# Waist to height ratio in relation to time to run 550 m in primary school children in the Waikato region.

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I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously written or published by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed: 

Date: 16 October 2013

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ABSTRACT

**Background:** Relationships between excess body fat, body fat distribution, and body proportions with physical fitness are important to explore because emphasis is placed on monitoring these health markers during interventions aimed at improving child health. It is known that physical activity and therefore cardiorespiratory fitness are essential for health and life. Therefore can improved physical functionality such as an ability to run 550 m, a measure of cardiorespiratory fitness, be inferred from anthropometric measures in children? There was no published evidence for children on the relationship of the waist to height ratio; a measure of abdominal fatness, in relation to cardiorespiratory fitness. Furthermore the external and relatively fixed influence of ethnicity and social deprivation on physical fitness and interrelations with body fatness are rarely examined together. Explorations undertaken in this body of work aimed to increase the understanding of the relationships of anthropometric measures with a cardiorespiratory fitness measure of 7 and 10-yr old New Zealand (NZ) children from different socioeconomic levels and ethnic groups.

**Methods:** Project Energize is a through-school nutrition and physical activity program provided to Waikato NZ primary schools (land area 25,000 $km^2$) since 2004. An extended evaluation of the program was undertaken in early 2011. Cross sectional data including school demography, ethnicity, location, anthropometric measurements, blood pressure, food and physical activity knowledge questions and time taken to run 550 m were measured, from more than 5000 children, aged mostly 7 or 10-yrs old. From the data a sub-set was utilised for this body of work including, height, weight, waist circumference, and total body fat by bioimpedance analysis measures. Body mass index and waist to height ratio were derived and the physical fitness test was time taken for children to run 550 m (run-$time_{550m}$) on an outdoor grass track. All school decile levels (a scale where 1 is the most and 10 the least socially deprived, which were ranked and grouped low, medium or high decile) were represented and one third of participants were self-identified as Maori. Just over half the children were NZ European and the remainder were represented by Pacific and Other ethnic groups. Potential confounding effects of asthma (17% prevalence) and rurality (64% of the participants lived rurally) were also examined.  To answer the main research question, stepwise multiple linear regression analysis was used establish the most influential predictors of run-time$_{550m}$.

**Results:** The strongest predictors of run-time$_{550m}$ were, fat mass percent, waist to height ratio, body mass index, waist circumference and school decile group (low, medium or high).  The best four models for each age group (7-yr olds, *n* = 2634; 10-yr olds, *n* = 2466) to predict run-time$_{550m}$ included:

$$waist\ to\ height\ ratio\ \boldsymbol{OR}\ body\ mass\ index\ \boldsymbol{OR}\ waist\ circumference\ \boldsymbol{OR}\ fat\ mass\ percent + age\ (years) + \ gender\ (girl) + \ school\ decile\ (low) + \ school\ decile\ (medium).$$

Similarly in all models, for the 7 and 10-yr old groups, up to 27% and 39%, respectively, of the total variation in run-time$_{550m}$ could be explained.  Before and after adjustments the waist to height ratio and fat mass percent appeared to be the most influential anthropometric measurement for prediction of cardiorespiratory fitness in these children.  After adjustments, for every 0.01 cm/cm increase waist to height ratio, time to complete 550 m increased in 7-yr olds, 2.8% (95% CI; 2.4%, 3.4%) and in 10-yr olds, 3.3% (2.9%, 3.8%).  Compared to body mass index where for every 1 kg/m$^2$ increase there was a 2.1% (95% CI; 1.9%, 2.3%) in 7-yr olds and in 10-y olds, 2.2% (2.0%, 2.3%) increase in run-time550m.  A separate analysis demonstrated waist to height ratio increased 0.013 cm/cm for every 1 kg/m$^2$ increase in body mass index after adjusting for age and gender, R = 0.86, P > 0.0001.  School decile was an important covariate in each model where the lower decile group took on average 7% and medium decile group 4% longer to run 550 m than the high decile group, after adjustments for body fatness, age and gender.  Run-time$_{550m}$ decreased with age and girls ran more slowly than boys.  Ethnic group, asthma, and rurality were not significant predictors in these models.

**Conclusion:** When examining the differences between proxy body fatness measurements and association with running performance an increase in waist to height ratio was associated with an increase in run-time$_{550m}$, suggesting that increased abdominal fat volume was associated with reduced cardiorespiratory fitness in children. Additionally social deprivation level had a significant impact on cardiorespiratory fitness independent of body fatness or body size.  The waist to height ratio and run-time$_{550m}$ are simple measures to use in children to assess risks of excess adiposity and poor physical fitness.

# GLOSSARY

| | |
|---|---|
| 2011-Energized-Children | The children who took part in the 2011 evaluation of Project Energize and provided the measurements for this thesis. |
| Adiposity | Excess fat mass. |
| Anthropometric measurements | Various measurements of the body. In this thesis they are referring to; height, weight, waist circumference, waist to height ratio, body mass index, fat free mass and fat mass. |
| Cardiometabolic disease risk | Risks characterised by; overweight and obesity, high blood glucose, high blood pressure, high triglycerides, increased low density lipoprotein cholesterol, reduced high density cholesterol & insulin resistance. |
| Cardiorespiratory fitness | A measure of volume of oxygen consumed during a physical fitness test. |
| Energizer | A trained physical activity and nutrition coach actively working within primary schools as a member of the Project Energize team. |
| Energizer team | The team who deliver the physical activity and nutrition intervention Project Energize. |
| Epigenotype | The inherited potential of genetic expression under control of functions outside of the base pairing of DNA. |
| Genotype | Genetic traits of individuals determined by the base pairing and sequences of DNA. |
| Phenotype | The appearance or objective characteristics of an individual which are influenced by epigenetic, environmental and genetic factors. |
| Physical fitness | Ability to perform physical tasks based on physical movement, power, strength and endurance. |
| Project Energize | A physical activity and nutrition intervention for primary schools. Delivered by Sport Waikato NZ for the Waikato District Health Board. |
| School decile level | A level determined by the proportion of the school's students living in the lowest socioeconomic areas of NZ. |

# ABBREVIATIONS

| | |
|---|---|
| 95% CI | 95 percent confidence interval |
| AAHPER | American Alliance for Health, Physical Education and Recreation |
| ANCOVA | Analysis of covariance |
| ANOVA | Analysis of variance |
| AUC | Area under the receiver operators characteristics curve |
| AUTEC | Auckland University Of Technology Ethics Committee |
| BIA | Bioimpedance analysis |
| BMI | Body mass index |
| CRF | Cardiorespiratory fitness |
| CT | Computerised axial tomography |
| CVD | Cardiovascular disease |
| DXA | Dual energy X-ray absorptiometry |
| FFM | Fat free mass |
| FM | Fat mass |
| FM% | Fat mass percent |
| HDL | High density lipoprotein |
| IOTF | International Obesity Task Force |
| LDL | Low density lipoprotein |
| MRI | Magnetic resonance imaging |
| N | Number of participants |
| NZ | New Zealand |
| OR | Odds ratio |
| P | P-value for a probability test statistic which determines if the null hypothesis is true |
| PA | Physical activity |
| PE | Physical education |
| r or R | Pearson's product-moment correlation coefficient |
| $r^2$ or $R^2$ | The coefficient of determination |
| $r_s$ | Spearman rank correlation |
| RCT | Randomised controlled trial |
| ROC | Receiver operating characteristic analysis |
| Run-time$_{550m}$ | The time taken to run 550m |
| SDS | Standard deviation scores |
| SES | Socioeconomic status |
| TBW | Total body water |
| TV | Television |
| USA | United States of America |
| USCDC | (United States) Centre for Disease Control and Prevention |
| VO2 max / VO2 | Oxygen consumption during exercise (including a maximum value) |
| WaistC | Waist circumference |
| WHtR | Waist to height ratio |
| yr / yrs | Years of age |

# 1. INTRODUCTION AND LITERATURE REVIEW

The purpose of this chapter is to outline the question of the relationship of physical fitness to body size and proportions. Evidence concerning the prevalence of childhood obesity and child health inequalities among Māori and NZ European and high and low deprivation areas in NZ is examined. Then common intervention strategies employed to improve child health, and anthropometric and physical fitness measurements used to screen and monitor disease risk and inform outcomes of such interventions are sequentially reviewed.

## 1.1 Introduction

Over two-thousand-years-ago Hippocrates, a Greek physician, wrote and taught about the relationships between diet, exercise and the environment alongside the development of good health and disease. Through translated writings Hippocrates was noted to say, *"those who are constitutionally very fat are more apt to die quickly than those who are lean"* (Jones, 1931). Despite this early acknowledgement, for the following thousand years fatness was either a rarity in some cultures or seen as a sign of good fortune and wellness to others, with very few medical advances in obesity management (Haslam, 2006). Then in the early 19th century author, surgeon William Wadd, published two versions of *Cursory Remarks on Corpulence* (Anon, 1810; Wadd, 1816). Wadd was noted to write, *"corpulency, as has already been shewn, is not only a disease itself but the harbinger of others"*. Furthermore throughout his book described details of deaths and disabilities, visceral fat accumulation, *'extreme'* weights (90kg to 140 kg), symptoms of cardiovascular disease and type-2-diabetes mellitus, fat families and even accounts of, "*extraordinary bulk in children and infants*" (Wadd 1816).

Hippocrates had also previously summarised that the environment, physical activity, physical fitness and food choice were the important contributors to any persons health status, *"Even when all is known, the care of a man is not yet complete because eating alone will not keep a man well; he must also take exercise. For food and exercise while possessing opposite qualities, yet work together to produce health..."* (Jones, 1931).

This early knowledge eventually materialised into the basis of the physical principles of energy balance whereby food in excess and physical activity in deficit is simplistically recognised as the main driver of an accumulation of stored energy in the form of body fat (Haslam, 2006).

Now in the 21st Century, there grows a deep concern that worldwide, more children, and adults, continue to accumulate excess adiposity and that the prevalence of associated morbidities and mortalities of cardiometabolic diseases are also increasing, while the age of incidence is decreasing (Lee, et al., 2010). Change in prevalence of excess adiposity varies depending on the country or region and survey dates (Wang & Lobstein, 2006). Wang & Lobstein (2006) summarised global rates of childhood overweight as increasing from 10% to 35%, and obesity from 2% to 17%, between the early 1970's and 2000's. In New Zealand (NZ) the most recent national health survey (prior to 2011) was in 2006/07 (Ministry of Health, 2008a). This survey summarised for children aged 2 to 14-yrs that 21% were classified overweight and 8% obese. More concerning was that 12% of Maori and 23% of Pacific children were obese compared to 6% of European and Asian children (Ministry of Health, 2008a). It has been estimated that nationwide prevalence of children experiencing extreme obesity, with a body mass index (BMI) at or over the 99th percentile for age and gender, is 3% and 8 out of 10 would be Maori or Pacific Island children (Goulding, et al., 2007). These inequalities within extreme obesity are not likely to be inflated by inaccuracies in body composition measures between ethnicities, but determined by actual total body fat volume, multi-socio-demographics, lifestyle habits, coexisting diseases and a genetic predisposition (Goulding, et al., 2007).

Children and adolescents who are obese have had more than four times the likelihood of becoming obese adults (Freedman, et al., 2005) than children whose BMI was below the median. In NZ the prevalence of obesity increases steadily from 8% in childhood to 36% by the time adults are in the middle of their fifth decade (Ministry of Health, 2008a). Obesity from a young age increases risk for co-morbidities associated with cardiometabolic disease risks e.g. hypertension, type-2-diabetes, stroke and heart disease (Reilly & Kelly, 2011). Also, reduced fitness in childhood can predict increases in obesity and insulin resistance in adulthood, whereas children who are physically fit are more likely to become physically fit adults (Dwyer, et al., 2009; Huotari, Nupponen, Mikkelsson, Laakso & Kujala, 2011; Dennison, Straus, Mellits & Charney, 1988). Increasing physical activity contributes to development of lifelong habits for health risk reduction (Cleland, Dwyer & Venn, 2012). This points to the need for early intervention and promotion of lifestyles for families and communities that support improved nutrition, increased physical activity and improved cardiorespiratory (CRF) fitness (World Health Organisation, 2010a & 2010b).

The World Health Organisation 2009 *Global Health Risk Report* stresses that increasing prevalence of overweight / obesity is of concern as being obese or overweight is one of the five leading risks for mortality in conjunction with high blood pressure, high blood glucose, physical inactivity and smoking (World Health Organisation, 2009). When combined these lifestyle modifiable factors and the inclusion of low consumption of fruit and vegetables can be attributed to 61% of cardiovascular deaths and over 75% of all ischemic heart disease (World Health Organisation, 2009). Physical inactivity is an important and modifiable factor for lifestyle disease because of its relationships with CRF and adiposity (Gill, Baur, & King, 2010). Physical activity and CRF are moderators of health risks alongside and independent of body adiposity or body weight throughout the entire life course (Telford, 2007).

Typically throughout the lifecourse excess adiposity is measured using the body mass index (BMI), a measure of weight adjusted by height. Less commonly waist circumferences are measured and monitored. The Ministry of Health (2009) recognises that research is warranted to verify the utilities of different body fatness measurements for children. Research has suggested that the Waist to height ratio (WHtR) may be a tool better than BMI and waist circumference for measuring health risks associated with excess adiposity in children and adults (Browning, Heish & Ashwell, 2010). Practical use of WHtR in obesity screening and monitoring is an area where research is lacking. The current gold standard for obesity risk identification in children is the BMI. However the BMI is either praised as the only well researched method to screen or monitor populations and individuals, or it is criticised for its lack of precision at defining excess adiposity during growth and among diverse populations. Particularly in New Zealand, there are body composition differences and related health inequalities between Maori and NZ European that need to be better understood.

### 1.1.1 The problem.

Reducing the risks of obesity and cardiometabolic disease during childhood is needed to lessen the incidences of disease and reduce economic burden later in life (Withrow & Alter, 2011). It appears to be an achievable task owing to the lifestyle modifiable nature of large portions of the disease risks. The main lifestyle modifications recognised by Hippocrates two thousand years ago concern nutrition and physical activity and these messages are suitable for people of all age groups. However children are not largely in control of their lifestyle behaviours e.g. when and what food to eat, when to exercise and when to go to sleep (Lee, Harris & Gordon-Larsen, 2009). Children are receptive to learning and change, which makes nutrition and physical activity common foundations for school based child health interventions. New Zealand children represent a unique study population where multiple contributing cultural, social, demographical and economic factors exist to expand findings. This diversity coexists with the inequalities of body composition and health status in New Zealand children. Most important is Maori and Pacific families have higher fertility than other groups and while the Māori and Pacific child population is projected to grow faster than NZ European (Statistics New Zealand, 2008), their prevalence of obesity and poorer health will also grow. The main problem reviewed for this thesis is the presence of the epidemic of childhood obesity in NZ (Ministry of Health, 2008a), alongside significant disparities among ethnic groups, e.g. Māori and NZ European, and by socioeconomic level, with the need to implement and monitor child health interventions among this diverse population.

Compared to NZ European children adjusted for age, Māori and Pacific have higher BMI (Ministry of Health, 2008a; Rush, Plank, Davies, Watson & Wall, 2003; Rush, Puniani, Valencia, Davies & Plank, 2003), and higher (Duncan, J., Schofield, Duncan, E. & Rush, 2008; Tyrrell, et al., 2001; Rush, Puniani, et al., 2003) or no difference (Rush, Plank, et al., 2003) in total body fat. Physical activity levels and activity energy expenditure have been demonstrated to be higher in Māori children (Rush, Plank, et al., 2003) and more Māori children used active transport between school (Ministry of Health, 2008a). Yet Māori children were more likely to watch two or more hours of television daily (Ministry of Health, 2008a). Physical activity levels may not be significantly different among socioeconomic levels, however children living in more deprived areas of NZ were also more likely to watch two or more hours of television daily (Ministry of Health, 2008a). This may mean that sleeping hours might be reduced to allow for more television watching. Reduced sleep has been shown to be associated with detrimental effects on health and weight status (Must & Parisi, 2009). Less sleeping hours, inactivity and fewer breakfast meals have been associated with higher fat mass percent (FM%) in NZ children (Duncan, et al., 2008). Physical activity levels and FM% have been inversely related (Duncan, J., Schofield & Duncan, E. 2006) but not always and gender differences exist (Rush, Plank, et al., 2003).

Given the limited knowledge about main contributors to childhood obesity and physical fitness, key methodological issues faced by intervention management is choosing the desired but also measurable outcomes that best indicate intervention effectiveness. There are persisting methodological debates surrounding the actual measurement and definitions of excess body fat that is harmful to health and the terms overweight and obesity (Sweeting, 2007). It is common to use BMI and physical fitness to measure effectiveness of childhood obesity intervention. However obesity classification systems, which utilise the body mass index in preset thresholds to detect high FM% (International Obesity Task Force – IOTF and United States Centre for Disease Control and Prevention – USCDC), in adults (Romero-Corral, et al., 2008; Stommel & Schoenborn, 2010; Rush, Freitas & Plank, 2009) and children (Duncan, S., Duncan, E. & Schofield, 2009; Kriemler, et al., 2010; Glasser, Zellner, Kromeyer-Hauschild, 2011; Zimmermann, Giibeli, Puntener & Molinari, 2004) can be inaccurate or equivocal and are especially complex among the spectra of ethnic diversity and social deprivation. In addition linkage of adiposity associated risks from childhood into adulthood are difficult to prove given longitudinal research is limited. Nevertheless monitoring height, weight and BMI (standardised for age and gender) at the population level remains a useful tool due to a long history of health record keeping, it's non invasiveness and the ability to see changes within a population over time (Patterson, Jarvis, Verma, Harrison, & Buchan, 2006).

In children the WHtR is currently supported by the one key message for children of "keeping waist circumference less than half height" (McCarthy & Ashwell, 2006) and, compared with BMI, for being better or equally related to cardiometabolic disease risks

(Browning, et al., 2010). The WHtR may be a good outcome measure for childhood health interventions. Accurate estimations of FM%, for example by bioimpedance analysis (BIA) have been more strongly related to physical activity levels, than BMI and waist circumference (Duncan, et al, 2006). It is not known how the WHtR relates with physical activity or physical fitness, and therefore poses the question how do various anthropometric measures relating to body fatness associate with physical fitness? The answer to this question would help validate if both the WHtR and physical fitness testing are useful and practical tools to monitor child health within the school environment.

## 1.2 Literature review

This literature review will explore some environmental factors contributing to pathogenesis of obesity and effect of inequalities, provide an introduction to Project Energize and methodologies surrounding design and implementation of lifestyle interventions. In addition some ways to measure body size, adiposity and physical fitness in children that are used to inform evaluations of childhood physical activity and nutrition interventions are reviewed.

### 1.2.1 Childhood obesity: Environment and inequalities.

The childhood obesity epidemic is a relatively new problem of the last 40 years. For this reason evidence based methods to address the problem are still in discovery, design or early stages of understanding. Social behaviour and environmental factors are identified as a medium to both help identify and intervene to reduce childhood, family-hood, and adulthood obesity (Lee, et al., 2009; Barlow, 2007). In developed and developing countries poverty is associated with higher prevalence of obesity. Children are not in control of their socioeconomic status therefore the related childhood obesity develops circumstantially, throughout early life, under parental monitoring and influence, having complex interactions e.g. genotype, epigenotype, culture and behaviour (Lee, et al., 2009). All which further interact with global influences such as the food supply, climate change and war / animosities (Finegood, Merth & Rutter, 2010). Within a country fixing the childhood obesity problem is essentially a public health issue, e.g. akin to anti-smoking campaigns and skin cancer prevention, because in children drastic measures like intense gym programmes, calorie restriction, surgery and medicines would not be acceptable (Barlow, 2007) or affordable. An expert committee formed out of convening US child health professionals, in 1998, originally published recommendations for evaluating and treating childhood obesity (Barlow & Dietz, 1998). This was reviewed and updated in 2007 (Barlow, 2007). In this later paper it was advocated that advice given to families to encourage weight loss should include more frequent consumption of fruits, vegetables and breakfast, reduced consumption of sugary drinks, takeaways and fast food, less screen / television time and more family meals at home with controlled food portions. Globally childhood obesity interventional strategies are utilising this advice to combat the epidemic (Doak, Visscher, Renders, Seidell, 2006; Greening, Harrell, Low, Fielder, 2011; Brown, Kelly & Summerbell, 2007; Graham, et al., 2008).

Many recommendations for obesity reduction are nutrition and physical activity based however there are different opinions from community health professionals and food manufacturers framing the obesity problem (what they think *IS* the cause of obesity and where responsibilities lie). A recent open inquiry initiated by NZ Parliament Health Select Committee in 2006 (Jenkin, Signal & Thomas, 2011), summarised that public health professionals claim obesity is an epidemic largely caused by an obesogenic (Swinburn, Egger & Raza, 1999; Swinburn, et al., 2011) environment and socioeconomic factors of which food is a common denominator. Whereas the food industry representatives claim obesity to be an issue of lifestyle choice (technological change, overconsumption and physical inactivity), lack of knowledge and poor willpower (Jenkin, et al, 2011). The framing of obesity illustrates varying degrees of ownership of the problem from food industry and public health sectors, and the overall issue remains very multidimensional (Finegood, et al., 2010). Deep-seated the core issue is balancing energy intake against energy expenditure for weight management where a positive balance results in weight gain (Spiegelman & Flier, 2001; Luis-Griera, et al., 2007). However differentiation and integration of the energy balance equation is everything but simple with multiple factors ranging from metabolism, assimilation and utilisation of fuel, to the complex regulation of expenditure (Hill, 2006) contributing to bodily effects. The factors interrelating with the disrupted energy balance are extensive, yet in the last few decades have had a relatively quick progression, which may appear to coincide with the rapid growth of the processed and packaged food industry, food prices and economic crises. Greater understanding of the pathophysiology of the human energy balance equation will help inform future obesity intervention methods.

Currently NZ public health services, e.g. well-child service and health promoting schools, use simple methods to advocate change in energy balance in children. These methods are driven by the basic assumption that, too many highly dense calories (sugar and fat) are taken in by children, combined with a more sedentary lifestyle are the main likely contributors to excess weight . In 2004 a NZ wide District Health Board based intervention stock-take (Blair, 2004) illustrated the various childhood obesity interventions that were in-place in NZ at that time, which included; a walking school bus incentive, school based (Project Energize) and community based (green prescription / active families) incentives. Often childhood obesity interventions are school-based and multi-component, proactively combining physical activity and nutrition education to modify behaviour (Gonzalez-Suarez, Worley, Grimmer-Somers & Dones, 2009). When children aged between five and eleven years are targeted, short term outcomes of improved diet and increased physical activity are evident while an intervention is active (Brown, et al., 2007). Behaviours gained in childhood may follow through their lifespan to improve or delay negative health complications of obesity (Ebbeling, Pawlak & Ludwig, 2002). But proof of the long term sustainability of school based interventions requires longitudinal design with good evaluation strategies. Project Energize is one Waikato District Health Board (NZ) through school intervention that is based on delivery and sustainability of these principles.

### 1.2.2 Project Energize: Healthy kids of all shapes and sizes.

Project Energize has been functioning as a through school interventional programme aimed at increasing physical activity and knowledge / consumption of healthy foods. Healthy, confident kids of all ages and sizes is the focus rather than clinical behaviour based on prevention and treatment of excess adiposity. The mantra is, “eat healthy, be active, have fun.” Project Energize first approached primary schools in the Waikato New Zealand in 2004 for recruitment and consent to participate in a randomised controlled trial and for the measurement of baseline information. Baseline measures were taken last quarter of year 2004 and followed-up in 2006. Project Energize main goals were aligned and implemented as part of the New Zealand Government Healthy Eating – Healthy Action strategy to improve obesity rates, cardiovascular risk factors, bone health and dental health, through changes in nutrition and increases in physical activity. Details of the Project Energize design and methods are published elsewhere (Graham, et al., 2008) and publication of outcomes and progress are ongoing.

When the Project Energize randomised control trial was initiated 124 primary (year 1 to 6) schools, and therefore 22,000 children, became a part of the largest randomised health intervention for New Zealand children, where 62 schools formed an inactive control group and 62 schools participated in the programme. Participation rates are summarised in Table 1.1. Schools were stratified by rurality and decile prior to random sampling. Children ultimately measured in the first randomised controlled evaluation were 5-yrs old ($n$ = 926) and 10-yr old ($n$ = 426), 692 receiving intervention and 660 controls. Participating schools each had a designated "Energizer" who was a trained physical activity and nutrition role model / agent for the children who endorsed the Project Energize brand messages throughout. "Energizers" were employed by Sport Waikato to deliver Project Energize; each Energizer was assigned 7 to 10 schools in a geographic cluster. The Energizers focus on health education was as a pro-active facilitator of change rather than 'falling into the trap' of simply being a 'teachers assistant'. This strategy encouraged a platform for problem solving and motivation which meant real-time delivery of the intervention strategies (Graham, et al., 2008). A schools Energizer sourced community resources, and provided a coordinated and managed execution of physical activity and healthy nutrition activities Each Energizer facilitated feedback and group learning through collective practices and allowed wide efficient coverage of the region (Graham, et al., 2008). Improving risk factors in children is a gradual multifactorial process owing to their dynamic growth, plasticity, evolutionary and developmental histories all cooperating with their growing environment (Hochberg, et al., 2011). Implementation of the Project Energize programme has been a multifaceted, regular direct contact intervention for greater than the last seven-years and continues (in 2013) to be delivered following this same model (Rush, Graham, McLennan & Latimer, 2011). It has not been expected to see dramatic change within only a few years but it is hoped that long term benefit will be apparent when these children become adults and in their future generations.

**Table 1.1 Participation in Project Energize evaluations**

| | **2004 - Baseline*** | **2006 - Evaluation*** | **2011- Extended evaluation^** |
|---|---|---|---|
| Schools | 124 schools total<br>62 schools participated<br>62 control schools | 124 Schools total<br>62 Schools participated<br>62 Control schools | 192 schools |
| Age | 5 &10-yr olds | 7 & 12-yr olds | 7 & 10-yr olds |
| Children participating in the intervention | 22,000 | 22,000 | 44,000 |
| Enrolment | 3,034 enrolled for evaluation | 3,034 enrolled for evaluation | 11,355 invited |
| Number of children evaluated | 2,752 measured | 1,352 measured<br>692 control<br>660 intervention | 5,110 measured |
| Māori participation | 31% Maori<br>62% NZ European | 26% Māori<br>66% European | 36% Māori<br>54% NZ European |

*(Graham, et al., 2008), ^(Rush, et al., 2011)

In 2011 at the time of the planned extended evaluation, all schools in the Waikato had been participating in the school programme for no less than one year since the last rollout occurring in 2009. Approximately half of the schools have participated for no less than five years when the rollout was prioritised and the lower decile schools invited first. The programme is activity based with clear short term, medium term and long term goals (Table 1.2). School leaders enter into a formal agreement to commit to the Energize goals. Goals are synergistically worked individually to meet a school's particular needs and wants within the Energize framework giving a personal touch that reflects the school and their community. Each Energizer works within their same community, however knowledge continues to be shared amongst the whole Energizer team and leaders which fosters a learning and changing environment, to gain from successes and learn from mistakes.

**Table 1.2 Summary of Project Energize goals***

| Activities | Short term goals | Medium term goals | Long term goals |
|---|---|---|---|
| | *For the children:* | | |
| Support and enhancing physical activity and healthy nutrition within schools | Increase knowledge and school environment to foster increased physical activity and healthy nutrition in children. | More children physically active and making healthier food choices in school time and home / family time. | Communities and schools becoming healthier because of increased quantity and quality of physical activity and improved nutrition. |
| | *For the bigger picture:* | | |
| Resources developed, professional development, community linkage, research / evaluations associated with implemented physical activity and nutrition support. | Improve children's and teachers confidence in role modelling physical activity and healthy nutrition, extending to the family and wider community. | Ensuring that Energize interventions are working, why and how to improve. | |

*Summarised from Rush, et al. (2011)

Among the many reviews undertaken to evaluate childhood obesity interventions, in 2005 an updated review was published (Summerbell, et al., 2005) which included community wide interventions of randomised controlled trials and controlled clinical trial design. This was followed by a high quality meta analysis (Gonzalez-Suarez, et al., 2009) and systematic review (Brown & Summerbell, 2009) All of these analyses recognise the difficulties related to methods of obesity classification and outcome measures adopted (Summerbell, et al., 2005). Furthermore dose, exposure and focus of interventions varied, for example, dietary management, dietary advice or education e.g. actual restrictions in sugary drink consumption or a handout resource suggesting a healthy swap. Physical activity was also encouraged through direct or indirect approaches e.g. active classes, physical education and reductions in sedentary behaviour (Summerbell, et al., 2005; Gonzalez-Suarez, et al., 2009). In 2005 it was concluded that interventions did not demonstrate any significant difference in change of body size or adiposity parameters between the control and intervention groups (Summerbell, et al., 2005). However in 2009 Gonzalez-Suarez, et al. (2009) and Brown and Summerbell (2009) reported in approximately 40% of articles they reviewed reductions in prevalence of excess adiposity. Longer term interventions (years not months) and those with well defined key focus and outcomes were considered more successful (Table 1.3).

The apparent failure of interventions to produce the desired outcome and/or the reported poor research qualities / methodologies (Summerbell, et al. 2005) allowed key elements, to be identified for the design and reporting of interventions to reduce childhood obesity (Table 1.3). The Project Energize programme and evaluation includes all these elements. The most commonly reported primary outcome measurements were change in BMI and/or prevalence of obesity and overweight (Brown and Summerbell, 2009). Secondary measures included waist circumference, skin fold measurements, waist to hip ratio and FM% (Gonzalez-Suarez, et al., 2009). Each measurement aims to estimate excess adiposity because of its relationship with risk.

**Table 1.3 Key elements for implementation and reporting of intervention outcomes**

| Element | Source |
|---|---|
| Include socioeconomic status.*<br>Give details of the design and modelling framework of the intervention.*<br>Include systematic follow-ups.*<br>Use the most effective and reliable measures for outcomes e.g. BMI or WHtR or FM%.*<br>Measure physical fitness not just physical activity levels.*<br>Cost effective and sustainable strategies.*<br>Frequent contact high intensity verses less contact low intensity.*<br>Utilise good statistical analyses.* | Summerbell, et al. (2005) |
| Long term intervention - longer than 12 months.* | Summerbell, et al. (2005) and Gonzalez-Suarez, et al. (2009) |
| Combined physical activity and nutritional intervention.* | Gonzalez-Suarez, et al. (2009) and Brown & Summerbell (2009) |
| Large participation numbers.* | Summerbell, et al. (2005) and Gonzalez-Suarez, et al. (2009 |
| Physical activity interventions may be more effective in primary aged children* and girls benefit more. | Brown & Summerbell (2009) |
| Significant results measured by change in BMI or prevalence of obesity were seen more with interventions that use methods including; reduced TV viewing, increased physical activity*, breakfast schemes and reduced sugary drinks. Also environmental, policy and marketing changes. | Brown & Summerbell (2009) |

* included in the Project Energize programme intervention and evaluation

### 1.2.3 Measuring adiposity in children.

Assessment of size, shape, proportions and functions of the human body structure and function are the foundations for understanding associations between good health and disease across the lifecourse (Halac & Zimmerman, 2004; Kuczmarski, et al, 2002). Complexities faced when measuring a growing child are related to their growth (differentiation and modelling) which occurs at variable rates dependent on developmental history, ages, genders and ethnicity (Fomon, Haschke, Ziegler & Nelson, 1982). This makes it important to validate the common in-field proxy measures used to assess excess body fat against what is called a healthy (usually called normal), and criteria that reflects the relative mass of fat, either total or regional, particularly abdominal fat (Ministry of Health, 2009; Duncan, E., Schofield, Duncan, S., Kolt & Rush, 2004).

Anthropometric methods utilising body mass index and waist circumference for referencing growth and possible health risk identification in children are adjusted for age and gender, however adjustment for ethnicity is not usual (Fomon, et al., 1982; Kuczmarski, et al, 2002; National Obesity Observatory, 2008). There are known differences by ethnic group in quantity, distribution and ratio of fat mass (FM) in children and adults (Ellis, Shypailo, Abrams & Wong 2000; Freedman, et al., 2005; Rush, Puniani, et al., 2003; Rush, Freitas et al., 2009; Rush, Scragg, Schaaf, Juranovich & Plank, 2009; Sluyter, Schaaf, Scragg & Plank, 2009).

Prior to the first national child health / nutrition survey (Ministry of Health, 2003), there was little published data concerning the prevalence of high BMI and excess adiposity for children in the different ethnic groups of NZ. In 2001 Tyrrell, et al. (2001) reported that in low socioeconomic status children aged 5 to 11 yrs ($n$ = 2273) Māori and Pacific children had higher prevalence of obesity and proportion of FM% than NZ European. In addition any ethnic group differences in the relationship of BMI with FM% in NZ children was significant but small and termed clinically irrelevant (Tyrrell, et al., 2001). More recent research does suggest that for the same BMI, young Māori and Pacific girls have less FM% than NZ European girls (Rush, Puniani, et al., 2003). It may be more important to consider that over time and at critical growth stages, such as puberty, body composition and excess fat differences may amplify differences among ethnic groups and genders (Rush, et al., 2012a) and predict increased risk for chronic disease in adulthood.

In the Waikato between 2003 and 2007, Maori adults with type-2-diabetes were more likely to die from related cardiovascular disease, renal disease and cancers than NZ European with type-2-diabetes (Joshy, Colomne, Dunn, Simmons & Lawrenson, 2010). Compared to NZ European adults, obesity classification (BMI >30 kg/m$^2$) and large waist circumference (102 cm, men and 88 cm, women) was prevalent 1.5 to 2 times more in Māori or Pacific adults alongside increased metabolic risk e.g. hypertension, elevated LDL cholesterol and triglycerides and hyperglycaemia (Simmons & Thompson, 2004). What these cross-sectional analyses do not do is imply causation or what is the driving factor between obesity and other biological risk markers in the development of cardiometabolic disease. While in general people with excess adiposity definitely have higher health risks, the point where the risks meet criteria to be classified as a disease and what screening biomarkers are better for earlier detection and monitoring of cardiometabolic risks needs addressing. All in consideration of what treatment is available, when and affordability.

Accurate and precise indirect measurement of body fatness requires that there are small errors in reporting, the process is cost and time effective, that there are reference ranges and the use of the measure is well-documented (Power, Lake & Cole, 1997). Additional and desirable elements include simplicity of process, easily understood calculations if any, minimal adjustment for ethnicity, age and gender, and that fat distribution can be visualised (Garnett, Baur & Cowell, 2008; Ashwell & Heish 2005; Ashwell & Gibson, 2009; Browning, et al., 2010). While BMI and waist circumference are the most frequently report measures other indirect evaluations of body fatness include bioelectrical impedance analysis (BIA) for total body water and therefore derived fatness and WHtR for abdominal obesity are recognised measures.

Increased fatness, with the exception of the sometimes hidden intraperitoneal and retroperitoneal fat, gives a visual appearance to the body, often expressed as gynoid (fat dominant trunk) verses an android shape (fat dominant hips and thighs). Monitoring body fat distribution rather than total body fat estimation may be a more important screening tool for obesity that relates stronger with increased health risks, as it is known in adults that the accumulation abdominal fat (commonly measured by increases in waist circumference), particularly visceral abdominal fat, accurately measured by computerised axial tomography (CT), increased cardiometabolic disease risk (Fox, et al., 2007).

Although there are very few childhood studies, there is evidence that from as young as three-yrs old (Goran & Gower 1999; Maffeis, Pietrobelli, Grezzani, Provera & Tato, 2001; Watts, Bell, Byrne, Jones & Davis, 2008) excess abdominal fatness (subcutaneous and visceral) accumulates in early life and may be associated with increased risks independent of whole body adiposity. Compared with relative body weight, waist circumference had a slightly stronger (significantly stronger for systolic blood pressure) association with blood pressure in 3 to 11-yr olds (Maffeis, Pietrobelli, Grezzani, Provera & Tato, 2001). It was demonstrated (Watts, Bell, Byrne, Jones & Davis, 2008) in a small ($n$ = 148) group of 6 to 13-yr old Australians, where just over half were overweight or obese, that increasing waist circumference (> 90th percentile for Australian children) compared to BMI standard deviation score (SDS), had slightly stronger associations with higher blood pressure, low HDL, higher, triglycerides, homocysteine levels, fasting insulin and increased insulin resistance. In multivariate analysis for each cardiometabolic risk factor only waist circumference was the significant predictor (Watts, et al. 2008). In a larger group ($n$ = 1201) of South Asian adolescents (Misra, et al., 2006), waist circumference had the highest odds of predicting clustered cardiometabolic risks that excluded hyperinsulinaemia. However the identification of hyperinsulinaemia was strongest (higher odds ratio) in relation with skinfold measurements (Misra, et al., 2006). Also in agreement a much larger sample ($n$ = 4811) of Iranian children and adolescents from diverse ethnic groups and socioeconomic status confirmed waist circumference was the best anthropometric measure for identification of clustered metabolic risk factors (Kelishadi, et al., 2006). While there is evidence that waist circumference measurements can detect cardiometabolic risks better than BMI, screening BMI remains to be the most popularised method to define a healthy weight and manage health risks.

1.2.4 Body mass index.

Body mass index, weight in kilograms divided by height in metres squared is considered to be the "single best measure of adiposity in children and adolescence" (Power, et al., 1997; Ministry of Health, 2009). However the index does not differentiate between lean and fat body mass or give any real impression of body proportions phenotype. In children age and gender specific BMI growth charts , - categorise body fat quantity and assess health risks related to obesity (McCarthy, Cole, Fry, Jebb & Prentice, 2006) for a population. The BMI is also an outcome measure for epidemiological research and validation of physical activity and nutrition interventions (Taylor, et al., 2010). Age and gender specific BMI cut-points identify a child as overweight (a weight considered above normal or desirable) or obese (grossly overweight or excessive body fat) or overall to imply body fat excess to functional requirements. There are a number of cut-points for BMI to identify children with higher risk of disease associated with body size and these have been derived from measurement of different populations of children at different times.

*BMI terminology and weight classifications.*

The method and cut-points used to classify child body size can add confusion when studies are compared. (Sweeting, 2007). This may be attributed to there being **four** commonly recognised systems for growth monitoring and overweight classification in children (Table 1.4). The International Obesity Task Force (**IOTF**) derived childhood obesity classifications after extrapolating international cross-sectional growth curves to predict BMI at 18-yrs old according to WHO definitions (Cole, Flegal, Nicholls & Jackson, 2007; Cole, Bellizzi, Flegal, Dietz, 2000). In the year 2000 the United States Centers for Diseases and Prevention (USCDC) used thirty years of American National Health Examination Surveys (NHANES and NHES) to construct smoothed and normalised growth reference charts which included BMI reference (**USCDC2000**) (Kuczmarski, et al., 2000; Kuczmarski, et al., 2002). When comparing the IOTF and USCDC classification systems, an adult BMI of 30 $kg/m^2$ (obese) is equal to the 95th centile (USCDC) for post-pubescent teenager boys at 19-yrs old and girls at 17-yrs old (Freedman, Mei, Srinivasan, Berenson, & Dietz, 2007). The IOTF thinness classification is equal to approximately the 1-5th centile of USCDC2000 BMI (Cole, et al., 2007)

Alternatively in 1977 the World Health Organisation (**WHO**) first recommended growth standards curves for children aged 5 to 24 yr. Later, in 1991 body mass index percentile curves were generated for 9 to 24-yr olds.. More recently the growth (2006) and body mass index percentile (2007) reference curves were reconstructed (de Onis, Garaza, Onyango & Borghi, 2007) for the 5 to 19-yr old age range (*n* = approximately 30, 000), using the same data but different statistical modelling techniques. In addition an extra sample (Multi Centre Growth Reference Study MGRS 1997 to 2003) (de Onis, et al., 2004) of internationally represented under 5-yr olds, from the WHO 2006 Child Growth Standards was also reworked (de Onis, et al., 2007). These healthy MGRS children were exclusively breastfed for six months and tracked for five years of life. Aims for this global update was to develop BMI references from 5-yrs old (previously only from 9-yrs old) and to achieve a smooth transition from the 2006 WHO Child Growth Standards for ideal growth of under 5-yr olds and the new charts for school-aged children (de Onis, et al., 2007).

