in 30 years time, may not be able to cope with this because thay would not know how construct and tend gardens and hunt unless the knowledge is passed down.

The needs of all villages are still great, with better housing essential. Sanitation must be taught with explanations on the proper way and whereabouts to construct toilets. Villagers must be trained on how to properly dig drainage ditches so that the villages do not become swamps and thus breeding grounds for mosquitos. Lastly, standpipes must be erected so that every village has fresh running water from clean streams.

I would like to finish by saying that because this was the first study of lung capacity, resting metabolic rate and physical fitness in the region, the limited resources, and the actual working environment, a clear picture of acculturation was not obtained. However some patterns are beginning to emerge. It would have been beneficial to have measured daily energy expenditure and related this to differences in lung capacity and physical fitness, but because of the limited resources and time it was not undertaken. It would therefore be very interesting to follow up each villager in five to ten years time to get measurement of secular trends and a clear picture of acculturation.

ADDENDUM

Because of the limitations of the Minitab statistical package (Minitab Inc., State College, Pennsylvania) used to analyse the data in this thesis, certain multivariate analyses could not be undertaken. However now that a more powerful package has become available, namely SYSTAT (SYSTAT Inc., Evanston, Illanois), multivariate analysis of variance (ANOVA) has been carried out on a few parameters.

Workers were significantly heavier than non-workers ($p<0.01$, Table 3.15), and it is this which may explain why the Wopkaimin and those living close to Tabubil were also heavier (Tables 3.1 and 3.9), because a greater number of these two groups were working compared to the other ethnic and village groups (see Table A). Two-way analysis of variance (see Table B) supports this analysis.

The same conclusions can also be drawn when looking at mid-upper-arm circumference (MUAC), muscle mass (FFM) and area (AMA) (Table B). In two-way ANOVA, when occupation groups were analysed with ethnic and village groups significant differences were found, whereas no differences were seen when the latter two were paired (Table B). This suggests that employment had the greater influence on body size and composition, which is probably because workers are able to eat in the canteens provided by OMTL, and receive wages with which they can purchase more food from the trade-stores.

Stature did not show any pattern. Although significant differences were seen when one-way analyses were carried out (Tables 3.1, 3.9, 3.15 and B) none were found when two- and three-way ANOVA's were performed. However greater F-values were obtained in analyses with village groups included (Table B); men living close to Tabubil being shorter than those living on the Tabubil-Kiunga road and in remote areas who were comparable (Table 3.9). Non-working men living on the road (158.7) were taller ($p<0.05$) than the other non-workers in remote areas (156.6) and close to Tabubil (156.1). No workers lived in remote areas and only one on the road (Table A).

No definate conclusions could be drawn about the lung capacity data from multivariate analysis, as two-way ANOVA did not uncover any significant differences.

In two-way ANOVA of relative physical fitness, a significant difference was obtained when village groups were included in the analysis. Wopkaimin who lived close to Tabubil had a greater mean $\dot{V}o_2max$ (48.8 ml/kg/min) than those living in remote areas (37.5 ml/kg/min; $p<0.05$). This trend was also seen in the Ningerum (36.9 cf 33.3 ml/kg/min), but those living on the road had a greater mean $\dot{V}o_2max$ (52.2 ml/kg/min; $p<0.01$). In contrast Awin living close to Tabubil (44.9 ml/kg/min) were much fitter than those on the road (39.1 ml/kg/min; $p<0.05$).

Non-workers living close to Tabubil (50.7 ml/kg/min; $p<0.01$) were significantly fitter than both those living on the road (43.6 ml/kg/min) and in remote areas (35.2 ml/kg/min). Again because only one worker lived on the road and none lived in remote areas no comparisons could be made here. Non-workers living close to Tabubil had a significantly greater $\dot{V}o_2max$ (50.7 ml/kg/min) than workers (46.0 ml/kg/min; $p<0.01$).

Non-workers living near to Tabubil, who are mainly Wopkaimin (96%), were probably fitter because they are able to purchase trade-store foods with the money they receive from royalties, etc., and part-time employment in Tabubil, and yet maintain a relatively active lifestyle keeping their gardens in order so as to provide a regular food supply. Men living on the road can buy trade-store foods with money they get from part-time employment when road maintenance is required close to their village, but they must keep their gardens going to maintain a constant food supply. However men in remote areas do not receive any money to buy trade-store foods and rely on their gardens to provide them with an adequate diet. So even though they are active, they cannot develop as good a $\dot{V}o_2max$ because of the poor quality of their diet (Ulijaszek and Pumuye, 1985 and 1987; Ulijeszek and Pumuye, 1987; Ulijaszek and Welsby, 1985). A poor diet has been shown to severely restrict $\dot{V}o_2max$ (Shepard, 1980).

We can observe from this multivariate analysis that occupation had the greatest influence on anthropometry and body composition; whereas locality of the village in relation to Tabubil exerted the greater effect on physical fitness indices.

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Table A: Distribution of men measured between ethnic, village and occupation groups.

VILLAGE GROUP	ETHNIC GROUP						Total
	Wopkaimin		Ningerum		Awin		
	Workers	Non-workers	Workers	Non-workers	Workers	Non-workers	
Close to Tabubil	39	27	12	0	13	1	92
Remote from Tabubil	0	22	0	34	0	0	56
On The Road	0	0	0	23	1	61	85
Sub-totals	39	49	12	57	14	62	
TOTAL	88		69		76		233

Table B: F-values and significance levels of anthropometric, body composition and physical fitness indices resulting from one-, two- and three-way analyses of variance.

Source	Stature		Weight		MUAC		FFM		AMA		$\dot{V}o_2$max (ml/kg/min)	
	F	Sig.*	F	Sig.	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Ethnic	5.7	0.01	4.9	0.01	2.4	NS	3.4	0.05	19.0	0.01	4.8	0.01
Village	6.3	0.01	8.4	0.01	20.9	0.01	3.7	0.05	79.9	0.01	9.7	0.01
Occupation	4.2	0.05	32.9	0.01	74.0	0.01	16.9	0.01	100.3	0.01	2.5	NS
Eth x Vill **	2.1	NS	3.3	0.01	0.2	NS	1.9	NS	0.1	NS	4.9	0.01
Eth x Occ #	0.7	NS	3.8	0.05	3.4	0.05	2.6	NS	12.5	0.01	1.3	NS
Vill x Occ ##	1.4	NS	7.0	0.01	20.4	0.01	6.5	0.01	77.8	0.01	0.9	NS
Eth x Vill x Occ $	1.1	NS	2.3	NS	0.4	NS	1.7	NS	1.0	NS	1.0	NS

* Significance. N.B. only p 0.01 and 0.05 levels are used even though certain parameters have a greater significance.

** Degrees of freedom are 4,215 for anthropometry, and 4,148 for Vo_2max

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6. APPENDICES

APPENDIX A

Repeatability of Anthropometric Measurements:

Repeated measurements were carried out for weight, stature, mid-upper-arm circumference, and skinfolds at the sites of biceps, triceps, subscapular and supra-iliac, on a number of men from Atemkit, Bultem and Wangbin to test for accuracy and repeatability. Measurements were taken at the beginning of a visit and repeated at the end. The average age was about 30, with a range of 18 to over 40. The standard error of measurement (S_{meas}) was chosen as an index of this accuracy. S_{meas} is the standard deviation of the differences of the two measurements divided by the square root of two. A related t-test was also carried out, to test for any significance differences between the means of the repeated measurements.

Table A.1: Repeated measures (A and B) of a number of anthropometric measurements.

Weight, kg		Stature, cm		MUAC, cm		Biceps, mm	
A	B	A	B	A	B	A	B
63.4	61.2	164.0	164.2	28.2	27.7	4.0	2.8
53.2	55.8	154.4	154.1	24.4	25.1	2.7	2.4
46.9	45.5	153.0	153.0	25.7	24.5	2.4	2.4
49.5	47.8	148.6	147.7	28.2	27.4	2.0	2.7
42.0	41.5	147.0	147.7	23.6	22.4	2.9	3.4
57.4	58.1	159.0	159.7	30.0	31.2	2.8	3.0
66.2	65.1	165.5	165.6	30.2	29.1	2.5	3.2
54.2	52.6	161.3	160.5	28.3	27.5	2.3	2.6
64.2	62.1	157.1	157.5	26.9	26.1	2.8	2.8
55.3	56.8	158.3	158.2	29.2	29.4	2.3	3.0
62.1	63.9	159.6	160.3	29.1	28.1	2.5	2.8
53.6	53.5	155.6	155.0	26.9	26.3	2.5	2.8
62.4	63.0	158.5	159.4	25.6	25.9	1.9	3.0
51.6	49.8	156.3	156.4	27.8	29.0	2.2	2.8
50.6	48.8	153.6	153.8	27.0	25.5	2.2	2.2
59.4	59.7	162.7	163.0	25.2	25.1	2.6	2.6
58.4	58.0	154.9	154.2	26.3	27.4	3.3	3.0
50.7	53.0	153.9	152.0	28.7	28.0	3.1	3.0
70.7	68.9	165.4	165.3	26.0	26.5	2.7	3.0
				30.5	30.3	3.6	3.6
S_{meas}: 1.08		S_{meas}: 0.49		S_{meas}: 0.61		S_{meas}: 0.31	
t = 1.606		t = 0.365		t = 1.382		t = -1.413	
($p>0.05$)		($p>0.05$)		($p>0.05$)		($p>0.05$)	

Table A.2: Repeated measures (A and B) of skinfolds (all in mm).

Triceps A	Triceps B	Subscapular A	Subscapular B	Supra-iliac A	Supra-iliac B	All Skinfolds
5.4	4.8	9.6	9.4	7.0	6.5	
3.7	3.4	5.7	5.4	3.8	5.5	
3.4	3.8	4.7	3.6	3.8	4.5	
4.3	4.3	5.3	6.0	5.3	7.1	
4.6	4.5	7.3	7.8	7.3	6.6	
5.4	4.6	4.7	5.6	4.7	5.8	
4.9	5.2	7.3	7.2	5.5	6.4	
4.9	4.4	7.1	8.0	5.0	6.4	
5.6	4.6	8.6	8.5	4.7	6.3	
3.8	5.2	6.3	7.3	5.6	7.1	
4.6	4.6	7.4	7.1	4.0	4.0	
3.5	3.8	8.1	7.2	4.1	5.6	
3.0	3.0	5.3	6.2	4.8	2.2	
4.2	4.2	4.9	5.9	4.7	6.3	
3.6	3.8	6.0	5.5	4.8	5.2	
4.6	4.4	6.6	7.6	5.4	5.5	
4.8	5.8	8.2	9.5	5.8	3.0	
5.4	6.0	9.9	9.6	5.7	4.0	
4.7	4.4	6.1	7.0	5.4	6.3	
5.8	6.8	8.9	8.3	8.4	7.2	
S_{meas}: 0.43		S_{meas}: 0.53		S_{meas}: 1.01		S_{meas}: 0.62
t = -0.513		t = -1.372		t = -0.887		t = -1.814
($p>0.05$)		($p>0.05$)		($p>0.05$)		($p>0.05$)

From tables A.1 and A.2, we can see that there was no significant difference between the measurements, indicating good repeatability.

APPENDIX B

Calculation of Leg Muscle-Plus-Bone Volume:

Using the method of Jones and Pearson (1969) the leg is divided into six truncated cones (Figure B.1). The volume of each cone is calculated as,

$$\text{Volume} = 1/3.h. \quad (a + (ab)^{1/2}\ b)$$

where h is the length of each cone, and a and b are the areas of the two parallel surfaces derived from the circumference measurements. For computation this reduces to:

$$1/3.h.Pi. \ (x^2 + xy + y^2)$$

where x and y are the radii of the two parallel surface areas. The anterior and posterior thigh, and lateral and medial calf skinfolds are then used to correct for the fat present after they are first corrected to a single, uncompressed, rontgenogrammetric value (y), using the equations for males in Jones (1970),

Anterior Thigh	$y = 1.01419 + 0.55696\ x$
Posterior Thigh	$y = 1.36874 + 0.53231\ x$
Medial Calf	$y = 0.98517 + 0.49945\ x$
Lateral Calf	$y = 0.87011 + 0.39259\ x$

(y is corrected and x uncorrected values, respectively). The sums of the thigh and calf fat layers are then subtracted from their respective diameters and the volumes calculated.

(i) Gluteal Furrow.

(ii) One-third subischial height measured up from the knee joint space.

(iii) Minimum circumference height of the lower thigh.

(iv) Tibio-femoral joint space.

(v) Minimum circumference height of upper-calf.

(vi) Maximum circumference of the Calf.

(vii) Minimum circumference of ankle above malleolus.

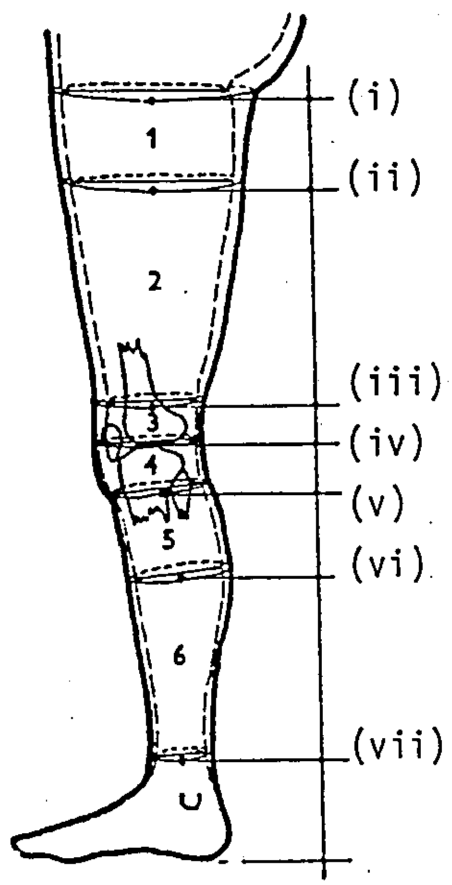

Figure B.1 : Illustrating the six truncated segments of the leg, and the sites from which the anthropometric measurements were taken.