In the United Kingdom specific growth curves were developed in 1990 (**UK90**) (Table 1.4). The UK90 definitions of overweight and obesity closely mirrors the IOTF recommendations. However when comparing child BMI growth curves (WHO 2007 verses IOTF and USCDC 2000) there is an over estimation of overweight and obesity, and underestimation of thinness prevalence by the IOTF and USCDC reference. These discrepancies are exaggerated in developing countries (Baya-Botti, Pérez-Cueto, Vasquez-Monllor, & Kolsteren, 2010) and among different ethnic groups (Ma, Wang, Song, Hu, & Zhang, 2010) where compared to their sample population, BMI percentiles for the USCDC, WHO and IOTF charts over and under estimated the prevalence of overweight and underweight respectively. This lack of sensitivity needs highlighting due to variations in nutritional status in different countries of over and under nutrition. Over and underestimating thinness and fatness might not allow for the most needed interventions to be given priority. New Zealand government recommends (Ministry of Health, 2009) that health professionals use the USCDC-2000 growth reference charts to screen for excess adiposity in children. New Zealand population based health surveys have used WHO BMI cut-points to define overweight and obesity in adults and IOTF cut-points for children (Ministry of Health, 2008b).

**Table 1.4. Body mass index classification systems for children worldwide.**

| Group & years of development | Data sets utilised | Methods for deriving BMI references | Age groups included | Body size classifications |
|---|---|---|---|---|
| IOTF 2000 & 2007 (updated) | Six international cross-sectional surveys from Brazil, Hong Kong, Netherlands, Great Britten, Singapore and the USCDC 2000 growth chart data (excluding NHANES III). | Extrapolation of BMI growth curves to predicted BMI at 18 yrs old.<br><br>Commonly used for international / population comparisons. | 2 to 18-yrs | Thinness (BMI ≤17 kg/$m^2$, normal (BMI 18-24 kg/$m^2$), overweight (BMI 25-29 kg/$m^2$) and obese (≥30 kg/m2) (Cole, et al., 2000; Cole, et al., 2007) |
| USCDC 2000 | Five national American National Health Examination Surveys (NHANES and NHES) (1963 to 1994). | Smoothed normalised growth centile curves generated age and gender specific BMI centile curves. | 2 to 20-yrs | The 85th centile is 'at risk for overweight'. 95th centile is 'overweight' (Kuczmarski, et al., 2000; Kuczmarski, et al., 2002). |
| WHO 1977, 1991, 2006 &2007 | American National Health Surveys (NHES II 1963-1965, NHES III 1966-1970 and NHANES I 1971-1975), Multi centre growth reference study (MGRS) 1997 to 2003. | 0 to 5-yrs growth charts are growth standards (for optimal growth).<br><br>5 to 19 yrs growth charts are growth references (for general population comparisons). | 0 to 5-yrs<br><br>5 to 19-yrs | Thresholds based on standard deviations eg thinness < -2 SD, overweight +1 SD and < +2SD, and obese > +2 SD (de Onis, et al., 2007).<br><br>Overweight, 85th centile for population and 91st centile for clinical assessment.<br><br>Obese, 95th centile for population and 98th centile for clinical assessment. |
| UK90 1990 | Twelve UK population surveys between 1978 to 1994 | Growth reference centile curves. | 0 to 23-yrs | Underweight 2nd centile.<br><br>Overweight 85th centile for population and 91st centile for clinical assessment.<br><br>Obese 95th centile for population and 98th centile for clinical assessment. (National Obesity Observatory, 2008). |

Additional source: National Obesity Observatory (Dinsdale, Ridler & Ells, 2011). IOTF = International Obesity Task Force. USCDC = United States Centers for Disease Control and Prevention. WHO = World Health Organisation. UK = United Kingdom. BMI = body mass index.

Although risks for chronic disease and physical dysfunction are well predicted in children with a USCDC-2000 BMI ≥99th centile (Freedman, Mei, et al., 2007) and thinner children BMI less than the 5th centile (Cole, Nicholls & Jackson, 2007). Cut-points for BMI based categories are for assessment, monitoring and screening purposes and not for diagnosis because individuals can have high BMI for age yet not have excess fat or increased risk. Valid determination of excess FM requires other measurements (Wright, et al., 2002; National Obesity Observatory, 2008). An additional complication is that an estimated one third of healthy-weight children also have at least one risk factor of cardiovascular disease or type-2-diabetes (Freedman, Mei, et al., 2007). Adding measures of central adiposity like waist circumference may increase sensitivity and specificity of risk assessment in non-overweight children where BMI and body fatness have negligible association due to influence of fat free mass (FFM) (Freedman, et al., 2005; Freedman & Sherry, 2009). The NZ Ministry of Health (2009) recommends a child’s waist circumference measurement "should be half or less than the child’s or young person's height in over-five-yr olds" and to be used alongside BMI. Waist circumference is not rationally detailed in the 2009 NZ guidelines however use of BMI for children is well defined.

### 1.2.6 Central adiposity.

The amount of fat in the abdominal regions is distributed between the subcutaneous and intra-abdominal compartments and can only be accurately quantified by CT or magnetic resonance imaging (MRI) or without differentiation using dual energy X-ray absorptiometry (DXA) (Goran & Gower 1999). However indirect methods of waist circumference, a measure of both intra-abdominal and subcutaneous fat, or truncal skin fold measurements, which measures subcutaneous fat only, are more practical and economic for large population based in-field assessment of central adiposity. The relationship between an increased waist circumference measurement and health risk was first described by physician Dr Jean Vague over 60 years ago (Browning, et al., 2010) and thereafter gained reputation for being associated with visceral (intra-abdominal) fat mass, in contrast with BMI associating more with whole body subcutaneous FM (Krebs, et al., 2007).

The prediction of metabolic risk in children from waist circumference is complex and there is no global recommendation for waist circumference reference values associated with excess adiposity and disease risk (Krebs, et al., 2007). Various derived cut-points for waist circumference measurements in children and adults vary by age, gender and height (World Health Organisation, 2011; Taylor, et al., 2010). From an examination of a group (N = 818) of Italian children 3 to 11-yrs old (Maffeis, et al., 2001) 47% of those with a waist circumference above the 90th percentile had a single cardiovascular risk (more likely, low HDL cholesterol, hypertension or a high total cholesterol / HDL ratio) and 19% had 2 risks, compared to 80% of those with waist circumferences below the 90th percentile having no risks. A trend analysis (Utter, Scragg, Denny & Schaaf, 2009) from 608 adolescents in 1997/1998 and 897 adolescents in 2005 (from lower socioeconomic areas) reported an increase in average waist circumference of 13 cm (or 17%) and at the 90th percentile 19 cm (20%) from 1997/1998 to 2005. Therefore the youth in 2005 were more likely to be accumulating central fat and increased cardiometabolic risk compared to their peers six years prior.

Waist circumference growth reference curves were developed (McCarthy, Jarrett & Crawley, 2001) from cross sectional analysis of more than 8,000 British children from 5 to 16-yrs old. These age-specific reference curves were compared with similar curves derived from Spanish, USA and Cuban children where considerable variation in average waist circumference was demonstrated (McCarthy, et al., 2001). Particularly after 7-yrs old, USA children had larger waist circumferences than other populations. Similarly to children, adults from different ethnic groups and populations (Wang, Ma & Si, 2010) have variable average waist circumference values and variance in ability to predict risk for disease independent of measurement methods and risk factors measured. This means that despite knowing that waist circumference is positively associated with risk for cardiometabolic diseases, waist needs to be referenced accordingly to specific population and ethnic groups (Qiao & Nyamdorj, 2010). Even so the sensitivity and specificity of cut-points derived may not be reliable (Qiao & Nyamdorj, 2010; Wang, et al., 2010). For example in 888 Iranian children 6 to 12-yrs old (Barzin, Hosseinpanah, Fekri, & Azizi, 2011) the odds of correct prediction of metabolic syndrome from BMI and waist circumference SDS were the same, OR = 2.6, and areas under the receiver operators characteristics curve (AUC) were also similar, ~ 0.73. Optimal cut-points of 16 kg/m$^2$ for BMI and 57 cm for waist circumference were reported without any consideration of age.  In contrast to Iranian children, in USA adolescents (Messiah, Arheart, Lipshultz, & Miller, 2008) cardiovascular risks were predicted with fairly similar sensitivity and specificity, however depending on age group and gender, cut-points ranged from 19 to 27 kg/m$^2$ for BMI and 67 to 87 cm for waist circumference. The underlying message is BMI and waist circumference can perform equally at risk prediction but require age and gender (and perhaps ethnic group) specific threshold values.  Waist circumference still requires accurate guidelines including growth curves and associated thresholds representative of diverse global populations before it can be recommended as an effective screening tool for children.  Another option is exploration of the index of waist circumference relative to height (WHtR), which may not need adjustment for age and gender, to be a simple predictor of risk.

During 1995 Heish and Yoshianga are acknowledged for providing evidence that in adults, disease risks were over or under estimated in people with variable heights and similar waist circumference therefore devising the WHtR ($\frac{waist\ circumference\ (cm)}{height\ (cm)}$) (Ashwell & Hsieh, 2005; Browning, et al., 2010).  Since then WHtR has been validated as an anthropometric parameter that should be included in adiposity and risk assessment of adults and children (Freedman, Khan, et al., 2007; Nambiar, Truby, Abbott & Davies 2009; Sung, et al., 2008; Garnett, Baur, Srinivasan, Lee & Cowell, 2007; Savva, et al., 2000; Goulding, Taylor, Grant, Parnell, Wilson & Williams, 2010; Browning, et al., 2010).

In children (Nambiar, et al., 2009; Mushtaq, et al., 2011), including those in NZ (Taylor, R., Williams, Grant, Taylor, B. & Goulding, 2011; Goulding, et al., 2010), it has been demonstrated the WHtR does not need further adjustments for age, gender, height or ethnic group.  The World Health Organisation (2011) recognises there is convincing evidence that the WHtR is associated with overall cardiovascular disease risk, type-2-diabetes, hypertension and overall mortality (mostly cross-sectional studies) and suggest  a universal cut-point of 0.50 cm/cm.  For children (Browning, et al., 2010; Savva, et al., 2000) and adults (Lee, Huxley, Wildman, & Woodward, 2008; Browning, et al., 2010) the WHtR and waist circumference (Rodriguez, et al., 2004) are more sensitive or no different (Taylor, et al., 2010; Huxley, Mendis, Zheleznyakov, Reddy & Chan, 2010; Jung, Fischer, Fritzenwanger, & Figulla, 2010) to BMI for screening for cardiometabolic risk, e.g. dyslipidemia, hypertension, insulin resistance, impaired glucose tolerance and type-2-diabetes. Independent of BMI, a WHtR greater than 0.50 cm/cm is associated with increased risk of chronic disease in adults, and immediate risk in children, and a WHtR greater than 0.60 cm/cm is indicative of high risk in adults (Garnett, et al., 2008; Nambiar, et al., 2009, Browning, et al., 2010). Non-overweight children with waist to height ratios greater than 0.50 cm/cm are demonstrated to have higher risk for increased abdominal fatness and cardiovascular disease than overweight children with waist to height ratios less than 0.50 cm/cm (Mokha, et al., 2010).

New Zealand children aged 5 to 14-yrs (*n* 3000) who took part in the National Children's Nutrition Survey 2002 were examined for relationship of WHtR with BMI SDS including ethnic group comparisons (Goulding, et al., 2010). Goulding, et al. (2010) report that WHtR was strongly but non-linearly associated with USCDC 2000 BMI-SDS in these children. For Māori, Pacific and NZ European and Others; age and gender, WHtR values at 85th, 95th and 99th percentile for BMI were similar. More than 90% of children with a WHtR greater than 0.50 cm/cm also had BMI above the 95th percentile (Goulding, et al., 2010). Overall 25.6% of the NZ child population aged 5 to 14-yr had increased WHtR and therefore potential health risk and WHtR exceeded 0.50 cm/cm for 33.1% and 43.4% of Māori and Pacific children respectively (Goulding, et al., 2010). This supports the use of promoting a public health goal of WHtR less than 0.50 cm/cm in NZ children aged 5-yrs or older and use for cardiometabolic risk assessment. While there is evidence to suggest the WHtR performs equally alongside BMI in relationship studies with cardiometabolic risk (Freedman et al., 2007), the WHtR message of, "keep your waist measure less than half your height", may be much more simple for people to understand (Browning, et al., 2010; Garnett, et al., 2007).

When making assessments of adiposity levels in children, a measure such as the WHtR has the ability to provide additional information about centrally distributed FM where others such as BMI and FM% estimations (BIA or skin-fold measurements) do not. Bioelectrical impedance analysis has the advantage of discriminating FM and FFM allowing for enhanced assessment of whole body fatness and lean mass in relation to associated risks.

### 1.2.6 Fat mass estimation: Bioimpedance analysis.

Bioelectrical impedance analysis is a fairly robust, simple, economical, non invasive method to predict a two compartment examination of FFM and FM (Pietrobelli, et al., 2003). In the simple, theoretical, two compartment model, body mass is equal to the sum of FFM and FM. Fat mass is every molecule that is soluble in ether. Fat free mass has constant hydration of 76% to 73% water in children (age dependent). The water in the FFM gives the body its resistive properties to an alternating current (single frequency, 50 kHz, 800 µamp signal) that is passed from the hand to the foot (or foot to foot or both hands to both feet in multiple frequency BIA) and the impedance, reactance, resistance and phase of the output current is measured. There is a constant relationship between body water and height squared divided by resistance, also known as the impedance index. Validated predictive equations are established when body water is measured by deuterium dilution or other less direct measurement such as DXA. Multiplication of the total body water by the age and gender specific hydration factor (Fomon, et al., 1982) allows FFM to be derived which may then be subtract from weight to derive absolute and relative FM (Houtkooper, Lohman, Going & Howell, 1996).

Nielsen, et al. (2007) reviewed more than 40 different predictive equations for child populations, representing multiple countries and ethnic groups. Generally equations included, $FFM = constant\ +\ \beta_1 \times \left(\frac{height^2}{impedance}\right) + \beta_2 \times Weight + \beta_3 \times Height + \beta_4 \times Age + \beta_5 \times Gender$, however height, age and gender are not considered in every equation and sometimes other anthropometric measurements are included (Nielsen, et al., 2007). There is not enough evidence to suggest BIA derived prediction equations do or do-not differ significantly among ethnicities, although one validation study on NZ children aged 5 to 14-yrs showed ethnicity as a non significant predictor (Rush, Puniani, et al., 2003). In other populations bioelectrical impedance analysis can however detect FM / FFM ratio differences between ethnicities for the same BMI (Rush, Scragg, et al., 2009). Several different child population specific BIA equations were applied to BIA measurements of a group of 5-yr old children (Williams, Wake & Campbell, 2007) and demonstrated that there is wide variation of FM% (by BIA) for a set BMI. Williams et al. (2007) also demonstrated in that while FM% derived from different BIA equations were very highly correlated (Spearman ranked) with each other, each equation applied gave different estimations of FM% in the same group of children. These findings suggest the most advantageous way to use BIA is to derive predictive equations from the reference population where the analysis is going to be used and follow the same methods each use e.g. equipment and electrode placement (Houtkooper, et al., 1996; Nielsen, et al., 2007), especially when examining populations who have different nutritional status e.g. Nigerian children (Leman, Adeyemo, Schoeller, Cooper & Luke, 2003). Disadvantages to BIA is that total body water volume fluctuates depending on dehydration, electrolyte balance, body temperature e.g. after exercise, and food or fluid consumption e.g. a full bladder (Houtkooper, et al., 1996).

Despite disadvantages of deriving FFM / FM by BIA, it is more user friendly and economical, especially for large sample sizes, and most importantly does not expose children to ionizing radiation, compared to more accurate calculations from DXA, CT and MRI imaging (Nielsen, et al., 2007). McCarthy, et al. (2006) developed FM% reference curves for children (5 to 18-yrs) using BIA, for clinical and research settings. The reference population was less than 2,000, Caucasian only school children, mostly in affluent living conditions in Southern England. Despite the non-representation of the wider population, reference FM% at the 85$^{th}$ and 95$^{th}$ percentile cut-points closely matched the IOTF definition of overweight and obesity, respectively (McCarthy, et al., 2006). However in a sample of 661 NZ Europeans, 3 to 18-yr olds (Taylor, Jones, Williams & Goulding, 2002) FM% (by DXA) at the IOTF overweight and obesity cut-points varied with age and gender (For boys overweight and obese 18% to 23% and 24% to 36%, respectively. For girls, 21% to 34% and 26% to 46%). Williams, et al. (2007) demonstrated mostly moderate correlations between FM% by different BIA prediction equations and BMI. Whereas there was high to very high correlation between FM% by DXA and BMI (Taylor, et al., 2002).

Using a prediction equation previously derived in a group of Māori, Pacific and European children (Rush, Puniani et al., 2003), longitudinal assessment (Rush, et al., 2012a) of children who were part of the Project Energize randomised controlled trial, demonstrated clear differences between Māori and European children in the relationship between BMI and FM%. These differences emphasised accelerated growth (for both FM and FFM) for Māori after tracking indices of FM and FFM (measurements were adjusted by $height^2$) (Rush, et al., 2012a). Tracking growth trajectory differences among ethnic groups may help better understand the timing of vulnerability to risk factors and when or how to best intervene e.g. increasing physical fitness.

In adults, disease risks (fasting glucose, HDL cholesterol, triglycerides, systolic blood pressure) may be equally associated with BIA predictions of FM % and BMI (Willett, K., Jiang, Lenart, Spiegelman & Willet, W., 2006). In children FM% by DXA (Daniels, Morrison, Sprecher, Khoury & Kimball, 1999) compared to BMI was a better predictor of plasma triglyceride concentration (positively) and HDL cholesterol concentration (negatively). At the same time BMI had predicted blood pressure better than FM%. estimated by DXA analysis (all low to moderate effect sizes). Body fat distribution (as the ratio of DXA determined truncal fat mass divided by hip and thigh fat mass) was the standout significant factor in association with risks assessment of triglycerides, HDL cholesterol and systolic blood pressure (Daniels, et al., 1999). These findings suggest that while total body fat estimations e.g. BIA and BMI may associate with risks differently, adding measures that include fat distribution and body composition indices may help to further explain variations in disease risk. Monitoring body adiposity is not the only outcome measure available to screen for related disease risks and assess the impact of childhood obesity interventions. Physical fitness testing is an effective method to provide objective information about the physical abilities of individual children and child populations.

### 1.2.7 Physical fitness, physical activity and obesity.

Establishing an active lifestyle and optimising physical fitness in childhood may initiate health improvements and behaviour which continue into adulthood (Huotari, et al., 2011). Physical activity and physical fitness are not equivalent but are synergistically related. They both develop early in life, vary during growth and development and can be followed into adulthood (Steele, Brage, Corder, Wareham & Ekelund, 2008). Physical fitness is a physiological measure of physical strength and motor performance or function. Cardiorespiratory fitness (CRF) is a measure of the ability of the heart and lungs to increase their capacity to allow the body to do more physical work. Physical activity is a measure of the quantity and level of physical movement over time (Malina, Bouchard & Bar-Or, 2004). Change in physical activity is often an outcome measure for obesity intervention, however measuring physical fitness may be the better objective indicator of change in function and therefore risk for chronic disease.

To benefit health the NZ Ministry of Health recommended adults do a minimum of 30 min of moderate and children 60 min of moderate to vigorous physical activity every day. In 2006/07 when NZ adults were questioned about their physical activity levels (Ministry of Health, 2008a), half said that they were regularly doing 30 min 5 to 7 days physical activity every week (a trend unchanged since 2002/03). Men reported doing more than women and the gender difference increased in older age. Māori and NZ European were fairly similarly active and more active than Pacific and Asian adults. Reported physical activity levels in adults did not differ by socioeconomic group. However women living in the lowest socioeconomic communities reported two fold more time spent in sedentary activities compared to women in the highest socioeconomic communities (Ministry of Health, 2008a). When NZ parents reported (Ministry of Health, 2008a) on physical activity behaviour of their children, just under half of children used active transport between home and school. In boys more Māori and Pacific use active transport compared to NZ European and Other boys, and in all children there were no differences among socioeconomic groups. However two thirds of children watched more than two hours of TV per day and were more likely to be Māori and living in the most deprived neighbourhoods (Ministry of Health, 2008a). In 2007 a survey of NZ adolescents (Adolescent Health Research Group, 2008) revealed only 11% met the current recommendation of 60 min moderate to vigorous daily activity. Over the last five decades aerobic physical fitness of NZ and Australian children (Tomkinson & Olds, 2007) has reduced although not at a constant rate. A similar trend is noted globally, however the plateau and decline of aerobic physical fitness beginning one decade later. This later decline is thought (Tomkinson & Olds, 2007) to be attributed to the physical activity and 'health spa' boom in the 1950's and 60's as a result of increased awareness and desire to improve adult and youth fitness in preparation for war and for better health (a credit to Dr. Kenneth Cooper's, book, *Aerobics*,1968) (Corbin, 2012).

There is general agreement that in adolescence, body composition and CRF are related and both track into adulthood, contributing to long term health outcomes (Kim & Lee, 2009). Adolescent CRF (treadmill time) can be demonstrated to be moderately related with adult BMI, waist circumference and FM % (Eisenmann, Wickel, Welk, & Blair, 2005). For adults there is evidence that CRF and physical activity have combined and independent inter-relationships with each other, fatness and health outcomes (Jakicic, Mishler & Rogers, 2011; Telford, 2007). There is limited evidence to suggest that clear interrelationships exist among physical activity, fitness and body composition in younger children, (Kim & Lee, 2009; Sveinsson, Arngrimsson & Johannsson, 2009; He, et al., 2011; Wang, et al., 2011; Kim, et al., 2005; Hussey, Bell, Bennett, O'Dwyer & Gormley, 2007). At most findings support trivial to moderate associations between physical activity and physical fitness (Kristensen, et al., 2010) and gender, age and ethnic group interactions may exist.

Study methodologies vary in the methods of physical activity data collection, e.g. questionnaire or accelerometer, and vary how activity levels are categorised (Kim & Lee, 2009; Harris, Kuramoto, Schulzer & Retallack, 2009). When accurately measured e.g. with accelerometers, doubly labelled water or heart rate monitoring, a higher level of physical activity is associated with smaller waist circumferences (Kim & Lee, 2009). and conversely more time spent in sedentary activities is associated with increased waist circumferences. In NZ boys (Rush, Plank, et al., 2003) aged 5 to 14-yrs, FM% (oxygen dilution space) was negatively associated with physical activity level, but not in girls. In these children (Rush, Plank, et al., 2003), while BMI was significantly higher in Māori and Pacific children compared to NZ European there was no statistical difference in FM %. In addition Māori and Pacific children expend more energy and have higher level of physical activity, therefore physical activity level may not be adequate at explaining body composition and health risk differences among the different ethnic groups in NZ.

Cardiorespiratory fitness ($VO_2$) and physical fitness also have variable methods of measurement (Tomkinson & Olds, 2007), but most commonly a 20 m shuttle run is utilised for in-field testing (Stabelini-Neto, et al., 2011; He, et al., 2011). For further analysis physical fitness is often categorise into fitness levels e.g. highs and lows, either by median splits (Wang, et al., 2011; He, et al., 2011), tertiles (Stabelini-Neto et al., 2011), quartiles, quintiles, and also cut-points relating to metabolic risk scores by sensitivity analyses (Ruiz, Ortega, Loit, Veidebaum & Sjostrom, 2007). Despite various measurements there is convincing evidence (Ortega, et al., 2011) that from childhood, in both genders, improving CRF can reduce risk of becoming overweight or obese in adolescence. Physical fitness is an independent predictor of weight gain or status in children (McGavolock, Torrance, McGuire, Wozny & Lewanczuk, 2009) and even within short periods of time ( e.g. 18 months), children who have the lowest levels of CRF may be more likely to become or remain, overweight and obese (He, et al., 2011). Improving cardiovascular disease risk by improving fitness in overweight children may also attenuate metabolic syndrome risks during their adolescence which often become exacerbated during and after puberty (DuBose, Eisenmann & Donnelly, 2007). With increasing age the negative association between adiposity and physical fitness strengthens (Brunet, Chaput & Tremblay, 2007). In adult males (Wong, et al., 2004) for a given BMI high CRF was associated with smaller waist circumference and less abdominal fat volume by computerised tomography. Similar findings have been found in both genders (Ross & Katzmarzyk, 2003) for associations of lower total body and abdominal FM with higher CRF, where waist circumference was also an independent (of BMI and age) predictor of CRF. In Adult women (Farrell, Braun, Barlow, Cheng & Blair, 2002) and men (Park, Chung, Chang, & Kim, 2009), all cause mortality is predicted by low levels of CRF independent of BMI and may be somewhat mediated by physical activity levels (Park, et al., 2009), which is also confirmed by a systemic review including both genders (Fogelholm, 2010).

When examining effects of childhood obesity intervention on adiposity and physical fitness in children it is controversial if physical activity is a necessary covariate to factor into the analysis. A review (Harris, et al., 2009) of school based physical activity interventions suggests increased physical activity may not significantly improve body mass index in children, but there is evidence that high intensity, longer duration (greater than 40 min in children (Ruiz et al. 2006)) physical activity improves several markers of health risk including increased physical fitness (Harris, et al., 2009; He, et al., 2011). Sveinsson et al., (2009), demonstrated 15-yr-olds had small to moderate positive relationship between physical activity parameters, as measured by accelerometer, and CRF by cycle ergometer, but no significant relationship was shown in 9-yr olds, despite the 9-yr olds being more physically active than the adolescents. In addition to CRF different body composition measures were not significantly correlated with physical activity except slightly with sum of four skinfolds ($r^2 = 0.03$, 9-yr and $r^2 = 0.12$, 15-yr olds) (Sveinsson et al., 2009). Lohman, et al. (2008) examined relationships among physical activity (accelerometer), physical fitness (cycle ergometer) and fatness (BMI and skin-folds) in a large number ($n$ > 1000) of multiethnic, 14-yr old girls and found a significant but trivial to low, negative association between fatness and physical activity levels. In addition there was moderate association between physical activity and physical fitness measurements (Lohman, et al. 2008). While physical activity was not a measurement included in the 2011 evaluation of Project Energize, in a 2010 survey involving 77 'Energized' schools estimated classroom-based, daily 'huff n puff' exercise to average 15 min a day and total physical activity (including sport and physical education) 39 min a day in school time (Rush, et al., 2011). This does not take into account school interval 'play' time where children may be moderately to vigorously physically active 40% to 55% of the time (Ridgers, Saint-Maurice, Welk, Siahpush & Huberty, 2011).

For children free play time during school hours is an opportunity to promote engagement in high levels of physical activity. It is also opportunity for teaching staff to promote and engage in, and benefit from physical activity. It is a concern if overweight or obese children and adolescents have difficulties performing activities of usual daily living like walking or running, as this can impact on current and future physical activity levels, enjoyment, potential injury and premature deterioration of body structures, e.g. lower limb joints and feet (Shultz, Browning, Schutz, Maffeis & Hills, 2011). Promotion of high levels of quality physical activity is still required to attain a measurable effect on physical fitness and obesity. Stabelini-Neto, et al. (2011) describe how physical activity levels fluctuate on a daily basis. In children increased training or volume of physical activity (Payne & Morrow, 1993) may not subsequently raise maximum aerobic capacity, or if does, is a small to moderate association. Cardiorespiratory fitness, which has genetic components (Bouchard, Donne, Simoneau & Boulay, 1992), and non- genetic (but probably epigenetic) components (Mustelin, et al., 2008), stays fairly stable over time, although physical fitness will increase and decrease depending on effort and health of the individual (Stabelini-Neto, et al., 2011). Meaning monitoring physical fitness as a whole is more essential than a focus solely on CRF / $VO_2$ level.

In summary, minimal daily time spent in vigorous physical activity is not being met by majority of people, which is related with excess body fat, however generalised monitoring of physical activity is not advantageous to the monitoring of physical activity and nutrition interventions because relationship studies are weak. This makes physical fitness testing a more objective and reliable measure of health e.g. improvements in nutrition, lifestyle and body composition. Prospective longitudinal studies in children relating interventions with physical fitness and disease outcomes are lacking. Cost and time efficient measures of physical fitness at a population level are few and are not usually a routine test in the NZ education system. In New Zealand the 550 m run test has been the most reported fitness measure.

*The 550 m run fitness test.*

The main functional outcome measure for the 2011 evaluation of Project Energize was the time for children to run 550 m. This is a simple running test which accommodates the need to test a large sample of children and can be administered consistently at schools across a large geographical area within a short time frame. However it is not a commonly recognised fitness test with only a few reports from the mid 1980's available in Department of Education NZ publications (Dawson, Hamlin, Ross & Duffy, 2001).

The recorded history of use of the 550 m run dates back to youth fitness testing for USA school children and adolescents in the early 1960's. This test was guided by the President's Council on physical fitness and sports; American Alliance for Health, Physical Education, and Recreation (AAHPER), where the recommended cardiorespiratory function test was a 600 yard (549 m) walk/run test, agility and speed were tested by a shuttle-run test and a 50 yard (46m) sprint and various measures for muscular power / strength / endurance e.g. sit-ups, pull-ups and standing broad jump (Dennison, Straus, Mellits & Charney, 1988; Simons-Morton, Parcel, O'Hara, Blaire and Pate, 1988) were recommended. The 600 yard run was traditionally promoted as a measure of cardiorespiratory function because runs around this magnitude have been shown to correlate moderately to highly with treadmill or cycle ergometer $VO_2$max testing (Dennison, et al., 1988; Krahenbuhl, Pangrazi, Petersen, Burkett & Schneider, 1978; Cumming & Keynes,1967; Castro-Piñero, Ortega, Mora, Sjöström, & Ruiz, 2009). There is historical evidence that the 600 yard run was a reliable test in junior and senior adolescents (Askew, 1966; Cotton & Singh, 1969) and evidence that junior adolescents may have less confounding effects from performance stress or individual motivation (Askew, 1966). Later in the 1980's the battery of US youth fitness tests were simplified to a cardiorespiratory endurance test (1-mile-run) and muscle strength / endurance (sit-ups), with the addition of flexibility (sit-&-reach) and body composition measures (skinfolds) (Simons-Morton, et al., 1988). In more recent times the 550 m run has been used as a fitness test for children with mental or physical disabilities (Fowler, et al., 2010). In NZ, the only published studies that report 550 m run times are with South Island, Cantabrian children (Hamlin, Ross & Sang-wan, 2002; Dawson, et al., 2001; Albon, Hamlin & Ross, 2010) and this was the justification for the use of this measure in the 2011 evaluation of Waikato children (Rush, et al., 2011).

From 1991 to 2003 the body size and time to run 550 m of Canterbury children (Albon, et al., 2010) aged 10 to 14-yrs (*n* = 3306) were assessed in a decile 5 school, up to twice a year. Children with higher BMI took longer to run 550 m and increased run time was moderately correlated with increasing BMI (r = 0.33) (Albon, et al., 2010). During the 12 years of measurement, average BMI increased by 1.4 $kg/m^2$ in boys (increase of 4.5 kg weight, 1.8 cm height) and 1.3 $kg/m^2$ in girls (increases of 3.9 kg weight, 2.4 cm height), with larger increases in the size of children in the upper quartile for BMI (Albon, et al., 2010). A similar trend was seen for the time to run 550 m which increased in boys and girls by 12% to 11% and those over the 50th percentile had much larger increase in run time. The authors summarised these findings as, "the fat and unfit are getting fatter and more unfit"(Albon, et al., 2010). Waist circumference measure was not utilised in their study and it may be hypothesised that the waist to height ratio may have shown a stronger association with running times. The inclusion of indirect measurements of abdominal fat with fitness measures may be more sensitive measures of fitness and risk (Brunet, et al., 2007; Hussey, et al., 2007). The association of functional measures such as run speed with measurements of body size such as WHtR needs to be explored further.

## 1.3 Aims and hypotheses

*The primary aim:* Explore in NZ children aged 7 and 10-yr, the relationships of BMI, WHtR and FM% with time (s) to complete a 550 m run (cardiorespiratory fitness endurance test).

*The primary research question:* In children is WHtR more strongly associated with completion time (s) in the 550 m run compared with BMI, waist circumference or FM%?

*Primary hypothesis:* The 550 m run times will associate more strongly with increasing WHtR than with increasing BMI in children.

*Secondary aims:* To investigate the gender, ethnic group and socioeconomic cofactors and their association with physical fitness and adiposity in childhood. To examine the sensitivity of the recommended cut-point for WHtR (0.50 cm/cm) to identify the current BMI classifications for overweight and obesity.

*Secondary Hypotheses:* Māori and Pacific children will take more time to run 550 m compared to NZ European children. There will be slower run times and larger body sizes for children attending lower decile schools. Between Māori and NZ European children there will be a smaller difference in WHtR despite a larger difference in BMI. The WHtR 0.50 cm/cm will have high sensitivity and specificity at identifying children classified as overweight or obese.

# 2. DESIGN AND METHODS

The data base of physical measurements of children and demographic characteristics of schools who participated in the 2011 extended evaluation of Project Energize (Rush, et al., 2011) was analysed to answer the questions around the associations of time to run 550 m (run-time$_{550m}$) with anthropometric measurements (height, weight, waist circumference, body mass index (BMI), waist to height ratio (WHtR), fat free mass (FFM) and fat mass percent (FM%) and demographic variables.

First this chapter presents the background design of the Project Energize extended evaluation and the participants, followed by acknowledgement of ethical approval, which is a component for any research with humans and especially children. The next sections describe details and processes of the data collection and management, and the final section will present the methods of statistical analysis applied to the data that inform this thesis.

## 2.1 Background design: Project Energize extended evaluation

The 2011 extended evaluation of Project Energize March 2011, was a quasi experimental evaluation of two age groups (7 and 10-yr old) of primary school children, attending schools in the Waikato region of New Zealand. The schools had been involved for a minimum of two years and maximum of six years, in an intervention aimed at increasing good nutrition and physical activity of their pupils. Goals of this physical activity and nutrition intervention include a desired trickledown, inclusive effect for families and the wider community (by, for example, providing take home resources). The intervention, Project Energize, is funded by the Waikato District Health Board and contracted to Sport Waikato. The intervention is delivered by 26 Energizers, who are qualified in subjects of child education, nutrition and physical activity, and who in 2011 worked with 8 to 12 schools each. They are the 'one stop shop' for all nutrition and physical activity needs of their school.

The Project Energize extended evaluation was a follow-on from the 2004 to 2006 two year randomised (by school) controlled trial (RCT) involving 2752, 5 and 10-yr olds of which 31% were Māori and 62% NZ European children, from 124 schools (62 enrolled in the program, 62 control schools) in the Waikato (Graham, et al., 2008; Rush, et al., 2012b). School randomisation by geography was aligned with the concurrent trial, Te Wai o Rona Diabetes Prevention Strategy (Simmons, Rush & Crook, 2008).

Moving forward from the RCT, implementation of the Project Energize programme has continued to be a multifaceted, regular direct contact within school intervention and as of 2011 there were 247 "Energized" schools reaching 44, 000 children of which 34% were self identified as Māori and 55% as NZ European. For the extended Evaluation, prior power calculations carried out by the lead researchers determined that a minimum of 600 of each European and Māori children in both age groups would be sufficient to find a meaningful difference between historical controls in 2004 and 2006 and current children (historical measurements are not a part of this thesis). Therefore approximately 11,355 of the 7 and 10-yr old children attending the selected schools were invited by classroom to participate in the extended evaluation. Parental and child consent was received from 45% of those invited, and one third of respondents were Māori.

The efforts undertaken by the author of this thesis to have some responsibility for and understanding of the data collection process and subsequent analysis included attendance of training sessions for the procedures around the collection of accurate and reliable measures of body size, composition and fitness measurements. The author also participated in the measurement protocols at some schools, child interviews and the process of data entry. The author was not involved in the design of the evaluation or methods of data collection which had occurred over the previous two years under the direction of the Project Energize Evaluation Reference Group. However, the author was able to attend several Reference Group (Appendix A) meetings to gain insight into the collaborative knowledge and participation of the stakeholders surrounding the research process e.g. Iwi Maori Council approval, planning and report writing.

## 2.2 Ethics

Ethics approval was given by the Northern Y Ethics Committee, NTY/10/04/041, for the collection of data for; 'Extended Evaluation of Project Energize'- investigators: Dr David Graham, Prof Elaine Rush, Kasha Latimer, Stephanie Mclennan, Mike Hamlin, Evaluation

Reference Group application and this information was supplied to the Auckland University of Technology Ethics Committee (AUTEC) . At the AUTEC meeting on 11 April 2011 the involvement of a post graduate student enrolled with AUT University was approved and the Northern Y ethics committee were also advised that the student would be undertaking this analysis under the direction of Professor Rush (Appendix B).

Parents or caregivers of the children provided written informed consent (mainly received at the end of 2010) for measurement protocols to be undertaken. The comfort and privacy of the children involved in this evaluation was considered of primary importance. Screens were used to provide private areas and each child was provided with a folder to privately store their record sheet during data collection. Children gave verbal consent prior to each measurement. Children were given the opportunity to ask questions to facilitate their reassurance and understanding of the measurment process.

## 2.3 Data collection

2.3.1 Extended evaluation measurement team.

The evaluation team consisted of approximately 50 people. There was 1 medical leader (Dr. D. Graham),1 academic leader (Professor E. Rush), 2 Sport Waikato supervisors, 26 Energizers (formed in teams), 9 nurses, 1 biostatistician, 2 AUT students and several other helpers. Training was attended by all, and the six teams of five to six members including one nurse each were encouraged to experiment with different models of structuring the measurement process, timing how long each took and assessing precision and accuracy of each of the measurements. Teams were then systematically deployed to each visit schools in the Waikato region and measure children. The entire process took seven weeks and included data entry and checking.

2.3.2 Participants.

School decile, number of children attending and the ethnic profile of schools was used to plan which classes to approach for measurement consent, in order to achieve sampling balance for Māori and NZ European participants. Planned recruitment was for 1416 children in each age group (7 and 10-yr olds), split between each main ethnic group (Māori and NZ European) with over sampling of the lowest decile schools (decile one to three) (Rush, et al.,2011).

Waikato schools initially consented to participating, prior to inviting their classes of 7 and 10-yr old pupils for participation and gaining consent from guardians. Mentally or physically impaired children or those attending special needs schools were excluded. As classrooms invited were attended by a range of ages the overall sample would include mostly 6 to 11-yr olds and few 5 and 12-yr olds, no children who gave consent for measurements were left out due to age.

### 2.3.3 Ethnic groups.

Ethnicity of the participating children was determined by self reported information recorded on each school roll (Rush, et al., 2011). Children participating in the Project Energize extended evaluation were priority grouped according to four different ethnic categories represented in New Zealand — Māori, Pacific, Others and NZ European. In 2010 ethnic proportions of Waikato school children aged 5 to12-yr old were, 55% (NZ European), 34% (Māori), 3.5% (Pacific) and 8% (Other) (Rush, et al., 2011 — based on Ministry of Education data). The 'Other' ethnic group included Indian, Asian and other nationality children. In this thesis ethnic comparisons have been made between the four ethnic categories, however acknowledgement is made that the numbers of Pacific and Other children participating are proportionally too low to make accurate comparisons. Post hoc adjustments (Games-Howell) were applied to ANOVA analysis for ethnic group comparisons to adjust for comparisons between unequal group sizes and unequal variances.

### 3.3.4 Physical data.

Measurements made or derived, that are analysed for this thesis are summarised in Table 2.1. Blood pressure (systolic blood pressure, diastolic blood pressure, pulse rate), knowledge and attitudes questions (pertaining to food and physical activity), and a household questionnaire (health, eating habits, physical activity, household food and drink), were also a part of data gathering, but not a part of any analyses in this thesis.

### 2.3.5 Measurement schedule.

Over 5100 participants were scheduled to be measured over the seven week period. Teams had their schedule of schools to attend on pre-organised days, as negotiated with each school. There were designated indoor rooms within the school reserved for the physical measurements, usually the school hall or library. Sometimes teams travelled to more than one school within one day and sometimes one school took several days to complete. This is because there were variable numbers of classrooms and children participating from each school. Team leaders were in-charge of group directions and managing the data sheets. Teams often developed their own systematic approach to how they processed their children through their measurements and were adaptable to changing environments (personal observation, Author). However the actual techniques of measurement were standardised to the protocols outlined in training (Refer to Operations Manual for the Extended Evaluation of Project Energize - Property of Sport Waikato).

**Table 2.1 Summary of measurements and precision**

| Measurement | Calculation | Precision |
|---|---|---|
| Age | Age from birth date and date of measurement | Calculated as decimal years |
| ***Body size*** | | |
| Height | Centimetres (cm), using a portable height scale. | Nearest 0.1cm |
| Weight | Kilograms (kg), using a portable electronic scale. | Nearest 0.1kg |
| Waist circumference | Centimetres (cm), using flexible non stretchy measuring tape | Nearest 0.1cm |
| Body mass index | $\frac{\text{weight (kg)}}{\text{height}^2\,(\text{m}^2)}$ | Two decimal places |
| Waist to height ratio | $\frac{\text{waist circumference (cm)}}{\text{height (cm)}}$ | Two decimal places |
| ***Body composition by single frequency hand to foot bioimpedance analysis*** | | |
| Fat free mass | Kilograms (kg) | Two decimal places |
| Fat mass | Kilograms (kg) | Two decimal places |
| Percentage fat mass | Percentage (%) | Two decimal places |
| ***Cardiorespiratory fitness*** | | |
| Time to run 550 m: *A standardised physical fitness test** | Running five times around an outdoor, grassy, 110 metre oval course. Timed with a stop watch in minutes and seconds. | Nearest 1.00 second |

*(Dawson, et al., 2001).

2.3.6 Data collection: Record sheet.

Each child was given a pre-printed record sheet identified by a unique number and clipped inside a file folder (for privacy) to carry between measurement stations. Before each measurement was made children were asked their name and age to match to their record sheet. Record sheets were designed to make it easy, and minimise errors in recording by using dedicated blocks for each digit of measurement. Decimal points were already printed. There were check boxes to tick (if measurement was within pre determined range) or cross (if measurement was out-of range). Page one contained all the physical data and page two (flipside) contained the knowledge and attitude survey. There was a final check box to tick when each page was fully completed.

There was space on the record sheet for additional notes where measures were deviant but were normal for that individual, for example, "measure accurate for this individual", "tall for age" or "very tiny waist". Or if there were malfunction issues with equipment or loss of cooperation with the child. If measures were missed on the scheduled day, for example if children were absent or had changed schools, if practicable a follow up occurred at a later date.

The rest of this chapter details how each physical measurement was made.

### 2.3.7 Height.

Height was measured with a portable height scale (Invicta; Modern Teaching Aids Auckland). Children were measured with shoes and hair ties removed. If they were unable to stand straight this was noted on their record sheet. The child was asked to stand straight with feet together, eyes level and weight even. Occiput, thoracic spine and heels were parallel to the vertical pole. At maximal inhalation the horizontal bar was lowered enough to touch the top of the head. Measurement was recorded to the nearest 0.1 cm, reading with the observer's eyes level to the bar to avoid parallax. The process was repeated after repositioning the horizontal bar. If the first two measures differed by more than 0.5 cm a third measurement was made. The average of the two values within the specified tolerance was used. Measures were also checked if they fell below the 2.5 percentile for age, (e.g. 7-yrs 116.3 cm, 10-yrs 138.3 cm), or above the 97.5 percentile for age, (7-yrs 131.0 cm, 10-yrs 158.2 cm) pre-determined from the measurements in 2004 and 2006.

2.3.8 Weight.

Weight was measured on portable electronic scales (TIHD316 and Soehnle Wedderburn, Auckland). Children were measured with shoes and any heavy clothing removed. Scales were electronically zeroed, then the child was asked to stand on the scales looking straight ahead, arms by their sides. The privacy cover on the scales was then lifted so that only the observer and not the child could see the weight and recorded. This process was repeated and if the first two measures differed by more than 0.5 kg a third measure was made. The average of the two values within the specified tolerance was used. Measures were also checked if they fell below the 2.5 percentile for age (7-yrs 20.4 kg, 10-yrs 43.8 kg) or above the 97.5 percentile for age (7-yrs 26.6 kg, 10-yrs 65.0 kg).

2.3.9 Waist circumference.

Waist measure was made using a non stretchy flexible measuring tape marked in centimetres. The position was anatomically defined as the circumference of the narrowest point between the bottom of the $10^{th}$ rib and the top of iliac crest, perpendicular to the long axis of the trunk. The child's arms were relaxed at their side. The tape was placed over light clothing or on the skin. The tape was gently tightened to be snug-fitting and measurement was made during the exhalation phase after instructing the child to, "take a breath in and now breathe out", and measured to the nearest 0.1 cm (eyes level to the tape). The measure was repeated after taking the tape away. If measures differed by more than 0.5 cm a third was taken. The average of the two values within the specified tolerance was used. Measures were also checked if they fell below the 2.5 percentile for age (7-yrs 50.9 cm, 10-yrs 78.5 cm) or above the 97.5 percentile for age (7-yrs 55.6 cm, 10-yrs 92.7 cm).

2.3.10 Whole body bioelectrical impedance analysis.

The bioimpedance analysis equipment used was a single frequency, 50 kHz hand-to-foot Bioimpedance analyser (Imp-DF50, Impedimed, Brisbane) in the direct measure mode which displays resistance, reactance, phase and impedance values. First the child removed their right shoe and sock. The child was instructed to stand, feet apart, on a rubber mat with their hands by their sides and making sure thighs were not touching. Skin was cleaned with alcohol swabs, two sites on right hand and two sites on right foot and Electrodes were placed (see Figure 2.1.) on the cleaned skin. The yellow / white - sensing electrode (centered on styloid process, on back of wrist), red - current electrode (centered between first and middle metacarpals, on back of palm ), blue - sensing electrode (centered, on top of ankle / middle foot) and black - current electrode (centered between first and middle metatarsals, on top of foot). Measures were recorded twice and a third was made if the first two differed by ±5ohm for resistance or impedance. Averaged values were used.

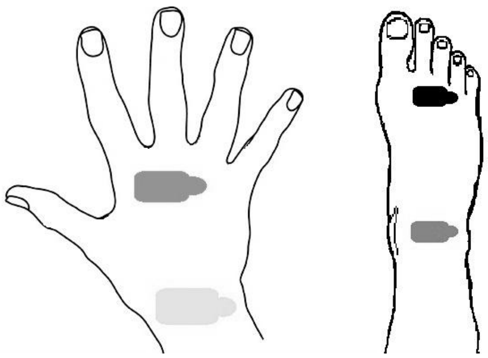

**Figure 2.1 Electrode placement for bioimpedance analysis**

Resistance was multiplied by 1.03 to adjust standing position measure to the equivalent lying measure (Rush, Crowley, Freitas & Luke, 2006), then using predefined equations suitable for New Zealand children of similar ethnic representation, resistance measure was converted to FFM (Rush, Puniani, et al., 2003) and FM % derived. These calculations were performed and added as variables to the data flat file before the complete data set was received by the author.

2.3.11 Physical fitness test: 550 m run.

The fitness test was performed, outside, on grass, after all other physical information was gathered. A 110 metre rope was arranged in an oval approximately 26.5m×42.5m. Cones clearly marked points around and the start and finish. Standardising the shape of the track is important to maintain high reliability. Although performance may be highly inter-correlated when the same distance is covered on different track dimensions (Cotton & Singh), run times can be significantly different between testing areas (likely due to number of corners involved).

Children were asked if they regularly used a bronchodilator / reliever asthma inhaler anytime and before exercise, and if they wanted to use it before the run. Children were instructed to run as fast as they could for all five laps of the course. Children were encouraged to run, however they were allowed to stop or walk whenever they wanted to. Completion time was recorded to the nearest minute and seconds. Children were not allowed to run if their blood pressure was over 200/130 mm/Hg or pulse over 110 beats / min at rest. It was important for this investigation that the 550 m run fitness test was staged accurately and homogeneously among schools and the individual to ensure reliable assessments. A run time was missing in approximately 3% of children (reason unknown to the author).

## 2.5 Data management: Post data collection

Data record sheets were transported by the evaluation team from schools to the Sport Waikato office at the end of each measurement day and they were stored in a locked cupboard. Data record sheets were grouped by school with a roll check list attached, prior to entry into preformatted Excel™ spreadsheets. Before entering records the unique codes, names and date of birth on the roll sheet were matched with each data record sheet and any conflicting information was put aside to check for the origin of the discrepancy. Data was entered into Microsoft Excel™ spread sheets by an experienced data entry team over several weeks. There were systems and checks in place to limit the number of data entry errors. These included ensuring matched unique codes for each child, specially designed spreadsheets with programmed limits or predetermined codes and ticking off sheets after data entry. After data entry, all record sheets were ordered and stored by unique code. Spreadsheet computer files were ultimately collated, data cleaned and calculations of derived variables undertake by bio-statistician (Victor Obolonkin) under the direction of Professor Elaine Rush. Using the Excel addin LMS-growth program version 2.71 (Pan & Cole 2010), calculations were performed to generate standard deviation scores (SDS) from the British 1990 child growth reference for age and gender specific SDS of weight, height, waist circumference and body mass index (Cole, Freeman & Preece, 1995), and body fat percent (McCarthy, et al., 2006), for comparisons with each-other and the reference populations. Calculations also included the body mass index based - International Obesity Task Force (IOTF) thinness / overweight / obesity grades (Cole, et al., 2000; Cole, et al., 2007) and run time was converted from minutes and seconds to total seconds.

The thesis author received records for a total of 5136 children and there were some additional changes and calculations performed. Missing data was re-coded uniformly throughout. Waist to height ratio was calculated by dividing height (cm) by waist circumference (cm). In preparation for comparisons and multiple regression analysis, categorical variables were transformed to numeric codes (e.g. females 1, boys 0) and dummy variables or binary variables (e.g. overweight, non overweight) created where required.

## 2.6 Data analysis

IBM SPSS Statistics Release Version 19.0.0 (SPSS Inc., 2010, Chicago IL) was used throughout to perform statistical analysis. Microsoft Office Excel™ 2007 was used for graph building and back transforming logged variables. Significance was set at alpha level 0.05 (5%). Also 95% confidence intervals for the mean have been reported in most cases to provide evidence of the range of middle values for this population (Cohen, 1994). Where 95% confidence intervals do not overlap statistical significance is accepted. Due to small proportions of Pacific and Other ethnic groups, the 95% confidence intervals are potentially *over-expanded*, however comparisons are still reported and inferences made.

Box plots and histograms were used to visually check for normal distribution and extreme outlier cases for continuous variables. Distributions for all non-standard deviation score variables had long positive tails. Eighteen cases of very extreme outliers were identified (in weight and run-time$_{550m}$), excessively extending the positive tail more than three box plot lengths, these were filtered out of analysis and five obvious biologically implausible results (waist circumference and waist to height ratio) were changed to missing values. Although there remained some extreme and many less extreme outliers in these long positively skewed measures, it would be inappropriate to remove such outliers as it is the right tails of the anthropometric measures and 550 m run that are of interest when overweight and obesity and long times to run are being examined. After cleaning, overall missing data ranged from 1% to 6% for each measure and a complete data set was available for 90% of the children.

Further analysis to test for normal distribution was performed (Appendix C) due to concern of skewness and unequal variances. It was decided to transform all variables (except for the standard deviation scores) to their natural logarithm ($\log_e(x)$), due to violations of normal distribution (Appendix D). Although height was normally distributed it was also log transformed to keep the analytical approach congruent within an analysis. These transformations did make means and medians approximate better than for the raw data, but some skewed distribution within body mass index, waist circumference and waist to height ratio variables persisted, and violations of the assumption of equal variances also persisted for most measures.

Age of the children measured is represented as a bimodal distribution (Appendix E). Analysis was limited to children aged from six to eleven yr old ($n$ = 5101). Most analyses were performed treating 7-yr olds and 10-yr olds as separate groupings. Where the continuous age in years measure was included, it was in scale (decimal) form calculated from birth date and date of measurement. There were 10 children with missing age values.

Comparisons within gender, ethnic group and decile for group differences were made using the log transformed anthropometric measures, non-logged SDS variables and the logged run-time$_{550m}$. Post hoc differences among geometric means or SDS means were determined by unpaired Student's t-test (for between gender analysis) and ANOVA (for ethnic group and decile group comparisons) and described as percentages (back transformed logged data) and mean difference (for non-logged data e.g. SDS). P-values and 95% confidence intervals are reported from Student's t-test and ANOVA / ANCOVA analysis.

Where there were violations of the assumption of homogeneity, either Levene F-test for unequal variance from the Student's t-test or the Welch robust test of equality of means from the ANOVA were used to determine if there was significant differences between groups tested. When quantifying the difference in means, further post- hoc adjustments for ANOVA ethnic group and decile group comparisons utilised Tukey HSD and Games—Howell adjustments for unequal variances and group numbers.

When interpreting the results, the percentage differences presented only reflect the direction being tested - for example girls are [a]% smaller than boys but boys are not [a]% bigger than girls - this is because confidence intervals are asymmetric about the geometric mean (natural phenomenon with logged variables). So the percentage difference between girls and boys is slightly different to the difference between boys and girls. Logged means (geometric mean) are based on a central tendency approximating the median of the raw data.

Prevalence's of thinness, overweight, obese and waist to height ratio ≥ 0.51 cm/cm were examined within ethnic group and by gender. Binary cross-tabulated comparisons were used to explore sensitivities and specificities of the relationships between overweight classification (Cole, et al., 2007) and waist to height ratio ≥ 51 cm/cm.

Non parametric, two tailed, spearman rank ($r_s$) correlation was used to assess association between variables in their non-logged states. Boys and girls and 7 and 10-yr olds were calculated separately as the strength of associations varied with age and gender. The resulting correlation matrices served the purpose of visually providing patterns of association to assess how anthropometric variables related to run-time$_{550m}$ and each-other. The anthropometric measures standard deviation scores did not enhance correlations so it was decided to not consider them for regression modelling to keep the models simple and practical. Magnitudes of effects scale for correlations have been reported based on a Likert-scale for effect statistics, suggesting correlation of; 0.0 to 0.1 = practically zero or trivial, 0.1 to 0.3 = low or small, 0.3 to 0.5 = moderate, 0.5

to 0.7 = high / strong and 0.7 to 0.9 = very-high / very strongly, + 0.9 = near perfect (Hopkins, 2002).

Separately for 7 and 10-yr olds, stepwise multivariate linear regression was utilised to explore the interrelationships of anthropometric measures (height, weight, waist circumference, body mass index, waist to height ratio, IOTF-grade and FM%) with the natural logarithm of run-time$_{550m}$. Potential effects of the covariates of; age, gender, ethnicity, decile, rurality, asthma and length of exposure of the schools to Project Energize were included. The stepwise regression process (Table 2.2) eliminated variables that had an insignificant F-test ($P > 0.05$) and allowed for self removal of variables that had less meaningful contributions to run-time$_{550m}$ prediction (< 0.5% change in $R^2$) and multicollinearity (very high bivariate correlations (r) > 0.7; variance inflation factor VIF of > 5; tolerance of < 0.2; condition index > 30) (Peat, & Barton, 2005). The first model generated for each age group, through the stepwise process, was WHtR, FM%, age, gender and school decile (Appendix N) and following models exchanged WHtR with BMI and waist circumference, leaving the adjustment variables (which included FM%) the same. The moderate multicolinerality FM% had with WHtR, BMI and waist circumference within the models was negotiable. After presenting these peliminary results (Appendix N) at the Australia and New Zealand Obesity Society 2012 conference, followed by discussion with other researchers, it was decided to remove FM% and place in its own model for comparisons. Therefore after thoroughly exploring the potential associates of run-time$_{550m,}$ and selection of the significant covariates, final models were recreated using a standard multiple linear regression analysis. Four models were created for each age group (total of eight models), which included one anthropometric measure (waist to height ratio **or** FM% **or** body mass index **or** waist circumference), **plus** age (yr), **plus** gender (girl), **plus** school decile group (low and medium). Residual scatter plots were uniformly spread and residual distribution plots were fairly close to normal, and there was no troublesome multicollinearity.

Concepts considered while building the models were:

- Both age groups would use the same models for congruency.
- The order variables were entered into the equation was, anthropometric measures, age, gender and other covariates.
- Ultimately, to answer the research question, models were to be simple and practical comparisons of the relationships of FM%, waist to height ratio, waist circumference and body mass index with run-time$_{550m}$, taking into consideration important covariates.
- While most anthropometric measures were significant predictors of run-time$_{550m}$, the waist to height ratio and FM% were preferentially chosen during the stepwise regression analysis ahead of body mass index and waist circumference and had larger contributing standardised beta coefficients.
- Strength of the bivariate correlations were taken into consideration throughout the model building process. Excluded variables were examined for reasons to exclude to make sure the decision was justified (Table 2.2).

**Table 2.2 Processing the stepwise multiple regression analysis**

| $^{\psi}$**Outcome = log(run-time$_{550m}$)** | | |
|---|---|---|
| **Measures Included** | **Measures Excluded** | **Reason for Exclusion** |
| waist to height ratio (0.01 cm/cm) * **or** fat mass percent (1%)* **or** waist circumference (1cm) * **or** body mass index (1 kg/m$^2$) * | height | non-significant or inconsistent predictor |
| | fat free mass | non-significant predictor |
| **plus** age (yr) | asthma | < 0.5% change in $R^2$ |
| **plus** gender (girl) | rurality | non significant predictor |
| **plus** school decile (low) | IOTF grade | < 0.5% change in $R^2$ |
| **plus** school decile (Medium) | | |
| | intervention exposure | < 0.5% change in $R^2$ |
| | weight | high multicollinearity with all other anthropometric measures, near perfect correlation with fat free mass and only moderate to high correlation with fat mass % |
| | ethnic group | ethnic group and decile group were collinear and decile had a stronger association with the outcome |

ψ 7 and 10-yr olds were examined as separate groups.
* due to multicollinearity and the research question these variables were used in separate comparative models. IOTF = International Obesity Task Force. Intervention = Project Energize.

# 3. RESULTS

The data analysis was progressive, and is presented in five parts. Part 3.1 describes and details the demographic and anthropometric characteristics and time to run 550 m (run-time$_{550m}$) of ~5100 children by gender and ethnic group. Part 3.2 details comparisons of anthropometric measures and run-time$_{550m}$ among grouped school decile levels for Māori and NZ European children. Part 3.3 examines relationship of body mass index (BMI) by the International Obesity Task Force (IOTF) classification system with the waist to height ratio (WHtR) cut-point of 0.51 cm/cm. Part 3.4 highlights the main associations between anthropometric measures and run-time$_{550m}$ and part 3.5 explores how the variation in run-time$_{550m}$ is explained by anthropometric measures taking into account important covariates. Analysis of the many measurements made, meant a large amount of comparative information, tables and figures have been placed in appendices and referred to throughout this chapter.

## 3.1 What were the demographic and anthropometric characteristics of the children and how fast could they run 550 meters (run-time$_{550m}$)?

In this section the demographic characteristics are presented separately for the 7 and 10-yr old age groups. Then anthropometric measures and run-time$_{550m}$ are presented first by 7 and 10-yr olds, by gender and followed by ethnic group comparisons.

### 3.1.1 Demographic characteristics.

Of the 5101 children measured nine out of ten identified as either Māori or NZ European (Table 3.1) and of these children four out of ten were Maori. Almost two thirds of the children lived in rural areas (Appendix F). Just over three quarters of the children attended schools which were from the lowest and medium decile levels (a measure derived from the governmental neighbourhood social deprivation index). Nearly two thirds of the children were attending a school that had received exposure to the Project Energize programme for more than two and up to six years.

Average age of the 7-yr old group was 7.5-yr (95% CI 6.5, 8.8) and for the 10-yr old group 10.3-yr (9.2, 11.3). The demographic characteristics of both age groups were similar (Table 3.1).

**Table 3.1 Demographic characteristics of the 5101 children measured in 2011**

| **Characteristics** | | **Total (*n*)** | **Percentage for 7-yr old group** | **Percentage for 10-yr old group** |
|---|---|---|---|---|
| Boys | | 2426 | 48.5% | 46.6% |
| Girls | | 2675 | 51.5% | 53.6% |
| Ethnicity | European | 2759 | 54.3% | 53.6% |
| | Maori | 1838 | 35.7% | 36.6% |
| | Other | 314 | 6.2% | 6.1% |
| | Pacific | 190 | 3.8% | 3.6% |
| Decile | high (8-10) | 1188 | 23.5% | 22.9% |
| | medium (4-7) | 2082 | 39.8% | 41.8% |
| | low (1-3) | 1831 | 36.8% | 35.3% |
| Urban living | | 1849 | 62.5% | 65.1% |
| Rural living | | 3252 | 37.5% | 34.9% |
| School exposure to intervention | 6-8 terms* | 1936 | 39.4% | 36.3% |
| | 9-16 terms* | 1706 | 32.4% | 34.6% |
| | 17-24 terms* | 1455 | 28.1% | 29.2% |

* There are four terms in each school year. *n*= number of children. Decile = estimation of schools social deprivation from low (1) = most deprived to high (10) = least deprived, based on national geographical socioeconomic indicators. Urban areas were defined as Hamilton and Tokoroa, and the rest of the Waikato region were rural. Intervention is Project Energize. Other ethnicity are predominately Indian, Asian or other nationality (not NZ European, Māori or Pacific Island).

### 3.1.2 Anthropometric and run-time$_{550m}$ measures.

Within age group, average age was the same, but boys compared to girls were on average, taller, had more FFM, lower FM% and had larger waist circumferences, but smaller WHtR and were no different in weight or BMI (Tables 3.2 and 3.3). For 7 and 10-yr olds, girls anthropometric SDS's indicated they were on average lighter and had a smaller waist circumference and BMI compared with the boys. In addition 10-yr old girls were shorter and had lower FM% SDS than 10-yr old boys. Seven-yr old (Table 3.2) and 10-yr old (Table 3.3) girls had 6% and 7%, respectively, longer run-time$_{550m}$ than boys ($P < 0.0001$).

**Table 3.2 Comparison of anthropometric and run-time$_{550m}$ measures of seven year old children.**

| | Girls | | | Boys | | | Gender | |
|---|---|---|---|---|---|---|---|---|
| | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | Difference girl - boy | t-test P-value |
| Age (yr) | 1361 | 7.5 | 7.5, 7.6 | 1277 | 7.5 | 7.5, 7.6 | 0 | 0.994 |
| Height (cm) | 1348 | 126.3 | 125.9, 126.6 | 1263 | 127.2 | 126.9, 127.6 | -0.7%* | <0.0001 |
| Weight (kg) | 1347 | 26.7 | 26.4, 26.9 | 1269 | 26.9 | 26.6 , 26.9 | -0.9%* | 0.241 |
| WaistC (cm) | 1330 | 56.8 | 56.5, 57.1 | 1253 | 57.6 | 57.3, 57.9 | -1.5%* | <0.0001 |
| FFM (kg) | 1280 | 20.2 | 20.0, 20.4 | 1199 | 21.4 | 21.7, 21.6 | -5.8%* | 0.001 |
| FM% | 1279 | 23.3 | 23.0, 22.6 | 1199 | 19.6 | 19.3, 19.9 | 1.6%* | <0.0001 |
| BMI (kg/m$^2$) | 1334 | 16.7 | 16.7, 16.6 | 1255 | 16.6 | 16.5, 16.8 | 0.5%* | 0.382 |
| WHtR (cm/cm) | 1318 | 0.45 | 0.45, 0.45 | 1239 | 0.45 | 0.45, 0.46 | 0.2%* | 0.027 |
| Height SDS | 1348 | 0.33 | 0.27, 0.39 | 1262 | 0.40 | 0.35, 0.46 | -0.07 | 0.077 |
| Weight SDS | 1347 | 0.41 | 0.35, 0.47 | 1269 | 0.55 | 0.49, 0.61 | -0.14 | 0.001 |
| Waist SDS | 1331 | 0.60 | 0.53, 0.66 | 1253 | 0.75 | 0.69, 0.80 | -0.15 | 0.001 |
| BMI SDS | 1335 | 0.34 | 0.28, 0.40 | 1255 | 0.47 | 0.41, 0.53 | -0.13 | 0.003 |
| FM% SDS | 1280 | 0.70 | 0.64, 0.77 | 1199 | 0.68 | 0.61, 0.76 | 0.02 | 0.702 |
| Run-time$_{550m}$ (s) | 1323 | 186 | 185, 188 | 1253 | 175 | 173, 176 | 6.2%* | <0.0001 |

* calculated as %difference = 100($e^{difference}$-1). *n* = number of children. 95% CI = Confidence Intervals. girl - boy = girls are different to boys by. WaistC = waist circumference, FFM = fat free mass, FM% = fat mass percent, BMI = body mass index, WHtR = waist to height ratio, SDS = standard deviation scores (Cole, et al., 1995; McCarthy, et al., 2006; Cole, et al., 2007). P value from unpaired t-test.

**Table 3.3 Comparison of anthropometric and run-time$_{550m}$ measures of ten year old children**

| | Girls | | | Boys | | | Gender Difference girl - boy | t-test P-value |
|---|---|---|---|---|---|---|---|---|
| | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| Age (yr) | 1314 | 10.3 | 10.3, 10.3 | 1148 | 10.3 | 10.3, 10.4 | 0 | 0.151 |
| Height (cm) | 1294 | 142.1 | 141.7, 142.5 | 1128 | 142.8 | 142.4, 143.2 | -0.5%* | 0.019 |
| Weight (kg) | 1305 | 37.3 | 36.8, 37.7 | 1130 | 37.4 | 36.9, 37.9 | -0.3%* | 0.757 |
| WaistC (cm) | 1273 | 62.7 | 62.5, 63.4 | 1125 | 64.1 | 63.7, 64.6 | -1.8%* | <0.0001 |
| FFM (kg) | 1248 | 27.2 | 26.9, 27.5 | 1080 | 28.3 | 28.0, 28.6 | -4.0%* | <0.0001 |
| FM% | 1248 | 26.1 | 25.8, 26.5 | 1079 | 23.1 | 22.7, 23.5 | 1.2%* | <0.0001 |
| BMI (kg/m$^2$) | 1287 | 18.4 | 18.3, 18.6 | 1112 | 18.3 | 18.1, 18.5 | 6.9%* | 0.326 |
| WHtR (cm/cm) | 1254 | 0.44 | 0.44, 0.45 | 1105 | 0.45 | 0.45, 0.45 | 3.8%* | 0.008 |
| Height SDS | 1294 | 0.34 | 0.28, 0.39 | 1128 | 0.47 | 0.41, 0.53 | -0.13 | <0.0001 |
| Weight SDS | 1307 | 0.49 | 0.43, 0.55 | 1131 | 0.67 | 0.61, 0.74 | -0.18 | 0.002 |
| Waist SDS | 1275 | 0.89 | 0.82, 0.96 | 1126 | 0.83 | 0.76, 0.90 | 0.06 | <0.0001 |
| BMI SDS | 1288 | 0.45 | 0.38, 0.51 | 1112 | 0.64 | 0.57, 0.71 | -0.19 | 0.234 |
| FM% SDS | 1248 | 0.63 | 0.56, 0.69 | 1079 | 0.89 | 0.83, 0.96 | -0.26 | <0.0001 |
| Run-time$_{550m}$ (s) | 1259 | 167 | 166, 168 | 1114 | 155 | 154, 157 | 7.2%* | <0.0001 |

* calculated as %difference = 100($e^{difference}$-1). *n* = number of children. 95% CI = Confidence Intervals. girl - boy = girls are different to boys by. WaistC = waist circumference, FFM = fat free mass, FM% = fat mass percent, BMI = body mass index, WHtR = waist to height ratio, SDS = standard deviation scores (Cole, et al., 1995; McCarthy, et al., 2006). P value from unpaired t-test.

### 3.1.3 Gender and ethnic group differences.

*Between gender within ethnic group comparisons.*

All girls had less FFM (except Pacific girls) and more FM% than the boys (Appendix H, Tables H2 & H6). There was no significant waist to height ratio differences between NZ European, Māori and Pacific boys and girls (Appendix H, Tables H2 & H6). In 7-yr olds, NZ European girls were shorter with a smaller waist circumference than the boys(Appendix H, Tables H1 & H5). Ten-yr old NZ European and Māori girls were smaller in weight SDS, body mass index SDS and FM% SDS than the 10-yr old boys, but similar differences were not found in 7-yr olds. Within each ethnic group run-time$_{550m}$ for girls ranged from 5% to 9% longer than boys (Appendix H, tables H4 & H8). Following summary of ethnic group differences for boys and girls is limited to NZ European, Māori and Pacific children (Table 3.4).

*Between ethnic group within gender comparisons.*

In both age groups, NZ European boys (Table 3.4) had lighter weight, less fat mass percent and smaller waist circumference, body mass index, than both Māori and Pacific boys. There was no apparent difference in height between NZ European boys and Pacific boys, however Pacific boys were relatively taller than all other Ethnic groups and height difference between NZ European and Māori boys did reach significance. For both age groups, NZ European boys had lower SDS for height, weight, waist circumference, body mass index and FM% than Māori and Pacific boys, except for 10-yr old Pacific boys, whose height and FM% SDS were relatively higher than NZ European, although significance was not reached (Appendix H; Tables H6, H7). There were no differences in anthropometric measurements or run-time$_{550m}$ between Māori and Pacific boys. Run-time$_{550m}$ for NZ European boys was 6% to 10% faster than Māori and Pacific boys (Appendix H; Tables H4, H8 & Table 3.4).

For both age groups, NZ European girls (Table 3.4) were smaller and lighter, with less FM%, less FFM and a smaller WHtR than Māori and Pacific, except there was no difference in WHtR between 10-yr old NZ European and Pacific girls. All Māori and Pacific girls were taller than NZ European girls, except for no height difference between

7-yr old NZ European and Pacific girls. The extra height difference between 10-yr old Pacific and NZ European girls was in proportion to the larger waist circumference in Pacific girls accounting for the lack of difference in WHtR. For both age groups SDS for height, weight, waist circumference, BMI and FM% were lower in NZ European compared Māori and Pacific, except 7-yr old Pacific girls (Appendix H; Tables H3 & H4, H7 & H8). There were no differences in anthropometric measures or run-time$_{550m}$ by age group between Māori and Pacific girls. Run-time$_{550m}$ for NZ European girls was 4% to 9% faster than Māori and Pacific girls (Appendix H; Tables H4, H8 & Table 3.4).

**Table 3.4 Summary of significant$^{\psi}$ differences between ethnic groups**

**NZ European* compared with Māori**

| Attribute* | 7 yr old boys % difference | 10-yr old boys % difference | 7 yr old girls % difference | 10-yr old girls % difference |
|---|---|---|---|---|
| Shorter | 1.0% | 1.2% | 1.3% | 1.2% |
| Lighter | 8.4% | 11.7% | 9.1% | 10.9% |
| Smaller WaistC | 3.5% | 5.5% | 3.6% | 5.2% |
| Smaller BMI | 6.6% | 9.4% | 6.7% | 8.6% |
| Less FFM | 5.4% | 7.8% | 6.9% | 8.5% |
| Less FM% | 12.3% | 12.5% | 7.2% | 6.3% |
| Smaller WHtR | 0.8% | 1.4% | 0.8% | 1.3% |
| Ran 550m faster | 6.1% | 7.6% | 4.8% | 4.3% |

**NZ European* compared with Pacific**

| Attribute* | 7 yr old boys % difference | 10-yr old boys % difference | 7 yr old girls % difference | 10-yr old girls % difference |
|---|---|---|---|---|
| Shorter | – | – | – | 2.5% |
| Lighter | 14.6% | 16.1% | 14.1% | 15.9% |
| Smaller WaistC | 6.5% | 8.6% | 5.7% | 8.0% |
| Smaller BMI | 11.4% | 13.1% | 11.1% | 10.9% |
| Less FFM | 8.9% | 12.2% | 10.4% | 10.8% |
| Less FM% | 16.5% | 12.4% | 11.0% | 11.2% |
| Smaller WHtR | 1.6% | 2.2% | 1.4% | – |
| Ran 550m faster | 6.5% | 10.4% | 5.1% | 8.5% |

* Attribute description relates to the marked (*) ethnic group for example, NZ European boys are shorter than Māori boys. WaistC = waist circumference, BMI = body mass index, WHtR = waist to height ratio, FFM = fat free mass, FM% = fat mass percent. ψAll P value < 0.05 (Games Howell or Tukey). Means and 95% CI are placed in Appendix H.

### 3.2 How did ethnic group, anthropometric measurements and run-time$_{550m}$ differ by decile grouping of schools?

*Within ethnic groups, how did the participation rates differ by school decile groups?*

For the participating Māori children, 58% were attending a low decile school, 34% a medium decile school and 8% high a decile school. In contrast for the NZ European children 21% were attending a low decile school, 46% and 33% attending a medium or high decile school, respectively.

*Within each school decile group, what proportion of attendance were Māori and NZ European children? (Figure 3.1).*

Within the participating lower decile schools, twice as many children were Māori compared to NZ European. Within medium decile schools twice as many children were NZ European compared to Māori. The number of NZ European children participating within the higher decile schools was 6-fold greater than Māori participation. Within all decile groups approximately 1 in 10 children were Pacific or Other children.

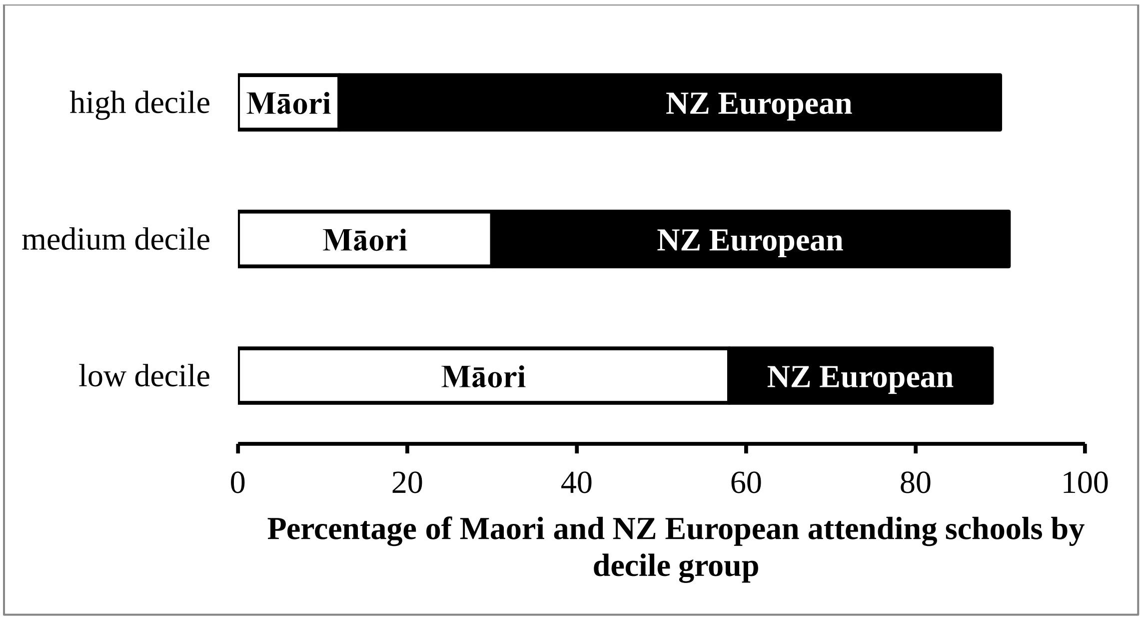


**Figure 3.1 Percentage of Māori and NZ European children attending schools in each decile group, low decile 1 to 3, medium decile 4 to 7, and high decile 8 to 10.** Remaining percentages for each decile group are made up from Pacific and Other ethnic groups.

### 3.2.1 Anthropometric measurements and run-time$_{550m}$ among school decile.

The anthropometric measurements and run-time$_{550m}$ differences of NZ European and Māori children among the school decile groups (low, medium and high) are examined. Detailed information is presented in Appendix I.

*Anthropometric measurements / school decile.*

For 7-yr old girls and boys there was a trend for all anthropometric measurements (except height) to be statistically different, between the low and medium decile schools and the low and high decile schools. The low decile school children were heaviest with on average the most FM% and FFM, largest waist circumferences, BMI and WHtR, and the highest weight, waist circumference, BMI and FM% SDS. There were no significant anthropometric differences between the medium and high decile school children, except medium decile,7-yr old boys had a larger BMI compared to7-yr old high decile boys. In 10-yr olds the same social gradients in body size were found as in the 7-yr olds, between low and medium, and, low and high decile school children, however there were several extra differences. Ten-year old boys and girls from medium decile schools had significantly larger BMI, waist circumference and WHtR than 10-yr old, higher decile school children.

*Run-time$_{550m}$ / school decile.*

There was a significant inverse association between school decile group and time taken for the children to complete the 550m run (Figure 3.2). Children ran faster in higher decile schools. In high decile schools, there was an average 7% and 9% reduction in run-time$_{550m}$ for 7 and 10-yr old girls, respectively, compared with low decile schools and similarly for 7 and 10-yr old boys a 9% and 11% reduction in run-time$_{550m}$. In medium decile schools there was an average 4% and 5% increase in run-time$_{550m}$ for 7 and 10-yr old girls, respectively, compared with low decile schools and similarly for 7 and 10-yr old boys 5% and 6%, increase in run-time$_{550m}$. Average increase in run-time$_{550m}$ for medium compared with high decile school children was approximately equal to the increase from low to medium decile school children.