Example: Village - 2; House - 27.

Skinfold caliper readings:

	Uncorrected Values (mm)	Corrected Values (mm)	Sums (mm)
Anterior Thigh	9.1	6.1	\ 12.8
Posterior Thigh	10.0	6.7	/
Medial Calf	4.5	3.2	\ 6.1
Lateral Calf	5.2	2.9	/

Table B.1: Measurements for subject 2/27, that are required for the calculation of leg muscle-plus-bone volume.

Site:	Circumference	Radius	Corrected Radius	Height	'h'
Gluteal					
Furrow	51.3	8.16	7.52	70.3	
Third					5.0
Subischial	49.2	7.83	7.19	65.3	
Lower Thigh					17.7
(min)	34.9	5.55	4.91	47.6	
Tib/Fem					3.0
Joint Space	34.1	5.43	4.79*	44.6	
			5.13		3.6
Upper Calf					
(min)	30.1	4.79	4.49	41.0	
Mid. Calf					8.4
(max)	32.5	5.17	4.87	32.6	24.8
Ankle (min)	24.1	3.84	3.54	7.8	

* Readings for the tib/fem joint space are corrected by the true thigh and calf fat readings for the truncated cones of the thigh and calf respectively.

Thigh Muscle + Bone Calculation:

Segment 1 = $(5.0/3).Pi.\ (7.52^2 + (7.52)(7.19) + 7.19^2)$

= 0.85 litres

Segment 2 = $(17.7/3).Pi.\ (7.19^2 + (7.19)(4.91) + 4.91^2)$

= 2.06 litres

Segment 3 = $(3.0/3).Pi.\ (4.91^2 + (4.91)(4.79) + 4.79^2)$

= 0.22 litres

Thus Thigh Muscle + Bone Volume = <u>3.13 litres</u>

For two legs, Volume = <u>6.26 litres</u>

Calf Muscle + Bone Calculation:

Segment 4 = $(3.6/3).Pi.\ (5.13^2 + (5.13)(4.49) + 4.49^2)$

= 0.26 litres

Segment 5 = $(8.4/3).Pi.\ (4.49^2 + (4.49)(4.87) + 4.87^2)$

= 0.58 litres

Segment 6 = $(24.8/3).Pi.\ (4.87^2 + (4.87)(3.54) + 3.54^2)$

= 1.39 litres

Thus Calf Muscle + Bone Volume = <u>2.23 litres</u>

For two legs, Volume = <u>4.46 litres</u>

Therefore, Leg Muscle + Bone Volume = <u>10.72 litres</u>

Appendix C

Reliability of Heart Rate Measurement:

Heart rate was measured by taking the pulse in the last 15 seconds of each work load. Although this method is accurate at low heart rates, at higher levels errors may occur in counting the pulse beats. An experiment was therefore carried out to test the reliability of measuring the pulse rate at various work loads, by comparing results with those obtained from a Gould electrocardiogram recorder.

Table C.1: Repeated measurements of heart rate, using pulse rate and the Gould electrocardiogram recorder.

Work Load (watts)	Pulse Rate Measurement	Heart Rate Measurement From Gould
0	64	62
"	68	70
"	72	70
"	72	68
100	104	104
"	100	106
"	112	110
"	120	120
150	124	128
"	128	130
"	140	136
"	136	140
200	152	150
"	144	150
"	160	160
"	172	178

Four students aged 18-21 years were connected to a Gould electrocardiogram recorder, and asked to exercise at various work loads for five minutes. In the last 15 seconds the pulse rate and heart rate via the Gould, were measured. The results and statistical significance are seen above.

Correlation between the two methods was 0.99, standard error of estimate 3.19, and there was no significant difference between the means ($p>0.05$).

APPENDIX D

Reliability Of Oxygen Analyser at Simulated Altitude:

In this study standard gases were hard to obtain because of the remoteness of the countryside. When available though they could not be taken out to the villages and so the instrument was calibrated to the fraction of oxygen in the air (FeO_2) of 0.2094. The analyser was used over an altitude range of 20-980m, which could have affected this calibration procedure. An experiment was therefore carried out in the laboratory to see if there was a significant change in the reading given by an oxygen analyser under conditions of altitude simulation.

The apparatus consisted of a calibrated manometer connected to an oxygen analyser at the inlet port and blocked at the other (Figure D.1). After flushing the analyser through with a gas of known composition, the outlet port was sealed and the analyser connected to the manometer. The left arm of the manometer was then lowered to create a small vacuum in the analyser, simulating ascent to altitude. The drop in the mercury level was noted and later converted to pressure, and the analyser reading taken. This was repeated for a number of pressures and different gas compositions.

In table D.1, section (2), the change in pressure was 105mmHg, which should have given a reading for FeO_2 of (661.5/766.5) x 0.209, or 0.180. However, the reading was about 13% greater. Similarly, the drop in section (3) should have given a change in FeO_2 to (590.5/766.5) x 0.152, or 0.117, but again the reading was about 26% greater, and nearer the actual value.

The analyser was also tested with 0% oxygen at simulated altitude (section (1)). Again there was only a small change in the meter reading to a minus number, suggesting good stability.

According to Astrand and Rodahl (1977) ascent to an altitude of 1000m leads to a drop in pressure of 86mmHg, which would lower the FeO_2 in the atmosphere to ((766.5 - 86)/766.5) x 0.209, which equals 0.186.

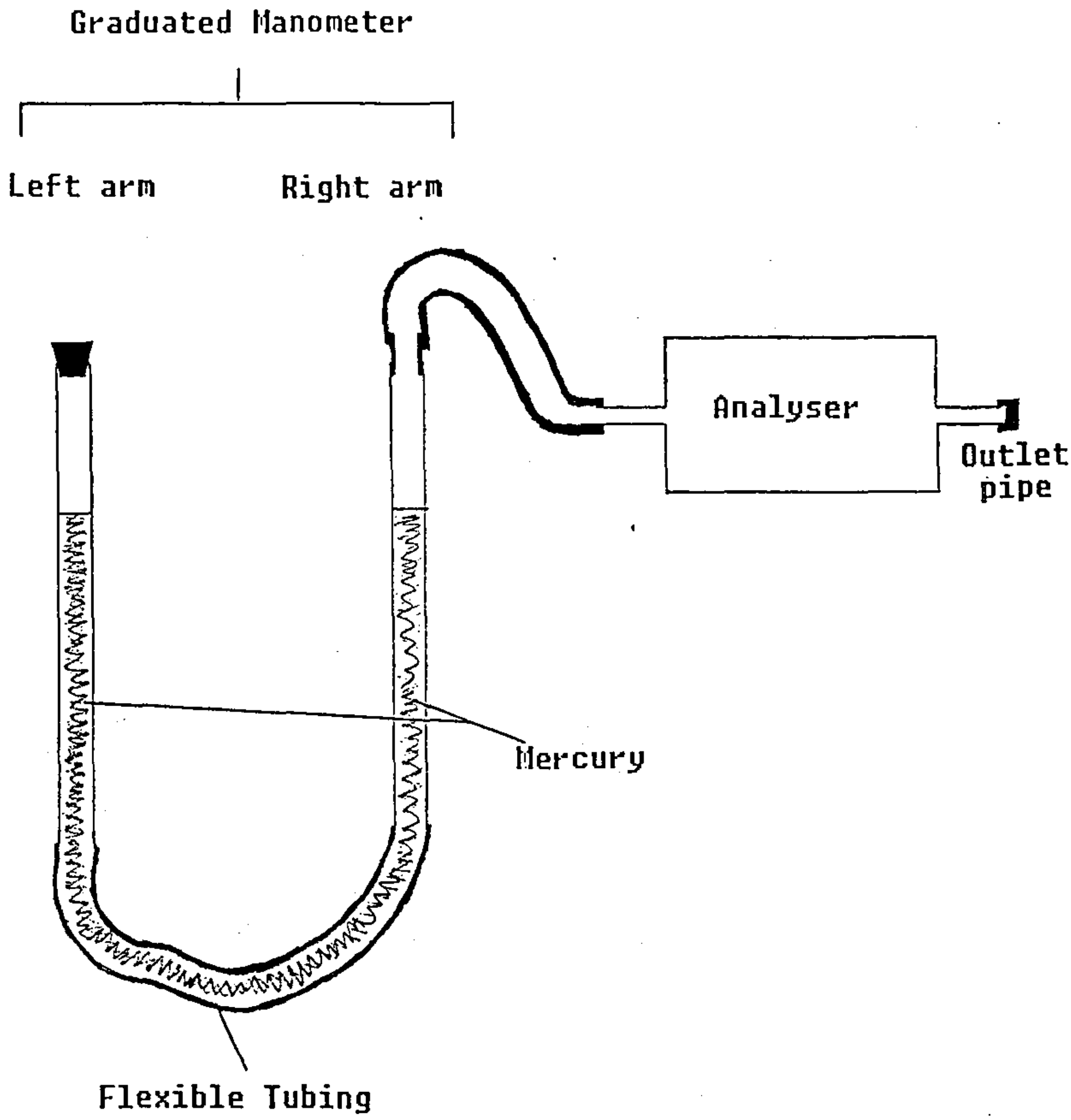

Figure D.1: Apparatus set-up for measuring oxygen at simulated altitudes.

Table D.1: Change in oxygen composition of a known gas with change in pressure.

(1)		(2)		(3)	
Pressure (mmHg)	FeO_2	Pressure (mmHg)	FeO_2	Pressure (mmHg)	FeO_2
*766.5	0.00	*766.5	0.209	*766.5	0.152
730.4	-0.01	735.3	0.208	732.8	0.151
700.2	-0.01	690.3	0.206	699.0	0.150
670.1	-0.03	661.5	0.203	641.5	0.149
				590.5	0.148

* Atmospheric pressure

Thus we can say ascending to an altitude of 1000m had a negligible effect on the calibration to zero, and therefore did not significantly affect the oxygen estimations.

APPENDIX E

Calculation of Oxygen Consumption and Energy Expenditure:

The usual way of calculating oxygen consumption ($\dot{V}o_2$) is given below,

$$\dot{V}o_2 = \dot{V}_e(STPD) \quad x \quad ([FeN_2 \times 0.265] - FeO_2) \qquad (1)$$

(Lamb, 1984)

FeN_2 is the fraction of nitrogen in the expired air and FeO_2 is the fraction of oxygen. The factor [FeN_2 x 0.265] - FeO_2 expired, is the 'true oxygen', which can be obtained from the measurement of FeO_2 and the fraction of carbon dioxide in the expired air ($FeCO_2$) collected in a Douglas bag. The V_e(STPD), is the volume of air expired per minute, corrected to standard temperature (0^oC) and pressure (760 mmHg), dry.

However, if only an oxygen analyser is available, then assumptions have to be made about the composition of the rest of the expired air. In this thesis $\dot{V}o_2$ was calculated assuming the FeN_2 to be 0.7904, the same as in the atmosphere. Thus, this method assumes that the respiratory exchange ratio, RER, is approximately 1.00. This method has been shown to produce a maximum error of 6.3% (Otis, 1964) in $\dot{V}o_2$ estimation, with figures obtained using the $FeCO_2$ aswell.

Inserting, $FeN_2 = 0.7904$ into equation 1, we get,

$$\dot{V}o_2 = \dot{V}_e(STPD) \times 0.01 \times (0.2095 - FeO_2) \qquad (2)$$

Energy Expenditure was calculated as follows,

$$RER = \frac{\text{Vol. of } CO_2 \text{ produced}}{\text{Vol. of } O_2 \text{ produced}} = \frac{FeCO_2 - 0.0003}{\text{'true } O_2\text{'}} \qquad (3)$$

Now,

$$FeCO_2 = 1 - FeN_2 - FeO_2$$

Again, assuming $FeN_2 = 0.7904$

$$FeCO_2 = 0.2096 - FeO_2 \qquad (4)$$

$$\text{'true } O_2\text{'} = (FeN_2 \times 0.265) - FeO_2$$

$$= 0.2095 - FeO_2 \qquad (5)$$

Inserting (4) and (5) into (3), we get,

$$RER = \frac{0.2096 - FeO_2}{0.2095 - FeO_2}$$

Energy Equivalent of
Expired air (En.Eqv.) $= (1.2321 \times RER) + 3.8149$

Energy Expenditure $= \dot{V}o_2 \times \text{En. Eqv.} \times 4.1855$ (KJ/min)

APPENDIX F

Oxygen Consumption Estimation Calculated in Two Ways:

In the laboratory students aged 18-21 years were asked to rest and exercise on a bicycle ergometer at various work loads to obtain a view of the method. Expired air was collected by the standard Douglas bag method. For each bag collected the fraction of oxygen (FeO_2) and carbon dioxide ($FeCO_2$) were measured, and the total volume which was then converted to standard temperature and pressure, dry. The results obtained are seen on the next page.