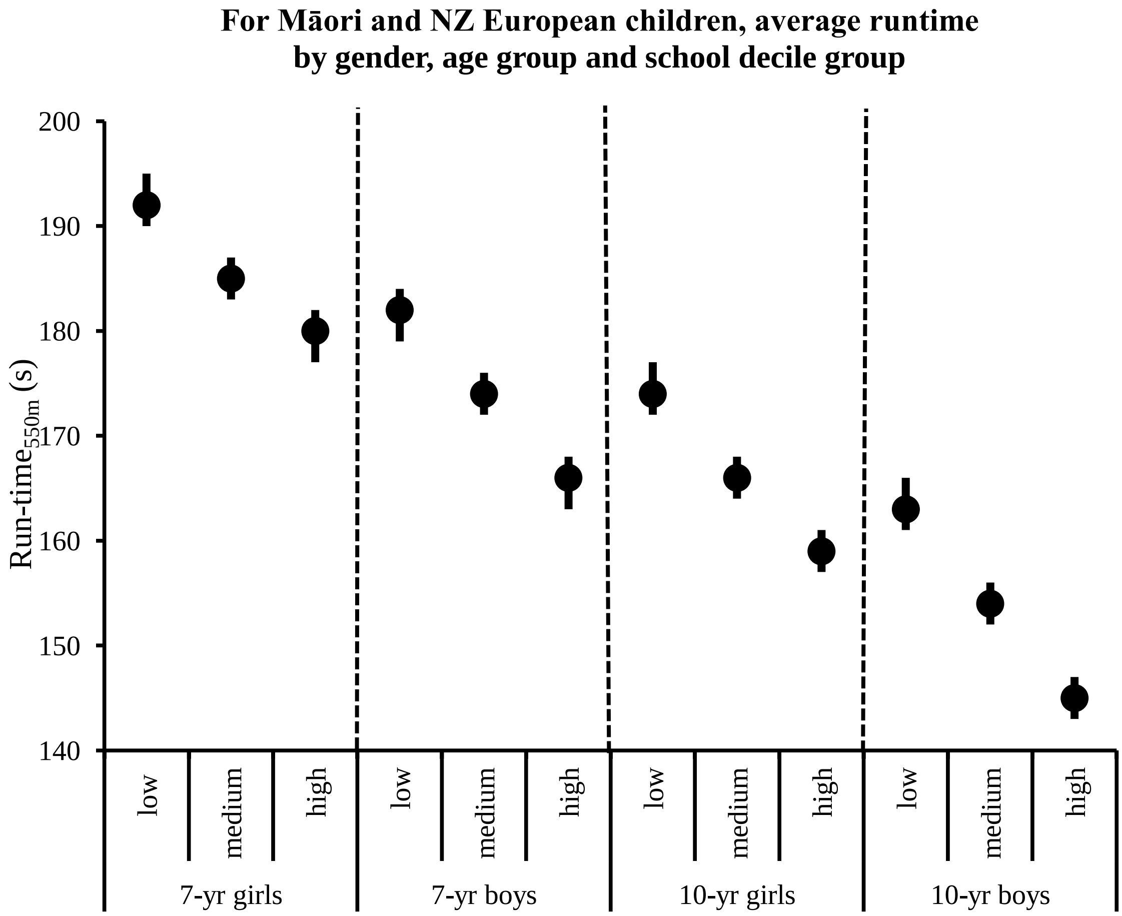


**Figure 3.2 Māori and NZ European run-time$_{550m}$ by school decile, age group and gender for children**
Average completion time of a 550 m run, including 95% confidence intervals, by school decile group, age and gender. Differences among all three decile groups, within each age and gender cluster were significant ($P<0.01$).

3.2.2 Variation in run-time$_{550m}$ for NZ European and Māori in relation to decile group.

After adjustment for FM%, height and age there were no differences in average run-time$_{550m}$ among all Māori and low or medium decile school children. There were no differences in run-time$_{550m}$ among NZ European and high or medium decile school children. With exception, 10-yr old NZ European children had a longer run-time$_{550m}$, compared to NZ European and Māori children from high decile schools. In both age groups Māori girls and boys took 3.0% and 4.0%, respectively, significantly longer than

NZ European children to complete run-time$_{550m}$ after adjustments for FM%, height and age.

In previous analyses (Figure 3.2) there was a significant inverse association between school decile group and time taken for the children to complete the 550 m run. This relationship slightly attenuated but remained statistically significant between low / high and medium / high decile school children, after adjustment for age, height and FM%. With exception there was no significant difference found in adjusted run-time$_{550m}$ in 7-yr old girls, between medium and high decile schools or in all 7-yr old children between low and medium decile schools (Figures 3.3 & 3.4).

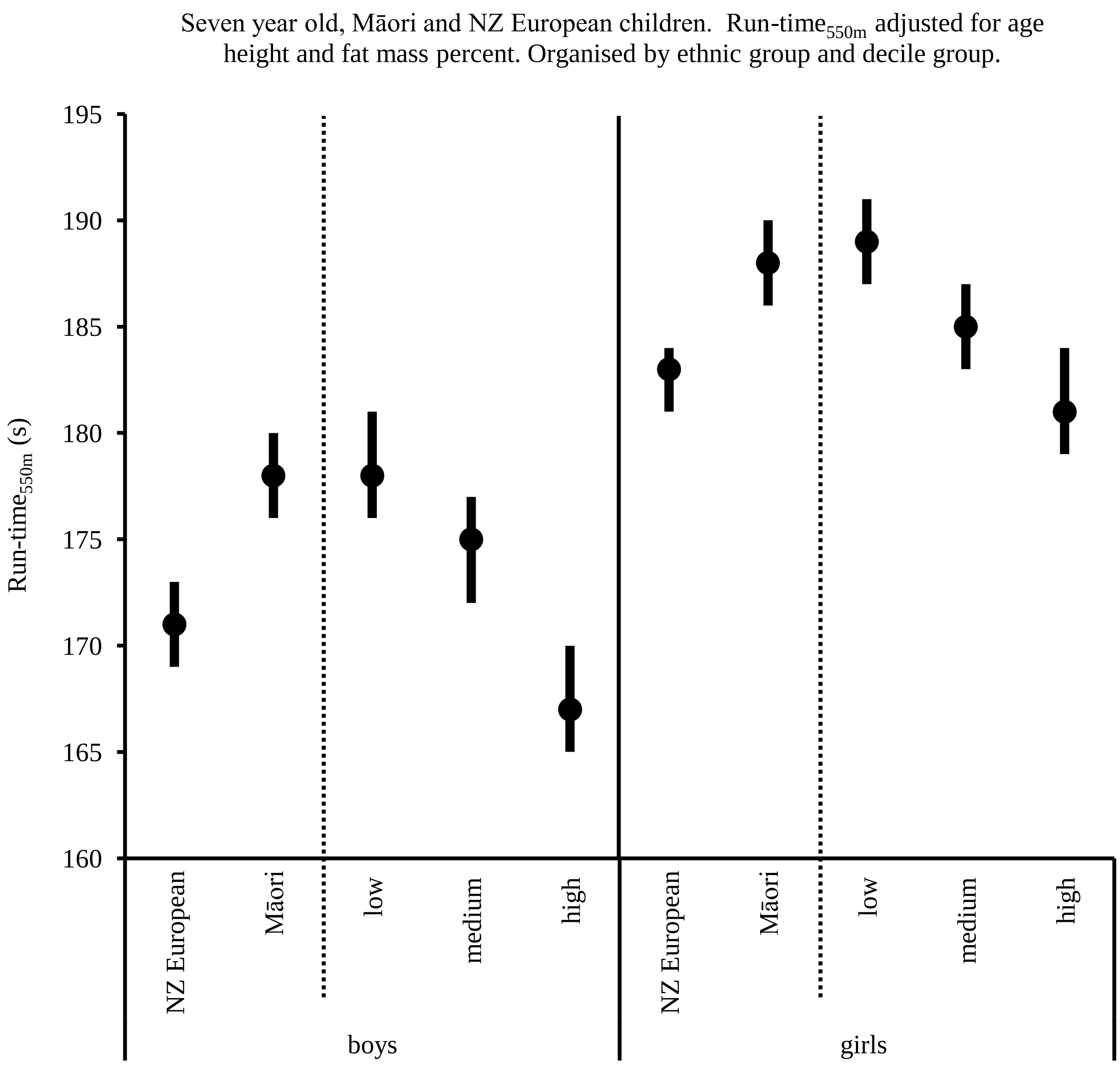


**Figure 3.3 Seven year olds run-time$_{550m}$ for Māori and NZ European by ethnic group and school decile group. Including 95% CI.**

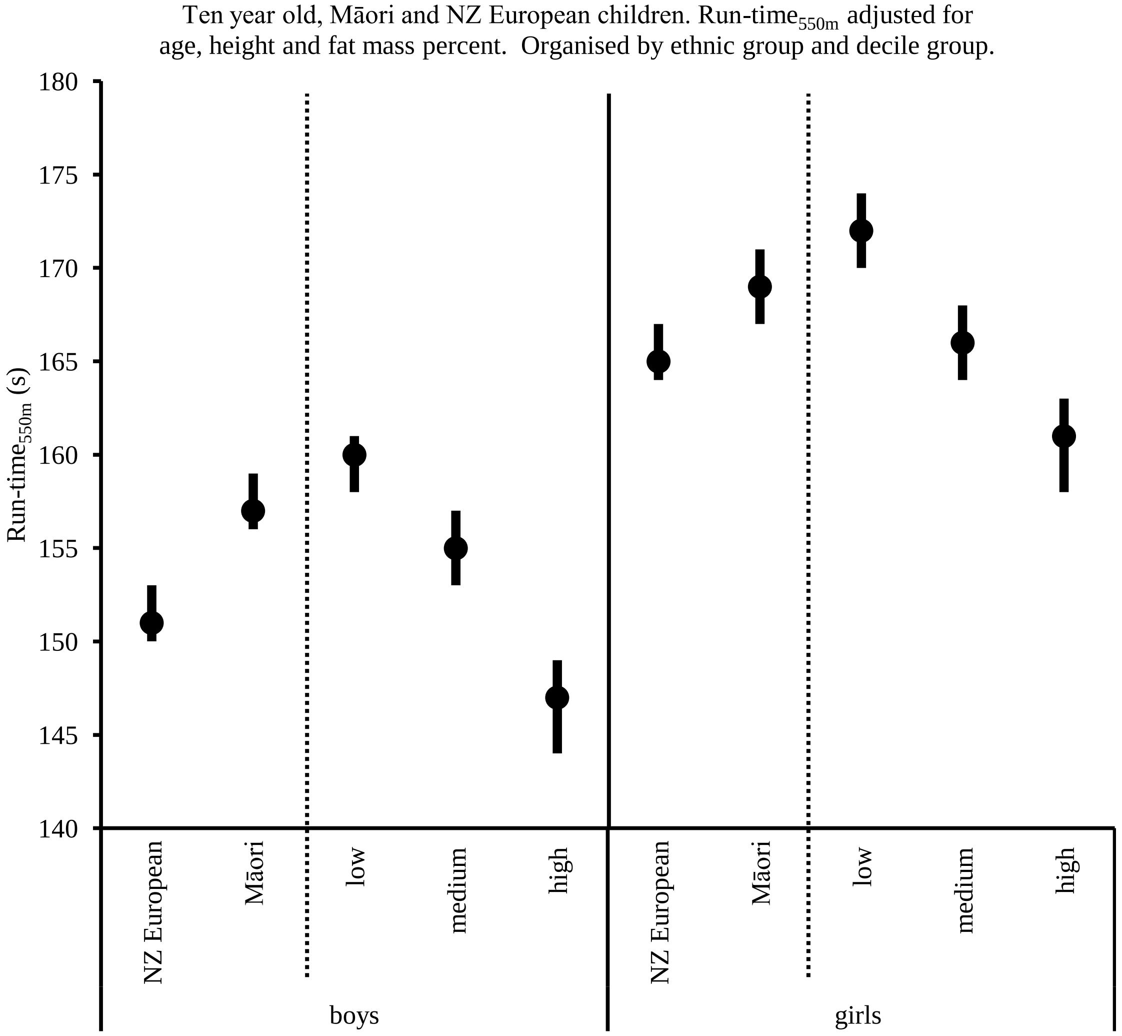


**Figure 3.4. Ten year olds run-time$_{550m}$ for Māori and NZ European by ethnic group and school decile group. Including 95% CI.**

## 3.3 How did body size classification of overweight and obese compare with classification of waist to height ratio?

There was no difference between girls and boys, prevalence of thinness, normal, overweight and obesity as defined by the IOTF body mass index classification system (Cole, et al., 2007; Cole, et al., 2000) and waist to height ratio ≤ 0.50 (Browning, et al., 2010) (Figure 3.5).

3.3.1 Prevalence of overweight and obesity, and high waist to height ratio by ethnicity.

Ethnic group comparisons (Figure 3.5) of the whole group were for thinness; 12% of Other children were likely to be classified as thin, which was twice as many compared to NZ European and five times more than Māori. Significantly more NZ Europeans were thin compared to Māori children and there was no apparent difference between Māori and Pacific children. For overweight, approximately12% of both NZ European and Other children were considered overweight. In contrast 21% and 26% of Māori and Pacific children, respectively, were overweight. For obesity, 3.3% and 4.6% of NZ European and Other children, respectively, were considered obese, which was significantly less than the prevalence of 11.6% and 18.8% for Māori and Pacific children. For waist to height ratio, 6.8% and 7.3% of NZ European and Others, respectively, had a waist to height ratio $\geq 0.51$ which was significantly less than prevalence of 15.1% and 23.3% in Māori and Pacific (Figure 3.5).

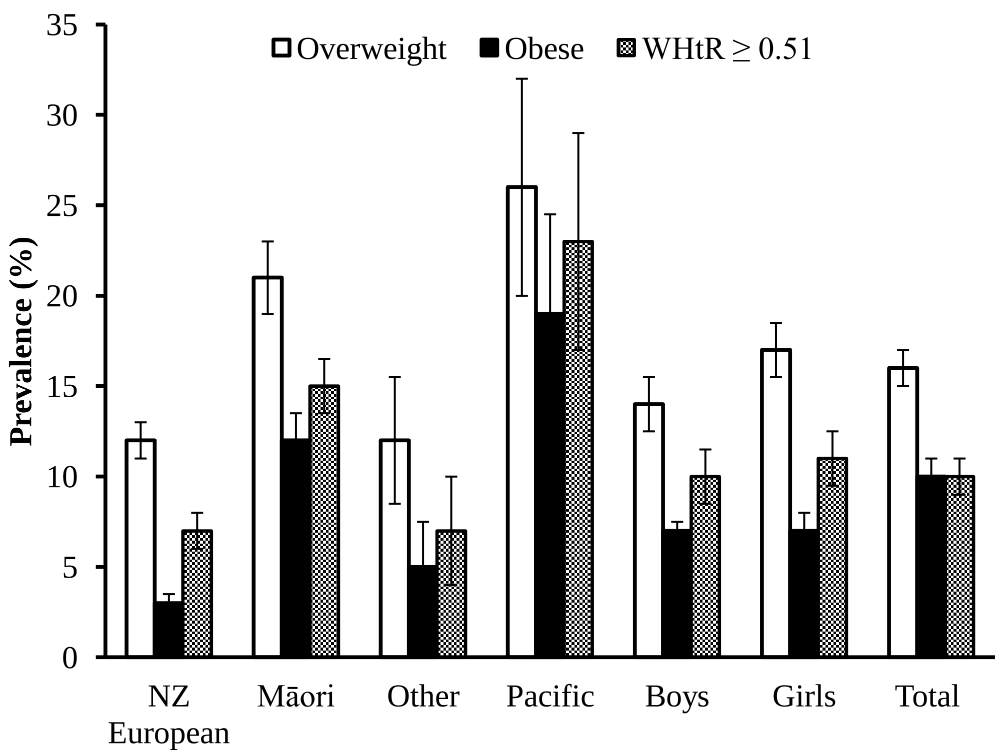


**Figure 3.5 Prevalence of overweight and obese and waist to height ratio > 0.50 cm/cm**

Prevalence (% 95% CI) of overweight or obese children aged 6–12 yrs, according to the International Obesity Task Force (IOTF) (Cole, et al., 2000) body mass index categorisation system and waist to height ratio more than half height (Browning, et al., 2010).

### 3.3.2 Sensitivity and specificity of waist to height ratio and body mass index.

Table 3.5 presents how overweight (overweight and obese together) and non-overweight children and WHtR $\geq$ 0.51 or $\leq$ 0.50 cm/cm, are related. The WHtR correctly identified non-overweight and overweight in 86% and 95% of the children, respectively. While the sensitivity and specificity of WHtR was high in all children, sensitivity was significantly higher, and specificity was significantly lower in Māori compared to NZ European. The lower specificity meant 20% of Māori children who had a WHtR $\leq$ 0.50 cm/cm were in the overweight or obese category by IOTF classification, compared to 10% of NZ European.

In a contrasting analysis more than half of the children who were classified overweight had a WHtR $\leq$ 0.50 cm/cm (Table 3.5). Therefore overweight classification had low sensitivity for detecting a WHtR $\geq$ 0.51cm/cm. However almost all (99%) of non-overweight children had a WHtR $\leq$ 0.50 cm/cm. There were no ethnic group differences in this analysis.

When the overweight and obese groups were examined separately (Figure 3.6), 75% and 10% of the overweight and obese children, respectively, had a WHtR $\leq$ 0.50 cm/cm.

**Table 3.5 Sensitivity and specificity of body size and WHtR of children aged 6-11 years.**

| | | Total | NZ European | Māori | Other | Pacific |
|---|---|---|---|---|---|---|
| a. | Proportion of children (n=1108) who are overweight/obese* with a WHtR ≥ 0.51cm/cm (sensitivity) | 0.44 (0.41, 0.47) | 0.41 (0.37, 0.46) | 0.46 (0.41, 0.50) | 0.38 (0.25, 0.53) | 0.52 (0.40, 0.62) |
| | Proportion of children (n=3768) who are non-overweight* with a WHtR ≤ 0.50 cm/cm (specificity) | 0.99 (0.99, 1) | 0.99 (0.99, 1) | 1.00 (0.99, 1) | 0.99 (0.97, 1) | 1.00 (1) |
| b. | Proportion of children (n=514) with a WHtR ≥ 0.51cm/cm and are overweight/obese* (sensitivity) | 0.95 (0.94, 0.97) | 0.91 (0.87, 0.95) | 0.98 (0.96, 1) | 0.86 (0.72, 1) | 1.00 (1) |
| | Proportion of children (n=4362) with a WHtR ≤ 0.50 cm/cm and are non-overweight* (specificity) | 0.86 (0.85, 0.87) | 0.90 (0.89, 0.92) | 0.79 (0.77, 0.81) | 0.89 (0.85, 0.93) | 0.72 (0.64, 0.79) |

Sensitivities and specificities include 95% CI in brackets.
* *overweight/obese*, derived from IOTF cut-points grouping overweight and obese individuals together.
*non-overweight* derived from thin and normal groups. P < 0.0001 for all percentages from chi square test.
a. Prevalence of overweight/obese 23% (95% CI, 22%, 24%).
b. Prevalence of WHtR ≥ 0.51cm 11% (95% CI, 10%, 11%).

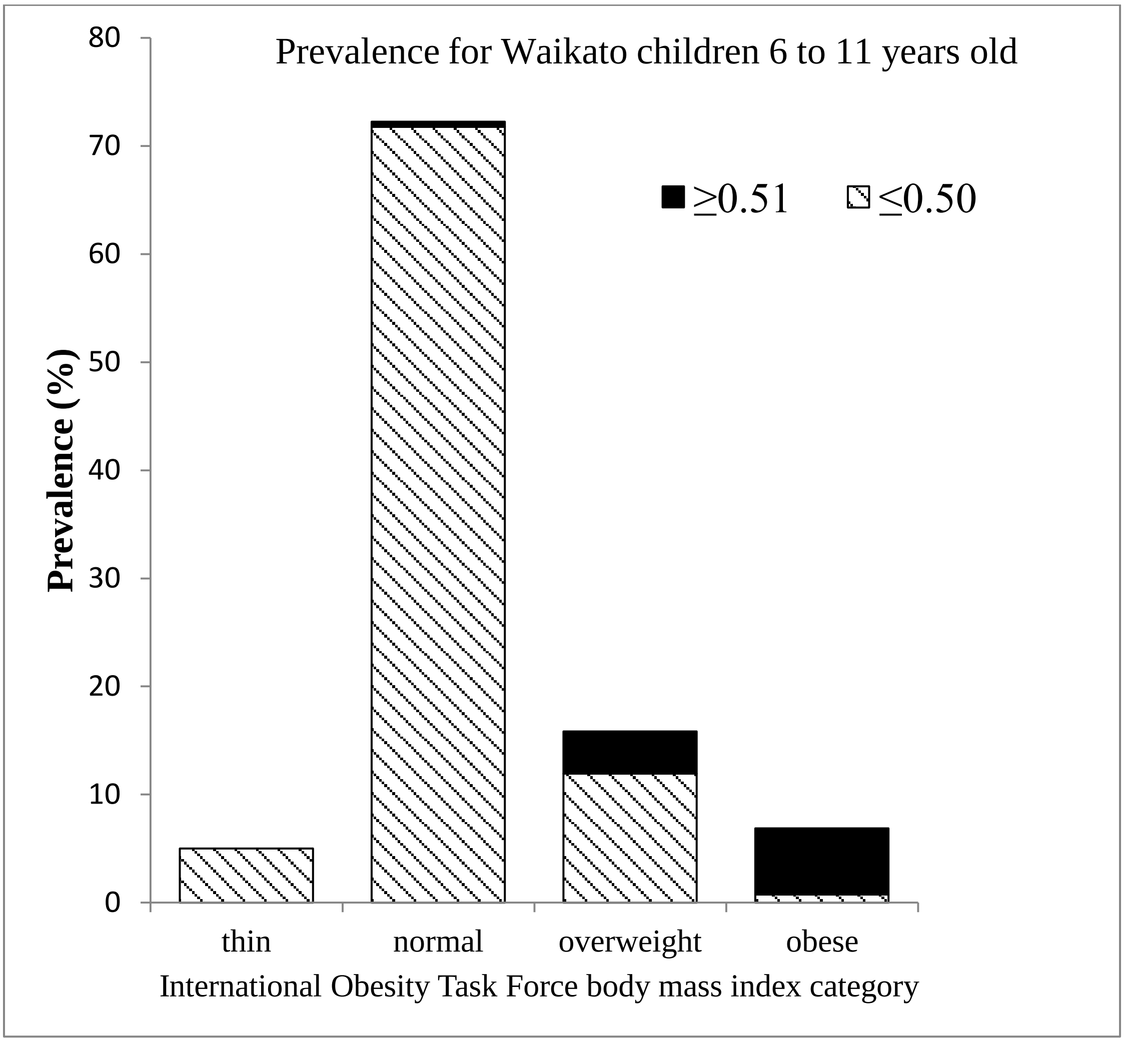


**Figure 3.6 Prevalence of body mass index classifications and waist to height ratio.**

Percentage of children classified as thin ($n$ = 245), normal ($n$ = 3523), overweight ($n$= 772), obese ($n$ = 336) and the proportion within those classifications with a WHtR ≤ 0.50 cm/cm ($n$ = 4362) or WHtR ≥ 0.51cm/cm ($n$ = 514)

## 3.4 What were the associations between anthropometric measures and run-time$_{550m}$?

This section details the non-causal associations between anthropometric measures and run time, presented by age group and gender. The WHtR was highly (Hopkins 2002) and positively associated with BMI in the 7-yr old girls and boys, $r_s$ = 0.72 (95% CI, 0.70, 0.74) and $r_s$ = 0.65 (0.63, 0.67), respectively, and very highly in the 10-yr old girls and boys, $r_s$ = 0.83 (0.81, 0.84) and $r_s$ = 0.81 (0.80, 0.82), respectively (Appendix J, Tables J1 & J2). A multiple regression analysis (Appendix M), demonstrated after adjustment for age and gender every 1 kg/m$^2$ increase in BMI associated with a 0.013 cm/cm increase in WHtR (R = 0.86, P $\leq$ 0.0001)

The WHtR showed small to moderate positive association with FFM in all children. Regardless of age and gender, fat free mass, height, weight, waist circumference and body mass index were very highly and positively associated with each other. In 7 and10-yr olds FM% was moderately to very highly positively associated with all anthropometric measurements, except height. For both age groups of children, taller children had higher BMI (moderate effect size) and height was not associated with WHtR or run-time$_{550m}$. Associations involving the anthropometric measures, standard deviation scores were very similar to the unstandardised measurement (Appendix J).

When all children were analysed together, un adjusted run-time$_{550m}$ had a trivial association with waist circumference, $r_s$= 0.06 (95%CI 0.02, 0.1), small positive association with BMI, $r_s$= 0.19 (0.15, 0.23), and moderate positive association with , FM%, $r_s$= 0.34 (0.30, 0.38) and WHtR, $r_s$= 0.41 (0.37, 0.44). When investigated within age groups and gender (Appendix J), run-time$_{550m}$ was low to moderately positively associated with FM%, BMI, waist circumference and WHtR in the 7-yr olds and moderate to high for the 10-yr olds. There was a trend for stronger associations as age increased and between run-time$_{550m}$ and WHtR or FM%, than with BMI or waist circumference. Inferring from both the simple linear and age group / gender adjusted associations suggests that the WHtR was the single best proxy predictor of performance in the 550 m run.

## 3.5 How was run-time$_{550m}$ explained by anthropometry and other covariates?

Multiple linear regression analysis showed significant positive associations with moderate to high multiple correlation values between run-time$_{550m}$ and each anthropometric measure of WHtR (Table 3.6) **or** BMI (Table 3.7) **or** waist circumference (Table 3.8) **or** FM% (Table 3.9), adjusted for age, gender and school decile group.

From these models, in 7 and 10-yr olds, up to 27.1% and 38.7%, respectively, of the variation in run-time$_{550m}$ could be explained. Girls took up to 8.6% longer to run 550 m than boys. Age was significantly inversely associated with run-time$_{550m}$ by reducing run-time$_{550m}$ up to 5.6% for each ageing year. Regardless of measurement method, as body fatness increased so did run-time$_{550m}$. The increasing WHtR (Table 3.6) appears to be associated with greater increase in run-time$_{550m}$, compared to BMI, waist circumference and FM%.

School decile group was a significant covariate included in each regression analysis. Children from low and medium decile schools took up to 7.8% and 4.3%, respectively, longer to run 550 m than children from high decile schools. Therefore independent of body fatness (as assessed by several proxy methods) all three decile groups had significantly different physical fitness, where children from the more deprived neighbourhoods were significantly more physically unfit than children from more affluent neighbourhoods.

*Asthma prevalence.*

Asthma was a self reported measure considered for a potential confounding effect on the children's run performance. While asthma was prevalent in 17% of the study population with gender and ethnic group differences (Appendix G), after accounting for adiposity and school decile level, it was only a trivial, but statistically significant predictor of the children's run performance. Asthma was therefore excluded from the regression analyses.

**Table 3.6 Percentage change in run-time$_{550m}$ in association with waist to height ratio (Model 1)**

| **Model 1** | waist to height ratio (0.01cm/cm) | Gender girls† | Increasing age (yr) | Decile low$^{\Psi}$ | Decile medium$^{\Psi}$ |
|---|---|---|---|---|---|
| a.7-yr olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 2.8% (2.4%, 3.4%) | 7.1% (6.0%, 8.1%) | -4.0% (-4.8%, -3.1%) | 7.5% (6.1%, 8.9%) | 4.2% (2.9%, 5.5%) |
| b.10-yr olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 3.3% (2.9%, 3.8%) | 8.6% (7.5%, 9.7%) | -3.6% (-4.5%, -2.6%) | 6.9% (5.5%, 8.3%) | 3.5% (2.2%, 4.9%) |

Percentages are expressed with 95% confidence intervals (in brackets).
B = constant of 123 (95% CI, 113, 135) run seconds (7-yr olds), 112 (95% CI, 100, 125) run seconds (10-yr olds).
† Girls are slower than boys. As children age run-time$_{550m}$ decreases.
Ψ Low (decile 1-3) and medium (decile 4-7) deciles are slower than higher (decile 8-10) deciles.

Table 3.9 describes the multiple regression analysis for **model 1** (WHtR) **a** (7-yr olds, R = 0.503, F(2490) = 168.38, P ≤ 0.0001; adjusted $R^2$ = 25.1%) & **b** (10-yr olds, R = 0.606, F(2266) = 262.36, P ≤ 0.0001; adjusted $R^2$ = 36.5%.). Unstandardised coefficients representing the change in run time are expressed as percentages, where a positive value is an increase in run time and a negative value is a reduction in run time, for the predictor variables.

**Table 3.7 Percentage change in run-time$_{550m}$ in association with body mass index (Model 2)**

| **Model 2** | body mass index (1kg/m$^2$) | Gender girls† | Increasing age (yr) | Decile low$^{\Psi}$ | Decile medium$^{\Psi}$ |
|---|---|---|---|---|---|
| a.7-yr olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 2.1% | 6.4% | -5.4% | 7.2% | 4.1% |
| | (1.9%, 2.3%) | (5.4%, 7.4%) | (-6.3%, -4.6%) | (5.8%, 8.6%) | (2.7%, 5.4%) |
| b.10-yr olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 2.2% | 7.6% | -5.2% | 6.4% | 3.6% |
| | (2.0%, 2.3%) | (6.5%, 8.6%) | (-6.1, -4.3%) | (5.0%, 7.8%) | (2.3%, 5.0%) |

Percentages are expressed with 95% confidence intervals (in brackets).
B (constant) = 181 run seconds (95% CI, 169, 194) (7-yr olds), 173 run seconds (95% CI, 156, 192) (10-yr olds)
† Girls are slower than boys. As children age run-time$_{550m}$ decreases.
Ψ Low (decile 1-3) and medium (decile 4-7) deciles are slower than higher (decile 8-10) deciles.

Table 3.10 describes the multiple regression analysis for **model 2** (BMI) **a** (7-yr olds R = 0.487, F(2520) = 156.74, P ≤ 0.0001; adjusted $R^2$ = 23.7%) & **b** (10-yr olds, R = 0.606, (R = 0.610, F(2306) = 273.07, P ≤ 0.0001; adjusted $R^2$ = 37.1%). Unstandardised coefficients representing the change in run time are expressed as percentages, where a positive value is an increase in run time and a negative value is a reduction in run time, for the predictor variables.

**Table 3.8 Percentage change in run-time$_{550m}$ in association with waist circumference (Model 3)**

| **Model 3** | waist circumference (1 cm) | Gender girls† | Increasing age (yr) | Decile low$^{\Psi}$ | Decile medium$^{\Psi}$ |
|---|---|---|---|---|---|
| a.7-yr olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 0.8% | 7.4% | -6.0% | 7.9% | 4.3% |
| | (0.7%, 0.9%) | (6.3%, 8.4%) | (-6.9%, -5.2%) | (6.5%, 9.3%) | (3.0%, 5.7%) |
| b.10-yr olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 0.9% | 8.6% | -5.6% | 7.3% | 3.9% |
| | (0.8%, 0.9%) | (7.5%, 9.6%) | (-6.6, -4.7%) | (5.8%, 8.7%) | (2.6%, 5.2%) |

Percentages are expressed with 95% confidence intervals (in brackets).
B (constant) = 168 run seconds (95% CI, 156, 181) (7-yr olds), 156 run seconds (95% CI, 141, 174) (10-yr olds).
† Girls are slower than boys. As children age run-time$_{550m}$ decreases.
Ψ Low (decile 1-3) and medium (decile 4-7) deciles are slower than higher (decile 8-10) deciles.

Table 3.11 describes the multiple regression analysis for **model 3** (waist circumference) **a** (7-yr olds, R = 0.478, F(2516) = 148.81, P ≤ 0.0001; adjusted $R^2$ = 22.7%) and **b** (10-yr olds, R = 0.590, F(2304) = 245.61, P ≤ 0.0001; adjusted $R^2$ = 34.6%). Unstandardised coefficients representing the change in run time are expressed as percentages, where a positive value is an increase in run time and a negative value is a reduction in run time, for the predictor variables.

**Table 3.9 Percentage change in run-time$_{550m}$ in association with fat mass % (Model 4)**

| **Model 4** | FM% (1 %) | Gender girls† | Increasing age (yr) | Decile low$^{\Psi}$ | Decile medium$^{\Psi}$ |
|---|---|---|---|---|---|
| a.7 y olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 1.0% (0.9%, 1.1%) | 2.6% (1.6%, 3.7%) | -5.2% (-6.0%, -4.4%) | 7.0% (5.6%, 8.4%) | 3.9% (2.6%, 5.2%) |
| b.10 y olds$^{B}$ | | | | | |
| Run-time$_{550m}$ change (%) | 1.2% (1.1%, 1.3%) | 4.4% (3.3%, 5.4%) | -4.6% (-5.5, -3.6%) | 7.6% (6.2%, 9.0%) | 3.9% (2.6%, 5.3%) |

Percentages are expressed with 95% confidence intervals (in brackets).
B (constant) = 204 run seconds (95% CI, 191, 218) (7 y olds), 181 run seconds (95% CI, 164, 201) (10 y olds).
† Girls are slower than boys. As children age run-time$_{550m}$ decreases.
Ψ Low (decile 1-3) and medium (decile 4-7) deciles are slower than higher (decile 8-10) deciles.

Table 3.12 describes the multiple regression analysis for **model 4** (FM%) **a** (7-yr olds, R = 0.521, F(2416) = 180.06, P ≤ 0.0001; adjusted $R^2$ = 27.1%) and **b** (10-yr olds, R = 0.623, F(2238) = 284.37, P ≤ 0.0001; adjusted $R^2$ = 38.7%). Unstandardised coefficients representing the change in run time are expressed as percentages, where a positive value is an increase in run time and a negative value is a reduction in run time, for the predictor variables.

Figure 3.7 represents the regression coefficients (plus 95% CI) for the increase in run-time$_{550m}$ associated with each unit increase in, WHtR (0.01cm/cm), BMI (1 kg/m$^2$), waist circumference (1 cm/cm) and FM% (1%). An increasing WHtR is associated with a greater increase in run-time$_{550m}$ compared to the other anthropometric measurements.

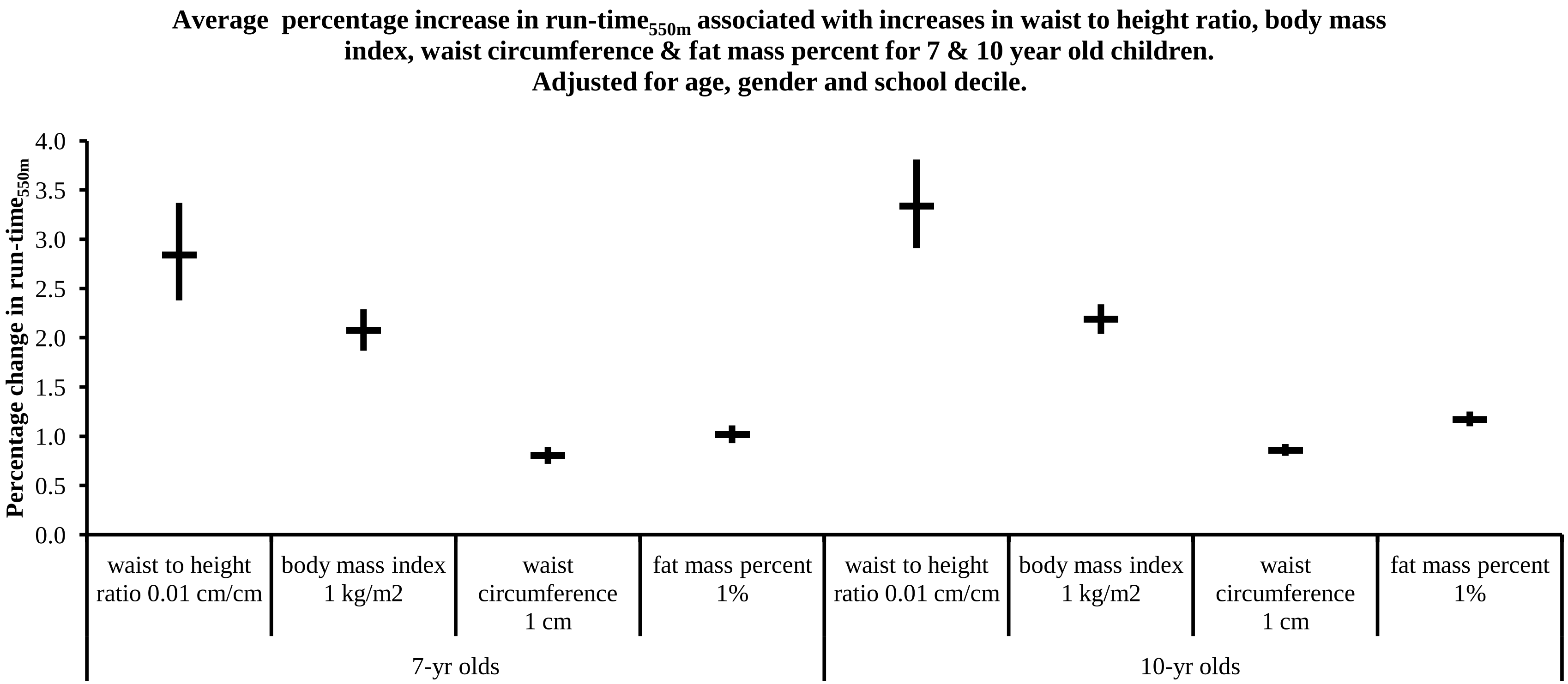


**Figure 3.7 Increase in run-time$_{550m}$ associated with increases in each anthropometric measure adjusted for age, gender and school decile.**

*Supporting analysis: Average run times across run percentiles.*

To visualise the variation in run time of 550 m for NZ European and Māori 7 and 10-yr olds simple percentile curves for average run time were constructed (Appendix K). There was approximately one and a half minutes (1 min. 30 sec.) difference between the fastest 5th percentile and the slowest 95th percentile of run-time$_{550m}$, which was an average 60% increase in run-time$_{550m}$.

*How did different body adiposity measures vary by ethnic group (Māori and NZ European), age group (half yearly increments) and gender?*

An additional regression analysis was performed to examine effect of age and gender on waist to height ratio, body mass index and waist circumference. Figures are placed in Appendix L. Results show that for WHtR there was a slight decrease in the ratio as the children age for both NZ European and Māori, while BMI and waist circumference show increases as children age. This may suggest that in children, monitoring the waist to height ratio for increases over time could be a simple method to detect increasing FM associated with potential negative health risks.

### 3.6 Summary of main findings

*Run-time$_{550m}$ and anthropometric measurements*.

- An increasing WHtR had the largest associated percentage increase in the time taken for children to run 550 m, when compared to BMI, waist circumference and FM%. This may indicate that the WHtR is a more direct measure that influences physical fitness.
- For the 7-yr old and 10-yr old groups, up to 27% and 39% of the variation in run-time$_{550m}$ could be explained by a body composition measure plus school decile, age and gender and there was no significant difference in variation explained between models except in the older group significantly more physical fitness was explained compared to the younger group.
- Approximately 60% to 70% of the variation of run-time$_{550m}$ for these children, was due to other factors not accounted for.

*Additional factors that influenced run-time$_{550m}$ and anthropometric measurements.*

- Ethnic groups: New Zealand European children ran faster than Māori and Pacific children but there was no significant difference in run-time 550 m among all of the non-NZ European children. All anthropometric measures were smaller in NZ European compared to Māori. Also NZ European and Māori boys had more FFM and less FM% than their girl peers. Only the 7-yr old NZ European boys were taller than their girl peers - showing overall the boys higher FFM is likely due to having more muscle mass.

- School decile level: Children attending lower decile schools ran slower and were heavier with larger body size and more body fat, than those attending medium and higher decile schools. There were no anthropometric differences between children attending medium and high decile schools despite medium decile school also running significantly slower than children attending high decile schools.

- Non-significant associations with physical fitness: Other cofactors tested included ethnic group, rurality, asthma and length of time schools were exposed to Project Energize had no meaningful confounding effect on run-time when included in the multiple regression analyses. This is likely due to stronger interrelationships among physical fitness, anthropometric measurements, age, gender and socioeconomic status.

*Prevalence and relationships of WHtR and overweight (IOTF) classifications.*

- In the whole group, approximately 10% of children had a WHtR over half their height, similarly 10% were considered obese (IOTF) and 16% were considered overweight (IOTF).
- Compared to NZ European children, just over twice as many Māori (15%) children and three times as many Pacific (23%) children, had a WHtR more than half their height.
- Compared to NZ European (15%) children, twice as many Māori (32%) children and three times as many Pacific (45%) children, were considered overweight or obese (IOTF). Obesity was prevalent in approximately 3% NZ European, 5% Others, 11% Māori and 19% Pacific children.
- WHtR 0.50 cm/cm had high sensitivity and specificity at identifying the children who were overweight (95%) and non-overweight (86%) respectively. Sensitivity was significantly higher in Māori compared to NZ European however Māori were more likely (20%) to have a WHtR less than half their height and be identified as overweight or obese (specificity) compared to NZ European children (10%).
- Being overweight had low sensitivity (44%) at identifying children with a WHtR greater than half their height, however specificity was 99% for children with a normal BMI to identify with a WHtR less than half their height.

# 4. DISCUSSION

New evidence, from more than 5000 primary school children (2011-Energized-children), has demonstrated that the WHtR had strong and negative associations with physical fitness measured as the completion time of a 550 m run. Furthermore the WHtR had strong positive associations with other common measures of adiposity; BMI, waist circumference and FM%. These other measures of estimated adiposity had weak to strong negative associations with run-time$_{550m}$. Run-time$_{550m}$ varied with age and gender, and there was greater run-time$_{550m}$ and greater adiposity in both Māori compared to NZ European children and children attending lower decile schools compared to other decile schools. What is unique about these findings is they come from a large group of 7 and 10-yr old school children, across the whole range of school decile level, living in both rural and urban settings, and with one third identifying as Māori. These findings, particularly the utility of the WHtR, which is a very simple, economical, indirect measure associated with adiposity related health risks, have important implications for future work. Specifically WHtR may be used as a tool for health promotion, when screening for risk, and to monitor change in risk during interventions aimed at increasing physical activity, improving nutrition, and reducing childhood obesity.

## 4.1 Physical fitness, body proportions and composition of children

Most of the 2011-Energized-children were able to complete the 550 m run in under 5 min and 95% ran the distance in under 4 min (Appendix K). Walking and running are basic locomotive skills learned from toddlerhood (Whitall & Getchell, 1995; Masci, et al., 2013) and which underpin the capability of children to engage in active play, sport and maintain good health. Yet locomotion may be negatively influenced by excess adiposity during childhood (Shultz, et al., 2011; Boreman & Riddoch, 2001). For the 2011-Energized-children percentage of variation in run-time$_{550m}$ was explained by either; BMI, waist circumference, FM% or WHtR, adjusted for age gender and school decile level (ranked and grouped) similarly within each age group, up to; $R^2$ = 27% for 7-yr olds and $R^2$ = 39% for 10-yr olds (all $P < 0.0001$). In all models, as indirect body-fat measures increased the children took longer to run 550 m and body fat explained a large portion (Hopkins, 2002) of the functionally meaningful outcome measure of physical fitness. Before and after statistical adjustments were applied, both FM% and WHtR had a tendency towards stronger relationships with run-time$_{550m}$ than BMI and waist circumference.

Eleven other studies that have examined relationships of physical fitness and cardiorespiratory fitness CRF (as $VO_2$ uptake) measures with anthropometric measures in youth have reported similar findings (Table 4.1) to this thesis. All, including this present study, are cross-sectional observations. In three of these studies (Sveinsson, et al., 2009; Ostojic, Stojanovic, M., Stojanovic, V., Maric, & Njaradi, 2011; Rump, Verstappen, Gerver & Homstra, 2002) and this study, where FM% or total body fat (TBF) was measured indirectly (skinfolds or BIA), the pattern of association was such that FM% or total FM, may associate more strongly with physical fitness compared to BMI. Waist circumference and estimated abdominal fat volume (MRI or DXA) appeared to share variably, by age and gender, low to high associations with physical fitness or CRF (Sevensson, et al., 2009; Ostojic, et al., 2011; Moliner-Urdiales, et al., 2011; Winsley, Armstrong, Middlebrooke, Ramos-Ibanez & Williams, 2006; Bailey, Boddy, Savory, Denton & Kerr, 2012; Hussey, et al., 2007; Dencker, et al., 2012). Only one of these studies reported the WHtR (Esmaeilzadeh, Kalantari & Nakhostin-Roohi, 2013) in boys only, where BMI was found to be slightly stronger associated with CRF than WHtR, but both performed better than waist circumference. Sveinsson et al. (2009) who examined waist circumference relative to height as, $waist\ circumference \times height^{-0.9285}$, revealed stronger associations with CRF than BMI.

For the 2011-Energized-children, waist circumference, not adjusted for height, was the weakest predictor of run-time$_{550m}$ within all age and gender groups and for the total sample there was no relationship between waist circumference and run-time$_{550m}$. For the BMI and FM% relationship, run-time$_{550m}$ was influenced by age and gender more than when run-time$_{550m}$ was examined in relation to WHtR. This suggests that the WHtR without needing adjustment for age or gender is a simple effective screening tool for child health related to adiposity and poorer physical fitness. This message is in agreement with the conclusions from a comprehensive systematic review (Browning, et al., 2010) which included children, and for adults a meta analysis (Ashwell, Gunn &

Gibson, 2012;) describes the WHtR as a good tool for health risk assessment of adiposity related, chronic cardiometabolic diseases. Many chronic diseases, e.g. type-2-diabetes (Sanz, Gautier & Hanaire 2010; Griffith, Younk & Davis, 2010), cardiovascular disease (CVD) (van Dijk, Takken, Prinsen & Wittink, 2012; Gastaldelli & Basta, 2010) and chronic kidney disease (Evans, McIntyre, N., Fluck, McIntyre, C. & Taal, 2012), are associated with excess abdominal adiposity, poor physical fitness (Lee, et al., 2012; Berman, Weigensberg & Spruijt-Metz, 2012; Anderssen, et al., 2007) and physical inactivity (Berman, Weigensberg & Spruijt-Metz, 2012; Andersen, et al., 2006). Waist circumference has traditionally been considered the best proxy measure of visceral and central fat in adults and related to low physical activity and chronic disease (van Dijk, et al., 2012; World Health Organisation, 2011). Although the WHtR has several advantages (Ashwell & Hsieh, 2005) and research pertaining to its use grows, it is currently an under-recognised screening tool.

Evidence that objectively measured abdominal adiposity in children is related to physical fitness is limited and only from small studies (Moliner-Urdiales, et al., 2011; Winsley, et al., 2006; Dencker, et al., 2012) (Table 4.1). Winsley, et al. (2006) examined a small group of young adolescents (13-yrs old, 30 male, 32 female) for aerobic fitness ($VO_2$max) and visceral fat volume (measured by MRI) (Table 4.1). Subcutaneous fat was measured by sum of seven skin folds and compared with visceral fat volume and aerobic fitness. While girls had significantly more subcutaneous and visceral fat compared to the boys, the overall ratio of subcutaneous to visceral fat, was similar between genders. Despite there being a moderate inverse bivariate association between visceral fat volume and $VO_2$max (ml/kg/min) in boys and girls, the sum of skin folds was found to be the only significant predictor ($r^2$ = 52% girls, 55% boys) of visceral fat volume. The model did not include; BMI, height and CRF – expressed as ml/kg$^{0.61}$/min, which includes a power function ratio for body mass adjustment (Winsley, et al., 2006) (Table 4.1). The authors recommended without clear reasoning, that to reduce abdominal obesity, a focus for interventions should be more on reducing total body fatness rather than focusing on increasing CRF. However longitudinal studies would be needed to show cause and effect and furthermore they did not suggest how body fatness should be reduced, except to say aerobic fitness can modify both subcutaneous and visceral fat volumes, and volume of energy expenditure could be more important than maximum aerobic capacity (Winsley, et al., 2006).

Winsley, et al. (2006) was the only paper reviewed here that used a power function ratio to allometrically scale $VO_2max$ to body size ($ml/kg^{0.61}/min$). It is unclear why they used allometric scaling and what influence it had over the stepwise regression results which excluded BMI and aerobic fitness from any of the proportion of explanatory power of visceral fat volume. Power function ratios are often used to lessen the effects of different body size and mass proportions between genders and age groups, before assessing independent associations of $VO_2max$ with other factors (Vanderburgh, 1998) but may be population-specific. However while understanding the mechanisms of this type of mathematical remodelling is beyond the scope of this thesis, it appears the process can be erroneous (Vanderburgh, 1998) and difficult to use in children who have dynamic changes within their compartmental proportions of FM and FFM throughout growth, e.g. larger bodies have longer legs with more leg muscle mass (Welsman, Armstrong, Nevil, Winter & Kirby, 1996; Janz, Burns, Witt & Mahiney 1998).

Total body mass is also considered when examining physical fitness capabilities as it is the mass moved during land based physical activities. Fat free mass, which is largely muscle mass is correlated with measures of absolute $VO_2max$ (ml/min) (Lazzer, et al., 2005). An increase in FFM partially accounts for the higher absolute $VO_2max$ (ml / min) in obese children, compared to their more lean peers. Meaning if measurements of absolute $VO_2max$ are utilised during performance assessment of different physical exercise, CRF may be overestimated in obese children compared to their actual physical capabilities. Despite their higher maximum aerobic capacity, heavier children expend more energy in order to perform weight bearing exercise like running, walking and many land based sports, which can account for early fatigue and poorer performance (Lazzer, et al., 2005). For this reason assessments of physical fitness by $VO_2max$ usually include adjustment for total body mass.

In the 2011-Energized-children FM % averaged 20% to 26%, which was higher in girls compared to boys. Girls had more FM% and less FFM than boys. Biological differences between boys and girls are important relative to physical function and were accounted for in analysis of run-time$_{550m}$. In addition increase in FM is associated with increase in FFM (Lazzer, et al., 2005). There were non-significant / trivial or small (0% to 6%) positive bivariate associations (Appendix J) found between run time$_{550m}$ and height or fat free mass (FFM), which were variable by age and gender. In the 10-yr olds and less so in the 7-yr-olds increasing weight had small positive bivariate associations with increase in run-time$_{550m}$ ($r_s$ = 0.10 to 0.39), total body mass is relative to increase in FM% therefore explaining poorer performance in physical fitness. Height, FFM and total body mass were not significant predictors of run-time$_{550m}$ once age, gender, body fatness and school decile group were taken into consideration. Some studies reviewed, in Table 4.1,(He, et al., 2011; Hussey, et al., 2007) did not consider age and gender during relationship studies of body composition and proportions with physical fitness. However given the variations in body form and function and other results summarised in Table 4.1, assessments should at least adjust for gender and age of children and adolescents.

**Table 4.1 (a) Summary of associations between physical fitness and anthropometric measures in children and adolescents**

| Study | Age (yr) | Gender (number) | Ethnicity | Fitness measure (outcome) | Anthropometric measures (explanatory) | Correlation or % explained variance (Effect size) | | | | Notes / other findings |
|---|---|---|---|---|---|---|---|---|---|---|
| Cooper, 2013 (this thesis) | 7 & 10 | Girls (2675) Boys (2425) | NZ European Māori Pacific Others | 550 m run (s) outdoors on grass | ***Adjusted*** | | | **7-yr** | **10-yr** | Adjusted for age, gender, medium and low school decile group. Younger group had lower variances. The more body fat, the slower children In unadjusted models WaistC in both age groups and BMI in 7-yr olds associated less than FM% with run-time. In 7-yr olds, WHtR associated stronger than BMI and WaistC with run time. Height was not associated and FFM explained up to 6% variance in run-time |
| | | | | | WHtR | $R^2$ = | | 25% | 37% | |
| | | | | | BMI | $R^2$ = | | 24% | 37% | |
| | | | | | WaistC | $R^2$ = | | 23% | 35% | |
| | | | | | FM% | $R^2$ = | | 27% | 39% | |
| | | | | | ***Unadjusted*** | | ***Total*** | ***7-yr boy & girl*** | ***10-yr boy & girl*** | |
| | | | | | WHtR | $r_s^2$ = | 17% | 12% | 22% & 26% | |
| | | | | | BMI | $r_s^2$= | 4% | 7% & 8% | 23% & 19% | |
| | | | | | WaistC | $r_s^2$= | < 1% | 4% & 6% | 18% & 17% | |
| | | | | | FM% | $r_s^2$ = | 12% | 12% & 26% | 29% & 25% | |
| Sveinsson, et al., 2009 | 9 & 15 | Girls (136) Boys (135) | Icelanders | Cycle ergometer (W/kg) | ***Adjusted*** | | | ***9-yr*** | ***15-yr*** | Adjusted for gender and PA. No significant difference between models. PA only associated with skinfolds. In 15-yr olds skinfolds explained significantly more variance of CRF than WaistC adjusted by height and BMI. WaistC adjusted by height explained significantly more variance of CRF than BMI. Younger group had lower variances. |
| | | | | | Skinfolds | $R^2$ = | | 45% | 65% | |
| | | | | | BMI | $R^2$ = | | 47% | 57% | |
| | | | | | WaistC/height$^{0.9285}$ | $R^2$ = | | 52% | 60% | |
| | | | | | ***Unadjusted*** | | | ***9-yr*** | ***15-yr*** | |
| | | | | | Skinfolds | $r^2$ = | | 40% | 54% | |
| | | | | | BMI | $r^2$ = | | 35% | 15% | |
| | | | | | WaistC/height$^{0.9285}$ | $r^2$ = | | 42% | 29% | |
| | | | | PA | Skinfolds | $r^2$ = | | 3% | 12% | |

PA = physical activity. CRF = cardiorespiratory fitness. WaistC = waist circumference. FM% = fat mass percent. BMI = body mass index FFM = fat free mass. WHtR = waist to height ratio.

**Table 4.1 (b) Summary of associations between physical fitness and anthropometric measures in children and adolescents**

| Study | Age (yr) | Gender (number) | Ethnicity | Fitness measure (outcome) | Anthropometric measures (explanatory) | Correlation or % explained variance (Effect size) | Notes / other findings |
|---|---|---|---|---|---|---|---|
| Ostojic, et al., 2011 | 6 to 14 | Girls (367)<br>Boys (754) | Serbian | 20 m multistage shuttle-run ($VO_2$max – ml/kg/min) | ***Unadjusted***<br>FM%<br>WaistC<br>BMI | ***Whole group***<br>$r^2$ = 58 %<br>$r^2$ = 18%<br>$r^2$ = < 1%* | *non-significant correlation.<br>FM% negatively associated with $VO_2$max, significantly stronger than WaistC or BMI with relative $VO_2$max. |
| He, et al., 2011 | 10 / 11 | Girls (894)<br>Boys (901) | Chinese | 20 m multistage fitness test (MFT) ($VO_2$max – ml/kg/min) | ***Unadjusted***<br>BMI | ***Whole group***<br>$r^2$ = 53% (T1)<br>$r^2$ = 55% (T2) | A follow-up study T1 to T2 = 18 months. No change in associations during the 18 months. |
| Rump, et al., 2002 | 7 | Girls (50)<br>Boys (50) | Netherlands | Multistaged treadmill$^{\psi}$ test – endurance time (min) a surrogate for relative $VO_2$max – ml/kg/min | ***Adjusted***<br>BMI<br>Skinfolds<br>FM%<br>FM kg<br>FFM kg<br>Height | ***Boys & Girls***<br>$R^2$ = 16% & 10%<br>$R^2$ = 29% & 24%<br>$R^2$ = 30% & 23%<br>$R^2$ = 30% & 18%<br>non-significant<br>non significant | Age adjusted regression analysis showed, inverse associations between endurance time and anthropometric measures.<br>For the same exercise test work load (joules) and power output (Watts) (estimate for absolute $VO_2$max – ml/min) were regressed with each anthropometric measure and found to correlate significantly, only with height, weight and FFM. Only in boys, fat mass and skinfolds explained 20% variance in heart rate at 6 min of exercise.FM%, FM & FFM derived from skinfold measures. |

CRF = cardiorespiratory fitness. WaistC = waist circumference. FM% = fat mass percent. BMI = body mass index. FFM = fat free mass
MFT = multistage fitness test (Brewer et al., 1988). ψBruce treadmill test protocol (Bruce 1972). TBF = total body fat.

**Table 4.1 (c) Summary of associations between physical fitness and anthropometric measures in children and adolescents**

| Study | Age (yr) | Gender (N) | Ethnicity | Fitness measure (outcome) | Anthropometric measures (explanatory) | Correlation or % explained variance (Effect size) | Notes / other findings |
|---|---|---|---|---|---|---|---|
| Moliner-Urdiales, et al., 2011 | 12.5 to 17.5 | Girls (186) Boys (177) | Spanish | 4 × 10 m shuttle-run test (s) (speed and agility) | ***Adjusted*** DEXA – TBF BodPod – TBF Skin folds Abdominal fat DXA WaistC | ***Boys & Girls*** $R^2$ = 21% & 17% $R^2$ = 23% & 14% $R^2$ = 29% & 10% $R^2$ = 16% & 14% $R^2$ = 15% & 11% | Adjusted for age, puberty stage and physical activity (accelerometer) There were mostly similar negative associations among all anthropometric measures of total fat and central fat with CRF. Girls agility is less associated with total and abdominal FM, and their CRF less associated with waist circumference. |
| | | | | 20 m multistage shuttle-run test (number of stages) | DXA – TBF BodPod – TBF Skin folds Abdominal fat DXA WaistC | $R^2$ = 27% & 33% $R^2$ = 28% & 25% $R^2$ = 34% & 20% $R^2$ = 26% & 28% $R^2$ = 28% & 7% | |
| Winsley, et al., 2006 | 13 to 14 | Girls (22) Boys (30) | Caucasian UK | Treadmill $VO_2$max – ml/kg/min | ***Unadjusted*** VAT – visceral adipose tissue (MRI) | ***Boys & Girls*** $r^2$ = 40% & 44% $r^2$ = 18% & 20%** | $VO_2$ max (ml/kg/min) and **not** absolute $VO_2$ max (ml/min) had negative associations with subcutaneous and visceral fat volume. Subcutaneous fat (TBF) had stronger associations with CRF in girls compared to boys. Sum of 7-skinfolds was the only significant predictor of VAT ($r^2$ = 52% girls, 55% boys) compared to allometric scaled $VO_2$max (ml/kg$^{0.61}$/min) |
| | | | | ** $VO_2$max – ml/kg$^{0.61}$/min | Skinfolds – subcutaneous fat | $r^2$ = 24% & 58% $r^2$ = 6% & 18%** | |
| Esmaeilzadeh, et al., 2013 | 7 to 11 | Boys (766) | Iranian | 1-mile-run $VO_2$max – ml/kg/min | ***Unadjusted*** BMI WHtR FM (kg) WaistC | ***Boys only*** $r^2$ = 66% $r^2$ = 59% $r^2$ = 51% $r^2$ = 49% | Strong negative associations between relative $VO_2$max and body composition. Physical activity was weakly positively associated $r^2$ = 5% with CRF. |

CRF = cardiorespiratory fitness. WaistC = waist circumference. FM% = fat mass percent. BMI = body mass index. MRI = Magnetic Resonance Image. TBF = total body fat. DXA = dual-energy X-ray absorptiometry.

**Table 4.1 (d) Summary of associations between physical fitness and anthropometric measures in children and adolescents**

| Study | Age (yr) | Gender (number) | Ethnicity | Fitness measure (outcome) | Anthropometric measures (explanatory) | Correlation or % explained variance (Effect size) | Notes / other findings |
|---|---|---|---|---|---|---|---|
| Gutin, Yin, Humphries & Barbeau, 2005 | 16 ± 1.2 | Girls & Boys (421) | Augusta, Georgia (US) White & Black | | ***Unadjusted*** | ***All*** | |
| | | | | Multi staged treadmill ($VO_2$max-ml/kg/min) | FM% | $r^2$ = 48% | Higher negative associations between CRF and FM% are described in relation to a significant but less association between PA and FM% in teenagers. |
| | | | | Physical activity accelerometer | FM%<br>FM% | $r^2$ = 4% (moderate PA)<br>$r^2$ = 12% (Vigorous PA) | |
| Hussey, et al., 2007 | 7 to 10 | Girls & Boys (224) | Dublin, Ireland | | ***Unadjusted*** | ***All*** | |
| | | | | 20 m multistage shuttle-run ($VO_2$max-ml/kg/min) | BMI (z-score) | $r^2$ = 7% (total)<br>$r^2$ = 18% (boys)<br>$r^2$ = 5% (girls) | Boys had stronger negative associations between body fatness and CRF than girls. Boys spent twice as long in PA each day (64 mins) than girls. Time spent in physical activity (various intensities) was related with BMI and WaistC in boys only. |
| | | | | | WaistC | $r^2$ = 25% (boys)<br>$r^2$ = 11% (girls) | |
| | | | | PA - Accelerometer (mins/day) | BMI (z-score)<br>WaistC | $r^2$ = 18%<br>$r^2$ = 10% to 29% | BMI in boys with moderate activity only. WaistC in boys with all activity levels. |
| Dencker, et al., 2012 | 8 to 11 | Girls & Boys (238) | Swedish | | ***Adjusted*** | ***All*** | Adjusted by gender. They also significantly related several increased CVD risk factors with increasing body fat mass |
| | | | | Cycle Ergometer ($VO_2$max – ml/kg/min) | FM%<br>Abdominal FM (DXA) | $R^2$ = 34%<br>$R^2$ = 37% | |
| Bailey et al., 2012 | 10 to 14 | Girls & Boys (100) | UK | | ***Unadjusted*** | ***All*** | 5% to 15% of variation in CRF was explained by different PA levels. |
| | | | | Cycle Ergometer (ml/kg/min) | WaistC | $r^2$ = 18% | |

PA = physical activity. CRF = cardiorespiratory fitness. WaistC = waist circumference. FM% = fat mass percent. BMI = body mass index. CVD = cardiovascular disease

## 4.2 Other factors that influenced run-time$_{550m}$

In the preceding section body proportions and composition of children have been considered in relation to associations with run-time$_{550m}$. When examining such associations it is apparent that anywhere from one to two thirds of the contributing factors to the variations in physical fitness are more difficult to identify or control for e.g. physiology and genetics. However there are other factors that are easily measured and important to consider e.g. age, gender and the child's environment. Therefore while considering existing literature, this section examines the differences in body composition and association with physical fitness between gender and age groups. Followed by how the school environment including ethnic group differences and socioeconomic status of the school (school decile level) are associated with CRF. Lastly the non-significant independent associations of rurality, the months of exposure schools have had to the Energize programme, and self-identified asthma with CRF are considered.

### 4.2.1 Age and gender differences in body proportions and composition, and physical fitness.

There are highly reproducible gender differences in anthropometric and physical performance testing largely attributed to sexual dimorphism. The 2011-Energized-boys, as mentioned had more FFM and less FM%, additionally they were taller with larger waist circumference, smaller WHtR and had no difference in BMI or body mass compared to the girls. Not all of these differences are in agreement with other reports where boys aged 6 to 14-yr have shown significantly lower; body mass, FM, FFM, BMI, sum of skin folds and waist circumference than girls however it was not stated if these differences were adjusted for age (Ostojic et al., 2011). Two articles under the same research project (HELENA-CSS) highlighted gender differences in adolescent boys aged 12 to 17-yr who were taller, had higher FFM, more body mass, less FM by skin folds than the girls (Moliner-Urdiales, et al., 2010 & Moliner-Urdiales, et al., 2011). In addition; the boys had less FM by DXA and BODPOD®, less abdominal fat mass by DXA but larger waist circumference and equal BMI (Moliner-Urdiales, et al., 2011). In younger children aged 8 to 10-yr, boys were taller, heavier and had larger waist circumference and BMI than the girls (Wang, et al., 2011). Overall findings from the 2011-Energized-children and other studies, girls have more FM, less FFM and often smaller waist circumferences than boys. Boys have greater total body mass and height difference varies with age. These findings indicate that BMI, waist circumference and WHtR alone cannot accurately indicate proportions of lean and adipose tissue in children's bodies. While the pattern of body proportions and composition varies with gender and age, CRF is higher in boys compared to girls explained by differences in body composition, physical activity, organ size and other unknown factors (Dencker, et al., 2007).

In addition having longer legs, a surrogate measure of which is height for age, would be expected to predict a faster time to complete the 550 m run due to the increased stride length (Schepens, Wikkems & Cavagna, 1998). During child growth, at maximum running speed, stride frequency remains fairly stable regardless of body size and age. Children compared to adults, take more strides which are shorter at any given speed. The increased stride frequency in children, compared to adults, reduces their power out-put for acceleration so their maximum running speed cannot increase until they grow longer legs (Schepens, et al, 1998). Therefore age is a major contributing factor for the mechanics of running performance in children.

The 7-yr old 2011-Energize-children took longer to run 550 m than the 10-yr olds. In general younger children have less of their physical fitness determined by anthropometric measures and have lower endurance than older children because their bodies are less developed. This means other factors such as organ development (e.g. lungs and heart), metabolic pathways, genetics and environment are associated more with their physical performance. Sub-maximal aerobic capacity or endurance testing at younger ages, which is less influenced by motivation, training and fitness level (Janz, et al., 1998), may highlight potential cardiometabolic risks earlier, e.g. insulin resistance, high blood glucose, hypertension, adverse lipid profiles and increased WHtR or waist circumference. Physical fitness level as an early indicator of disease risk may be independent from typical body composition changes during childhood. Therefore longitudinal studies to determine contributions of early physical fitness performance to screen for future obesity and health risks and to inform interventions are feasible and desirable.

This thesis presents evidence (Tables 3.2 & 3.3) along with other studies that for the same age boys have stronger CRF than girls during staged shuttle run test (Ostojic et al., 2011; Wang, et al., 2011; He, et al., 2011), ergometer tests (Sveinsson, et al., 2009; Kwon, Burns & Janz, 2010), physical activity scores (Moliner-Urdiales et al., 2011) and run-time$_{550m}$ as shown by the 2011-Energized-children and Albon, et al. (2010). This thesis presents evidence (Tables 3.2 & 3.3) that the best explanation for girls to take more time to run 550 m is more FM% and less FFM, rather than gender differences merely in BMI, WHtR or waist circumference. Furthermore it has been demonstrated that prepubescent boys not only have greater CRF, but also power in their upper and lower limbs than prepubescent girls (Marta, Marinho, Barbosa, Izquierdo & Marques, 2012). No gender difference in strength or endurance testing in muscles of the trunk, abdomen and upper limbs has been reported, however girls do have greater flexibility and better balance than boys (Marta, et al., 2012). It is likely that these gender differences in physical fitness may track from birth (differences attained from birth and followed through development) as do the differences in body composition of girls and boys (Fomon, et al., 1982; Butte, Hopkinson, Wong, Smith & Ellis, 2000). Overall differences mean that age and gender need to be accounted for when examining and making conclusions about the relationships between CRF and different adiposity measures in children (also alongside health risk assessments). Most of the studies reviewed (Table 4.1) did not make adjustments for confounding factors.

Another important co-factor is the ethnic diversity within the NZ population and the known health risk differences between Māori or Pacific and NZ European e.g. asthma prevalence is higher in Māori children, proportionally more Māori and Pacific children are obese, and more likely to need removal of diseased teeth or not visit a dental practitioner (Ministry of Health, 2012a). Because of health disparities among ethnic groups in NZ, especially in obesity prevalence, it was expected that Māori and Pacific children would run 550 m slower.

### 4.2.2 Ethnic group, body proportions and composition and physical fitness.

In New Zealand, across the lifecycle, Māori have higher rates of overweight and obesity and poorer health and socioeconomic status than NZ European (2011-2012 National

Health Survey) (Ministry of Health, 2012a; Ministry of Health 2012b). The 2011-Energized-Māori, for the same age, boys and girls were in general taller and heavier with more FFM (by 1.2kg to 2.5kg) and FM% (by 1.8% to 3.1%) than their NZ European peers. Equally for boys and girls (Appendix H, H2 & H6), the average WHtR for Māori was 0.46 (7 & 10-yr olds) and NZ European 0.45 (7-yr olds) and 0.44 (10-yr olds) cm/cm, which demonstrates a small but significant difference between the ethnic groups. Previously in a sample of 400 (90 Māori, 129 Pacific, 89 Asian Indian and 91 European) 12 to 19-yr old NZ adolescents, no difference in waist circumference and WHtR (adjusted for age, height and weight) were reported but there were significantly higher values in NZ European and Asian Indian boys compared to Māori and Pacific boys (Sluyter, et al., 2011). In Sluyter et al. (2011) sample of adolescents, obesity prevalence was high which was more pronounced in Māori and Pacific adolescents whose average unadjusted BMI was considered overweight by IOTF standards and average FM% for girls was 33%-37% and boys, 21-26%. For the girls especially, adjusted and unadjusted WHtR by ethnic group was between 0.47 and 0.52 cm / cm, which suggests a higher likelihood of cardiometabolic risk in these youth. Adjusting WHtR by age, height and weight raised the relative ratio in NZ European and Asian / Indian boys and girls, but lowered it for the Māori and Pacific adolescents (Sluyter, et al., 2011). This suggests that while there were less intra-ethnic group differences in overall WHtR and abdominal fat mass (kg) in the girls, there were interactions with muscle mass, which for the same weight was higher in Māori and Pacific, and attenuated the absolute WHtR. A similar interaction was seen in the boys however the NZ European and Asian / Indian also had a significantly higher volume of abdominal fat mass (kg) compared to the Māori and Pacific boys (Sluyter, et al., 2011). The use of body composition differences among different ethnic groups in NZ (and worldwide) to explain differences in physical fitness performance comparatively is a little more difficult due to the lack of research within this field.

In the 2011-Energized-children cardiorespiratory fitness did show some interactions between ethnic groups that were independent of age, height and FM%, where on average Māori took longer to run 550 m than NZ European. This pattern where NZ European ran the fastest was evident but not significant for the comparison with Pacific and Other children who were represented in small numbers. Comparative international investigations have shown that in a small sample of Portuguese (Santos, et al., 2011), African-Portuguese adolescent girls had higher CRF than Caucasian-Portuguese girls, there was no CRF difference in the boys, and within gender there were no difference in BMI, FM% or FFM between the two ethnic groups. In over 4600 children from Georgia USA (Powell, et al., 2009), 40% African American, 20% Hispanic, 10 to 14-yrs, the non-Caucasian youth generally had lower BMI and better strength / muscular endurance fitness scores compared to the other ethnic groups (FITNESSGRAM®). However in this group there was no ethnic group difference for prevalence of unfit scored physical fitness by an endurance run test (Powell, et al., 2009). In contrast in 215 children age 7 to 12-yrs the African American had significantly lower CRF independent of FM and FFM than Hispanic and Caucasian children, while Hispanic children had the highest CRF out of all the children, which attenuated towards the Caucasian CRF level once adjusted for lean mass (Casazza, Gower, Willig, Hunter & Fernandez, 2009). While there are significant body composition differences, and higher prevalence of obesity in non-Caucasian ethnic groups, globally, there are less clear independent associations between CRF and ethnicity during childhood.

In adults it has been demonstrated (Farrell, Kohl & Rogers, 1987) that ethnicity is independently associated with CRF (sub-maximal graded treadmill test) and non-Caucasian were more likely to have lower CRF than Caucasian adults. A group of young adults who had completed CRF testing (sub-maximal graded treadmill test) during the US NHANES surveys, 1999 to 2004 ($n$ = 3247, aged 20 to 49-yr) (Ceaser, Fizhugh, Thompson & Bassett, 2013) were assessed for associations with CRF, physical activity, body proportions and environmental factors. After adjusting CRF for volume of physical activity, there was a significant difference in CRF among the four ethnic groups, where non-Caucasians reported lower intensity of physical activity levels and poorer CRF was measured. When examined by gender the same association was seen in women, but for men, the physical activity co-factor eliminated ethnic group differences in CRF (Ceaser, et al., 2013). When grouped by ethnicity; waist circumference, tobacco smoking and socio-demographics made up a significant proportion of explained variance of CRF ($R^2$ = 16% to 31%, African-Americans with the larger $R^2$ value), physical activity parameters only added another 1% to 2% of explanatory power. In addition African-Americans with at-risk waist circumferences had approximately twice the reduction in CRF than the at-risk group within all other ethnic groups (Ceaser, et al., 2013). This analysis did not account for other factors such as FM%, BMI, or height or weight, and physical activity was a self-reported variable. But it does raise the importance of disparities among ethnic groups , socio-demographic and health behaviours in childhood that are collectively associated with physical fitness in adulthood.

Disparities in health and socioeconomic status are also associated with ethnicity and geographical location. This work has demonstrated that Māori children, who in the majority attend lower decile level schools, have lower physical fitness than NZ European after accounting for age, height and FM%. However school decile level itself also had a significant association that contributed to greater variation in CRF than ethnic group.

4.2.3 School decile level, physical fitness and anthropometric measurements.

Accounting for age, gender and body fatness the 2011-Energized-children (Māori and NZ European only examined) from lower decile schools ran more slowly than those from medium and high decile schools. On average 6-out-of-10 children attending low decile schools and 3-out-of-10 children attending medium decile schools were Māori. High decile schools averaged just over 1-out-of-10 proportion of the role being Māori. Six-out-of-ten of the whole group of Māori children were attending low decile schools in 2011. The difference in run speed between all Māori and NZ European 2011-Energised-children was less than the difference for the same children, compared between high and low decile schools. All anthropometric measurements (except height) were significantly larger for age in the children at low decile schools compared to those at high decile schools. In addition there were no body composition differences between medium and high decile school children, yet medium decile school children ran more slowly.

Nine studies reviewed in this discussion (Table 4.2) have demonstrated the association of lower socioeconomic status with poorer physical performance and/or more time in sedentary activity. At the same time as the 2011-Energized children were evaluated the National Health Survey 2011/12 (Ministry of Health 2012a) reported that more than half of children surveyed watch two or more hours of television per day and more often than this for Māori, Pacific and children from the most deprived living areas. On the other hand Māori, Pacific children and children from least deprived areas were more likely than other NZ ethnic groups, to use active transport between home and school. There are a number of other factors that may account for socioeconomic differences.

Esmaeilzadeh, et al. (2013) explain that because they found a trivial yet significant positive association between socioeconomic status and FM ($r^2 < 1\%$) and in a separate analysis CRF associated strongly and negatively with body fatness measures (Table 4.1) that an indirect relationship between lower socioeconomic status and poor CRF exists. Evidence for this assumption is weak and determinants of body composition by CRF by socioeconomic status interrelationships requires more exploration. This thesis presents evidence to suggest that there are other factors independent from fatness that were more prevalent in lower socioeconomic neighbourhood clusters of NZ which associated with poorer CRF in the children. Body fatness and self-identification with an ethnic group interacts with socioeconomic disparities. The National Health Survey 2011/12 (Ministry of Health, 2012a) also demonstrated this interaction by showing health disparities between most and least deprived children still exist after adjustments for age, gender and ethnic group (Table 4.2).

Other researchers demonstrate the least deprived children have the highest CRF (Table 4.2), however there appear to be gender, age and socioeconomic level interactions (Jimenez-Pavon, et al., 2010; Prista, Marques & Maia, 1997), which may also be compounded by the different methods used to assess socioeconomic status (Table 4.2) e.g. town versus. rural (Prista, et al., 1997; Thomas, Cooper, Willliams, Baker & Davies, 2005), affluence (Mutunga, et al., 2006) and parental education and occupations (Jimenez-Pavon, et al., 2010 Esmaeilzadeh, et al., 2013). It was difficult to find studies that concurrently examined interrelationships of CRF, anthropometric measures and socioeconomic status.

The question about how much of the socioeconomic effects on cardiovascular health risks may be reversible and what interventions may be effective is beyond the scope of this thesis. Given the high level of engagement and activities the Project Energize programme has within each school, other factors that may influence change such as, a reduction in unemployment of parents may have a more profound effect than active promotion of healthy food, increased physical activity and vigorous exercise in the schools. Other factors that may influence cardiometabolic health risk e.g. exposure to tobacco smoke, infant feeding patterns, generational epigenetic programming related with the poverty environment, sleep patterns, food availability (not just types), behaviours, belief systems / culture and family health history, may be amenable to change, and Project Energize could be a way to engage with parents / caregivers and industry. Other school based interventions (Brown and Summerbell, 2009) that focus on reducing television viewing, increasing physical activity, breakfast schemes, reducing fizzy drinks and those with environmental, policy and marketing changes, have demonstrated the most significant reductions in obesity prevalence and or reductions in BMI compared to control groups. Emphasis on strategies for change in these areas could be explored in the lower decile schools considering national statistics also point out increasing disparity between children living in the most and least deprived areas (Ministry of Health, 2012a).

**Table 4.2 (a) Summary of associations of socioeconomic status with fatness and fitness (or other health parameters)**

| Study | Age (yr) | Gender (number) | Ethnicity | Socio-Economic Status | Anthropometric measures | health or fitness measures | Notes / other findings |
|---|---|---|---|---|---|---|---|
| Cooper, 2013 (this thesis) | 7 & 10 | Girls (2675) Boys (2425) | NZ European, Māori, Pacific, Others | School decile level; Low (1 to 3) Medium (4 to 7) High (8 to 10) | Children at low decile were larger and fatter in all measures (not height) than medium & high decile. No significant difference between medium & high decile in 7-yr olds but 10-yr olds had higher BMI, WHtR & WaistC than high decile. | All three decile levels had significantly different CRF - running times (s); high / fastest > medium > low / slowest. | School decile level is a value calculated from 5 yearly census results with 10% of schools falling within each of the 10 levels. Where the students live determines the catchments examined for home income, occupation, crowding, education and income support. |
| Esmaeilzadeh, et al., 2013 | 7 to 11 | Boys (766) | Iranian | A scaled score by parents education & occupation. | SES / FM (kg) $r^2 < 1\%$ ($p < 0.05$) | Did not assess association with a 1-mile-run – $VO_2$max – ml/kg/min. | A trivial significant association with fat mass in kg and SES. |
| Ministry of Health, 2012a | 0 to 14 | Boys & Girls ( > 4000) | Māori, Pacific, Asian, European/ Other | Neighbourhood deprivation in quintiles. From census information. | More obesity in deprived areas 19% Vs. least deprived 3%. | More TV watched by the more deprived. More use of active transport between school by the more deprived. | SES results are adjusted by age, gender & ethnic group. |
| Jimenez-Pavon, et al., 2010 | 12 to 18 | Boys (819) Girls (931) | Spanish | Parental occupation level; high medium, low. Education level; primary, secondary, university. | WaistC and skinfolds smaller in higher parental education (boys only). | CRF significantly higher in higher parental occupation and education (girls only). | Differences varied across all six different levels e.g. sometimes high / university Vs. medium / secondary or high / university Vs. low / primary. There were no clear trends. |

CRF = cardiorespiratory fitness. SES = socioeconomic status. FM = fat mass. TV = television. WaistC = waist circumference

**Table 4.2 (b). Summary of associations of socioeconomic status with fatness and fitness (or other health parameters)**

| Study | Age (yr) | Gender (number) | Ethnicity | Socio-Economic Status | Anthropometric measures | health or fitness measures | Notes / other findings |
|---|---|---|---|---|---|---|---|
| Drenowatz et al., 2010 | 8 to 11 | Girls (222) Boys (180) | 88% American Caucasian | Low & High by household income. | Larger BMI in low SES Lower BMI in high SES. | Lower physical activity – pedometer and accelerometer in low SES. Less time watching TV in high SES. | PA not significant after adjusting for BMI. TV watching time remained significant after adjusting for BMI. |
| Freitas, et al, 2007 | 7 to 18 | Boys (256) Girls (251) | Portuguese | High / Medium / Low Questionnaire of socio-demographic characteristics. | High SES had more adiposity were also taller and heavier than low SES. | In boys high SES perform significantly more physical activity than low and medium SES. In girls similar trend but significance only at age 12 to 14-yrs. CRF was higher in boys and girls of high SES between the ages 10 to 14-yrs. | Mixed-longitudinal follow-up design. Many of the PA and strength or endurance tests had mixed variation across the three SES groups. |
| Prista, et al., 1997 | 8 to 15 | Boys (277) Girls (316) | Mozambique | Regions (1) urban centre,(2) non urban reed houses, (3) reed house, mixture of land and town workers. | Higher SES (region 1) had more FM% than other regions. FFM was variable among the SES but usually higher in region 1. | Region 2 & 3 more flexible. Region 1 better for sit ups. Region 1 higher CRF. PA patterns were variable but region 1 played more sports and region 2 were least active. | This population has some stunting but not acute under-nutrition. Age and gender had various interactions with the results. |

CRF = cardiorespiratory fitness. SES = socioeconomic status. PA = physical activity. BMI = body mass index. FFM = fat free mass FM = fat mass. TV = television

**Table 4.2 (c). Summary of associations of socioeconomic status with fatness and fitness (or other health parameters)**

| **Study** | **Age (yr)** | **Gender (number)** | **Ethnicity** | **Socio-Economic Status** | **Anthropometric measures** | **health or fitness measures** | **Notes / other findings** |
|---|---|---|---|---|---|---|---|
| Mutunga, et al., 2006 | 12 or 15 | Boys & Girls (2016) | Northern Ireland | Affluent families & deprived families. | No significant difference in obesity prevalence between the two SES groups. | Adolescents from the affluent group did more physical activity and had higher CRF than the deprived group. | |
| Thomas, et al, 2005 | 12 to 13 | Boys (100) Girls (108) | All Caucasian | Rural-high Vs. Town - low | No significant difference in BMI & FM. | Lower CRF in the town children. | Little difference among other risk factors such as obesity, serum lipids & hypertension. |
| Sallis, et al., 1996 | 11 to 19 | Boys & Girls (1871) | African-American Asian-pacific Latino | High Vs. Low by school district - subsidised school lunches. | Lower BMI in high SES (but no age adjustments). | More vigorous PA, sport participation, more PE class time in high SES. | It is important to note adolescents are able to choose to participate in PE or not. Boys did 40% more PA than girls. |

CRF = cardiorespiratory fitness. SES = socioeconomic status. PA = physical activity. BMI = body mass index. FM = fat mass. PE = physical education.