For each work rate the oxygen consumption, $\dot{V}o_2$, was calculated in the normal way (see Appendix D), and also assuming the percentage nitrogen expired, FeN_2, to be 0.7904. These results are seen in the last two columns of the table overpage. Statistical analysis of these two columns showed a correlation of 0.99, a standard error of estimate of 0.07, and no significant difference between the means ($p>0.05$).

Table F.1: Calculation of oxygen consumption using standard equations (see Appendix E), and assuming the fraction of nitrogen expired equals 0.7904.

Work Rate (watts)	FeO_2	$FeCO_2$	$\dot{V}_e$(STPD) (l)	$\dot{V}o_2$ (l/min)	$\dot{V}o_2$ (FeN_2-0.7904) (l/min)
0	0.159	0.045	5.47	0.28	0.28
"	0.161	0.044	7.51	0.37	0.36
"	0.160	0.046	7.85	0.40	0.39
"	0.167	0.043	10.06	0.43	0.43
100	0.157	0.052	31.86	1.68	1.67
"	0.168	0.042	33.19	1.37	1.38
"	0.152	0.058	36.94	2.12	2.12
150	0.157	0.056	46.08	2.37	2.42
"	0.157	0.053	38.76	2.03	2.03
200	0.153	0.057	51.18	2.89	2.89
"	0.158	0.052	43.02	2.21	2.21
250	0.164	0.051	58.50	2.80	2.66
300	0.150	0.057	71.09	4.27	4.23
"	0.153	0.055	68.45	3.89	3.87
"	0.161	0.034	81.38	3.84	3.94
350	0.149	0.058	78.86	4.83	4.77
"	0.152	0.054	76.56	4.47	4.40
		Means	43.93	2.25	2.36

APPENDIX G

Raw Data:

(i) Leg Anthropometric Measurements:

Legend:

Ant Thi : Anterior Thigh skinfold.

Post Thi : Posterior Thigh skinfold.

Med Calf : Medial Calf skinfold.

Lat Calf : Lateral Calf skinfold.

Glut Ht : Height of Gluteal Furrow.

Glut Cir : Circumference of leg at Gluteal Furrow.

Sub Ht : Height of one-third subischial height above knee joint space.

Sub Cir : Circumference of leg at Sub Ht.

Abov Ht : Height of minimum circumference above the knee.

Abov Cir : Minimum circumference above the knee.

Knee Ht : Height of the maximum circumference around the knee joint space.

Knee Cir : Maximum circumference around the knee joint space.

Belo Ht : Height of minimum circumference below the knee.

Belo Cir : Minimum circumference below the knee.

Calf Ht : Height of maximum circumference around calf.

Calf Cir : Maximum circumference around calf muscle.

Ankl Ht : Height of minimum circumference around ankle.

Ankl Cir : Minimum circumference around ankle.

Village	House	Ant Thi	Post Thi	Med Calf	Lat Calf	Glut Ht	Glut Cir
1	1	11.5	15.6	5.1	6.7	69.4	62.0
1	2	6.1	5.8	3.3	3.6	75.4	54.6
1	3	5.8	5.2	3.0	4.8	73.3	53.0
1	4	6.0	5.5	3.3	3.7	72.0	45.9
1	5	6.8	5.8	4.8	4.7	72.8	51.0
1	6	5.5	4.6	3.0	3.5	72.5	51.3
1	7	6.1	5.6	3.3	3.6	72.7	51.5
1	8	5.3	4.2	3.1	3.1	72.6	46.9
1	9	5.1	5.5	2.6	3.0	76.7	55.7
1	10	6.2	7.3	3.5	4.0	76.4	56.8
1	11	4.4	3.5	2.4	2.6	70.8	49.6
1	12	3.5	2.9	2.0	2.6	70.5	44.1
1	13	4.4	3.5	2.9	2.9	72.7	51.2
1	14	3.5	3.5	2.2	2.2	72.8	46.8
1	15	5.1	4.3	2.5	3.2	74.5	53.3
1	16	5.3	4.0	2.7	2.9	66.9	48.6
1	17	6.5	4.4	2.7	3.1	69.2	51.0
1	18	5.9	4.8	3.6	3.7	72.9	55.4
1	19	5.0	5.5	2.8	3.1	71.6	57.3
1	20	5.0	4.5	2.8	3.0	76.1	52.9
1	21	4.4	3.6	2.4	2.5	72.0	52.5
1	22	5.4	4.4	2.8	3.0	70.8	52.8
2	1	5.7	4.3	3.2	4.0	72.2	50.0
2	2	6.4	5.6	2.8	3.3	70.8	51.0
2	3	7.1	5.5	4.4	4.4	64.1	54.2
2	4	6.7	6.3	3.5	3.9	71.7	53.1
2	5	5.7	5.8	3.9	3.6	74.3	51.8
2	6	6.2	5.2	3.3	3.5	72.3	50.3
2	7	5.5	5.3	3.1	3.3	74.0	50.9
2	8	6.8	9.0	3.8	3.9	73.5	58.1
2	9	5.2	3.9	2.8	3.4	74.3	53.1
2	10	6.2	4.7	2.8	2.8	69.2	50.7
2	11	7.2	4.6	3.2	3.6	69.3	53.2
2	12	5.8	4.3	2.3	3.8	70.4	50.3
2	13	7.1	6.8	3.7	4.0	71.7	53.5
2	14	5.3	4.8	2.9	3.2	72.6	50.2
2	15	5.9	5.0	4.2	3.8	73.4	49.2
2	16	5.7	5.0	3.1	3.3	73.6	50.3
2	17	7.3	7.1	3.8	4.1	72.2	54.3
2	18	6.2	5.7	3.3	3.6	72.6	51.5
2	19	5.7	5.0	3.1	3.3	72.9	50.2
2	20	6.3	5.8	3.5	3.8	72.9	51.7
2	21	6.8	5.9	3.5	3.4	70.2	48.5
2	22	5.4	3.6	2.8	2.8	67.8	46.6
2	23	4.3	3.5	3.2	3.2	75.5	52.7
2	24	6.9	6.5	3.7	4.1	72.1	53.3
2	25	4.9	4.3	2.5	2.7	74.7	52.6
2	26	7.3	7.3	3.7	3.6	66.0	55.4
2	27	9.1	10.0	4.5	5.2	70.3	51.3
2	28	5.3	6.9	4.1	3.9	69.0	50.9
2	29	6.4	9.6	4.0	3.7	67.5	53.8
2	30	6.1	7.2	3.9	3.8	68.1	55.9
2	31	5.1	6.2	3.6	4.1	69.0	48.0
2	32	5.6	5.2	3.3	3.3	68.1	55.3

2	33	6.0	6.8	3.6	4.0	65.9	52.7
2	34	6.7	5.8	3.7	5.0	75.7	52.8
9	1	6.1	5.8	3.7	4.2	69.2	57.2
9	2	7.1	7.8	4.6	4.6	74.0	59.9
9	3	10.6	9.6	6.1	7.1	65.4	61.5
9	4	6.4	7.6	3.5	4.6	65.5	47.6
9	5	4.5	4.2	2.6	2.9	66.2	47.5
9	6	7.6	7.0	5.1	4.3	71.5	51.5
9	7	11.4	9.2	3.7	4.6	69.8	51.0
9	8	6.4	6.4	3.9	4.0	70.4	52.7
9	9	9.4	10.0	4.5	4.7	69.6	57.4
9	10	5.5	5.0	3.1	3.5	68.0	46.9
9	11	8.4	6.8	4.3	4.7	69.1	59.9
9	12	6.5	6.1	4.4	4.1	76.8	52.9
9	13	6.8	9.0	3.8	3.9	73.8	58.4
9	14	5.4	7.1	3.3	3.5	75.4	52.1
9	15	5.4	5.6	3.0	3.5	76.0	55.7
9	16	5.7	6.6	3.9	3.6	74.5	52.1
9	17	10.9	10.7	4.6	5.9	73.6	62.8
9	18	6.4	5.6	2.8	3.3	70.8	51.0
9	19	6.7	6.7	3.0	3.5	73.4	57.3
9	20	5.3	5.0	2.8	3.1	71.1	48.3
9	21	7.6	5.9	3.4	3.5	71.0	56.3
9	22	4.9	5.2	2.4	2.9	73.6	53.0
9	23	8.5	8.2	3.6	4.6	74.7	54.0
9	24	4.5	5.1	2.9	3.2	73.2	54.8
9	25	5.3	5.1	2.9	3.4	74.7	59.1
14	1	6.0	6.6	3.4	3.4	72.8	53.2
14	2	4.1	4.8	3.4	3.0	76.1	46.4
14	3	4.2	4.0	2.6	2.9	70.8	47.4
14	4	7.5	6.6	4.0	4.5	74.3	53.6
14	5	7.1	4.1	2.0	2.7	69.7	44.4
14	6	4.9	4.3	2.5	2.7	74.4	52.3
14	7	5.7	5.8	3.1	3.0	73.4	51.9
14	8	5.1	5.8	3.5	3.3	76.5	48.9
14	9	4.0	4.4	2.6	2.9	71.2	51.6
14	10	4.1	4.3	2.0	2.3	73.2	43.2
14	11	6.6	6.2	4.4	3.8	72.7	52.6
14	12	4.9	4.9	2.6	2.9	69.7	49.4
14	13	5.4	6.3	3.4	3.2	73.2	54.3
14	14	6.1	6.2	3.7	3.7	71.8	52.5
14	15	5.3	4.6	2.6	3.5	76.0	50.8
14	16	6.6	4.4	2.8	2.7	71.0	52.0
14	17	4.6	4.6	2.7	2.8	74.8	46.7
14	18	6.0	5.0	3.1	3.3	72.1	50.1
15	1	6.2	5.6	3.4	2.9	68.4	52.8
15	2	4.1	4.2	2.5	2.7	71.4	48.4
15	3	4.6	4.2	2.7	2.8	80.0	52.9
15	4	4.5	3.8	2.2	2.8	78.4	46.2
15	5	4.0	3.9	2.7	2.9	71.9	48.3
15	6	5.5	4.4	3.1	2.9	73.9	50.9
15	7	4.6	4.7	2.4	2.6	71.2	47.4
15	8	3.5	3.4	2.9	2.6	74.4	45.0
15	9	4.3	3.8	3.0	3.0	68.6	52.5
15	10	5.0	4.2	2.9	3.3	69.6	50.5
15	11	8.8	6.2	2.5	4.0	71.0	50.3
15	12	3.6	3.0	1.8	2.8	68.8	47.8
15	13	5.2	3.7	2.3	2.7	74.3	50.0
15	14	4.0	3.6	2.3	2.8	73.4	46.0
15	15	5.0	4.6	3.3	3.6	75.4	50.4

15	16	5.0	4.9	3.5	3.2	70.1	52.[illegible]
15	17	5.2	4.5	3.2	3.4	68.5	51.[illegible]
15	18	4.6	3.9	2.3	3.0	77.1	47.[illegible]
15	19	6.4	5.0	3.1	4.0	74.7	54.[illegible]
15	20	4.8	6.2	3.2	3.4	76.6	54.[illegible]
15	21	5.3	5.0	2.5	2.7	70.1	51.[illegible]
15	22	5.3	4.3	2.6	3.3	74.9	55.[illegible]
15	23	5.0	4.7	2.9	3.2	69.6	53.[illegible]
15	24	5.1	4.7	3.0	3.0	72.3	51.[illegible]
15	25	6.6	6.8	3.5	4.2	67.5	54.[illegible]
15	26	4.5	3.6	3.0	3.0	70.5	49.[illegible]
15	27	5.3	3.8	3.1	2.7	71.5	46.[illegible]
15	28	5.2	4.3	3.2	3.1	73.8	53.[illegible]
15	29	6.0	4.0	2.8	3.6	76.6	53.[illegible]
15	30	7.3	3.9	3.7	3.0	74.6	49.[illegible]
15	31	4.6	4.8	3.1	3.2	67.6	46.9
15	32	6.8	7.1	3.4	4.2	72.6	51.9
15	33	4.2	3.5	2.8	2.9	77.2	48.0
15	34	5.8	5.1	2.6	2.4	74.5	46.3
16	1	6.0	5.3	3.4	3.8	75.2	55.2
16	2	4.0	4.4	2.5	2.8	72.0	51.2
16	3	3.9	3.5	2.7	2.4	69.7	48.2
16	4	4.3	4.3	2.2	3.4	75.8	53.9
16	5	5.6	4.6	2.5	2.4	77.7	49.6
16	6	5.5	6.1	4.3	3.6	76.3	54.3
16	8	4.9	5.7	2.8	2.9	74.9	55.2
16	9	5.0	3.6	2.6	2.2	71.6	49.6
16	10	5.0	3.5	2.2	3.2	69.5	48.4
16	11	4.7	4.4	2.9	3.0	77.4	51.0
16	12	4.5	4.2	2.7	2.6	71.2	49.5
16	13	5.6	4.6	2.7	3.3	73.5	55.2
16	17	4.0	4.2	2.8	3.2	73.0	50.6
16	20	4.6	5.3	2.6	3.2	69.1	50.1
16	21	4.5	4.6	2.6	3.4	78.0	53.3
16	22	5.1	4.9	2.8	3.7	75.7	48.7
16	23	4.6	3.7	2.6	3.2	76.9	51.9
16	24	4.8	5.0	3.1	3.5	76.0	51.1
16	25	5.5	4.8	3.2	3.4	78.3	52.9
16	26	5.4	5.1	3.8	3.6	74.9	52.1
16	27	4.2	5.4	2.9	3.6	77.2	57.2
16	28	4.2	4.0	2.2	2.6	71.8	47.0
16	29	6.2	4.4	2.7	3.1	81.5	50.8
16	30	4.0	3.8	2.3	2.6	70.7	45.6
16	31	4.2	3.8	3.2	3.4	74.1	49.6
16	32	6.5	4.0	3.0	2.8	70.5	44.7
16	33	4.3	5.6	3.1	3.0	72.8	51.7
17	1	4.8	5.1	2.6	3.3	74.3	53.9
17	2	4.9	4.9	3.0	2.8	72.9	54.0
17	3	5.2	4.5	2.3	3.0	75.5	49.7
17	4	5.4	5.6	3.3	3.6	76.1	55.7
17	5	6.4	6.8	2.8	3.5	74.1	55.[illegible]
17	6	5.1	4.6	3.8	3.0	74.7	53.2
17	7	9.8	6.9	3.4	6.0	72.1	59.3
17	8	4.3	4.9	2.2	2.4	78.6	52.3
17	9	4.6	4.6	2.9	2.7	78.4	53.3
17	10	6.1	4.4	2.4	3.2	72.8	51.0
17	11	4.5	4.4	2.3	2.6	73.9	49.1
17	12	6.1	4.3	2.9	4.4	72.9	57.[illegible]
17	13	4.5	4.5	2.4	3.0	78.4	51.[illegible]
17	14	6.7	5.2	3.8	3.7	67.3	53.0