4.2.4 Physical fitness, rurality, intervention exposure and asthma prevalence.

In the 2011-Energized-children there were several potential covariates considered for their possible interaction with run-time$_{550m}$. Previous discussion has already addressed how body fatness, age, gender and school decile level have significant associations with CRF and height, weight, FFM and ethnic group as less strong predictors. Other factors considered included rurality, length of exposure of the school to the Project Energize intervention and asthma prevalence. In 2004 baseline measures from 2752, 5 and 10-yr old Waikato school children (Rush, Reed, et al., 2013) demonstrated higher FM% and lower blood pressure in urban compared to rural children. Physical fitness assessment was not reported in these children. Moving forward to 2011, while the majority of the 2011-Energized-children lived rurally, it was a non-significant predictor for CRF in this population after body fatness, age, gender and school decile were considered. However other research presents contrasting evidence where among approximately 4600 urban and rural 10 to 14-yr olds, in the proportion of youth who fell below the healthy fit zone of FITNESSGRAM® (half of the total sample) during assessments for CRF, rural youth were more likely to be unfit, at the same time there was no difference in prevalence of high BMI between urban and rural youth (Powell, et al., 2009). Previously where rurality has been used as a marker for socioeconomic status, town children considered poorer have had lower CRF (Thomas, et al, 2005), and urban living was associated with increased fatness but higher CRF compared with rural living children (Prista, et al., 1997). These types of geographical differences are better at explaining physical fitness when there are disparities in socioeconomic conditions between them and the developmental status of the country. Therefore the likely reason there is little interaction of rurality on CRF in these NZ children is the observed relatively even spread of deprivation throughout the Waikato region (White, Gunston, Salmond, Atkinson & Crampton, 2008).

The length of time of exposure to the intervention programme may also have reduced any small effect of rurality because the programme reaches all areas of the Waikato and prioritises contact time to the most deprived areas. The number of months exposure the school had to the physical activity and nutrition had a very small significant association ($R^2 < 0.5\%$) with CRF but was not significant in the final stepwise regression models because of the small effect. School clusters were not accounted for and the school environment may interact with the way the programme is delivered e.g. the Principals and Board Of Trustees are different.

Self-reported asthma prevalence was 17% of the 2011-Energized-children which was higher than the current national average of 14% for medicated asthma (Ministry of Health, 2012a) The prevalence of asthma had a very small but significant association with CRF, but was excluded from the final analysis due to minimal overall contribution to run-time$_{550m}$ after other factors were considered. Meta-analysis of longitudinal research demonstrates that children with higher levels of physical activity are less likely to report the development of asthma over time and cross-sectional research suggests high physical activity lowers asthma prevalence (Eijkemans, Mommers, Draaisma, Thijs, & Prins, 2012). Therefore because CRF is lower in children with asthma, physical fitness based interventions may improve quality of life alongside some improvements in CRF (Crosbie, 2012). In NZ there is higher prevalence of asthma in Māori children and children living in the most deprived areas (Ministry of Health, 2012a). Speculatively the allowance of medication use before the 550 m run and exposure to the intervention, which may have over time improved CRF in children with asthma, and socioeconomic disparities may give rise the trivial independent association between CRF and Asthma in the2011-Energized-children.

## 4.3 Waist to height ratio relationships with other measures of adiposity

Previous sections have discussed in detail the associations of fatness with CRF and other important cofactors. Previous investigations of the utility of WHtR in NZ children have been limited (Taylor, et al., 2011; Sluyter, et al., 2011; Goulding, et al., 2010). The following discussion is of WHtR in relation to other measures of adiposity in the 2011-Energized-children and how this adds to the existing body of evidence.

While BMI is used extensively as a measure of relative body size in health research and for public health screening, it may not be the easiest or most accurate measure to use. On the other hand waist circumference (gender and age specific cut-points) (van Dijk, et al., 2012) and the WHtR (0.50 cm/cm) have proven to work cohesively or better than BMI in terms of prediction of multiple cardiometabolic risk factors in children

(Browning, et al., 2010; Ashwell, et al., 2012). Preschoolers (Campagnolo, Hoffman & Vitolo, 2011) who were more likely to have two or more risks out of low HDL cholesterol, high LDL cholesterol, high triglycerides or high systolic and or systolic blood pressure also had a higher WHtR.

In the 2011-Energized-children, adjusted for age and gender, for every 1 kg/m$^2$ increase in BMI, WHtR increased by 0.013 cm/cm, ($R = 0.87$, $P < 0.0001$). Sveinsson et al., (2009) found similar very high correlations between BMI and waist adjusted by height (waist circumference cm / height m $^{0.9282}$) in 270, 9 and 15-yr olds, $r = 0.86$ and 0.91, respectively. As did Freedman, Kahn, et al. (2007) for 3066 children aged 5 to 17-yr between WHtR and USCDC 2000 BMI SDS ($r = 0.88$). Additionally bivariate associations in the 2011-Energized-children suggest the WHtR performs well at being a measure of fatness that is independent of height in growing children, in contrast with the small to moderate positive relationship height has with FM% and BMI (Appendix J).

For the 2011-Energize-children, the WHtR had high sensitivity and specificity (95% and 86%, respectively) to correctly identify children who were overweight / obese and non overweight (by the IOTF classification). In NZ children and adolescents (mostly European, aged 5 to 18-yr) the WHtR has been compared with total abdominal fat measured by DXA to show that the recommended cut-point of 0.50 cm/cm accurately predicts risk of excess abdominal fat without need for further height adjustment (Taylor, et al., 2011). Children who did not have excess abdominal adiposity almost always (> 90% specificity) had a WHtR less than 0.50cm/cm but there was lower sensitivity for identifying excess abdominal fat (Taylor, et al., 2011). Taylor, et al., (2011) defined a cut-point to describe excess abdominal adiposity by DXA at the 85th percentile of abdominal fat mass and the waist to height cut-point less than 0.50 cm/cm. Whereas in this body of work the cut-point for WHtR was less than or equal to 0.50 cm/cm and used the IOTF classification for overweight or obesity. These cut-points vary and may refer to different estimations of excess abdominal adiposity. When Taylor, et al. (2011) re-examined with a raised cut-point for abdominal fat mass to the 95th percentile, sensitivity of WHtR 0.50 cm/cm to detect high abdominal fat mass was raised to 93% with no change in specificity. Goulding, et al (2010) also analysed data from NZ children (37% Māori and 33% Pacific, aged 5 to 14-yr), and concluded that a WHtR less than 0.50 cm/cm was approximately related to below the 91st percentile of BMI.

Similarly Freedman, Kahn, et al. (2007) demonstrated that the USCDC2000 BMI for age SDS (1.654) at the 95th percentile was equal to a WHtR of 0.512. From these studies it appears that the WHtR cut-point 0.50cm/cm is in good agreement with adiposity levels representing more than the 90th percentiles of other truncal or body mass fatness measures.

Seventy five percent of the overweight 2011-Energized-children and 10% of obese children had a WHtR that was less than or equal to half their height. In a separate analysis, while all non-overweight children had a WHtR less than half their height, the sensitivity of overweight / obesity to correctly identify a WHtR greater than half height was not strong, where over half of the time when a child was classified overweight / obese their WHtR was considered not indicative of excess central adiposity (WHtR $\leq$ 0.50). This was more likely to occur in Māori compared to NZ European children. Therefore it is not that the WHtR is insensitive to measuring body fatness by BMI or DXA, it may be the BMI classifications (particularly the overweight category) that are less sensitive to detecting excess fat mass.

An issue which requires more detailed longitudinal analysis in children is what levels of adiposity relate to increased risk of disease and which indirect methods to measure and screen for the risk are best. For the time being the WHtR has good utility to indicate a low risk of excess adiposity in all children whose waist circumference is equal to or less than half their height, even if that child is classified as overweight by IOTF standards. But a child whose BMI is initially considered overweight should also have their WHtR assessed. The WHtR has been demonstrated in the 2011-Energized-children to relate closely with BMI yet have an overall slightly stronger association with physical fitness and fatness despite the ethnic group and socioeconomic diversity present in the population.

Māori children are generally larger in bulk, rather than height, and during growth accumulate FM and FFM faster than NZ European children (from the Waikato) (Rush, et al., 2012a). Māori and Pacific adolescents (from Auckland), 12 to 19-yr, have shown a greater volume of bone mineral mass and skeletal muscle mass as measured by DXA, and for a given BMI, Māori and Pacific children had less FM% (within a range of 2% to 5%) than NZ European (Sluyter, et al., 2011). This provides some explanation of why BMI may not be the best measure of body fatness in NZ children and adolescents, representing different ethnic groups, with different proportions of FM and FFM for the same BMI and different growth patterns (Rush, et al., 2012a). Measures that can accommodate differences in body fat distribution or body shape, muscle and osseous tissue development / volume, may help to make more precise associations of excess adiposity within multiethnic groups (Sluyter, et al., 2011). Slyuter et al. (2011) demonstrated that measurements of waist circumference, WHtR or waist relative to height and weight, partially account for ethnic group differences in relative FM%, at the same time as being good indirect measures of abdominal fat volume, confirmed by DXA. Further investigations are required to assess cardiometabolic risk factors associated with the WHtR in the multi ethnic groups of the NZ population and across the lifecourse.

## 4.4 Strengths and limitations

The main strength of this investigation is that it has provided robust evidence about the interrelationships of body proportions and composition with CRF. The evidence is robust because it is from a large population of children, 36% were Māori, the whole range of socioeconomic status was represented, and broadly representative of the Waikato region. This information will be useful to inform future measures of the effectiveness of Project Energize which continues to be funded and is currently operative in all 244 primary schools in the Waikato. The 2011-Extended Evaluation of Project Energize was not a randomised controlled trial and the cross sectional design means that cause and effect cannot be established, only relationships and associations in Waikato primary school children in 2011. The budget was limited and the measures undertaken were simplified to allow measurement of large numbers of children, to get good Māori representation and participation, and cover a large area of the North Island in less than two months. The planned numbers of Māori participants and low socioeconomic status school representation were achieved, and as such is the largest sample size for an investigation of this type in New Zealand.

Measurements were collected by six teams over six weeks with rigorous quality control around the anthropometric measurements and CRF test. For the 2011 Project Energize Extended Evaluation, the measurement team members were all qualified health or education professionals and each team included one qualified nurse. Together, they all participated in training, learnt how to use the equipment and procedures for each measurement. This helped minimise measurement errors and confidently provide homogeneous records given the large number of children measured in a short time frame and covering a large land area. Evidence of this quality control lends strength to the strong group differences and effect sizes reported.

In the 2011-Energized-children run-time$_{550m}$ was recorded as a time (s) to completion with no other post test calculations e.g. volume of oxygen consumed. Research has demonstrated that sub-maximal or moderate intensity fitness testing is viable in children of all shapes and sizes, as maximal $VO_2$ tests can be technically and physically more challenging for children and researchers to carry out (Breithaupt, Adamo & Colley, 2012; Ahler, Bendiksen, Krustrup & Wedderkopp, 2012). Maximal $VO_2$ tests are also not a field test because specialist test equipment such as a treadmill and indirect calorimeter are required, electricity is necessary and data analysis and interpretation require specific expertise. Validity and reliability of the main outcome measure of physical fitness is important. Run-time$_{550m}$ was only measured once however this was in a large group of children and the Energizer team facilitating the run were known by the children which encouraged co-operation e.g. following instructions. The run was performed outdoors on grass and rain did not eventuate during the measurement process.

The measurement of waist is more problematic with higher measurement error than height and weight (Ministry of Health, 2008b; Verweij, Terwee, Proper, Hulshof & van Mechelen, 2012. Comparing waist circumference measurements between; follow-ups, individuals, other studies and populations, can be difficult due to no single standardised method of measuring waist circumference. Error is easily introduced through tape measure placement, the presence of clothing, respiratory phases, stance, and fasting status or fluid in the bladder (Wang, et al., 2003; Rudolf, Walker & Cole, 2007; Agarwal, et al., 2009; Mason & Katzmarzyk, 2009). For example the most recent NZ body size technical report (Ministry of Health, 2008b), in children, described an error rate where 21.3% of the time repeated waist circumference measures differed by more than 1% (precision, 0.1 cm), compared to 2.2% and 2.4% error during repeat measures of height (0.1 cm) and weight (0.1 kg), respectively (Table 4.3). This body of work did not check the precision or variability of waist measurements among assessors however proper training and repeated measures may reduce errors (World Health Organisation, 2011; Verweij, et al., 2012). Similarly errors will also be accumulative when using multiple measures to derive other parameters, for example (Table 4.3), when deriving the WHtR and when using bioelectrical impedance analysis (BIA) to derive body fatness from calculations involving estimated total body water using resistance, height and weight.

**Table 4.3 Example of accumulating variation in measurements.**

| | Measure 1 | Percentage variation | Measure 2 (± % allowed variation) | How often variation exceeded 1%* |
|---|---|---|---|---|
| WaistC | 60 cm | ± 1%* | 59.4 to 60.6 cm | 21.3% |
| Height | 120 cm | ± 1%* | 118.8 to 121.2 cm | 2.2% |
| WHtR | 0.50 cm/cm | ± 2% | 0.49 to 0.51 cm/cm | unknown |

WHtR = waist to height ratio. WaistC = waist circumference. *The 1% variation is based on an allowable maximum difference, if measurement was more than 1% different to the first measure a third measure was taken (Ministry of Health, 2008b)

The implications of measurement errors and choice of measurement methods may inaccurately estimate proportions of those with increased health risks associated with particular set 'cut-points' (Mason & Katzmarzyk, 2009). Recently Ashwell & Browning (2011), from 84 papers, acknowledged 5 differences in waist circumference measurement location (including not mentioning location) and greater than 10 terminology differences (including abbreviations) for research pertaining to the WHtR from 1995 to 2009. Half of the articles reviewed by Ashwell and Browning (2011) used the World Health Organisation waist measure protocol (mid way between the lower costal margin and top of the iliac crest) (World Health Organisation, 2011), as did this thesis, and another third of the articles used the umbilicus as a reference point. Terminology and waist circumference location variations were also an ongoing issue faced during literature searches and comparisons between studies, over the course of this thesis. There has been development of a portable non-contact BIA method (ViScan) to measure waist circumference and truncal fat volume / percentage with accurate results related with tape measurement results ($r > 0.95$) in supine and standing position (Schutz, Sarafian, Miles, Montani, & Dulloo, 2012). This type of equipment although expensive, may reduce some measurement error (although introduce other error types) and be especially good for longitudinal monitoring of abdominal fatness (Schutz, et al., 2012).

Although comparisons were reported, it was decided not to use the standard deviation scores in the consideration of predictors of physical fitness in the multiple regression analysis. This was because there were minimal to no differences in the bivariate correlations between absolute measure and relative measures. Standard deviation scores have use in research and differences can be inferred between the measured and reference populations. The main questions of this thesis required that the results could be disseminated to the public in a way that could be simply understood and practically utilised.

The statistical approach was limited and comparison with other research not always easy. Not all articles reviewed specified which method of correlation analysis was applied and generally readers might assume Pearson's r for parametric correlations. It should be noted that in this thesis that for the untransformed data Spearman rank correlations were chosen over parametric correlations due to non-normal distribution of the variables. This approach was confirmed as adequate as a set of parametric correlations of the variables after log transformation yielded similar strengths. However it is questionable if comparing a non-parametric correlation with a parametric alternative among different studies has any erroneous inference. Also statistical error may be present when making inferences from the Pacific and Other groups of children due to small participation numbers. Post-hoc adjustments were made where possible however confidence intervals (margin of error) remained expanded in these groups. For this reason the Pacific group have been included in inferences but with caution as true differences may be different in magnitude. The Others group are presented in tables (Appendix H) but are discussed less because additional to the low participation this group is a mix of several ethnic groups e.g. Indian and Asian making comparisons less meaningful. The main purpose of separating ethnic groups was to make comparisons between Māori and NZ European.

Physical activity was not assessed and this would have added to participant burden and likely affected participation if questionnaires were too long. The validity of subjective physical activity questioning in children is not strong. Furthermore physical activity appears to have trivial to moderate associations with body composition (Dencker, et al., 2010; Sveinsson, et al., 2009) which could be dependent on other factors such as, method of quantifying time spent in physical activity, types of activity, age and gender differences and all the pitfalls of self or proxy reporting.

Puberty status was not measured in the 2011-Energized-children. The majority of studies reviewed (Table 4.1) who did measure puberty status reported children under the age of about 11-yr were most likely to be within Tanner stage 1 or 2 (Marshall & Tanner, 1969 & 1970) yet we know in New Zealand children the age of puberty in Māori is younger than for European (Ministry of Health, 2003). Puberty is related to age, height and weight – the adolescent growth spurt (Marshall & Tanner, 1969 & 1970). Puberty is an important co-factor to account for, when it is feasible to accurately measure, because early puberty in males and females has been associated with having more cardiometabolic risks later in adulthood, which are relative to and independent of BMI (Widen, et al., 2012). Differences in physical fitness levels and body fatness status may (Ortega, et.al., 2011), or may not (Lewit, Barker, Mooney, Hall & Thomas, 2012) exist between adolescents of early or late puberty.

Finally it is essential to approach the intervention or prevention of childhood obesity from the life course perspective of disease prevention but the evidence base is complex and not strong due to rapid secular change. While the 2011-Energize-children can demonstrate the need and the short term efficacy of goals of interventions to improve physical fitness and to lower adiposity the long term reduction in risk for cardiovascular disease and type-2-diabetes has not been demonstrated. Primary school is only a small span of time and risk accumulates from conception and into adulthood (Gluckman, Hanson & Mitchell, 2010). Never-the-less school based physical activity and nutrition interventions such as Project Energize are fitting with global goals and strategies which are primarily focused on increasing daily habitual physical activity, improving physical fitness, and healthy nutrition (World Health Organisation, 2010a & 2010b; World Health Organisation, 2012). Aiming to lessen the life course burden of chronic but modifiable cardiometabolic and other non-communicable diseases (Ben Shlomo & Kuh, 2002; Lee, et al., 2012).

### 4.5 Future direction and activities

The 2011-Energized-children were part of an ongoing public health programme aimed at reducing overweight and obesity and increase physical fitness of primary school aged children. Now Project Energize is a main budget line in the Waikato District Health Board funding and planning and this is likely to continue for many years. The evidence presented in this thesis and associated work such as the generation of run time percentiles for boys and girls (personal communication E. Rush) means that the 550 m run times are being and will be used in future assessment of the programme. Furthermore the programme has been rolled out into schools in Franklin and Northland and the 550 m run measure is being used as a measure of effectiveness in preference to height and weight measures. The physical fitness measure gives immediate feedback to the Energizer team, teachers and schools about the overall ability of their children in comparison to the 2011-Energized-children. Long term it is hoped that the Waikato child health statistics will improve and this will be related to the Energize programme.

Evidence such as this thesis and the 2011 extended evaluation report (Rush, et al. 2011) is essential to inform future actions in public health. A cost effectiveness analysis of Project Energize and the BMI changes from the control children in the RCT and the 2011-Energized-children has recently been accepted for publication (Rush, et al., 2013 in press). At $NZ45/y/child the intervention is considered to be cost effective across the lifetime from the point of view of medical and health costs with a lifetime cost for each quality adjusted life year gained of $25000. This economic modelling does not take into account the other gains that may be made with improved health literacy and possibly academic performance of the children. The teachers and schools in general are very committed to Energize which makes further interactions with the schools much more likely to be effective (Mrkusic, 2011).

In the 2011-Energized-children, resting blood pressure and pulse rate were also measured and therefore further analysis may be carried out to assess inter-relationships among physical fitness and body size and composition with these vital measurements. In particular utility of WHtR in risk screening in children. Examining in more depth the relationships of obesity and physical fitness with different cardiovascular biomarkers is important due to inter-relationships with negative morphological changes in the cardiac muscle caused from essential hypertension, increased cardiac work load and output

(Daniels, Witt, Glascock, Khoury & Kimball, 2002). While others have shown that in children the presence of cardiovascular disease risk factors such as higher systolic blood pressure, higher pulse and mean arterial pressure, higher left ventricular mass and left atrial enlargement, were significantly associated with increasing body fat percentage and abdominal fat volume (Dencker, et al., 2012). It has also been shown that waist circumference was the only significant independent factor associated with increased left atrial area and higher incidences of insulin resistance, hypertension and obesity signalling the importance of abdominal obesity management from a young age (Hirschler, et al., 2006). Continued research into the association of physical fitness, abdominal obesity and cardiovascular / cardiorespiratory function, especially longitudinal studies, are necessary from childhood to measure what effects obesity reduction and physical fitness improvement might have on these risks during childhood and later in adulthood.

## 4.6 Conclusion

The main finding is that the WHtR, is inversely associated with physical fitness. The main recommendation is that the WHtR should be considered as a screening tool for abdominal fatness and physical fitness in all primary school children in NZ. Longitudinal studies are required to show whether a reduction in the WHtR is directly associated with an increase in physical fitness brought about by interventions such as Project Energize.

Major effects were related to Māori and Pacific ethnicity and lower socioeconomic status. Māori children attending lower decile schools have the greatest chance of having the lowest physical fitness independent of body fatness. This supports a need for children, from an early age and attending the lower decile schools, to receive enhanced physical activity and nutrition interventions to help improve their physical fitness capabilities, and growth and development. There are many environmental, psychological and physiological factors that were not measured but could impact on physical fitness such as, nutritional deficiencies, sleep quality / quantity and tobacco exposure.

In conclusion the simple measure of WHtR, can be used with confidence to assess children for risk of excess adiposity. The WHtR had a stronger independent relationship with physical fitness compared with both BMI and waist circumference measurements. The ability to run 550 m was inversely associated with body fatness and therefore may be a useful tool for screening and monitoring not only physical fitness but also immediate risks of excess adiposity.

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# APPENDICES

## Appendix A Directors, stakeholders, collaborators and partners of Project Energize

Medical leader
Dr David Graham

Project consultant
Professor Bevan Grant

Academic leader
Professor Elaine Rush

Project director
Stephanie McLennan

Evaluation funding

Other funding

Partners

# Appendix B Ethics

MEMORANDUM

Auckland University of Technology Ethics Committee (AUTEC)

| | |
|---|---|
| To: | Elaine Rush |
| From: | **Dr Rosemary Godbold and Madeline Banda** Executive Secretary, AUTEC |
| Date: | 5 May 2011 |
| Subject: | Ethics Application Number 11/88 **Extended evaluation of project energize (a Master's thesis being undertaken by Rebecca Cooper).** |

Dear Elaine

We are pleased to advise that the Auckland University of Technology Ethics Committee (AUTEC) approved your ethics application at their meeting on 11 April 2011. Your application is now approved for a period of three years until 11 April 2014.

We advise that as part of the ethics approval process, you are required to submit to AUTEC the following:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 11 April 2014;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. This report is to be submitted either when the approval expires on 11 April 2014 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this. Also, if your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply within that jurisdiction.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 8860.

On behalf of the AUTEC and ourselves, we wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Dr Rosemary Godbold and Madeline Banda

**Executive Secretary**

**Auckland University of Technology Ethics Committee**

Cc: Rebecca Cooper rebecca@justaswell.com

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From the desk of …

Dr Rosemary Godbold and Madeline Banda

Executive Secretary

AUTEC

Private Bag 92006, Auckland 1142

New Zealand

E-mail: ethics@aut.ac.nz Tel: 64 9 921 9999 ext 8860 Fax: 64 9 921 9925 

## Appendix C Tests for assumptions of normal distribution.

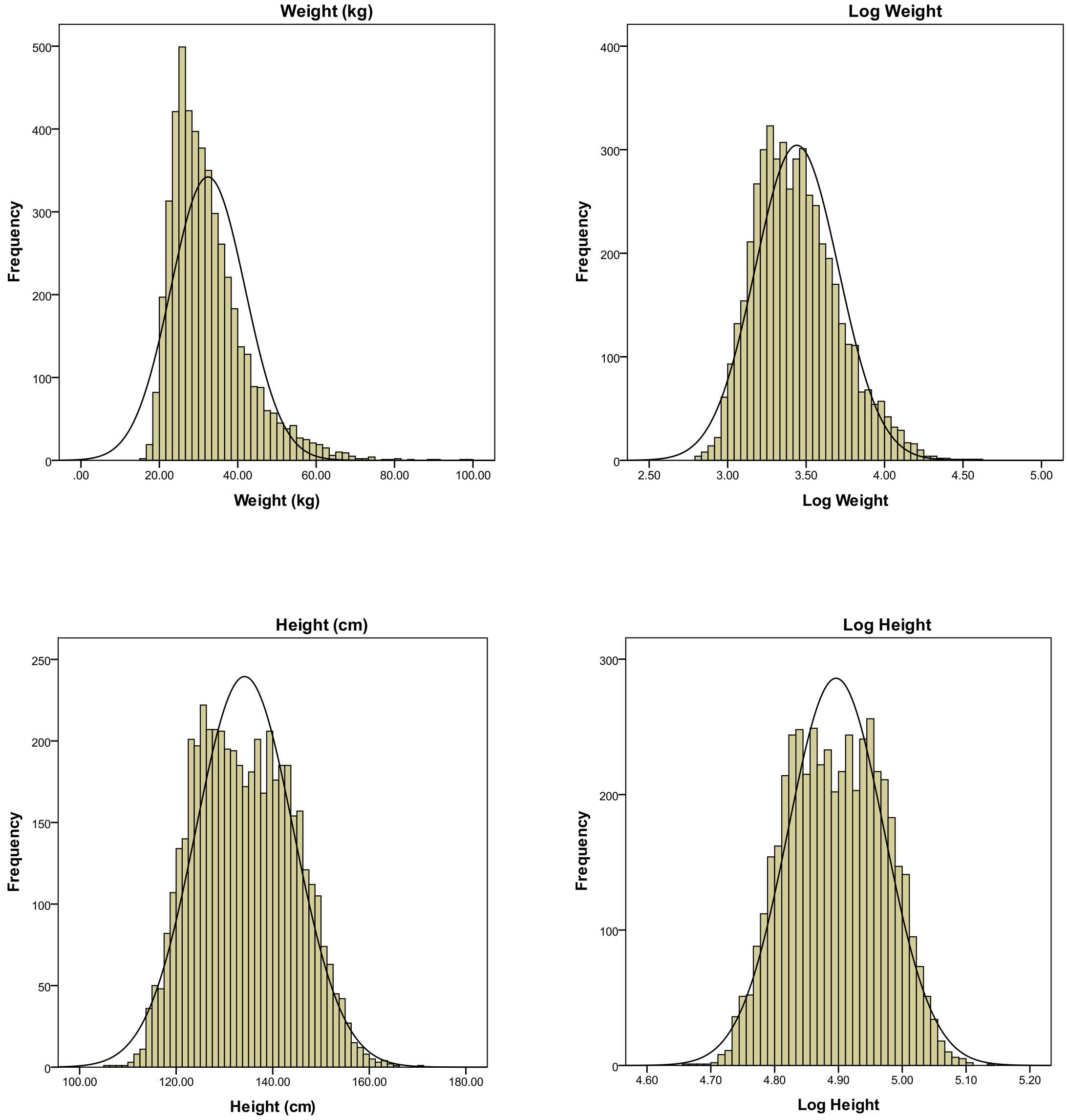
**Table C1. Tests for assumptions of normal distribution.**

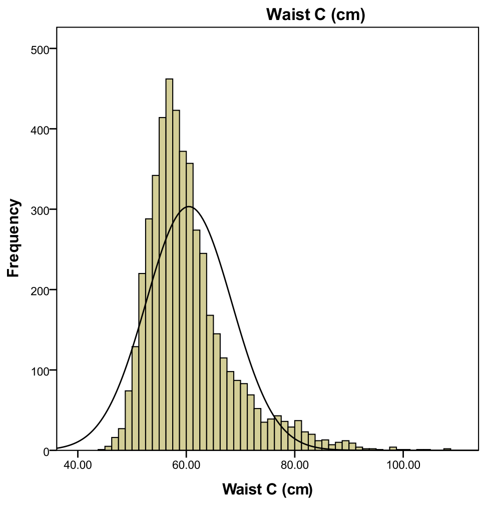
| | **mean - median %difference*** | **mean +/- 2SD & SD<1/2mean** | **skewness** | **kurtosis** | **critical values**** | **Equal variance (Levene) gender /age group** | **K-S test**<br><br>**S-W test** | **box plots, histograms, Q-Q plots,** | ***overall decision of normality.*** |
|---|---|---|---|---|---|---|---|---|---|
| **Height (cm)** | yes | yes | yes | yes | no | yes | no | yes | ***yes*** |
| **Weight (kg)** | no | yes | maybe | no | no | no | no | no | ***no*** |
| **Waist (cm)** | no | yes | maybe | no | no | no | no | no | ***no*** |
| **BMI (kg/m$^2$)** | no | yes | maybe | no | no | no | no | no | ***no*** |
| **FFM** | no | yes | yes | no | no | yes | no | no | ***no*** |
| **FM%** | no | yes | yes | yes | maybe | no | no | no | ***maybe*** |
| **WHtR (cm/cm)** | maybe | yes | maybe | no | no | no | no | no | ***no*** |
| **Run time (s)** | maybe | yes | maybe | maybe / no | no | yes | no | no | ***no*** |

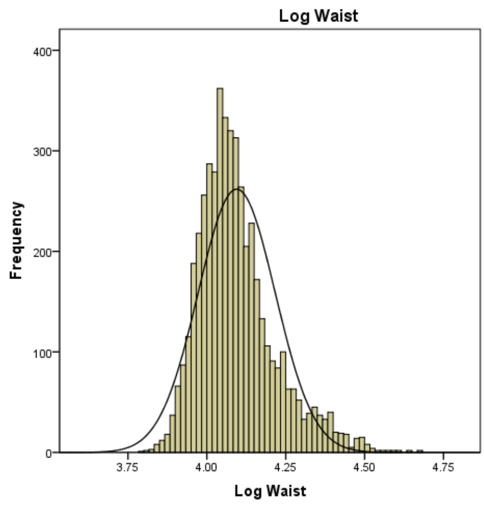
yes = likely normal    no = not normal    maybe = moderately not normal
K-S test = Kolomogorov-Smirnov.    S-W test = Shapiro-Wilk
* deviation from normal distribution was more apparent in the 10-yr old group.
** derived from skewness/standard error and kurtosis /standard error, a value over 1.96 is deviation from normal.

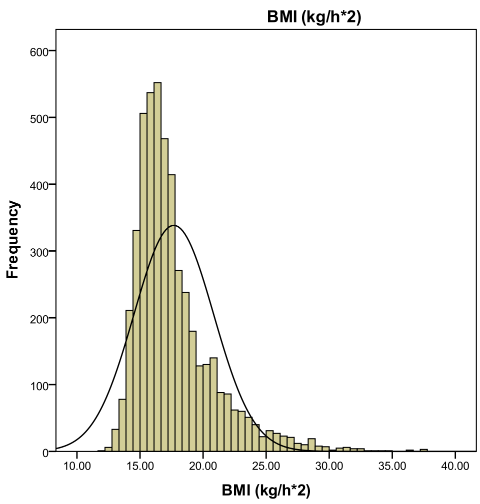
# Appendix D Histograms of before and after log transformation

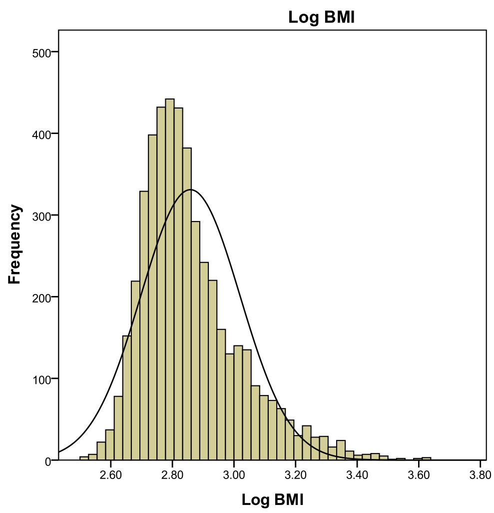
Distributions of body composition and fitness measures before and after transformation.

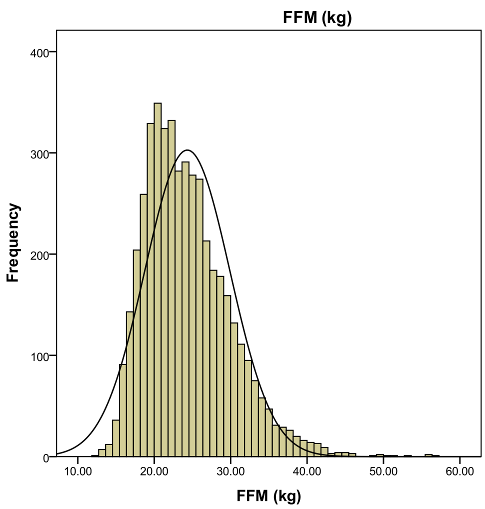


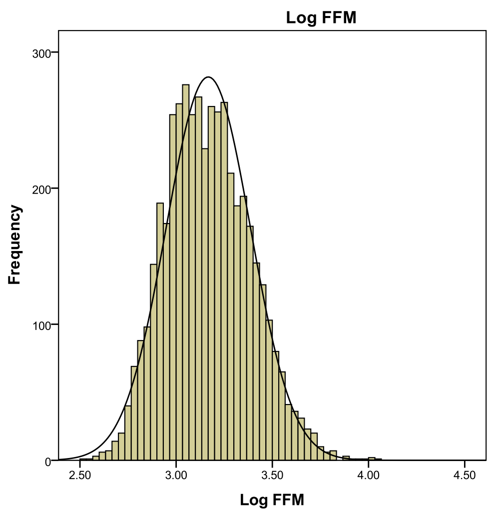

Waist C (cm)
Frequency
0
100
200
300
400
500
40.00
60.00
80.00
100.00
Waist C (cm)

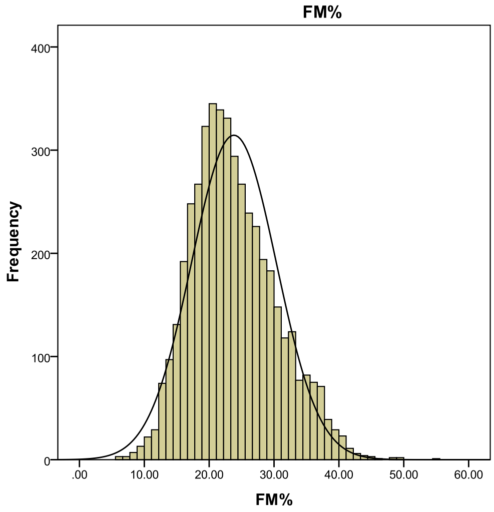

Log Waist
Frequency
0
100
200
300
400
3.75
4.00
4.25
4.50
4.75
Log Waist

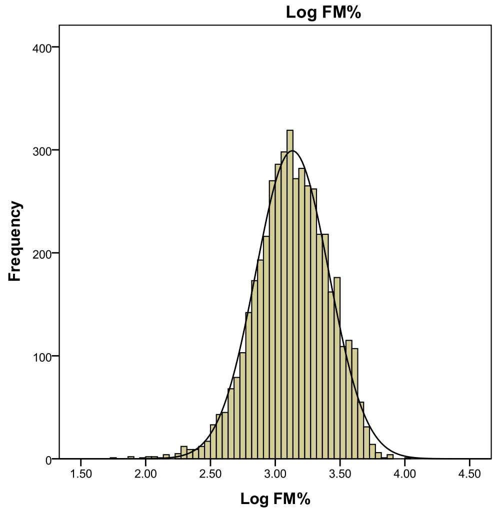

BMI (kg/h*2)
Frequency
0
100
200
300
400
500
600
10.00
15.00
20.00
25.00
30.00
35.00
40.00
BMI (kg/h*2)

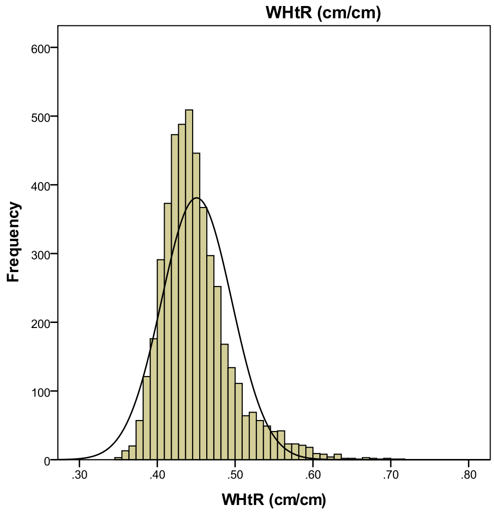

Log BMI
Frequency
0
100
200
300
400
500
2.60
2.80
3.00
3.20
3.40
3.60
3.80
Log BMI

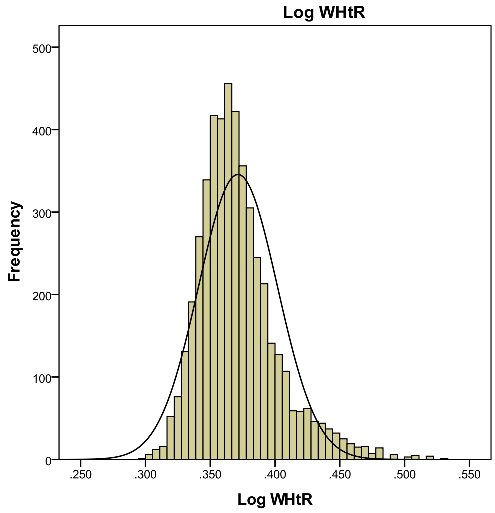

FFM (kg)
Frequency
0
100
200
300
400
10.00
20.00
30.00
40.00
50.00
60.00
FFM (kg)

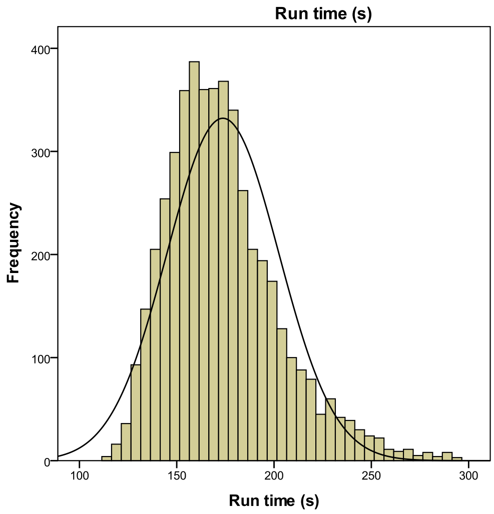

Log FFM
Frequency
0
100
200
300
2.50
3.00
3.50
4.00
4.50
Log FFM

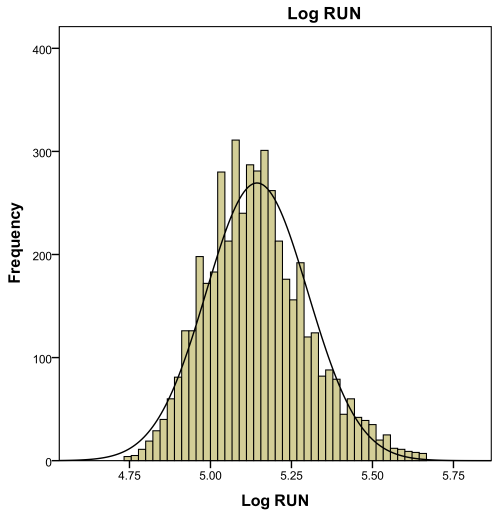

FM%
Frequency
0
100
200
300
400
.00
10.00
20.00
30.00
40.00
50.00
60.00
FM%


Log FM%
Frequency
0
100
200
300
400
1.50
2.00
2.50
3.00
3.50
4.00
4.50
Log FM%


WHtR (cm/cm)
Frequency
0
100
200
300
400
500
600
.30
.40
.50
.60
.70
.80
WHtR (cm/cm)


Log WHtR
Frequency
0
100
200
300
400
500
.250
.300
.350
.400
.450
.500
.550
Log WHtR


Run time (s)
Frequency
0
100
200
300
400
100
150
200
250
300
Run time (s)


Log RUN
Frequency
0
100
200
300
400
4.75
5.00
5.25
5.50
5.75
Log RUN

## Appendix E Age distribution

**Table E1. Frequencies of participants by 6 month age bands, gender and ethnicity.**

| Age | Boy | Girl | Total | European | Maori | Other | Pacific | |
|---|---|---|---|---|---|---|---|---|
| *(yr)* | | | | *frequency (n)* | | | | |
| ***5*** | ***2*** | ***2*** | ***4*** | ***1*** | ***3*** | ***0*** | ***0*** | |
| ***5.5*** | ***10*** | ***5*** | ***15*** | ***4*** | ***11*** | ***0*** | ***0*** | |
| **6** | 17 | 19 | 36 | 18 | 16 | 1 | 1 | **7 yr old group** |
| **6.5** | 161 | 167 | 328 | 157 | 137 | 19 | 15 | |
| **7** | 431 | 490 | 921 | 547 | 276 | 66 | 32 | |
| **7.5** | 389 | 412 | 801 | 482 | 241 | 53 | 25 | |
| **8** | 180 | 161 | 341 | 154 | 155 | 14 | 18 | |
| **8.5** | 97 | 110 | 207 | 78 | 108 | 11 | 10 | |
| **9** | 91 | 120 | 211 | 94 | 97 | 13 | 7 | **10 yr old group** |
| **9.5** | 167 | 221 | 388 | 197 | 154 | 25 | 12 | |
| **10** | 458 | 493 | 951 | 533 | 326 | 57 | 35 | |
| **10.5** | 364 | 413 | 777 | 435 | 262 | 51 | 29 | |
| **11** | 49 | 48 | 97 | 51 | 41 | 3 | 2 | |
| **11.5** | 20 | 22 | 42 | 15 | 23 | 1 | 4 | |
| ***12*** | ***2*** | ***1*** | ***3*** | ***1*** | ***1*** | ***1*** | ***0*** | |
| ***12.5*** | ***2*** | ***2*** | ***4*** | ***1*** | ***2*** | ***0*** | ***1*** | |

Table E1. shows the age distribution of the 7 and 10-yr old groups and the whole group by gender and ethnicity. Italic bands represent excluded children whose age was outside 6 and 11 yr old, this left 5101 children included (10 children had missing ages). *n* = number / frequency

## Appendix F Waikato schools map by school roll number and highlighting urban locations.

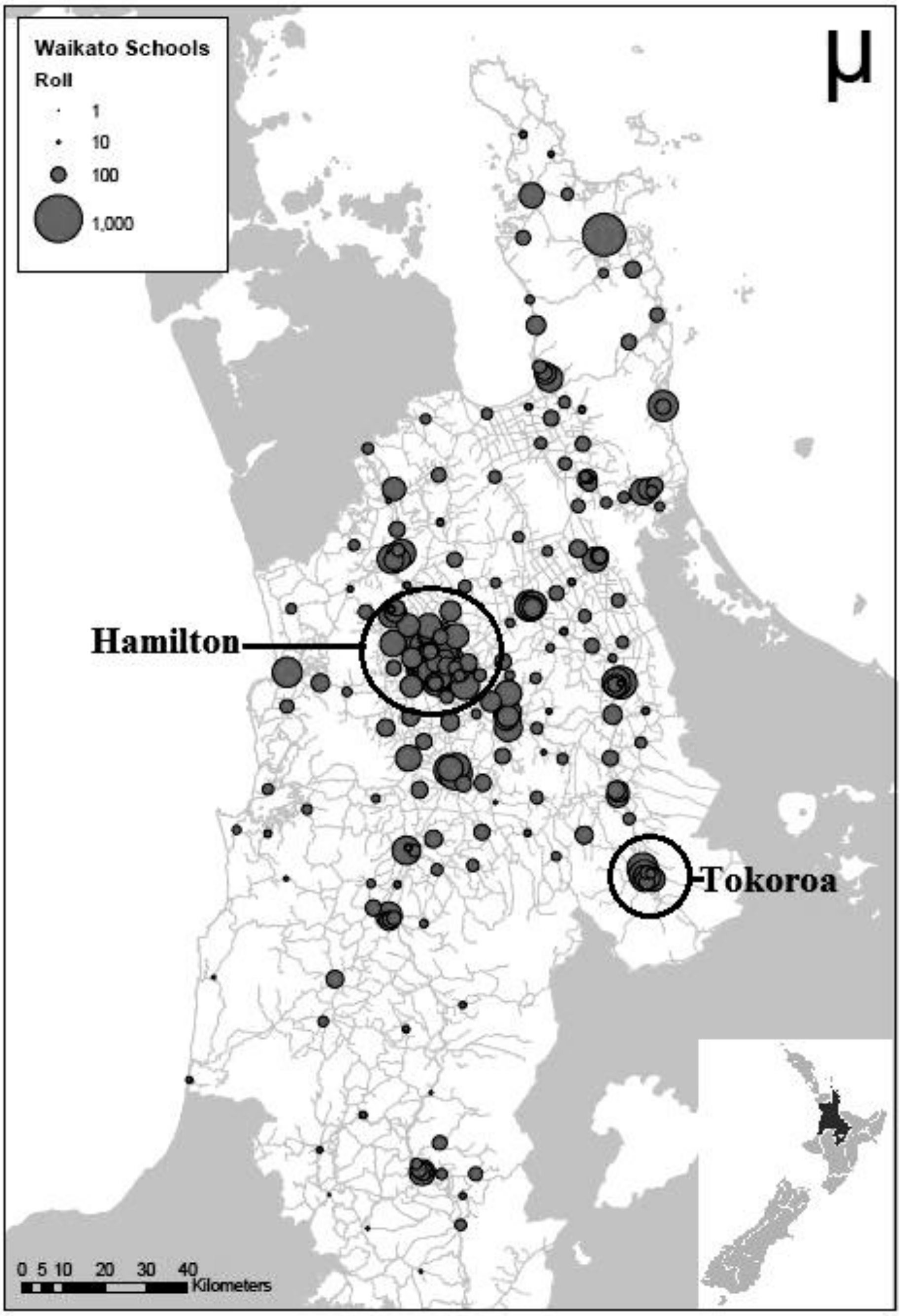



**Figure F1. Primary schools within the Waikato District Health Board.** Dots are scaled proportionally by role size (map courtesy of Professor Elaine Rush, AUT University), Hamilton and Tokoroa are considered urban living and the rest rural.

# Appendix G Asthma prevalence in the children

Asthma was self-reported by 17% of all children measured, by answering yes to the usual use of a bronchodilator / reliever asthma inhaler. In the total group, significantly more boys (18.64%, 95% CI 17.09%, 20.19%) were asthma positive than girls (15.66%, 14.29%, 17.04%). Prevalence of asthma in all ethnic groups and by gender was greater than 12%. NZ European boys had a significantly higher prevalence of asthma than NZ European girls and NZ European girls had significantly less asthma than Māori girls and boys. There was no difference in asthma prevalence between the 7 and 10-yr old group and no statistically significant difference between run-time$_{550m}$ of 10-yr old boys and 7-yr old girls with and without asthma. Seven-yr old boys with asthma took on average 6 s (95% CI 2, 9 s, p=0.007) longer to run than the 7-yr old boys without asthma. Ten-yr old girls took on average 8 s (95% CI 3, 12 s, p=0.001) longer to run than the 10-yr old girls without asthma. When asthma was factored into an initial stepwise regression analysis it was not a significant predictor of run-time$_{550m}$ and was consequently dropped from further regression analyses. This suggests that the other factored variables such as body composition and social deprivation may reduce independent effects asthma might have on run-time$_{550m}$.

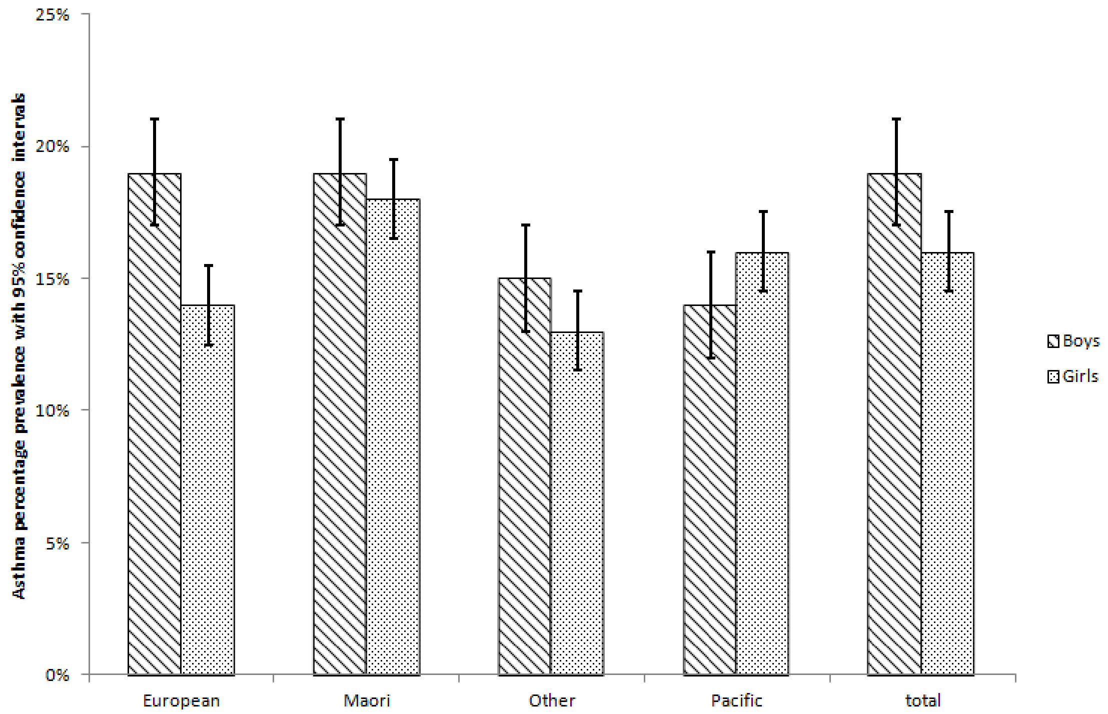



**Figure G1. Prevalence and 95% confidence interval of self reported asthma for the whole group by gender and ethnic group.**

# Appendix H Anthropometric and run-time$_{550m}$ differences, by age, gender and ethnic group

These tables represent the average anthropometric measurements and run-time$_{550m}$ differences among the different ethnic groups; NZ European, Māori, Pacific and Other children. Differences are compared within each ethnic group between boys and girls and among ethnic groups within same gender.

**Table H1. Seven year old ethnic / gender comparisons (height, weight, waist circumference and body mass index)**

| | | Girls | | | Boys | | | Gender Difference* | t-test |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | G - B† | P-value |
| Height (cm) | NZ European | 726 | 125.6[a] | 125.2, 126.1 | 697 | 126.8[a] | 126.3, 127.2 | -0.84% | 0.001 |
| | Māori | 479 | 127.3[d] | 126.7, 128.0 | 448 | 128.1 | 127.3, 128.6 | -0.49% | 0.176 |
| | Other | 85 | 124.6[f] | 123.1, 126.1 | 75 | 126.1 | 124.8, 127.9 | -1.41% | 0.112 |
| | Pacific | 58 | 127.7 | 126.2, 129.3 | 43 | 129.0 | 126.7, 131.4 | -1.01% | 0.363 |
| Weight (kg) | NZ European | 727 | 25.7[abc] | 25.4, 26.0 | 700 | 25.9[ac] | 25.6, 26.2 | -0.66% | 0.453 |
| | Māori | 476 | 28.3[d] | 27.7, 28.9 | 451 | 28.3 | 27.7, 28.8 | 0.06% | 0.967 |
| | Other | 87 | 24.1[f] | 23.1, 25.1 | 75 | 26.6[f] | 25.4, 28.0 | -10.8% | 0.002 |
| | Pacific | 57 | 29.9 | 28.2, 31.8 | 43 | 30.3 | 27.8, 33.0 | -1.26% | 0.810 |
| WaistC (cm) | NZ European | 714 | 56.0[abc] | 55.7, 56.4 | 689 | 56.7[ac] | 56.4, 57.1 | -1.23% | 0.005 |
| | Māori | 470 | 58.1[d] | 57.5, 58.7 | 446 | 58.9 | 58.2, 59.4 | -1.16% | 0.112 |
| | Other | 88 | 54.2[f] | 53.2, 55.3 | 76 | 57.3[f] | 56.2, 58.6 | -5.77% | <0.0001 |
| | Pacific | 58 | 59.5 | 57.5, 61.5 | 42 | 60.7 | 58.0, 63.5 | -2.08% | 0.465 |
| BMI (kg/$m^2$) | NZ European | 719 | 16.26[abc] | 16.12, 16.40 | 693 | 16.12[ac] | 16.00, 16.25 | 0.84% | 0.161 |
| | Māori | 474 | 17.43[d] | 17.19, 17.67 | 445 | 17.28 | 17.05, 17.48 | 0.90% | 0.340 |
| | Other | 84 | 15.59[f] | 15.17, 16.01 | 74 | 16.77 | 16.24, 17.31 | -7.58% | 0.001 |
| | Pacific | 57 | 18.29 | 17.45, 19.16 | 43 | 18.19 | 17.15, 19.29 | 0.54% | 0.884 |

Differences between ethnicity within age and gender groups are marked where P<0.05, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. * calculated as %difference = 100($e^{difference}$-1). BMI = body mass index, WaistC = waist circumference, *n* = number of children, CI = confidence interval

**Table H2. Seven year old ethnic / gender comparisons (fat free mass, fat mass percent and waist to height ratio)**

| | | Girls | | | Boys | | | Gender Difference* G - B† | t-test P-value |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| FFM (kg) | NZ European | 687 | 19.68[abc] | 19.48, 19.89 | 664 | 20.89[ac] | 20.67, 21.10 | -6.10% | <0.0001 |
| | Māori | 455 | 21.14[d] | 20.80, 21.49 | 423 | 22.13[d] | 21.72, 22.44 | -4.40% | <0.0001 |
| | Other | 81 | 18.49[f] | 17.75, 19.25 | 70 | 20.66[f] | 19.99, 21.52 | -12.21% | <0.0001 |
| | Pacific | 57 | 21.97 | 21.01, 22.96 | 42 | 22.93 | 21.52, 24.43 | -4.38% | 0.268 |
| FM% | NZ European | 686 | 22.58[ac] | 22.19, 22.98 | 664 | 18.46[abc] | 18.08, 18.84 | 18.27% | <0.0001 |
| | Māori | 455 | 24.34[d] | 23.78, 24.90 | 423 | 21.03 | 20.54, 21.55 | 13.55% | <0.0001 |
| | Other | 81 | 22.50[f] | 21.24, 23.83 | 70 | 21.33 | 19.76, 23.07 | 5.10% | 0.281 |
| | Pacific | 57 | 25.37 | 23.66, 27.21 | 42 | 22.10 | 20.20, 24.18 | 12.88% | 0.017 |
| WHtR (cm/cm) | NZ European | 707 | 0.45[abc] | 0.44, 0.45 | 982 | 0.45[ac] | 0.45, 0.45 | 0.14% | 0.245 |
| | Māori | 468 | 0.46[d] | 0.45, 0.46 | 440 | 0.46 | 0.46, 0.46 | 0.19% | 0.312 |
| | Other | 85 | 0.44[f] | 0.43, 0.44 | 75 | 0.46 | 0.45, 0.46 | -1.37% | <0.0001 |
| | Pacific | 58 | 0.47 | 0.45, 0.48 | 42 | 0.47 | 0.45, 0.46 | 0.31% | 0.675 |

Differences between ethnicity within age and gender groups are marked where P<0.05, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. * calculated as %difference = $100(e^{difference}-1)$. FFM = fat free mass, FM% = fat mass percent, WHtR = waist to height ratio, *n* = number of children, CI = confidence interval

**Table H3. Seven year old ethnic / gender comparisons (height, weight & waist circumference standard deviation scores)**

| | | Girls | | | Boys | | | Gender Difference G - B† | t-test P-value |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| Height SDS | NZ European | 726 | 0.26[a] | 0.19, 0.33 | 699 | 0.33[ac] | 0.25, 0.40 | -0.07 | 0.175 |
| | Māori | 479 | 0.47[d] | 0.37, 0.57 | 458 | 0.52 | 0.41, 0.62 | -0.05 | 0.581 |
| | Other | 85 | 0.05 | -0.21, 0.31 | 76 | 0.22[f] | -0.06, 0.50 | -0.17 | 0.377 |
| | Pacific | 58 | 0.47 | 0.21, 0.74 | 43 | 0.81 | 0.45, 1.16 | -0.34 | 0.130 |
| Weight SDS | NZ European | 727 | 0.25[abc] | 0.18, 0.31 | 703 | 0.33[ac] | 0.26, 0.41 | -0.08 | 0.083 |
| | Māori | 476 | 0.70[d] | 0.60, 0.80 | 461 | 0.82 | 0.72, 0.92 | -0.12 | 0.099 |
| | Other | 87 | -0.19[f] | -0.45, 0.07 | 76 | 0.46[f] | 0.15, 0.77 | -0.65 | 0.002 |
| | Pacific | 57 | 0.97 | 0.67, 1.28 | 43 | 1.23 | 0.77, 1.68 | -0.26 | 0.350 |
| WaistC SDS | NZ European | 714 | 0.44[abc] | 0.31, 0.58 | 692 | 0.59[ac] | 0.52, 0.66 | -0.15 | 0.061 |
| | Māori | 471 | 0.79[d] | 0.65, 0.93 | 456 | 0.95 | 0.85, 1.05 | -0.16 | 0.061 |
| | Other | 88 | 0.06[f] | -0.18, 0.31 | 77 | 0.69 | 0.43, 0.95 | -0.63 | 0.001 |
| | Pacific | 58 | 1.04 | 0.72, 1.36 | 42 | 1.26 | 0.81, 1.71 | -0.22 | 0.429 |

Differences between ethnicity within age and gender groups are marked where P<0.05, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. WaistC = waist circumference, SDS = standard deviation score, *n* = number of children, CI = confidence interval

**Table H4. Seven year old ethnic / gender comparisons (body mass index, body fat standard deviation scores & run-time$_{550m}$)**

| | | Girls | | | Boys | | | Gender Difference G - B† | t-test P-value |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| BMI SDS | NZ European | 720 | 0.15[abc] | 0.08, 0.27 | 696 | 0.21[ac] | 0.14, 0.28 | -0.06 | 0.241 |
| | Māori | 474 | 0.65[d] | 0.56, 0.75 | 455 | 0.79 | 0.69, 0.89 | -0.14 | 0.058 |
| | Other | 84 | -0.24[f] | -0.47, -0.01 | 75 | 0.54 | 0.26, 0.82 | -0.78 | <0.0001 |
| | Pacific | 57 | 0.99 | 0.67, 1.30 | 43 | 1.16 | 0.73, 1.59 | -0.17 | 0.517 |
| FM% SDS | NZ European | 687 | 0.57[ac] | 0.49, 0.67 | 667 | 0.41[ac] | 0.30, 0.52 | 0.16 | 0.024 |
| | Māori | 455 | 0.89 | 0.78, 1.00 | 430 | 1.01 | 0.90, 1.12 | -0.12 | 0.129 |
| | Other | 81 | 0.50 | 0.13, 0.87 | 70 | 0.98 | 0.59, 1.36 | -0.48 | 0.079 |
| | Pacific | 57 | 1.06 | 0.74, 1.38 | 42 | 1.22 | 0.88, 1.56 | -0.16 | 0.495 |
| Run-time$_{550m}$ (s) | NZ European | 716 | 182[abc] | 181, 184 | 688 | 170[abc] | 168, 172 | 6.69%* | <0.0001 |
| | Māori | 469 | 191 | 189, 194 | 447 | 181 | 179, 184 | 5.37%* | <0.0001 |
| | Other | 84 | 191 | 186, 196 | 73 | 179 | 173, 185 | 6.42%* | 0.002 |
| | Pacific | 54 | 193 | 186, 201 | 42 | 182 | 173, 191 | 5.84%* | 0.050 |

Differences between ethnicity within age and gender groups are marked where P<0.05, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. * calculated as %difference = $100(e^{difference}-1)$. BMI = body mass index, FM% = body fat percent, SDS = standard deviation score, *n* = number of children, CI = confidence interval

**Table H5. Ten year old ethnic / gender comparisons (height, weight, waist circumference and body mass index)**

| | | Girls | | | Boys | | | Gender Difference* G - B† | t-test P-value |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| Height (cm) | NZ European | 697 | 141.4[ac] | 140.9, 141.9 | 600 | 142.0[a] | 141.5, 142.8 | -0.44% | 0.095 |
| | Māori | 472 | 143.2[d] | 142.5, 143.9 | 422 | 143.7 | 143.0, 144.5 | -0.39% | 0.272 |
| | Other | 82 | 140.5[f] | 138.8, 142.3 | 65 | 142.4 | 140.7, 144.2 | -1.31% | 0.136 |
| | Pacific | 43 | 145.0 | 142.9, 147.2 | 45 | 144.9 | 142.6, 147.3 | 0.09% | 0.937 |
| Weight (kg) | NZ European | 708 | 35.7[abc] | 35.2, 36.2 | 608 | 35.4[ac] | 34.9, 36.0 | 0.79% | 0.463 |
| | Māori | 470 | 40.0[d] | 39.2, 40.9 | 416 | 40.1[d] | 39.2, 41.1 | -0.17% | 0.918 |
| | Other | 83 | 33.4[f] | 31.8, 35.0 | 66 | 36.1[f] | 34.2, 38.2 | -8.31% | 0.033 |
| | Pacific | 44 | 42.5 | 38.7, 46.6 | 44 | 42.2 | 38.6, 46.2 | 0.58% | 0.928 |
| WaistC (cm) | NZ European | 688 | 61.7[ac] | 61.2, 62.2 | 604 | 62.6[ac] | 62.0, 63.1 | -1.37% | 0.022 |
| | Māori | 458 | 65.1[d] | 64.3, 65.9 | 416 | 66.2[d] | 65.3, 67.1 | -1.63% | 0.075 |
| | Other | 83 | 59.8[f] | 58.4, 61.2 | 64 | 62.9[f] | 61.0, 64.8 | -5.13% | 0.010 |
| | Pacific | 44 | 67.1 | 63.8, 70.5 | 44 | 68.4 | 65.3, 71.8 | -2.05% | 0.554 |
| BMI (kg/m$^2$) | NZ European | 694 | 17.84[abc] | 17.64, 18.05 | 596 | 17.55[ac] | 17.35, 17.76 | 1.65% | 0.045 |
| | Māori | 468 | 19.53[d] | 19.21, 19.86 | 410 | 19.37[d] | 19.04, 19.71 | 0.83% | 0.493 |
| | Other | 82 | 16.89[f] | 16.33, 17.48 | 65 | 17.85[f] | 17.06, 18.68 | -5.67% | 0.054 |
| | Pacific | 43 | 20.02 | 18.63, 21.51 | 44 | 20.18 | 18.86, 21.60 | -0.82% | 0.868 |

Differences between ethnicity within age and gender groups are marked where P<0.05, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. * calculated as %difference = 100($e^{difference}$-1). WaistC = waist circumference, BMI = body mass index, *n*= number of children, CI = confidence interval

**Table H6. Ten year old ethnic / gender comparisons (fat free mass, fat mass percent and waist to height ratio)**

| | | Girls | | | Boys | | | Gender Difference* G - B† | t-test P-value |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| FFM (kg) | NZ European | 669 | 26.34[abc] | 26.03, 26.67 | 579 | 27.33[ac] | 27.01, 27.66 | -3.75% | <0.0001 |
| | Māori | 457 | 28.79[d] | 28.29, 29.29 | 397 | 29.63[d] | 29.06, 30.21 | -2.93% | 0.029 |
| | Other | 80 | 24.77[f] | 23.76, 25.82 | 63 | 27.14[f] | 25.98, 28.35 | -9.57% | 0.003 |
| | Pacific | 42 | 29.52 | 27.39, 31.82 | 44 | 31.12 | 29.07, 33.31 | -5.41% | 0.297 |
| FM% | NZ European | 669 | 25.45[ac] | 24.98, 25.92 | 579 | 21.71[abc] | 21.21, 22.21 | 14.68% | <0.0001 |
| | Māori | 457 | 27.15[d] | 26.56, 27.75 | 396 | 24.80 | 24.16, 25.46 | 8.65% | <0.0001 |
| | Other | 80 | 24.78[f] | 23.46, 26.18 | 63 | 24.49 | 23.01, 26.06 | 1.20% | 0.773 |
| | Pacific | 42 | 28.66 | 26.56, 30.92 | 44 | 24.78 | 22.56, 27.22 | 1.35% | 0.017 |
| WHtR (cm/cm) | NZ European | 679 | 0.44[a] | 0.43, 0.44 | 591 | 0.44[ac] | 0.44, 0.44 | 0.25% | 0.135 |
| | Māori | 455 | 0.46[d] | 0.45, 0.46 | 409 | 0.46 | 0.46, 0.47 | 0.31% | 0.214 |
| | Other | 83 | 0.43[f] | 0.42, 0.44 | 63 | 0.44[f] | 0.43, 0.46 | -1.16% | 0.033 |
| | Pacific | 43 | 0.46 | 0.44, 0.48 | 44 | 0.47 | 0.46, 0.49 | -0.78% | 0.390 |

Differences between ethnicity within age and gender groups are marked where P<0.05, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. * calculated as %difference = $100(e^{difference}-1)$. FFM = fat free mass, FM% = fat mass percent, WHtR = waist to height ratio, *n* = number of children, CI = confidence interval

**Table H7. Ten year old ethnic / gender comparisons (height, weight & waist circumference standard deviation scores)**

| | | Girls | | | Boys | | | Gender Difference G - B† | t-test P-value |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| Height SDS | NZ European | 697 | 0.22[ac] | 0.14, 0.29 | 600 | 0.33[a] | 0.25, 0.41 | -0.11 | 0.039 |
| | Māori | 472 | 0.52[d] | 0.43, 0.62 | 422 | 0.63 | 0.53, 0.73 | -0.11 | 0.110 |
| | Other | 82 | 0.06[f] | -0.18, 0.29 | 65 | 0.49 | 0.24, 0.75 | -0.43 | 0.014 |
| | Pacific | 43 | 0.80 | 0.49, 1.11 | 45 | 0.70 | 0.36, 1.03 | 0.10 | 0.658 |
| Weight SDS | NZ European | 708 | 0.29[abc] | 0.21, 0.36 | 608 | 0.41[ac] | 0.33, 0.48 | -0.12 | 0.029 |
| | Māori | 472 | 0.85[d] | 0.75, 0.95 | 416 | 1.03[d] | 0.93, 1.14 | -0.18 | 0.017 |
| | Other | 83 | -0.11[f] | -0.35, 0.13 | 66 | 0.56 | 0.28, 0.83 | -0.67 | <0.0001 |
| | Pacific | 44 | 1.08 | 0.66, 1.50 | 44 | 1.14 | 0.70, 1.58 | -0.06 | 0.838 |
| WaistC SDS | NZ European | 690 | 0.70[ac] | 0.60, 0.79 | 604 | 0.63[ac] | 0.55, 0.71 | 0.07 | 0.272 |
| | Māori | 458 | 1.22[d] | 1.12, 1.33 | 417 | 1.10[d] | 0.97, 1.22 | 0.12 | 0.127 |
| | Other | 83 | 0.38[f] | 0.13, 0.63 | 64 | 0.69 | 0.40, 0.97 | -0.31 | 0.109 |
| | Pacific | 44 | 1.39 | 0.96, 1.83 | 44 | 1.30 | 0.89, 1.70 | 0.09 | 0.740 |

Differences between ethnicity within age and gender groups are marked where $P<0.05$, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. WaistC = waist circumference, SDS = standard deviation score, *n* = number of children, CI = confidence interval

**Table H8. Ten year old ethnic / gender comparisons (body mass index, body fat standard deviation scores & run-time$_{550m}$)**

| | | Girls | | | Boys | | | Gender Difference G - B† | t-test P-value |
|---|---|---|---|---|---|---|---|---|---|
| | | *n* | Mean | 95% CI of mean | *n* | Mean | 95% CI of mean | | |
| BMI SDS | NZ European | 695 | 0.23[abc] | 0.15, 0.31 | 596 | 0.34[ac] | 0.25, 0.43 | -0.11 | 0.063 |
| | Māori | 468 | 0.84[d] | 0.74, 0.95 | 410 | 1.05[d] | 0.94, 1.16 | -0.21 | 0.008 |
| | Other | 82 | -0.21[f] | -0.47, 0.04 | 65 | 0.43[f] | 0.10, 0.77 | -0.64 | 0.003 |
| | Pacific | 43 | 0.92 | 0.45, 1.38 | 44 | 1.20 | 0.76, 1.65 | -0.28 | 0.371 |
| FM% SDS | NZ European | 669 | 0.50[ac] | 0.41, 0.59 | 579 | 0.66[ab] | 0.56, 0.76 | -0.13 | 0.021 |
| | Māori | 457 | 0.82[d] | 0.72, 0.92 | 396 | 1.17 | 1.08, 1.26 | -0.35 | <0.0001 |
| | Other | 80 | 0.37[f] | 0.10, 0.64 | 63 | 1.15 | 0.93, 1.37 | -0.78 | <0.0001 |
| | Pacific | 42 | 1.06 | 0.70, 1.42 | 44 | 1.11 | 0.76, 1.47 | -0.05 | 0.833 |
| Run-time$_{550m}$ (s) | NZ European | 682 | 164[ac] | 162, 166 | 593 | 150[ac] | 148, 151 | 8.68%* | <0.0001 |
| | Māori | 454 | 171 | 169, 174 | 415 | 162 | 160, 164 | 5.45%* | <0.0001 |
| | Other | 80 | 165[f] | 161, 170 | 64 | 156 | 149, 164 | 5.36%* | 0.042 |
| | Pacific | 43 | 179 | 170, 189 | 43 | 167 | 159, 175 | 6.84%* | 0.041 |

Differences between ethnicity within age and gender groups are marked where P<0.05, described between: [a]NZ European-Māori, [b]NZ European-Other, [c]NZ European-Pacific, [d]Maori-Other, [e]Maori-Pacific, [f]Other-Pacific. †Within ethnicity gender difference = girls are less (negative value) or more (positive value) than boys. * calculated as %difference = $100(e^{difference}-1)$. BMI = body mass index, FM% = body fat percent, SDS = standard deviation score, *n* = number of children, CI = confidence interval

# Appendix I Anthropometric and run-time$_{550m}$ differences among school decile, by gender and age.

These tables represent the average anthropometric measurements and run-time$_{550m}$ differences among the school decile group (low, medium and high), only NZ European and Māori children were factored in these analyses.

**Table I1. Seven year old decile comparisons for Māori and NZ European, girls and boys (height, weight, waist circumference, body mass index & fat free mass)**

| | | Girls | | | | | Boys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decile | *n* | Mean | 95% CI of mean | Difference† | with$^{\Psi}$ | *n* | Mean | 95% CI of mean | Difference† | with$^{\Psi}$ |
| Height (cm) | Low | 490 | 126.7 | 126.1, 127.3 | 0.3% | medium | 466 | 127.8 | 127.1, 128.4 | 0.5% | medium |
| | Medium | 543 | 126.3 | 125.8, 126.9 | 0.7% | high | 494 | 127.1 | 126.5, 127.6 | 0.2% | high |
| | High | 315 | 125.5 | 124.9, 126.1 | -1.0%* | low | 302 | 126.8 | 126.2, 127.5 | -0.7% | low |
| Weight (kg) | Low | 487 | 27.8 | 27.2, 28.4 | 5.8%** | medium | 466 | 27.9 | 27.4, 28.4 | 5.1%** | medium |
| | Medium | 543 | 26.3 | 25.8, 26.7 | 2.8% | high | 502 | 26.6 | 26.1, 27.0 | 2.2% | high |
| | High | 317 | 25.5 | 25.1, 26.0 | -8.1%** | low | 301 | 26.0 | 25.5, 26.4 | -6.9%** | low |
| WaistC (cm) | Low | 480 | 58.1 | 57.5, 58.7 | 3.2%** | medium | 462 | 58.6 | 58.1, 59.1 | 2.5%** | medium |
| | Medium | 536 | 56.3 | 55.8, 56.8 | 1.1% | high | 492 | 57.2 | 56.7, 57.7 | 0.4% | high |
| | High | 314 | 55.7 | 55.2, 56.2 | -4.1%** | low | 299 | 57.0 | 56.5, 57.4 | -2.8%** | low |
| BMI ($kg/m^2$) | Low | 484 | 17.32 | 17.07, 17.57 | 5.3%** | medium | 461 | 17.12 | 16.90, 17.34 | 3.9%** | medium |
| | Medium | 538 | 16.44 | 16.26, 16.62 | 1.3% | high | 493 | 16.48 | 16.30, 16.66 | 2.1*% | high |
| | High | 313 | 16.23 | 16.01, 16.45 | -6.3%** | low | 301 | 16.14 | 15.95, 16.34 | -5.7%** | low |
| FFM | Low | 462 | 20.70 | 20.36, 21.05 | 3.0%* | medium | 442 | 21.92 | 21.58, 22.27 | 3.3%** | medium |
| | Medium | 514 | 20.09 | 19.81, 20.38 | 2.2% | high | 468 | 21.21 | 20.91, 21.51 | 1.8% | high |
| | High | 304 | 19.65 | 19.37, 19.94 | -5.1%** | low | 289 | 20.83 | 20.53, 21.14 | -4.9%** | low |

†difference between deciles per gender. Games Howell or Tukey P-value for the difference in means indicated by *P<0.05, **P<0.01 (unmarked P>0.05). Difference in means shown as percentages (%) are calculated from - %difference = 100($e^{difference}$-1). WaistC = waist circumference, BMI = body mass index, FFM = fat free mass. *n* = number of children. CI = confidence interval of the mean. Ψ first row example using "with$^{\Psi}$" = low decile girls have a 0.3% increase in height compared with medium decile girls (a negative sign means a decrease).

**Table I2. Seven year old decile comparisons for Māori and NZ European, girls and boys (fat mass percent, waist to height ratio, standard deviation scores for height, weight & waist circumference).**

| | | Girls | | | | | Boys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decile | *n* | Mean | 95% CI of mean | Difference† | withΨ | *n* | Mean | 95% CI of mean | Difference† | withΨ |
| FM% | Low | 462 | 24.55 | 24.01, 25.10 | 7.1%** | medium | 442 | 20.62 | 20.10, 21.15 | 7.1%** | medium |
| | Medium | 514 | 22.91 | 22.47, 23.37 | 3.2% | high | 468 | 19.25 | 18.77, 19.73 | 2.7% | high |
| | High | 304 | 22.19 | 21.54, 22.87 | -9.6%** | low | 289 | 18.74 | 18.15, 19.35 | -9.1%** | low |
| WHtR (cm/cm) | Low | 477 | 0.46 | 0.46, 0.46 | 0.9%** | medium | 457 | 0.46 | 0.46, 0.46 | 0.6%** | medium |
| | Medium | 531 | 0.45 | 0.44, 0.45 | 0.1% | high | 483 | 0.45 | 0.45, 0.45 | 0.1% | high |
| | High | 310 | 0.44 | 0.44, 0.45 | -1.1%** | low | 299 | 0.45 | 0.45, 0.45 | -0.7%** | low |
| Height SDS | Low | 490 | 0.32 | 0.22, 0.42 | 0.00 | medium | 466 | 0.41 | 0.31, 0.50 | 0.36 | medium |
| | Medium | 543 | 0.32 | 0.23, 0.41 | -0.02 | high | 494 | 0.37 | 0.28, 0.47 | -0.48 | high |
| | High | 315 | 0.34 | 0.23, 0.45 | 0.02 | low | 302 | 0.42 | 0.31, 0.53 | 0.12 | low |
| Weight SDS | Low | 487 | 0.58 | 0.48, 0.69 | 0.27** | medium | 466 | 0.71 | 0.61, 0.81 | 0.25** | medium |
| | Medium | 543 | 0.32 | 0.22, 0.41 | 0.03 | high | 502 | 0.46 | 0.37, 0.56 | 0.05 | high |
| | High | 317 | 0.29 | 0.18, 0.39 | -0.30** | low | 301 | 0.41 | 0.31, 0.52 | -0.30** | low |
| WaistC SDS | Low | 480 | 0.82 | 0.72, 0.92 | 0.35** | medium | 462 | 0.91 | 0.81, 1.00 | 0.27** | medium |
| | Medium | 537 | 0.47 | 0.35, 0.59 | 0.10 | high | 492 | 0.64 | 0.54, 0.74 | -0.27 | high |
| | High | 314 | 0.46 | 0.35, 0.57 | -0.36** | low | 299 | 0.67 | 0.57, 0.77 | -0.24** | low |

†difference between deciles per gender. Games Howell or Tukey P-value for the difference in means indicated by *P<0.05, **P<0.01 (unmarked P>0.05). Difference in means shown as percentages (%) are calculated from - %difference = $100(e^{difference}-1)$. FM% = fat mass percent, WHtR = waist to height ratio, WaistC = waist circumference, SDS = standard deviation score, *n* = number of children. CI = confidence interval of the mean. Ψ first row example using "with$^{Ψ}$" = low decile girls have a 7.1% increase in FM% compared with medium decile girls (a negative sign means a decrease).