17	15	7.4	4.6	3.1	3.0	75.8	52.9
17	16	4.4	6.0	2.5	2.6	62.7	55.7
17	17	5.9	4.3	1.9	2.4	74.5	48.5
33	1	6.2	5.1	3.1	3.8	72.7	52.0
33	2	6.6	4.4	2.9	3.5	68.8	48.6
33	3	8.1	5.6	2.4	3.4	68.7	45.9
33	4	8.1	6.4	3.4	5.3	70.4	46.3
33	5	8.2	5.2	3.2	2.8	70.9	49.2
33	6	5.5	4.1	2.7	3.0	72.2	50.3
33	7	3.9	3.2	2.5	[illegible]	73.4	50.9
33	8	6.3	4.9	3.2	3.0	73.2	49.5
33	9	5.3	5.8	5.4	3.0	74.9	54.7
33	10	23.1	13.6	13.2	10.5	67.8	52.8
33	11	5.7	5.4	2.7	3.2	72.4	55.3
33	12	7.4	6.6	4.1	4.2	75.2	54.0
33	13	7.0	6.5	3.4	4.2	70.8	53.7
33	14	7.9	5.4	4.0	3.9	75.3	55.1
33	15	4.3	3.7	2.1	2.7	67.3	49.8
33	16	6.4	4.7	2.3	2.4	75.5	49.7
33	17	7.3	5.0	4.0	4.0	70.5	48.4
33	18	5.3	4.9	3.9	3.6	75.6	47.2
33	19	6.1	3.4	2.8	3.7	74.1	47.5
33	20	6.0	4.8	2.1	2.5	72.3	44.7
33	21	6.1	4.7	3.1	3.5	71.6	48.5
33	22	5.3	5.1	2.9	3.1	73.8	50.7
84	1	5.6	6.2	3.2	3.2	75.1	49.2
84	2	8.3	10.6	4.0	3.5	72.0	57.1
84	3	6.5	9.0	4.0	4.1	71.1	54.5
84	4	18.0	9.9	7.2	12.0	72.4	63.2
84	5	7.2	6.1	3.4	3.7	72.9	52.2
84	6	7.2	11.8	3.7	4.2	78.1	60.5
84	7	10.6	7.7	3.4	6.5	71.4	57.6
84	8	7.0	6.3	3.6	2.5	75.4	58.8
84	9	6.3	5.7	3.5	4.4	71.7	54.2
84	10	9.8	8.6	3.4	3.7	69.1	57.1
84	11	10.3	8.0	6.7	6.2	68.8	59.6
84	12	8.2	6.3	4.3	3.8	74.1	55.0
84	13	8.9	6.3	4.4	4.1	72.4	56.3
84	14	8.0	5.6	3.7	3.1	70.6	55.1
84	15	7.7	6.9	3.9	4.5	72.9	60.1
84	16	6.1	5.1	3.0	3.4	71.8	55.2
84	17	7.6	6.0	4.9	3.2	71.0	51.0
84	18	6.0	7.3	3.9	4.6	72.6	55.4
84	19	5.3	4.4	2.6	3.1	69.5	52.2
84	20	10.6	10.9	3.9	3.9	68.9	61.1
84	21	6.5	4.2	3.0	3.3	76.1	52.9
84	22	7.9	9.2	3.9	4.0	70.1	56.7
84	23	6.5	6.9	4.3	4.1	77.2	56.7
84	24	8.6	7.8	4.6	5.1	75.4	60.1
84	25	9.0	7.8	4.4	4.4	71.6	56.4
84	26	10.1	8.8	3.6	5.0	75.2	53.4
84	27	6.8	5.3	4.3	3.6	72.0	56.5
84	28	6.0	7.8	4.4	4.1	71.4	48.8
84	29	6.0	7.4	3.9	4.2	79.0	55.2
84	30	4.7	5.0	2.8	3.5	72.0	55.2
84	31	4.6	6.5	2.6	3.2	72.9	56.7
84	32	12.2	9.8	3.0	3.8	75.6	61.7
84	33	7.4	7.6	4.2	4.3	70.9	58.0
99	1	6.8	5.7	4.4	4.2	71.6	52.1

Sub Ht	Sub Cir	Abov Ht	Abov Cir	Knee Ht	Knee Cir	Belo Ht	Belo Cir
61.5	54.7	45.7	40.2	41.4	35.4	32.7	32.7
69.0	52.1	51.6	35.0	46.6	34.2	42.7	31.3
67.8	47.6	48.2	32.5	44.9	33.9	40.8	31.9
66.1	43.9	48.[illegible]	30.3	44.5	32.2	39.8	27.4
68.6	47.3	50.5	35.1	47.2	34.8	43.9	32.3
69.2	49.8	50.9	31.5	46.7	32.4	41.0	28.6
66.3	48.4	49.8	33.3	45.9	33.0	41.4	30.1
65.1	46.1	49.6	31.7	45.8	33.4	42.0	32.2
69.7	53.5	51.1	35.4	46.6	34.8	42.1	32.0
69.7	53.3	53.5	35.6	51.3	35.0	47.2	32.0
63.0	45.3	48.7	30.5	44.3	31.4	40.1	28.6
54.2	41.8	48.1	30.0	44.7	31.3	40.5	27.9
66.4	48.1	51.7	33.5	47.8	33.6	43.6	29.5
68.8	46.9	51.4	31.4	47.1	32.9	42.9	29.1
68.4	52.3	50.8	36.1	45.2	35.1	41.3	32.2
62.4	45.7	46.2	30.4	42.7	30.0	38.3	27.4
66.1	49.3	49.1	32.4	46.0	32.0	40.7	28.2
68.2	52.7	49.9	34.6	46.4	34.4	42.5	30.0
65.2	54.5	48.0	36.2	45.4	35.3	41.1	31.7
69.0	50.8	53.4	34.3	50.1	34.4	44.9	30.2
66.6	49.9	49.2	31.8	46.3	32.1	41.1	29.7
63.0	48.0	50.5	33.5	47.2	32.5	42.7	30.1
67.6	47.4	48.4	32.2	44.7	33.0	39.8	27.8
65.5	49.6	47.4	33.4	44.9	33.6	40.2	31.2
59.3	46.1	44.5	33.5	41.0	32.9	37.1	28.7
65.4	49.9	48.9	34.2	15.3	33.5	41.0	30.5
65.4	47.0	46.9	32.4	44.2	32.0	40.7	28.9
67.0	47.6	49.7	32.9	45.7	32.4	41.1	29.6
66.8	47.7	50.6	32.7	46.7	33.1	42.1	30.1
66.7	56.2	49.3	37.6	46.9	36.3	42.3	33.1
70.0	49.0	52.0	34.8	48.1	35.2	43.1	30.3
63.5	47.5	47.4	34.0	44.1	34.1	39.9	29.5
63.8	47.8	45.7	32.4	41.3	32.9	36.9	28.6
67.0	49.4	48.1	33.3	43.9	33.9	39.7	28.0
65.6	50.5	48.9	34.8	45.3	33.9	40.9	30.9
67.1	47.2	50.4	32.3	46.7	32.2	42.1	29.3
68.9	48.1	49.5	34.6	46.4	34.9	41.3	31.4
66.6	47.2	50.2	32.4	46.0	32.7	41.3	29.7
65.9	51.4	49.2	35.3	45.7	34.2	41.2	31.3
66.4	48.6	49.7	33.4	45.9	33.1	41.4	30.1
66.5	47.2	50.0	32.4	46.0	32.5	41.5	29.5
66.5	48.6	50.0	33.5	46.1	33.2	41.6	30.3
64.2	44.9	48.4	33.1	44.4	31.9	40.3	30.4
61.9	45.7	47.8	31.2	43.2	31.4	38.8	28.1
69.8	48.9	52.6	34.1	48.7	34.7	43.7	31.0
65.6	50.1	49.1	34.4	45.5	33.7	41.2	30.7
67.7	49.2	52.3	35.8	46.5	36.1	42.4	30.9
52.4	52.2	46.4	36.9	42.4	33.9	38.7	30.2
65.3	49.2	47.6	34.9	44.6	34.1	41.0	30.1
63.2	48.4	46.5	34.3	43.2	34.2	38.9	30.5
61.4	51.6	47.5	37.3	44.3	36.4	40.2	33.5
63.3	55.6	44.6	36.9	42.4	34.9	38.8	31.3
63.4	48.2	45.6	34.7	42.6	33.9	39.1	29.5
63.2	54.8	46.2	36.5	43.7	31.1	39.4	31.7
61.1	49.7	48.3	35.3	45.5	34.2	40.6	30.1
67.9	49.9	51.7	33.0	48.5	32.9	43.7	30.6
64.5	54.6	49.9	39.9	46.0	36.9	42.0	31.4
61.8	51.3	52.1	36.1	48.7	36.5	46.2	34.5

59.1	57.1	44.4	39.4	40.1	39.0	35.6	35.1
56.4	41.1	47.4	32.6	33.7	33.6	38.4	29.5
60.3	41.4	44.6	32.3	42.1	31.3	37.7	28.0
65.6	47.0	50.1	35.9	46.2	35.0	44.2	34.1
65.3	49.6	46.1	33.7	42.7	32.9	37.9	28.9
65.1	52.5	47.1	36.6	43.7	35.7	39.4	32.6
66.0	56.7	47.9	38.3	44.4	36.4	40.8	33.4
65.9	46.6	47.7	32.7	44.2	32.3	40.2	28.4
65.1	58.1	47.4	39.7	44.3	36.4	41.0	34.1
68.0	50.3	51.9	36.9	47.9	38.6	42.5	35.2
67.0	56.5	49.6	37.9	47.2	36.6	42.5	33.4
69.9	51.7	48.6	35.0	45.2	33.7	41.9	31.4
68.2	52.3	53.2	35.8	50.3	45.3	46.2	33.4
65.7	47.3	47.2	32.7	44.5	32.3	41.0	29.2
65.9	60.0	47.8	40.4	44.7	37.9	39.8	34.0
65.5	49.6	47.4	33.4	44.9	33.6	40.2	31.2
67.3	53.3	48.8	43.7	43.3	31.6	41.5	30.0
65.1	23.6	45.7	31.5	42.3	30.1	37.8	27.9
63.4	51.2	48.6	35.4	45.4	34.4	40.7	30.8
66.0	48.0	49.5	31.5	46.0	31.6	41.5	27.8
67.1	50.9	49.6	35.3	47.0	33.1	41.6	30.7
65.0	51.1	47.2	33.5	43.9	33.7	39.8	30.2
68.3	55.6	49.5	35.7	46.6	35.0	42.5	32.2
68.8	50.3	47.7	31.8	44.2	33.7	40.1	31.7
68.7	43.6	51.3	31.0	47.8	31.3	41.9	28.3
52.3	44.6	48.5	31.5	46.4	31.7	40.9	29.4
69.7	51.6	49.9	34.7	46.6	36.7	41.6	32.2
58.7	35.2	46.8	28.0	42.8	30.2	38.5	25.9
67.4	48.9	52.0	35.5	46.2	35.8	42.1	30.6
65.0	48.8	52.4	33.2	47.1	33.5	42.7	30.3
59.9	46.4	44.4	31.5	41.0	30.4	36.5	27.9
65.7	47.6	49.6	33.3	45.2	34.0	40.4	30.4
67.4	38.2	51.3	29.1	46.5	32.4	41.5	28.3
66.1	49.9	47.6	36.1	44.8	34.8	40.4	32.4
52.3	47.0	44.8	31.5	40.1	30.9	36.4	28.3
65.9	52.3	50.2	35.8	45.5	35.5	42.5	33.0
63.8	49.1	48.5	33.4	45.4	35.7	40.4	31.2
68.2	48.7	51.9	35.8	47.0	36.9	43.1	32.3
64.9	47.0	47.8	35.2	42.4	34.0	37.7	30.5
67.6	46.2	50.2	31.7	46.3	33.5	42.3	29.2
66.8	47.4	49.5	32.7	45.5	32.2	40.9	29.4
65.6	49.7	49.5	32.6	47.3	32.0	44.4	29.7
66.1	45.7	49.2	30.5	45.3	30.9	41.2	27.5
74.3	50.4	56.4	32.9	52.1	32.4	47.9	31.2
71.8	44.1	54.2	29.4	50.0	31.7	45.3	28.5
68.9	46.4	49.6	30.0	46.9	30.5	43.3	29.3
68.4	48.5	52.6	34.1	48.7	35.3	45.2	33.4
67.2	46.4	48.2	30.0	45.2	30.8	41.9	27.6
66.9	41.3	51.6	30.1	47.4	31.9	43.3	27.9
62.9	48.8	46.9	33.3	43.6	32.8	39.5	29.2
65.8	46.6	49.9	31.8	45.3	32.3	41.0	29.6
65.7	43.6	47.3	30.6	42.3	30.5	39.7	27.1
64.6	42.4	48.2	29.0	44.3	30.4	40.4	26.6
66.6	45.4	49.4	31.2	46.5	32.8	41.1	28.1
69.9	44.8	51.0	29.3	47.6	31.0	42.3	28.0
70.3	49.4	53.4	35.3	49.8	36.3	43.0	30.5
67.7	51.9	47.4	53.6	45.4	33.6	40.2	30.4
61.3	47.5	48.0	35.2	45.7	35.1	41.0	33.0
69.2	43.4	52.8	28.2	47.1	30.3	42.9	27.6
69.8	51.7	53.7	33.5	50.4	34.4	44.9	30.9

70.4	52.0	53.4	35.6	47.9	34.1	43.6	31.[illegible]
66.0	48.7	47.8	33.3	44.7	32.7	39.1	29.0
70.3	53.9	54.1	38.1	49.3	37.2	43.6	32.[illegible]
63.0	48.9	51.8	34.4	46.7	33.3	42.1	30.5
70.1	50.4	52.0	34.8	48.3	33.4	43.8	30.[illegible]
65.5	52.8	47.0	34.5	44.6	34.4	40.5	31.[illegible]
65.1	46.6	46.7	31.1	44.3	32.0	39.7	28.5
67.1	42.9	52.4	31.4	48.2	31.6	43.9	28.7
69.7	51.8	50.5	35.4	47.2	35.2	42.6	31.[illegible]
72.8	47.7	55.8	32.3	50.1	33.2	44.9	30.6
70.1	45.9	52.7	32.0	48.1	33.5	43.8	29.7
63.5	45.8	47.2	31.4	44.6	31.6	41.2	28.5
67.1	49.6	50.5	33.1	47.2	33.2	42.7	29.8
71.0	41.0	52.8	29.7	48.3	33.0	42.8	28.6
70.0	42.2	51.9	28.3	47.6	30.9	43.0	27.5
67.2	52.3	49.7	33.2	46.0	33.1	41.6	29.9
63.5	46.5	48.1	33.0	44.2	32.6	40.1	29.3
54.2	43.6	45.7	29.9	41.9	30.8	37.5	26.8
67.6	47.3	53.5	31.5	48.7	31.5	44.2	28.0
72.0	46.2	55.3	31.9	50.0	33.1	45.4	29.0
69.4	47.4	51.3	33.3	47.1	35.2	42.7	30.6
71.3	51.9	54.2	37.3	51.3	37.3	45.8	34.0
65.2	45.3	46.8	29.4	43.4	32.0	39.7	29.1
67.2	47.5	49.0	31.7	45.5	32.4	40.8	29.0
69.9	49.1	50.7	32.2	47.5	33.2	41.9	29.2
66.3	47.2	52.3	35.0	47.4	35.4	42.4	31.0
68.2	51.1	49.2	36.7	44.9	34.9	40.7	31.0
67.5	48.3	49.9	31.3	46.1	32.1	42.3	29.4
62.5	47.5	47.2	32.0	43.0	31.5	38.3	29.2
72.6	51.2	52.9	33.0	48.9	34.0	43.5	30.8
69.9	44.7	54.3	33.0	48.8	35.2	43.7	28.8
70.8	48.1	51.2	34.0	48.3	34.2	44.0	31.7
71.6	48.2	50.5	33.1	46.7	33.0	42.2	29.8
67.6	44.7	55.5	33.0	50.6	34.6	45.4	31.2
67.5	47.2	50.7	31.2	46.7	31.2	42.1	28.7
68.9	54.2	50.2	35.5	47.0	35.0	42.6	31.8
64.2	42.0	49.0	29.6	44.3	30.0	41.0	27.4
75.2	47.6	56.6	32.0	50.2	33.4	45.4	30.1
54.2	41.6	48.2	28.3	43.2	31.8	37.7	26.8
69.0	47.4	49.0	30.6	44.8	31.3	40.5	28.9
68.5	43.6	50.5	28.0	45.4	30.4	40.4	27.5
65.8	46.9	48.9	32.4	45.3	32.9	41.5	29.4
65.9	50.2	53.9	33.5	45.8	35.0	41.5	31.5
66.7	52.4	50.2	35.5	46.4	34.6	40.4	31.6
58.0	46.1	52.0	32.1	48.1	34.2	43.6	29.7
68.7	51.2	53.8	38.7	49.1	38.0	43.9	34.8
69.0	54.5	51.5	37.4	49.1	36.4	45.5	34.5
68.7	51.6	52.2	35.8	47.5	32.6	42.6	30.3
65.4	55.2	51.8	39.0	47.9	36.9	41.3	33.3
71.6	48.7	54.4	33.6	51.2	34.8	45.4	30.0
71.6	50.4	53.9	34.0	49.0	33.9	44.4	31.1
70.3	47.6	52.2	30.7	47.1	32.5	41.6	30.3
69.5	48.5	51.8	34.3	48.2	34.2	43.3	29.8
66.3	52.9	50.0	36.6	47.6	36.1	43.5	31.6
73.5	50.4	54.0	34.8	50.0	34.5	46.4	31.0
52.6	48.5	45.4	34.6	41.2	34.3	36.4	28.9
73.2	52.9	54.6	33.9	51.9	35.1	47.2	33.7
73.7	54.2	55.4	35.3	52.3	36.7	47.1	31.1
70.0	43.0	53.8	29.5	49.5	31.2	44.5	26.8
67.2	48.1	49.3	32.1	46.3	32.8	31.6	29.2

65.6	47.2	47.0	32.6	43.5	32.2	38.4	28.8
63.6	45.5	47.1	32.0	42.3	31.5	38.5	27.7
65.3	45.8	49.9	32.6	45.3	31.5	40.9	29.5
65.2	46.2	47.3	31.5	43.6	30.5	39.0	28.5
67.3	49.4	43.2	35.7	39.4	32.1	32.5	36.0
70.6	49.3	53.4	33.5	48.5	31.9	44.4	29.8
68.9	48.5	49.4	34.3	44.2	34.1	46.4	34.9
68.0	51.5	50.1	37.5	46.6	36.0	41.2	31.2
62.6	50.0	49.8	39.6	42.9	35.4	38.0	33.0
65.9	52.1	49.4	34.0	43.6	32.4	39.7	28.5
66.2	52.4	49.1	35.3	44.1	35.3	40.0	30.9
65.8	51.9	46.5	35.7	44.1	35.7	39.8	32.4
70.0	53.2	50.6	36.7	46.4	35.5	41.3	31.7
60.0	46.6	44.0	31.4	40.2	31.2	36.5	26.6
67.6	45.6	49.2	31.0	44.5	32.0	40.6	28.6
64.6	45.1	46.4	30.9	42.9	31.8	37.7	28.9
68.7	44.9	51.6	34.1	47.6	35.0	43.7	31.4
67.5	43.8	49.5	32.9	45.3	32.9	41.2	29.5
67.5	39.2	49.7	29.2	43.6	31.0	39.0	27.3
66.2	46.5	46.7	32.0	42.3	32.2	37.2	28.1
66.6	47.5	50.4	32.5	46.5	32.9	41.9	29.9
71.0	48.0	55.3	35.3	52.2	34.9	46.6	31.2
68.6	56.3	49.6	38.0	47.0	36.8	42.3	33.2
67.9	53.0	50.7	36.6	46.9	35.8	42.2	31.0
69.1	59.7	51.7	40.5	47.7	38.7	42.5	35.3
69.2	48.4	50.2	35.0	46.2	33.2	40.9	28.9
71.3	56.0	49.9	34.5	45.8	33.4	43.3	30.2
54.5	51.9	47.3	35.8	43.1	32.9	39.7	30.7
67.5	54.4	49.9	37.2	47.3	36.2	41.3	33.6
66.9	52.2	50.5	36.5	46.4	35.6	41.4	31.6
61.2	54.2	49.5	34.5	47.4	33.6	40.8	31.6
64.2	57.6	46.6	41.9	43.4	39.0	37.6	34.1
66.1	51.0	49.0	36.0	46.7	35.2	41.9	31.7
68.5	52.0	50.0	36.2	45.7	35.3	40.5	31.8
64.5	53.6	45.1	35.5	42.5	32.8	39.1	32.2
66.0	58.1	47.8	38.8	46.5	38.2	42.0	33.9
66.1	50.9	46.7	33.0	43.6	33.1	38.4	30.0
66.5	50.9	50.3	37.1	46.0	35.2	41.9	32.0
69.8	54.3	51.2	38.2	46.8	37.7	42.4	32.7
54.1	50.7	47.7	34.2	44.4	34.0	39.3	30.8
63.6	58.4	47.5	41.5	43.5	38.1	39.0	33.3
72.1	50.6	53.6	35.3	44.4	34.3	32.9	30.7
68.4	54.7	47.4	36.3	43.6	34.8	40.1	32.3
71.3	55.9	52.4	37.3	48.8	37.9	44.2	33.8
69.5	55.8	49.8	40.5	47.3	39.5	43.5	37.2
54.5	53.8	46.1	36.1	43.8	34.7	39.6	31.7
69.2	50.0	55.3	34.6	52.6	35.3	47.1	31.7
68.5	53.3	49.4	35.1	44.9	32.9	41.0	30.0
66.4	47.7	50.8	34.2	46.1	35.2	41.9	30.4
73.6	53.9	53.2	36.8	48.6	35.0	43.4	32.4
65.5	51.1	49.5	34.5	46.0	33.2	42.2	31.6
67.0	53.7	49.0	36.6	44.0	34.9	40.7	31.6
70.8	65.9	53.2	40.0	49.9	38.5	44.7	33.7
68.2	56.0	50.2	41.0	47.5	40.2	43.0	36.5
65.9	49.4	50.7	33.6	47.0	34.1	43.0	31.5

Calf Ht	Calf Cir	Ankl Ht	Ankl Cir
29.0	38.2	7.6	22.1
34.0	38.1	11.0	24.3
30.5	32.3	9.4	22.5
30.4	31.6	8.7	20.0
31.4	35.0	9.9	21.3
35.2	34.7	10.1	20.7
32.0	34.1	10.0	21.1
32.1	33.1	10.0	20.8
34.9	38.3	11.7	23.9
35.4	39.6	11.1	22.7
32.2	33.1	10.8	19.8
31.2	30.1	9.5	19.7
31.7	34.0	10.7	20.1
31.8	33.6	10.9	20.9
32.9	38.5	11.2	21.3
31.0	30.7	8.7	19.4
32.8	34.8	10.7	21.1
32.9	34.6	10.5	21.6
31.9	38.2	10.8	21.5
34.5	34.2	10.3	22.1
33.7	33.7	10.4	20.1
33.9	35.9	9.6	20.9
30.4	32.4	9.1	20.7
30.3	34.9	9.5	21.3
26.4	32.8	8.7	22.1
31.5	35.3	9.6	21.8
31.1	33.1	9.6	21.3
31.8	33.0	10.2	20.3
32.7	33.9	10.1	21.1
32.4	41.0	9.0	24.7
33.2	35.8	9.8	23.2
30.2	32.5	10.0	21.9
29.3	30.7	9.6	20.4
30.2	32.4	8.3	21.6
31.4	35.5	9.5	22.3
32.9	33.2	10.5	20.5
32.7	31.2	8.5	22.5
32.0	33.3	10.2	20.5
31.7	36.1	9.6	22.4
32.0	34.2	10.0	21.2
32.1	33.3	10.2	20.6
32.2	34.3	10.2	21.3
30.3	33.7	9.9	20.3
29.2	29.8	9.6	20.4
32.2	36.3	10.1	21.4
31.7	35.5	9.8	22.0
33.9	35.8	10.5	20.9
29.4	34.6	9.8	20.2
32.6	32.5	7.8	24.1
29.7	33.1	8.1	23.5
32.4	37.6	9.5	24.2
27.3	37.0	8.3	26.6
30.2	32.0	8.3	23.7
31.9	37.2	9.1	23.1
29.5	35.0	8.0	24.1
32.6	34.6	10.1	23.8
35.1	39.2	9.4	25.9
32.8	40.6	9.6	26.1
28.5	39.2	8.5	24.3
28.8	33.2	9.5	21.9
28.8	34.9	8.7	21.8
32.0	34.3	9.3	24.8

28.6	30.4	7.6	22.0
30.3	37.4	8.4	23.0
33.9	37.9	9.2	23.7
29.4	33.9	8.2	24.0
32.8	39.2	9.1	26.2
35.4	37.0	10.3	24.6
32.7	41.3	9.3	25.0
31.7	36.4	9.3	23.8
34.5	36.7	8.6	25.2
31.4	33.4	9.9	21.6
32.4	39.3	9.1	23.7
30.3	34.9	9.5	21.3
31.5	37.1	8.2	22.5
28.4	32.9	9.3	20.1
31.0	37.9	9.2	24.4
29.2	33.1	9.2	19.4
30.8	37.0	8.8	21.5
30.0	36.7	8.3	23.6
32.1	39.4	10.2	21.7
31.4	36.8	10.8	20.9
32.7	31.6	10.4	19.6
29.7	34.9	9.3	19.5
32.9	34.0	9.4	22.1
28.9	28.0	10.2	18.4
33.6	35.5	10.2	20.6
32.7	35.5	10.1	20.0
30.1	33.8	9.6	19.8
30.7	36.4	11.0	21.3
33.4	29.9	9.6	19.5
32.1	36.4	9.7	22.0
28.3	34.3	9.9	19.3
33.3	39.3	11.1	22.9
31.7	36.0	9.6	21.7
34.9	37.4	10.6	22.6
29.9	35.6	10.7	21.2
32.5	34.4	10.0	21.3
31.6	32.8	10.0	20.1
32.7	33.1	10.2	20.6
33.1	33.5	11.9	20.2
34.1	34.8	11.3	21.8
35.8	31.6	11.6	19.2
32.3	33.0	10.0	19.7
33.6	36.0	10.6	21.8
31.9	30.2	10.0	19.2
33.5	29.7	10.1	20.4
30.1	35.3	9.8	21.0
31.9	33.8	10.3	19.9
31.2	29.6	10.9	19.0
31.1	29.6	9.8	17.9
32.6	31.5	10.4	21.1
33.0	31.6	11.4	19.4
36.4	34.5	10.9	23.9
31.4	35.2	9.8	21.4
31.2	33.1	11.0	23.6
33.7	31.1	9.9	19.4
35.8	34.7	10.6	19.8
32.8	37.1	9.9	22.4
31.8	34.9	10.7	21.8
34.1	38.0	11.3	22.9
33.4	35.1	10.6	19.9

32.5	32.2	10.4	21.2
33.7	34.7	8.7	22.4
31.4	33.1	9.8	20.2
32.4	30.6	10.3	19.2
33.6	34.7	11.7	21.4
35.2	32.1	11.9	21.1
36.2	30.7	12.0	21.5
31.6	33.3	10.1	20.3
33.5	34.2	10.7	21.1
34.5	29.2	11.2	19.8
33.7	29.2	11.6	18.8
33.9	34.0	10.5	20.9
31.6	34.5	9.7	20.5
28.2	29.2	9.9	18.8
30.0	34.3	11.0	21.5
34.6	33.3	11.1	20.5
32.1	35.2	9.3	22.2
36.1	37.6	11.3	22.5
38.0	29.7	10.6	19.1
31.2	32.3	9.6	20.0
30.7	34.7	10.9	20.4
33.6	35.0	11.4	22.1
31.4	35.5	10.9	22.3
33.6	34.4	10.1	20.4
29.3	35.2	9.8	20.4
35.0	34.8	9.2	22.5
34.6	30.2	11.1	22.0
34.5	35.0	9.8	23.5
32.0	34.6	10.5	20.9
37.1	33.5	10.5	22.6
31.5	33.0	9.2	20.2
33.1	36.8	8.6	24.2
29.9	31.0	10.5	20.0
35.7	33.2	10.3	23.1
29.9	28.6	10.3	19.3
31.7	30.7	10.6	19.2
30.8	29.2	9.9	20.3
31.3	31.5	9.1	20.9
32.5	34.5	10.0	20.1
31.4	36.5	11.1	21.3
32.5	31.6	10.9	21.8
34.5	36.6	12.5	21.9
33.3	36.6	10.5	22.3
35.2	34.7	10.0	20.1
33.4	37.3	10.0	21.8
34.4	32.1	9.5	21.5
33.2	35.6	10.6	22.7
33.6	33.9	11.0	19.5
30.5	34.4	11.2	21.5
31.2	37.6	10.8	23.9
34.2	37.3	11.0	21.7
30.1	32.2	9.8	20.0
35.8	35.5	10.6	20.1
36.8	37.0	10.5	23.1
33.1	30.3	10.3	18.6
21.6	31.4	9.2	20.1
31.3	30.7	10.6	19.0
30.2	30.5	10.8	19.3
31.1	32.5	11.3	19.4
32.6	33.4	9.5	19.9

10.7	22.0	9.9	21.3
34.4	34.5	9.9	21.3
32.5	35.2	9.7	21.0
33.9	35.6	9.9	22.4
31.2	36.0	10.1	23.4
31.4	34.3	9.1	20.6
33.1	35.1	10.2	21.6
32.0	35.6	8.3	21.2
31.4	38.5	10.5	21.4
27.8	32.1	9.8	18.7
30.7	32.1	9.8	19.4
30.6	32.2	7.6	21.2
33.9	31.9	9.8	20.3
33.2	31.2	10.4	20.3
30.5	28.9	9.6	19.8
31.1	32.2	10.1	20.3
32.5	33.7	9.9	20.9
36.2	34.2	10.1	24.4
30.2	39.1	10.3	24.4
31.7	34.5	9.5	23.4
33.2	41.9	10.2	24.0
31.9	32.3	9.9	21.2
33.9	34.6	9.7	20.4
31.2	36.1	9.3	22.2
28.6	36.5	10.5	21.3
33.8	35.1	9.6	21.1
32.5	36.0	10.8	20.4
29.7	40.3	9.9	23.5
32.7	37.1	9.7	22.6
31.8	37.0	10.5	21.3
29.6	38.0	9.0	22.0
33.6	40.0	10.6	21.5
30.2	36.5	9.5	20.9
32.2	37.1	10.6	20.7
33.9	38.0	11.3	21.5
28.9	35.5	9.6	20.7
31.4	39.2	8.5	24.2
19.9	34.0	9.7	21.0
31.2	36.0	9.8	21.7
34.6	38.7	10.5	24.5
34.1	39.2	9.3	35.1
31.3	37.1	8.7	21.8
36.8	36.1	9.7	22.6
33.5	34.5	9.6	20.3
32.9	34.3	10.3	21.8
34.2	37.4	10.2	22.8
32.7	37.2	9.8	23.1
30.6	38.1	8.9	24.0
33.6	42.5	12.6	22.7
34.1	35.4	10.0	24.2
31.2	35.4	9.9	21.2

(ii) Exercise Test Measurements:

Legend:

Work	:	Work rate (ascents per minute).
Fh	:	Heart rate (beats/min).
$\dot{V}_e$	:	Ventilation rate (l/min).
$\dot{V}o_2$	:	Oxygen consumption (l/min).
EEKJ	:	Energy expunditure (kilojoules per minute).
1,2,3,4	:	Successive work loads, i.e., first, second, etc.

Village	House	Work-1	Eh-1	Ve-1	Vo2-1	EE(J)-1	Work-2	Eh-2
1	1	*	*	*	*	*	*	*
1	2	15	100	18.5	0.78	16.462	18	11[illegible]
1	3	15	104	32.7	1.25	26.379	18	120
1	4	*	*	*	*	*	*	*
1	5	*	*	*	*	*	*	*
1	6	*	*	*	*	*	*	*
1	7	*	*	*	*	*	*	*
1	8	14	112	34.7	1.07	22.575	16	136
1	9	15	116	39.6	1.67	35.245	17	128
1	10	15	100	36.5	1.22	25.742	18	112
1	11	14	96	24.3	0.76	16.035	16	120
1	12	*	*	*	*	*	*	*
1	13	15	96	34.5	1.00	21.096	18	112
1	14	15	96	34.2	1.12	23.632	18	104
1	15	15	96	30.4	1.28	27.014	18	116
1	16	14	108	24.9	0.85	17.936	16	120
1	17	15	96	35.7	1.19	25.109	17	116
1	18	15	92	31.6	0.96	20.254	18	108
1	19	15	96	35.1	1.50	31.658	18	112
1	20	15	100	31.9	1.31	27.647	18	112
1	21	15	96	32.6	0.96	20.253	18	112
1	22	15	100	31.6	1.31	27.647	17	112
2	1	14	108	26.9	1.08	22.771	15	116
2	2	15	84	14.6	0.36	7.530	17	112
2	3	*	*	*	*	*	*	*
2	4	*	*	*	*	*	*	*
2	5	15	108	23.7	0.90	19.014	17	124
2	6	*	*	*	*	*	*	*
2	7	*	*	*	*	*	*	*
2	8	15	92	20.3	0.82	17.242	17	108
2	9	15	92	28.3	1.09	23.045	17	104
2	10	*	*	*	*	*	*	*
2	11	*	*	*	*	*	*	*
2	12	*	*	*	*	*	*	*
2	13	*	*	*	*	*	*	*
2	14	*	*	*	*	*	*	*
2	15	*	*	*	*	*	*	*
2	16	*	*	*	*	*	*	*
2	17	*	*	*	*	*	*	*
2	18	15	105	29.7	1.12	23.607	17	122
2	19	*	*	*	*	*	*	*
2	20	*	*	*	*	*	*	*
2	21	*	*	*	*	*	*	*
2	22	*	*	*	*	*	*	*
2	23	*	*	*	*	*	*	*
2	24	*	*	*	*	*	*	*
2	25	*	*	*	*	*	*	*
2	26	*	*	*	*	*	*	*
2	27	15	96	17.6	0.72	15.132	18	112
2	28	*	*	*	*	*	*	*
2	29	15	108	25.9	0.97	20.427	17	122
2	30	*	*	*	*	*	*	*

2	31	*	*	*	*	*	*	
2	32	15	96	17.9	0.53	11.139	17	[illegible]
2	33	15	108	16.0	0.75	15.830	16	[illegible]
2	34	*	*	*	*	*	*	
9	1	15	108	21.7	0.93	19.670	17	[illegible]
9	2	*	*	*	*	*	*	
9	3	*	*	*	*	*	*	
9	4	*	*	*	*	*	*	
9	5	*	*	*	*	*	*	
9	6	*	*	*	*	*	*	
9	7	*	*	*	*	*	*	
9	8	*	*	*	*	*	*	
9	9	15	96	23.5	0.92	19.436	17	11[illegible]
9	10	15	104	14.1	0.56	11.776	16	1[illegible]
9	11	*	*	*	*	*	*	*
9	12	15	108	24.2	1.06	21.105	17	11[illegible]
9	13	15	108	26.2	0.91	19.139	16	12[illegible]
9	14	*	*	*	*	*	*	
9	15	*	*	*	*	*	*	*
9	16	15	104	20.4	0.96	20.178	17	112
9	17	15	120	33.2	1.24	26.104	17	136
9	18	15	112	24.6	1.04	21.886	17	13[illegible]
9	19	15	120	39.9	1.86	39.238	17	132
9	20	15	72	23.6	1.03	22.014	18	9[illegible]
9	21	15	108	28.1	0.87	18.440	18	124
9	22	*	*	*	*	*	*	*
9	23	15	120	28.1	0.91	19.200	17	132
9	24	15	104	25.9	1.06	22.455	18	11[illegible]
9	25	*	*	*	*	*	*	*
14	1	15	84	29.7	1.59	33.564	18	1[illegible]
14	2	15	84	11.6	0.46	9.708	16	1[illegible]
14	3	15	108	29.6	1.36	28.705	17	14[illegible]
14	4	15	116	20.2	0.95	20.052	17	14[illegible]
14	5	13	120	32.0	0.94	19.831	15	13[illegible]
14	6	15	92	19.1	1.14	24.066	18	1[illegible]
14	7	15	96	40.4	1.59	33.555	18	116
14	8	15	100	29.4	1.41	29.761	18	1[illegible]
14	9	15	100	21.0	0.82	17.305	18	12[illegible]
14	10	13	96	37.5	1.20	25.319	15	10[illegible]
14	11	15	102	26.7	1.16	24.520	17	11[illegible]
14	12	15	120	34.7	1.37	28.912	17	14[illegible]
14	13	15	100	30.6	1.51	31.673	18	11[illegible]
14	14	15	84	21.9	0.86	18.149	18	11[illegible]
14	15	15	120	42.0	1.65	34.821	17	13[illegible]
14	16	14	96	34.7	1.37	28.[illegible]	16	10[illegible]
14	17	[illegible]	104	34.1	1.35	28.490	17	130
14	18	15	104	30.5	1.21	25.520	17	12[illegible]
15	1	15	112	28.4	1.06	22.369	18	12[illegible]
15	2	15	92	29.1	0.77	16.242	18	108
15	3	15	116	25.6	0.95	20.047	17	128
15	4	14	104	27.7	0.69	14.553	15	12[illegible]
15	5	15	108	35.2	0.86	18.139	17	12[illegible]
15	6	15	104	27.4	1.06	22.384	17	120
15	7	14	104	30.4	0.75	15.819	16	116
15	8	15	107	31.1	1.27	26.730	17	124
15	9	14	120	30.1	0.91	19.199	16	140
15	10	15	100	36.2	1.09	22.996	18	12[illegible]
15	11	14	100	25.9	0.72	15.189	16	12[illegible]
15	12	15	104	30.7	1.12	23.580	17	121
15	13	14	116	36.6	0.57	12.012	16	132

15	14	*	*	*	*	*	*	
15	15	*	*	*	*	*	*	
15	16	*	*	*	*	*	*	
15	17	15	112	29.8	1.01	21.312	18	[illegible]
15	18	14	96	22.3	0.75	15.825	16	[illegible]
15	19	*	*	*	*	*	*	*
15	20	15	96	35.2	1.57	33.137	18	[illegible]
15	21	14	100	26.0	0.92	19.413	16	[illegible]
15	22	15	105	30.4	1.03	21.730	17	[illegible]
15	23	15	107	26.1	1.10	23.090	17	[illegible]
15	24	*	*	*	*	*	*	*
15	25	15	100	21.8	1.03	21.740	18	[illegible]
15	26	15	108	24.1	0.84	17.725	17	[illegible]
15	27	14	100	22.8	0.63	13.290	16	[illegible]
15	28	*	*	*	*	*	*	*
15	29	14	120	25.6	0.79	16.668	15	132
15	30	14	104	37.1	0.95	20.038	16	128
15	31	*	*	*	*	*	*	*
15	32	15	124	39.2	1.41	29.754	17	132
15	33	15	104	30.6	1.01	21.410	17	120
15	34	14	96	34.9	1.04	21.941	16	124
16	1	15	88	30.9	1.13	23.845	18	112
16	2	15	100	43.1	1.08	22.779	18	120
16	3	15	103	30.3	1.14	24.030	17	120
16	4	15	112	25.4	0.97	20.470	17	136
16	5	15	106	30.6	0.91	19.250	17	122
16	6	14	124	14.5	0.43	9.072	16	149
16	8	14	120	21.8	0.90	19.079	15	144
16	9	14	140	30.0	0.76	16.072	15	148
16	10	14	108	31.2	1.04	21.860	16	127
16	11	15	112	31.8	1.18	24.901	17	124
16	12	15	118	28.8	1.34	28.170	17	133
16	13	15	106	26.0	1.21	25.490	17	121
16	17	15	120	27.8	0.94	19.813	17	132
16	20	15	124	26.5	1.12	23.638	16	132
16	21	15	100	28.7	1.34	28.357	18	124
16	22	15	109	32.0	1.27	26.800	17	127
16	23	15	99	28.9	1.15	24.240	17	115
16	24	*	*	*	*	*	*	*
16	25	15	96	37.9	1.09	22.995	18	112
16	26	14	120	25.4	0.93	19.541	16	132
16	27	*	*	*	*	*	*	*
16	28	14	120	37.1	0.73	15.370	15	140
16	29	*	*	*	*	*	*	*
16	30	*	*	*	*	*	*	*
16	31	14	96	32.6	0.97	20.401	16	104
16	32	*	*	*	*	*	*	*
16	33	15	96	23.4	1.07	22.584	18	108
17	1	15	116	48.9	0.81	17.071	17	128
17	2	15	84	43.6	0.88	18.554	18	100
17	3	15	120	32.7	1.02	21.521	17	156
17	4	15	110	31.2	1.18	24.787	17	128
17	5	15	88	30.6	1.48	31.239	18	116
17	6	15	84	29.1	1.56	32.930	18	104
17	7	15	84	30.0	0.38	8.003	18	112
17	8	15	116	30.0	0.49	10.327	17	140
17	9	15	92	28.5	0.70	14.764	18	120
17	10	14	96	26.3	0.47	9.907	16	112
17	11	15	100	27.7	0.70	14.765	17	116
17	12	15	100	40.8	0.46	9.684	17	108

17	13	15	100	28.2	1.06	22.427	17	116
17	14	15	96	23.8	0.73	16.453	18	[illegible]
17	15	15	112	27.4	1.15	24.245	17	[illegible]
17	16	15	112	37.0	0.68	18.560	18	148
17	17	14	128	35.5	0.8[illegible]	17.293	15	144
33	1	15	106	22.2	0.81	17.135	18	128
33	2	15	112	26.7	1.06	22.263	18	120
33	3	15	124	32.2	0.63	13.226	18	140
33	4	15	124	12.8	0.65	13.627	18	140
33	5	15	108	34.1	1.69	35.564	18	128
33	6	15	112	33.3	1.71	36.125	18	[illegible]
33	7	15	76	31.8	1.89	39.933	18	[illegible]
33	8	15	80	26.8	1.86	39.264	18	100
33	9	15	128	32.9	2.35	49.573	18	140
33	10	15	100	35.4	1.86	39.168	18	112
33	11	15	100	38.2	1.97	41.477	18	116
33	12	15	92	36.7	2.00	42.175	18	104
33	13	15	104	28.3	1.90	40.057	18	120
33	14	15	112	35.1	2.20	46.333	18	124
33	15	15	104	30.8	1.28	26.947	17	132
33	16	15	105	31.3	1.19	25.170	17	123
33	17	15	96	51.9	1.53	32.240	17	104
33	18	15	124	33.5	1.62	34.289	17	140
33	19	15	124	30.5	1.69	35.744	18	144
33	20	15	116	44.0	1.30	27.342	17	132
33	21	15	100	38.6	1.91	40.260	18	126
33	22	15	103	23.9	0.94	19.670	17	119
84	1	*	*	*	*	*	*	*
84	2	15	96	30.2	1.59	33.479	17	132
84	3	14	120	27.6	1.13	23.827	15	128
84	4	*	*	*	*	*	*	*
84	5	15	112	27.4	1.27	26.830	17	127
84	6	*	*	*	*	*	*	*
84	7	14	140	28.3	1.19	25.031	15	148
84	8	15	120	24.7	1.03	21.675	17	140
84	9	14	96	31.2	1.18	24.817	16	120
84	10	*	*	*	*	*	*	*
84	11	14	112	26.3	1.49	31.475	16	128
84	12	15	120	30.1	1.26	26.550	17	132
84	13	*	*	*	*	*	*	*
84	14	15	108	35.6	1.91	40.212	18	128
84	15	14	104	17.6	0.75	15.871	16	112
84	16	15	108	28.4	1.39	29.298	16	136
84	17	14	104	29.2	1.18	24.797	16	120
84	18	*	*	*	*	*	*	*
84	19	14	128	35.3	1.37	28.848	16	132
84	20	*	*	*	*	*	*	*
84	21	15	108	27.0	1.33	27.989	16	116
84	22	15	109	26.5	1.13	23.700	17	124
84	23	*	*	*	*	*	*	*
84	24	*	*	*	*	*	*	*
84	25	15	120	19.6	1.10	23.221	17	136
84	26	*	*	*	*	*	*	*
84	27	*	*	*	*	*	*	*
84	28	15	104	29.6	1.19	25.093	17	116
84	29	*	*	*	*	*	*	*
84	30	15	108	29.3	1.37	29.001	18	120
84	31	*	*	*	*	*	*	*
84	32	15	108	43.8	1.74	36.721	17	116
84	33	15	114	27.9	1.18	24.885	17	130
99	1	15	102	24.8	1.04	21.936	17	117

Ve-2	Vo2-2	EEKJ-2	Work-3	Fh-3	Ve-3	Vo2-3	EEKJ-3	Work-4
*	*	*	*	*	*	*	*	*
40.9	1.61	33.977	20	132	44.2	1.81	38.199	2
33.7	1.43	30.180	22	132	35.4	1.46	30.813	22
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
33.0	1.10	23.206	18	148	43.3	1.29	27.215	20
38.5	1.64	34.613	19	144	43.7	1.78	37.566	22
46.1	1.47	31.016	21	128	44.7	1.82	38.410	24
30.6	1.00	21.100	18	132	40.2	1.26	26.584	20
*	*	*	*	*	*	*	*	*
30.0	1.14	24.057	20	124	41.7	1.69	35.455	22
38.7	1.24	26.163	21	120	42.9	1.33	28.061	24
38.6	1.64	34.613	21	128	45.7	1.88	39.677	24
24.7	0.91	19.203	18	136	31.5	1.03	21.783	20
30.6	1.25	26.381	19	136	38.8	1.26	26.585	21
41.0	1.29	27.217	21	128	45.3	1.89	39.888	24
40.4	1.67	35.245	21	124	47.1	1.83	38.619	25
34.7	1.45	30.602	21	128	45.6	1.80	37.987	24
37.9	1.31	27.642	21	124	38.0	1.30	27.431	24
34.8	1.41	29.757	20	128	34.7	1.41	29.757	23
27.0	1.05	22.201	16	120	30.1	1.19	25.029	18
33.0	1.00	21.013	19	136	39.4	1.44	30.324	21
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
42.4	1.61	33.913	19	144	46.4	4.41	29.832	20
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
45.3	1.81	38.135	20	112	43.4	1.80	38.052	23
28.5	1.07	22.559	19	120	48.6	1.87	39.463	22
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
35.3	1.36	28.692	19	137	40.4	1.58	32.852	21
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
29.9	1.39	29.402	20	120	33.6	1.64	34.617	22
*	*	*	*	*	*	*	*	*
37.3	1.51	31.889	18	132	42.2	1.64	34.694	20
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
44.5	1.38	29.179	19	116	46.9	1.44	30.880	22
23.8	1.13	23.694	17	132	27.5	1.36	28.601	1
*	*	*	*	*	*	*	*	*

36.3	1.83	38.691	19	140	31.6	1.55	32.633	21
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	
36.9	1.49	31.382	19	124	39.1	1.55	32.936	22
23.5	0.89	18.824	17	140	37.4	1.51	31.762	18
*	*	*	*	*	*	*	*	*
35.1	1.46	30.898	19	135	42.0	1.81	38.095	22
32.0	1.08	22.788	17	136	39.9	1.75	36.830	18
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
40.0	1.65	34.886	19	120	47.8	1.94	40.900	22
23.1	0.85	18.021	18	148	39.3	1.16	24.430	19
26.5	1.06	22.265	18	144	32.4	1.29	27.266	19
36.3	1.72	36.241	19	152	46.9	1.90	40.141	21
28.8	1.23	26.044	21	124	33.3	1.36	21.105	24
32.3	1.42	29.928	20	136	37.6	1.76	37.233	22
*	*	*	*	*	*	*	*	*
43.7	1.75	36.974	19	148	53.8	1.91	40.367	21
26.5	1.10	23.152	21	128	36.2	1.49	31.446	24
*	*	*	*	*	*	*	*	*
32.3	1.60	33.773	20	136	36.9	1.86	39.261	22
14.2	0.56	11.818	21	120	18.8	0.75	15.828	24
43.5	1.72	36.299	19	150	45.7	1.80	37.987	21
25.9	1.02	21.526	19	150	39.5	1.56	32.922	21
36.8	1.34	28.290	17	146	40.2	1.42	33.030	19
27.3	1.35	28.496	21	132	36.3	1.80	37.994	24
32.8	1.62	34.195	21	136	44.1	2.10	44.325	24
33.3	1.65	34.825	21	124	35.1	1.74	36.723	24
39.8	1.57	33.133	20	132	41.8	1.65	34.821	22
35.8	1.36	28.700	17	132	50.1	1.45	30.590	19
34.8	1.50	31.720	19	133	40.8	1.74	36.710	22
37.0	1.46	30.812	19	152	31.5	1.53	32.295	21
33.9	2.02	42.644	21	124	37.0	2.20	46.444	24
39.1	1.93	40.738	20	128	45.8	2.27	47.915	22
46.0	1.81	38.198	19	152	50.8	2.01	42.419	21
37.3	1.47	31.023	18	124	38.7	1.53	32.289	21
35.7	1.41	29.756	19	144	44.4	1.75	36.932	21
36.0	1.43	30.080	20	136	40.4	1.64	34.260	22
35.0	1.34	28.278	20	140	31.2	1.39	29.337	22
30.1	0.98	20.678	21	120	30.6	1.26	26.585	24
36.5	1.34	28.277	19	144	39.0	1.49	31.444	20
34.3	0.89	18.773	16	136	42.2	1.07	22.569	18
31.6	0.91	19.198	19	140	35.8	1.20	25.320	20
34.4	1.35	28.551	19	133	40.3	1.65	33.260	21
32.6	0.81	17.085	19	140	33.5	0.80	16.873	20
35.4	1.46	30.860	19	139	38.8	1.62	34.250	22
35.2	1.02	21.518	18	160	38.2	1.09	22.995	20
38.1	1.13	23.840	19	136	45.9	1.31	27.636	21
33.2	0.94	19.830	17	140	42.4	1.14	24.047	19
35.8	1.35	28.413	19	137	40.7	1.54	32.529	22
46.5	0.99	20.876	18	142	50.3	1.12	23.619	20
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
38.2	1.22	25.741	20	140	38.4	1.26	26.586	22

34.3	1.04	21.942	19	124	40.2	1.26	26.584	[illegible]
*	*	*	*	*	*	*	*	*
38.9	1.62	34.190	21	132	46.9	1.90	40.095	[illegible]
27.8	1.22	25.749	18	136	36.5	1.31	27.643	[illegible]
36.1	1.27	26.700	19	139	42.1	1.47	31.080	[illegible]
34.0	1.40	29.560	18	136	39.8	1.70	34.050	[illegible]
*	*	*	*	*	*	*	*	*
41.8	1.20	25.315	21	136	50.3	1.38	29.111	[illegible]
31.4	1.16	24.479	19	140	33.2	1.21	25.500	21
24.3	0.91	19.203	18	144	26.3	0.94	19.835	[illegible]
*	*	*	*	*	*	*	*	*
30.3	0.86	18.142	16	152	32.5	0.99	20.887	17
39.1	1.01	21.304	18	152	39.0	1.04	21.938	[illegible]
*	*	*	*	*	*	*	*	*
41.4	1.48	31.231	19	152	42.0	1.46	30.808	[illegible]
35.6	1.21	25.572	19	136	40.1	1.37	28.850	[illegible]
39.4	1.21	25.529	17	136	39.4	1.14	24.050	19
42.0	1.40	29.540	21	128	38.2	1.48	31.223	24
43.0	1.13	23.836	20	136	41.5	1.41	29.752	22
35.4	1.35	28.440	20	136	39.1	1.49	31.520	22
32.3	1.29	27.224	19	148	34.6	1.38	29.124	20
35.8	1.14	24.060	19	138	41.1	1.36	28.740	21
41.6	1.34	28.273	17	152	45.8	1.45	30.593	18
28.4	1.11	23.425	16	160	26.1	1.01	21.315	17
38.3	1.15	24.262	16	156	36.1	1.10	23.208	17
34.5	1.23	25.920	18	140	42.4	1.54	29.460	20
43.7	1.34	28.271	19	140	42.8	1.37	28.906	21
38.8	1.65	37.750	19	146	41.0	1.91	40.240	[illegible]
33.3	1.49	31.440	19	132	37.1	1.73	36.400	[illegible]
27.9	1.06	22.369	19	140	32.2	1.26	26.591	21
27.8	1.20	25.327	17	140	30.5	1.31	27.648	19
33.3	1.45	30.603	20	140	39.7	1.60	33.767	[illegible]
37.8	1.49	31.580	20	143	42.4	1.72	35.970	22
34.0	1.36	28.580	20	129	38.4	1.56	32.550	[illegible]
*	*	*	*	*	*	*	*	*
63.0	1.39	29.312	21	128	64.8	1.33	28.043	[illegible]
32.3	1.21	25.534	17	140	32.3	1.21	25.534	18
*	*	*	*	*	*	*	*	*
34.7	0.91	19.195	16	148	38.0	1.02	21.516	17
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
38.7	1.17	24.684	18	128	39.4	1.21	25.529	[illegible]
*	*	*	*	*	*	*	*	*
28.9	1.13	23.847	21	132	32.8	1.26	26.590	[illegible]
52.0	1.16	24.462	19	156	52.3	1.20	25.307	[illegible]
44.0	0.90	18.976	21	132	39.9	1.20	25.317	[illegible]
30.6	1.21	25.536	19	168	44.3	1.31	27.637	21
37.1	1.43	30.127	19	144	42.4	1.66	34.495	21
37.4	1.83	38.627	21	128	52.0	2.30	48.544	[illegible]
35.5	1.92	40.530	21	140	50.6	2.11	44.531	[illegible]
39.7	1.54	32.499	21	132	54.2	1.91	40.304	[illegible]
34.9	0.54	11.379	19	156	38.9	1.09	22.994	[illegible]
36.8	0.75	15.814	21	136	38.9	1.13	23.839	[illegible]
35.1	0.54	11.379	18	132	87.7	1.39	29.292	[illegible]
19.4	0.78	16.453	19	120	30.9	0.85	17.931	21
43.6	0.49	10.316	19	120	49.0	0.88	18.550	[illegible]
33.6	1.29	27.257	19	130	38.4	1.50	31.209	[illegible]
33.5	0.76	16.027	21	120	40.5	0.91	19.192	[illegible]
35.7	1.47	31.038	18	143	41.8	1.78	35.753	[illegible]
42.4	0.91	19.189	20	156	51.2	1.07	22.562	[illegible]

33.5	0.78	16.450	16	160	41.9	1.04	21.933	17
26.8	1.08	22.771	21	149	30.3	1.48	31.134	24
32.5	1.57	33.204	21	144	33.6	1.73	36.585	24
37.5	0.73	15.397	21	156	51.5	1.52	31.991	24
23.2	1.08	22.847	21	154	31.1	1.85	39.019	24
35.4	1.75	37.000	21	144	33.3	1.98	41.710	24
30.7	2.03	42.489	21	140	37.1	2.13	44.959	24
33.7	2.04	43.057	22	104	38.2	2.27	47.954	25
35.0	2.15	45.448	21	112	36.0	2.18	45.983	24
34.5	2.39	50.544	21	156	43.4	2.70	56.346	24
32.6	1.94	40.916	20	120	36.5	1.95	41.241	22
37.8	2.11	44.621	20	128	42.4	2.31	48.748	22
40.1	2.37	49.543	21	120	42.9	2.55	53.873	24
33.6	1.93	40.760	21	138	35.6	2.19	46.229	24
43.3	2.21	46.552	21	132	38.6	2.45	51.743	24
33.8	1.67	35.279	19	144	36.1	1.64	34.660	21
35.9	1.42	29.970	20	138	40.9	1.63	34.440	22
47.6	1.74	36.656	19	112	47.9	1.79	37.850	21
34.8	1.72	36.332	19	156	35.2	1.76	37.115	21
35.0	1.77	37.299	20	148	40.1	2.42	51.151	22
42.0	1.66	35.014	19	140	43.7	1.72	36.353	21
41.2	2.04	43.018	20	132	41.4	2.05	43.234	22
33.3	1.34	28.290	19	132	39.8	1.72	33.030	21
*	*	*	*	*	*	*	*	*
34.2	1.69	35.694	18	148	35.7	1.56	32.925	19
30.7	1.21	25.578	17	148	37.5	1.48	31.255	18
*	*	*	*	*	*	*	*	*
35.1	1.57	33.090	19	139	39.1	1.82	38.320	22
*	*	*	*	*	*	*	*	*
30.0	1.16	24.522	16	156	35.4	1.37	28.975	18
26.4	1.18	24.800	18	152	30.6	1.45	30.542	19
33.8	1.13	23.906	18	132	35.9	1.45	30.643	20
*	*	*	*	*	*	*	*	*
33.9	1.43	30.138	17	136	36.4	1.82	38.501	18
38.6	1.58	33.430	18	144	46.6	1.85	38.958	20
*	*	*	*	*	*	*	*	*
45.1	2.41	50.847	20	144	49.9	2.47	52.049	22
36.3	1.52	32.037	18	124	45.6	1.87	39.402	21
31.8	1.51	31.809	17	144	35.2	1.74	36.812	18
40.0	1.58	33.425	18	128	36.2	1.48	31.319	20
*	*	*	*	*	*	*	*	*
35.5	1.40	29.630	17	158	42.0	1.61	33.934	18
*	*	*	*	*	*	*	*	*
31.4	1.51	31.957	18	132	32.1	1.53	32.315	20
33.8	1.40	29.530	18	138	39.5	1.70	33.820	20
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
28.9	1.15	24.333	18	140	36.2	1.48	31.235	20
*	*	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*
36.4	1.49	31.382	19	128	45.0	1.78	37.480	21
*	*	*	*	*	*	*	*	*
32.2	1.27	26.781	20	136	41.2	1.49	31.336	22
*	*	*	*	*	*	*	*	*
47.0	1.90	40.098	19	140	53.0	2.06	43.473	21
35.5	1.47	31.007	18	145	41.5	1.78	35.510	20
32.3	1.33	28.082	18	129	37.8	1.61	32.348	20

Fh-4	Ve-4	Vo2-4	EEKJ-4
*	*	*	*
144	44.60	1.74	36.720
140	40.60	1.66	35.033
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
156	47.30	1.37	28.902
152	49.10	1.96	41.365
144	54.50	2.18	46.007
144	48.40	1.44	30.380
*	*	*	*
144	41.90	1.74	36.722
144	40.70	1.54	32.498
140	47.60	1.94	40.943
148	31.80	1.05	22.155
152	44.00	1.36	28.694
144	45.70	1.89	39.888
144	48.20	1.92	40.520
140	51.10	1.94	40.940
144	42.50	1.67	35.243
140	40.00	1.60	33.767
132	29.90	1.20	25.240
144	49.30	1.52	32.111
*	*	*	*
*	*	*	*
156	55.90	1.72	36.965
*	*	*	*
*	*	*	*
120	48.00	1.83	38.619
132	58.70	2.16	45.666
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
151	45.10	1.73	36.477
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
132	36.80	1.81	38.142
*	*	*	*
144	49.40	1.94	40.920
*	*	*	*
*	*	*	*
128	48.60	1.88	39.569
152	28.90	1.50	31.726
*	*	*	*
152	37.60	1.88	39.620
*	*	*	*
*	*	*	*
*	*	*	*

*	*	*	*
*	*	*	*
*	*	*	*
*	*	*	*
132	46.30	1.86	38.536
152	38.40	1.53	31.972
*	*	*	*
146	38.90	1.79	37.739
148	46.10	1.75	36.930
*	*	*	*
*	*	*	*
144	43.00	1.78	37.524
152	59.40	1.75	36.893
156	32.50	1.30	27.372
166	52.50	2.09	44.150
136	36.80	1.50	31.678
148	38.20	1.79	37.824
*	*	*	*
160	43.30	1.81	38.179
140	37.10	1.55	32.797
*	*	*	*
152	38.20	1.89	39.894
148	24.90	0.98	20.681
160	46.20	1.82	38.409
160	39.50	1.95	41.161
152	45.30	1.50	40.356
144	43.40	2.15	45.382
144	45.80	2.25	47.493
140	41.50	2.03	42.849
156	49.40	1.95	41.152
160	56.40	1.54	32.465
147	45.13	1.87	39.420
160	35.80	1.77	37.361
144	42.10	2.50	52.777
140	50.00	2.45	51.714
160	52.00	2.05	43.263
144	45.70	1.80	37.987
156	44.60	2.21	46.649
150	44.90	1.83	38.510
152	45.20	1.68	35.452
132	43.00	1.33	28.061
160	38.60	1.52	32.078
148	48.40	1.16	24.465
160	40.50	1.40	29.541
150	44.13	1.74	36.636
148	41.40	1.01	21.302
153	43.90	1.80	37.870
168	40.50	1.09	22.993
148	52.90	1.49	31.432
160	51.80	1.39	29.321
151	45.60	1.71	36.058
168	59.60	1.18	24.879
*	*	*	*
*	*	*	*
*	*	*	*
148	55.10	1.33	28.051
140	44.80	1.40	29.538
*	*	*	*
144	46.70	1.84	38.831
148	45.90	1.28	27.002

153	47.10	1.66	34.960
148	43.50	1.78	37.470
*	*	*	*
160	66.50	1.97	41.561
160	48.10	1.38	29.113
170	36.70	0.99	20.884
*	*	*	*
164	39.60	0.95	20.036
160	44.30	1.15	24.257
*	*	*	*
164	44.90	1.67	35.241
151	45.80	1.50	31.630
160	42.90	1.25	26.371
140	43.50	1.67	35.243
148	58.50	1.42	29.949
149	43.60	1.68	35.430
160	36.50	1.40	29.544
153	48.30	1.57	33.060
164	48.10	1.48	31.225
164	52.50	1.93	40.727
164	39.50	1.21	25.528
154	47.30	1.52	32.010
156	44.80	1.41	29.749
160	43.30	2.09	44.000
144	39.13	1.89	39.810
152	37.00	1.43	30.178
148	41.40	1.65	34.822
156	44.70	1.60	33.763
158	47.20	1.92	40.436
143	42.70	1.73	36.590
*	*	*	*
140	76.40	1.57	33.104
152	36.70	1.33	28.066
*	*	*	*
156	54.60	1.01	21.291
*	*	*	*
*	*	*	*
144	41.00	1.29	27.217
*	*	*	*
148	39.70	1.46	30.809
168	55.20	1.76	37.134
144	50.10	1.25	26.365
172	38.90	1.35	28.486
159	47.40	1.82	38.301
144	50.00	2.34	49.391
160	46.60	2.27	47.915
164	64.80	2.03	42.830
172	45.30	1.22	25.735
148	44.90	1.31	27.637
148	92.40	1.60	33.724
140	34.70	0.96	20.251
132	60.40	1.20	25.3[illegible]
143	42.90	1.64	34.653
141	45.40	1.17	24.679
155	15.70	1.87	39.344
168	68.30	1.51	31.843
169	43.70	1.22	25.736
160	35.20	1.79	37.721
160	35.10	2.00	42.188
164	45.80	1.81	38.117

[illegible]	[illegible]	1.92	40.472
160	35.60	2.05	43.341
152	36.70	2.18	46.010
121	39.40	2.34	49.451
124	40.50	2.25	48.237
164	44.90	3.10	66.611
148	41.00	2.03	42.795
156	44.90	2.60	54.958
132	49.00	2.92	61.478
152	41.40	2.73	57.615
144	47.20	2.81	59.225
156	37.60	1.82	38.478
152	45.70	1.83	38.680
120	49.40	1.95	41.106
164	35.90	2.01	42.366
164	44.90	2.31	48.784
152	49.50	1.95	41.176
148	45.50	2.25	47.530
144	43.40	1.72	36.370
*	*	*	*
156	40.30	1.77	37.379
160	40.50	1.61	33.872
*	*	*	*
152	41.20	1.99	41.900
*	*	*	*
160	37.60	1.47	30.959
160	34.80	1.68	35.376
140	42.60	1.67	35.138
*	*	*	*
148	40.30	2.07	43.652
152	50.10	1.86	39.272
*	*	*	*
160	53.80	2.77	58.389
136	47.00	2.00	42.105
152	47.00	1.95	41.070
160	44.50	1.78	37.523
*	*	*	*
160	43.70	1.71	36.108
*	*	*	*
148	38.20	1.54	32.395
150	43.60	1.79	37.734
*	*	*	*
*	*	*	*
160	40.30	1.68	35.456
*	*	*	*
*	*	*	*
136	41.40	1.66	34.927
*	*	*	*
152	40.80	1.83	38.667
*	*	*	*
156	58.50	2.31	48.750
158	45.80	1.88	39.621
141	41.30	1.69	35.597