**Table I3. Seven year old decile comparisons for Māori and NZ European, girls and boys (standard deviation scores for body mass index and fat mass percent, and run-time$_{550m}$).**

| | | Girls | | | | | Boys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decile | *n* | Mean | 95% CI of mean | Difference† | with$^{\Psi}$ | *n* | Mean | 95% CI of mean | Difference† | with$^{\Psi}$ |
| BMI SDS | Low | 484 | 0.59 | 0.49, 0.69 | 0.37** | medium | 461 | 0.71 | 0.61, 0.81 | 0.32** | medium |
| | Medium | 538 | 0.22 | 0.14, 0.31 | 0.07 | high | 493 | 0.39 | 0.29, 0.48 | 0.16 | high |
| | High | 313 | 0.15 | 0.04, 0.26 | -0.44** | low | 301 | 0.23 | 0.11, 0.34 | -0.48** | low |
| FM% SDS | Low | 462 | 0.94 | 0.83, 1.04 | 0.31** | medium | 442 | 0.89 | 0.77, 1.02 | 0.28** | medium |
| | Medium | 514 | 0.63 | 0.52, 0.74 | 0.15 | high | 468 | 0.60 | 0.48, 0.73 | 0.12 | high |
| | High | 304 | 0.48 | 0.32, 0.64 | -0.46** | low | 289 | 0.49 | 0.31, 0.66 | -0.40** | low |
| Run-time$_{550m}$ (s) | Low | 478 | 192. | 190, 195 | 3.7%** | medium | 464 | 182 | 179, 184 | 4.6%** | medium |
| | Medium | 534 | 185. | 183, 187 | 3.1%** | high | 490 | 174 | 172, 176 | 4.8%** | high |
| | High | 311 | 180 | 177, 182 | -6.5%** | low | 296 | 166 | 163, 168 | -8.7%** | low |

†difference between deciles per gender. Games Howell or Tukey P-value for the difference in means indicated by *P<0.05, **P<0.01 (unmarked P>0.05). Difference in mean shown as percentages (%) are calculated from - %difference = 100($e^{difference}$-1). FM% = fat mass percent, BMI = body mass index, SDS = standard deviation score, *n* = number of children. CI = confidence interval of the mean. Ψ first row example using "with$^{\Psi}$" = low decile girls have a 0.37 increase in BMI SDS compared with medium decile girls (a negative sign means a decrease).

**Table I4. Ten year old decile comparisons for Māori and NZ European, girls and boys (height, weight, waist circumference, body mass index & fat free mass)**

| | | Girls | | | | | Boys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decile | *n* | Mean | 95% CI of mean | Difference† | with[Ψ] | *n* | Mean | 95% CI of mean | Difference† | with[Ψ] |
| Height (cm) | Low | 434 | 142.5 | 141.8, 143.3 | 0.4% | medium | 415 | 143.0 | 142.2, 143.7 | 0.7% | medium |
| | Medium | 569 | 141.9 | 141.3, 142.5 | 0.0% | high | 443 | 142.0 | 141.4, 142.6 | -1.2%** | high |
| | High | 291 | 141.8 | 141.1, 142.6 | -0.5% | low | 270 | 143.7 | 142.9, 144.5 | 0.5 | low |
| Weight (kg) | Low | 433 | 38.9 | 38.0, 39.9 | 5.9%** | medium | 419 | 39.4 | 38.4, 40.6 | 8.4%** | medium |
| | Medium | 581 | 36.8 | 36.1, 37.5 | 2.9% | high | 442 | 36.3 | 35.6, 37.0 | 0.8% | high |
| | High | 293 | 35.7 | 34.9, 36.6 | -8.2%** | low | 270 | 36.0 | 35.2, 36.8 | -8.5%** | low |
| WaistC (cm) | Low | 424 | 64.4 | 63.6, 65.2 | 2.7%* | medium | 412 | 66.1 | 65.2, 67.0 | 4.3%** | medium |
| | Medium | 564 | 62.7 | 62.1, 63.3 | 2.2%* | high | 447 | 63.4 | 62.7, 64.1 | 1.7% | high |
| | High | 285 | 61.4 | 60.6, 62.1 | -4.7%** | low | 266 | 62.3 | 61.6, 63.1 | -5.7%** | low |
| BMI ($kg/m^2$) | Low | 429 | 19.16 | 18.83, 19.50 | 4.9%** | medium | 408 | 19.29 | 18.93, 19.65 | 7.3%** | medium |
| | Medium | 569 | 18.27 | 18.01, 18.53 | 2.9%* | high | 436 | 17.97 | 17.72, 18.24 | 3.0%* | high |
| | High | 290 | 17.76 | 17.45, 18.08 | -7.3%** | low | 268 | 17.45 | 17.15, 17.75 | -9.5%** | low |
| FFM | Low | 416 | 28.13 | 27.61, 28.66 | 4.6%** | medium | 393 | 29.16 | 28.56, 29.76 | 5.2%** | medium |
| | Medium | 549 | 26.89 | 26.49, 27.31 | 1.8% | high | 423 | 27.71 | 27.28, 28.14 | -0.6% | high |
| | High | 283 | 26.41 | 25.93, 26.91 | 6.1%** | low | 264 | 27.87 | 27.40, 28.34 | -4.4%** | low |

†difference between deciles per gender. Games Howell or Tukey P-value for the difference in means indicated by *P<0.05, **P<0.01 (unmarked P>0.05). Difference in means shown as percentages (%) are calculated from - %difference = $100(e^{difference}-1)$. WaistC = waist circumference, BMI = body mass index, FFM = fat free mass. *n* = number of children. CI = confidence interval of the mean. Ψ first row example using "with[Ψ]" = low decile girls have a 0.4% increase in height compared with medium decile girls (a negative sign means a decrease).

**Table I5. Ten year old decile comparisons for Māori and NZ European, girls and boys (fat mass percent, waist to height ratio, standard deviation scores for height, weight & waist circumference).**

| | | Girls | | | | | Boys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decile | *n* | Mean | 95% CI of mean | Difference† | with[Ψ] | *n* | Mean | 95% CI of mean | Difference† | with[Ψ] |
| FM% | Low | 416 | 26.89 | 26.25, 27.55 | 3.5% | medium | 392 | 24.67 | 23.99, 25.36 | 9.7%** | medium |
| | Medium | 549 | 25.99 | 25.47, 26.52 | 2.8% | high | 423 | 22.49 | 21.91, 23.08 | 3.1% | high |
| | High | 283 | 25.29 | 24.58, 26.02 | -6.0%** | low | 264 | 21.81 | 21.07, 22.58 | -11.6%** | low |
| WHtR (cm/cm) | Low | 420 | 0.45 | 0.45, 0.46 | 0.7%** | medium | 401 | 0.46 | 0.46, 0.47 | 1.2%** | medium |
| | Medium | 552 | 0.44 | 0.44, 0.45 | 0.7%* | high | 440 | 0.45 | 0.44, 0.45 | 0.9%** | high |
| | High | 282 | 0.43 | 0.43, 0.44 | -1.3%** | low | 263 | 0.43 | 0.43, 0.44 | -2.1%** | low |
| Height SDS | Low | 434 | 0.43 | 0.33, 0.53 | 0.12 | medium | 415 | 0.54 | 0.44, 0.65 | 0.19* | medium |
| | Medium | 569 | 0.31 | 0.23, 0.40 | 0.07 | high | 443 | 0.35 | 0.26, 0.44 | -0.18 | high |
| | High | 291 | 0.24 | 0.14, 0.35 | -0.19* | low | 270 | 0.53 | 0.41, 0.65 | -0.01 | low |
| Weight SDS | Low | 433 | 0.72 | 0.61, 0.83 | 0.28** | medium | 419 | 0.93 | 0.82, 1.04 | 0.38** | medium |
| | Medium | 581 | 0.44 | 0.35, 0.53 | 0.17 | high | 442 | 0.55 | 0.45, 0.65 | 0.08 | high |
| | High | 293 | 0.27 | 0.16, 0.39 | -0.45** | low | 270 | 0.47 | 0.35, 0.58 | -0.46** | low |
| WaistC SDS | Low | 424 | 1.12 | 1.01, 1.23 | 0.30** | medium | 413 | 1.08 | 0.96, 1.21 | 0.33** | medium |
| | Medium | 566 | 0.82 | 0.71, 0.94 | 0.15** | high | 447 | 0.75 | 0.65, 0.85 | 0.18 | high |
| | High | 285 | 0.68 | 0.56, 0.80 | -0.44** | low | 266 | 0.57 | 0.46, 0.69 | -0.51** | low |

†difference between deciles per gender. Games Howell or Tukey P-value for the difference in means indicated by *P<0.05, **P<0.01 (unmarked P>0.05). Difference in means shown as percentages (%) are calculated from - %difference = 100($e^{difference}$-1). FM% = fat mass percent, WHtR = waist to height ratio, WaistC = waist circumference, SDS = standard deviation score, *n* = number of children. CI = confidence interval of the mean. Ψ first row example using "with[Ψ]" = low decile girls have a 3.5% increase in FM% compared with medium decile girls (a negative sign means a decrease).

**Table I6. Ten year old decile comparisons for Māori and NZ European, girls and boys (standard deviation scores for body mass index and fat mass percent, and run-time$_{550m}$).**

| | | Girls | | | | | Boys | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Decile | *n* | Mean | 95% CI of mean | Difference† | with$^{\Psi}$ | *n* | Mean | 95% CI of mean | Difference† | with$^{\Psi}$ |
| BMI SDS | Low | 429 | 0.71 | 0.59, 0.82 | 0.32** | medium | 408 | 1.00 | 0.88, 1.12 | 0.47* | medium |
| | Medium | 569 | 0.39 | 0.29, 0.48 | 0.20* | high | 436 | 0.53 | 0.42, 0.64 | 0.25* | high |
| | High | 290 | 0.18 | 0.06, 0.31 | -0.53** | low | 268 | 0.28 | 0.15, 0.41 | -0.71** | low |
| FM% SDS | Low | 416 | 0.77 | 0.65, 0.89 | 0.16 | medium | 392 | 1.14 | 1.04, 1.24 | 0.33** | medium |
| | Medium | 549 | 0.61 | 0.51, 0.71 | 0.15 | high | 423 | 0.81 | 0.71, 0.91 | 0.15 | high |
| | High | 283 | 0.47 | 0.33, 0.60 | -0.30** | low | 264 | 0.66 | 0.51, 0.81 | -0.48** | low |
| Run-time$_{550m}$ (s) | Low | 423 | 174 | 172, 177 | 4.9%** | medium | 414 | 163 | 161, 166 | 6.1%** | medium |
| | Medium | 556 | 166 | 164, 168 | 4.5%** | high | 427 | 154 | 152, 156 | 6.2%** | high |
| | High | 280 | 159 | 157, 161 | -8.7%** | low | 270 | 145 | 143, 147 | -11.2%** | low |

†difference between deciles per gender. Games Howell or Tukey P-value for the difference in means indicated by *P<0.05, **P<0.01 (unmarked P>0.05). Difference in mean shown as percentages (%) are calculated from - %difference = 100($e^{difference}$-1). FM% = fat mass percent, BMI = body mass index, SDS = standard deviation score, *n* = number of children. CI = confidence interval of the mean. Ψ first row example using "with$^{\Psi}$" = low decile girls have a 0.32 increase in BMI SDS compared with medium decile girls (a negative sign means a decrease).

# Appendix J Associations between anthropometric measures and run-time$_{550m}$

**Table J1. Spearman correlation for body size and run-time$_{550}$ for the seven year old group.** **Girls** / Boys

| *n* = 2377 | Height | Weight | WC | BMI | FFM | FM% | RUN | WHtR | Height SDS | Weight SDS | WC SDS | BMI SDS | FM% SDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Height | | 0.805 | 0.547 | 0.325 | 0.800 | 0.286 | -0.083 | -0.090 | 0.835 | 0.660 | 0.458 | 0.283 | 0.227 |
| Weight | **0.783** | | 0.804 | 0.796 | 0.927 | 0.490 | 0.095 | 0.334 | 0.682 | 0.911 | 0.738 | 0.765 | 0.444 |
| WC | **0.535** | **0.828** | | 0.750 | 0.713 | 0.492 | 0.194 | 0.742 | 0.495 | 0.779 | 0.975 | 0.735 | 0.467 |
| BMI | **0.362** | **0.841** | **0.807** | | 0.695 | 0.511 | 0.257 | 0.654 | 0.288 | 0.808 | 0.739 | 0.995 | 0.497 |
| FFM | **0.809** | **0.923** | **0.717** | **0.716** | | 0.170 | -0.011* | 0.239 | 0.675 | 0.830 | 0.644 | 0.663 | 0.122 |
| FM% | **0.293** | **0.584** | **0.605** | **0.646** | **0.268** | | 0.343 | 0.398 | 0.259 | 0.489 | 0.485 | 0.506 | 0.991 |
| RUN | **-0.072†** | **0.133** | **0.239** | **0.275** | **0.005*** | **0.403** | | 0.341 | 0.020* | 0.189 | 0.247 | 0.278 | 0.371 |
| WHtR | **0.001*** | **0.459** | **0.813** | **0.722** | **0.323** | **0.541** | **0.353** | | -0.040* | 0.414 | 0.790 | 0.671 | 0.416 |
| Height SDS | **0.820** | **0.664** | **0.465** | **0.330** | **0.688** | **0.257** | **0.009*** | **0.029*** | | 0.761 | 0.512 | 0.293 | 0.263 |
| Weight SDS | **0.629** | **0.911** | **0.787** | **0.848** | **0.830** | **0.574** | **0.208** | **0.513** | **0.744** | | 0.798 | 0.815 | 0.490 |
| WC SDS | **0.460** | **0.781** | **0.982** | **0.805** | **0.667** | **0.599** | **0.275** | **0.848** | **0.488** | **0.814** | | 0.744 | 0.486 |
| BMI SDS | **0.312** | **0.807** | **0.787** | **0.993** | **0.681** | **0.638** | **0.295** | **0.734** | **0.339** | **0.859** | **0.805** | | 0.503 |
| FM% SDS | **0.212** | **0.523** | **0.569** | **0.625** | **0.206** | **0.984** | **0.434** | **0.555** | **0.266** | **0.579** | **0.592** | **0.636** | 0.637 |

*n* = number of children. SDS = standard deviation score. * P > 0.05, †P < 0.05 (all other unmarked values are p<0.001)
WC waist circumference, BMI body mass index, WHtR waist to height ratio, FFM fat free mass, FM% fat mass percent.

**Table J2. Spearman correlation for body size and run-time$_{550m}$ for the ten year old group** **Girls** / Boys

| *n* = 2183 | Height | Weight | WC | BMI | FFM | FM% | RUN | WHtR | Height SDS | Weight SDS | WC SDS | BMI SDS | FM% SDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Height | | 0.706 | 0.492 | 0.328 | 0.769 | 0.247 | 0.080† | 0.057* | 0.919 | 0.626 | 0.434 | 0.293 | 0.235 |
| Weight | **0.724** | | 0.866 | 0.882 | 0.923 | 0.642 | 0.394 | 0.609 | 0.678 | 0.965 | 0.835 | 0.861 | 0.636 |
| WC | **0.487** | **0.876** | | 0.848 | 0.740 | 0.689 | 0.422 | 0.870 | 0.478 | 0.849 | 0.983 | 0.835 | 0.685 |
| BMI | **0.366** | **0.892** | **0.884** | | 0.749 | 0.709 | 0.479 | 0.801 | 0.336 | 0.889 | 0.843 | 0.994 | 0.708 |
| FFM | **0.792** | **0.928** | **0.744** | **0.754** | | 0.332 | 0.236 | 0.445 | 0.724 | 0.847 | 0.701 | 0.724 | 0.342 |
| FM% | **0.234** | **0.639** | **0.715** | **0.731** | **0.334** | | 0.536 | 0.666 | 0.264 | 0.653 | 0.690 | 0.709 | 0.999 |
| RUN | **-0.007*** | **0.313** | **0.416** | **0.438** | **0.169** | **0.495** | | 0.464 | 0.153 | 0.437 | 0.449 | 0.494 | 0.542 |
| WHtR | **0.060†** | **0.619** | **0.880** | **0.826** | **0.444** | **0.706** | **0.504** | | 0.079† | 0.631 | 0.885 | 0.806 | 0.667 |
| Height SDS | **0.898** | **0.682** | **0.486** | **0.367** | **0.730** | **0.244** | **0.071†** | **0.105** | | 0.694 | 0.484 | 0.338 | 0.266 |
| Weight SDS | **0.637** | **0.960** | **0.873** | **0.897** | **0.874** | **0.650** | **0.370** | **0.662** | **0.710** | | 0.863 | 0.894 | 0.655 |
| WC SDS | **0.439** | **0.848** | **0.990** | **0.880** | **0.710** | **0.714** | **0.445** | **0.898** | **0.490** | **0.881** | | 0.848 | 0.692 |
| BMI SDS | **0.322** | **0.864** | **0.874** | **0.993** | **0.722** | **0.729** | **0.462** | **0.840** | **0.369** | **0.902** | **0.885** | | 0.711 |
| FM% SDS | **0.209** | **0.624** | **0.708** | **0.726** | **0.316** | **0.998** | **0.507** | **0.712** | **0.244** | **0.651** | **0.715** | **0.732** | |

*n* = number of children. SDS = standard deviation score. * P > 0.05, †P < 0.05 (all other unmarked values are p<0.001)
WC waist circumference, BMI body mass index, WHtR waist to height ratio, FFM fat free mass, FM% fat mass percent.

## Appendix K Average run-time$_{550m}$ by percentiles and ethnic group

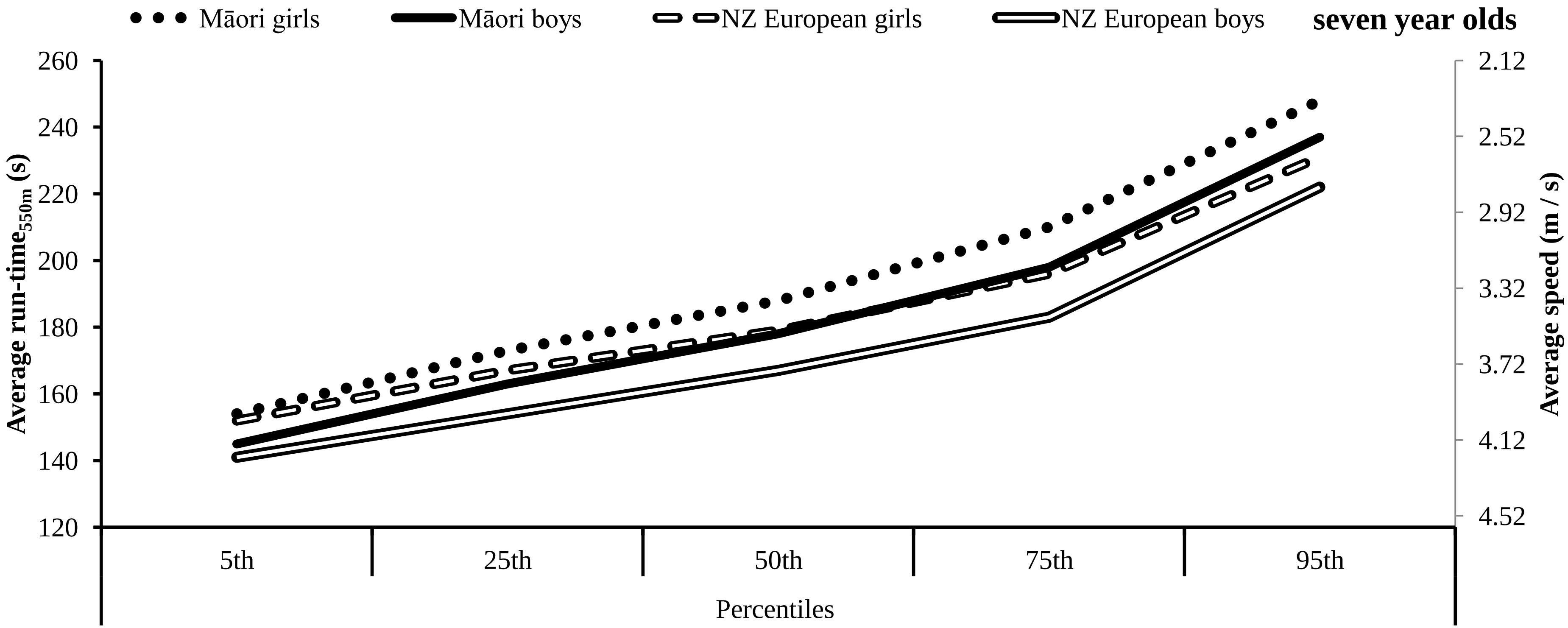



**Figure K1.** Seven-yr olds average run-time$_{550m}$ from the 5th to the 95th percentile arranged by gender and ethnic group.

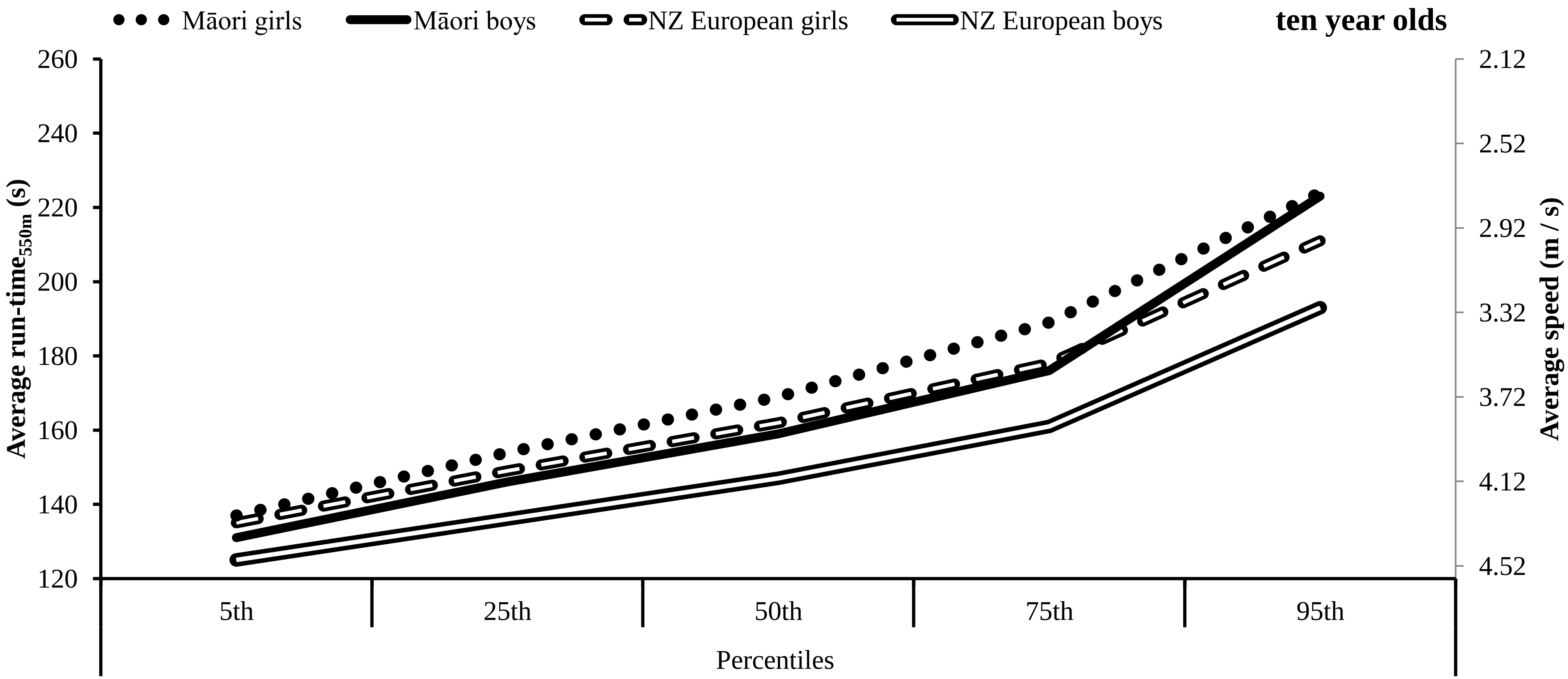



**Figure K2.** Ten-yr olds average run-time$_{550m}$ from the 5th to the 95th percentile arranged by gender and ethnic group.

## Appendix L Multiple regression analysis of waist circumference waist to height ratio, and body mass index adjusted for by age and ethnic group

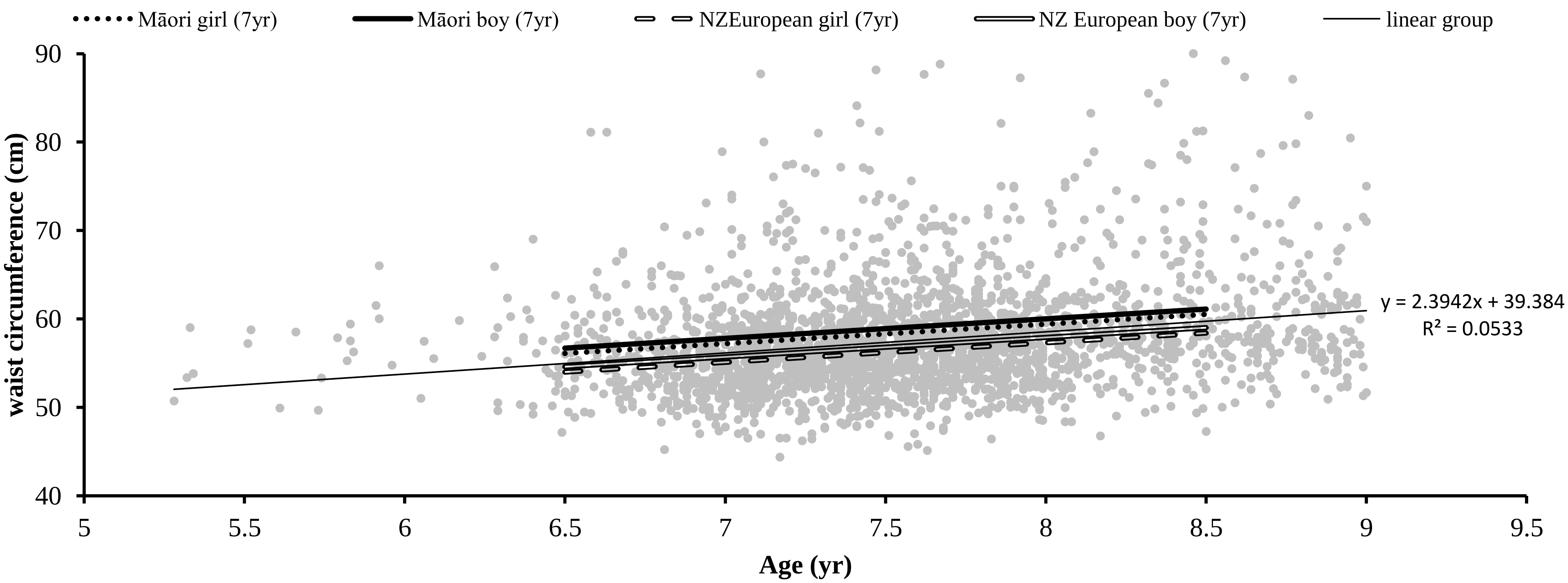



**Figure L1 (a)** Multiple regression of waist circumference by age adjusted for ethnic group and gender (7-yr olds). As age increases waist circumference increases and is different among ethnic groups. Therefore in children standardised growth charts (specific to the population they are used in) are essential for accurate waist circumference risk screening.

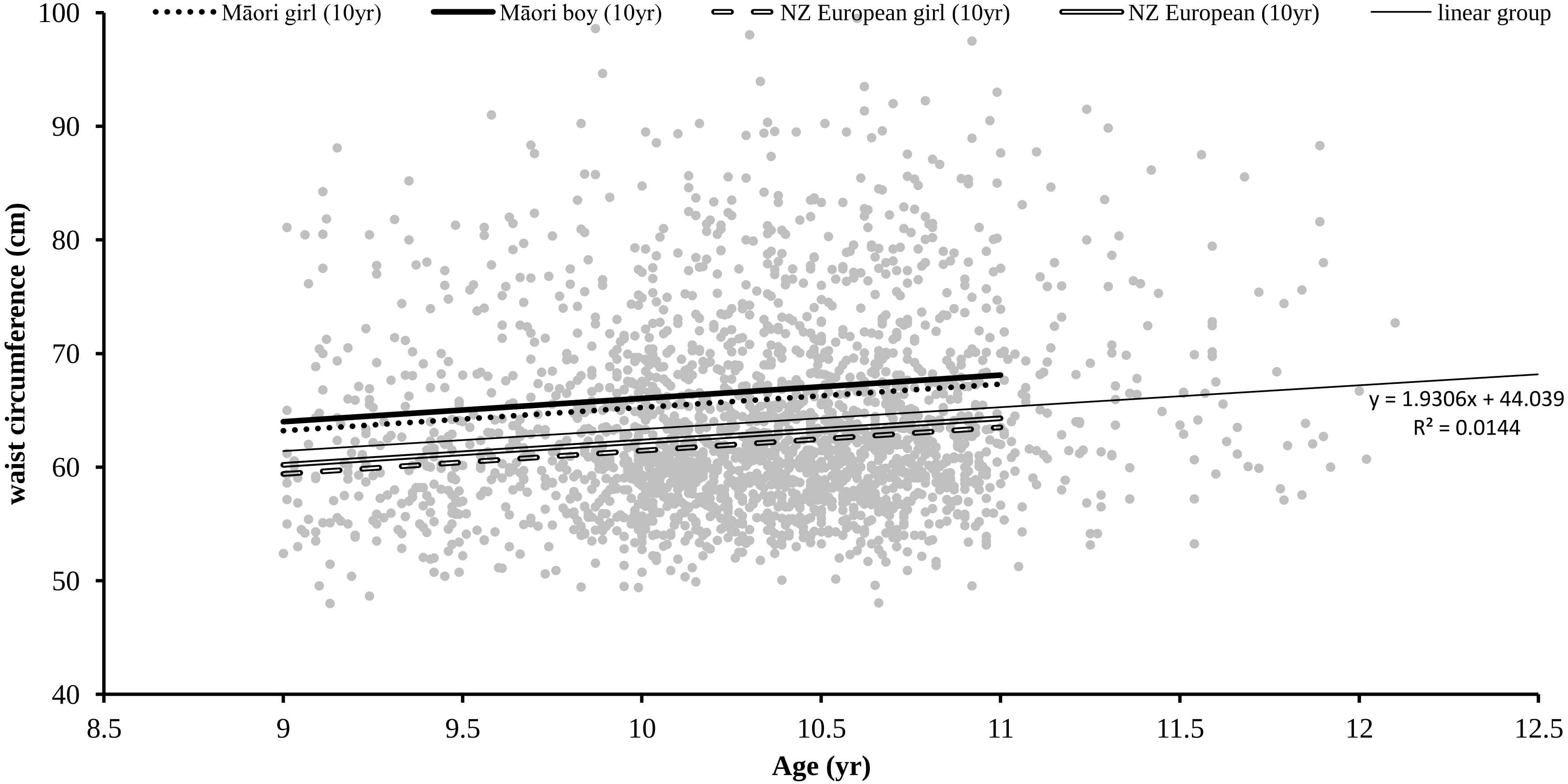



**Figure L1 (b)** Multiple regression of waist circumference by age adjusted for ethnic group and gender (10-yr olds). Pattern follows that of the 7-yr old group. However there was more variation in the older children and between Māori and NZ European children,

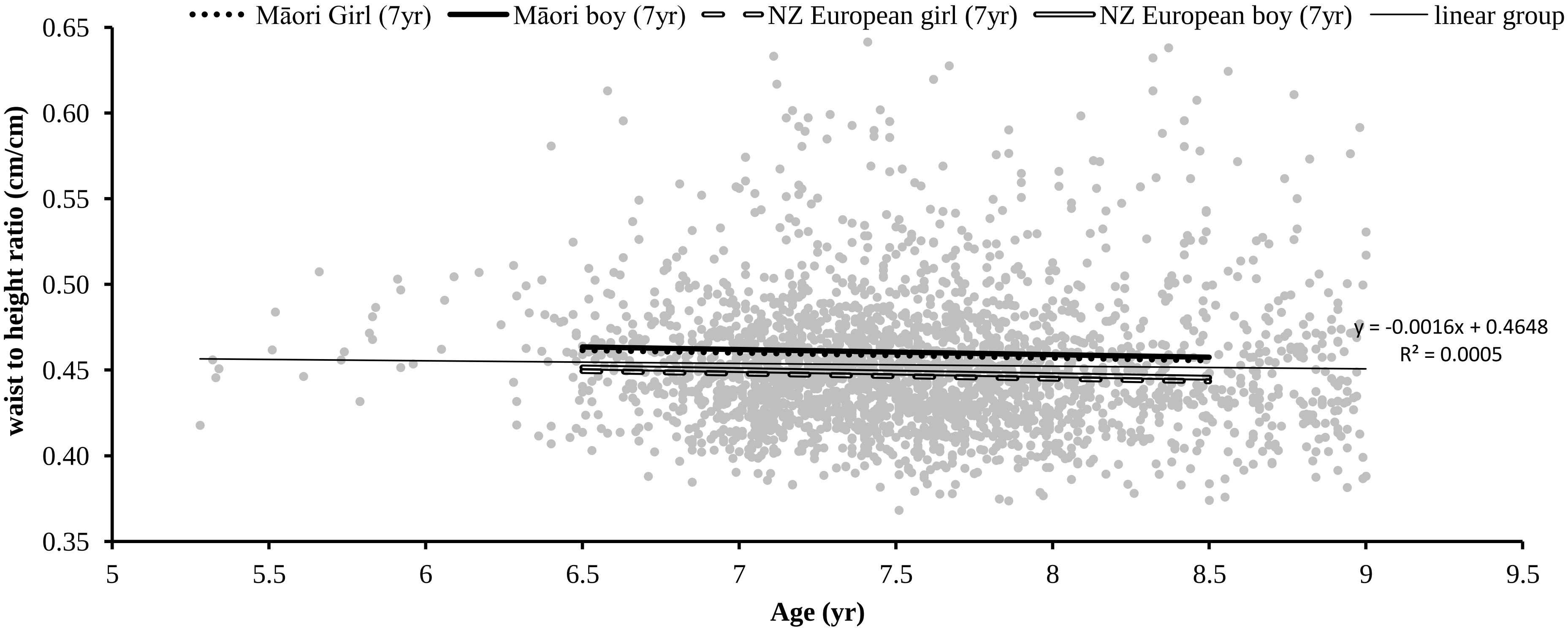



**Figure L2 (a)** Multiple regression of waist to height ratio by age adjusted for ethnic group and gender (7-yr olds). As children age the waist to height ratio decreases slightly. Therefore in health screening if waist to height ratio was increasing over time this could indicate an increase in adiposity risk.

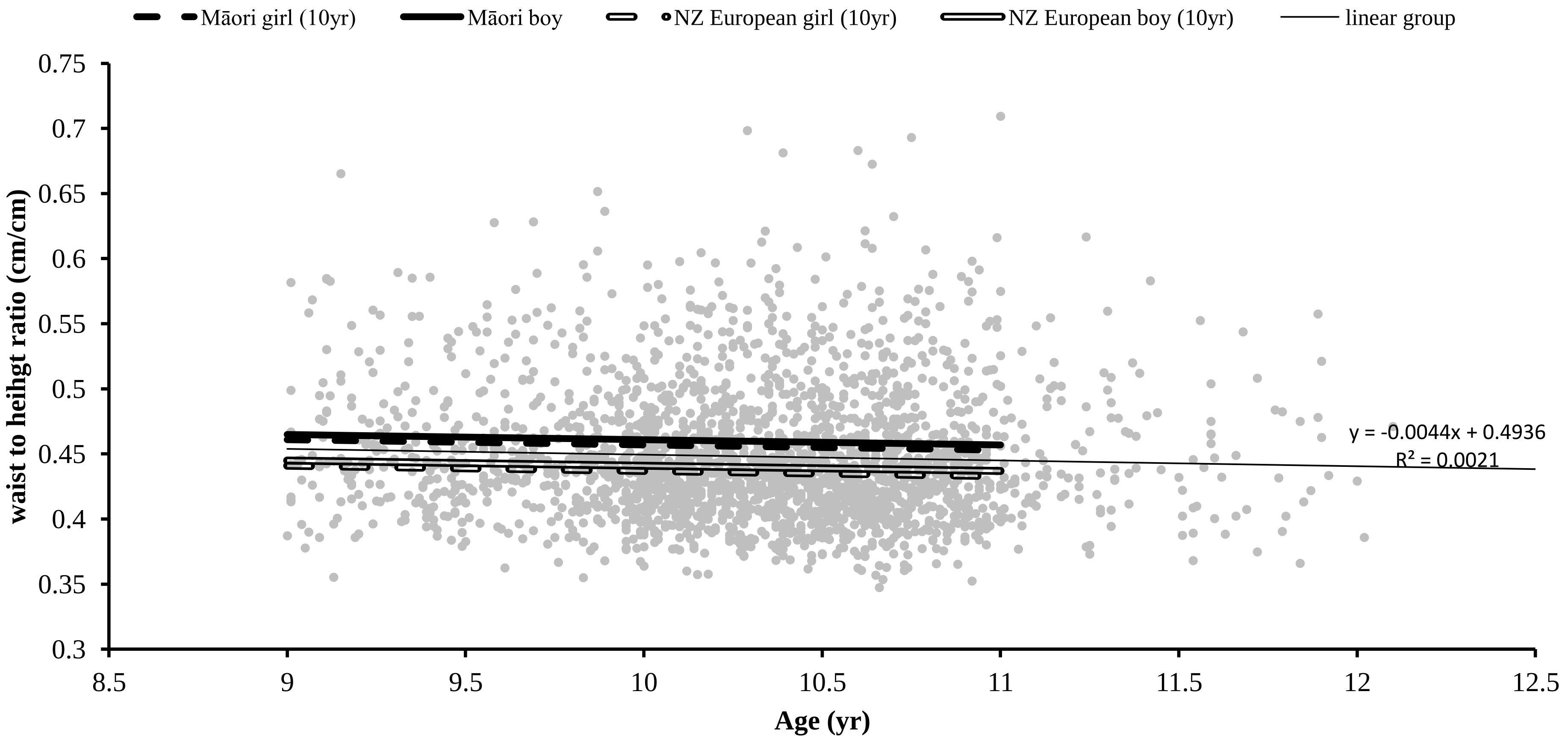



**Figure L2 (b)** Multiple regression of waist to height ratio by age adjusted for ethnic group and gender (10-yr olds). Pattern follows that of the 7-yr old group.

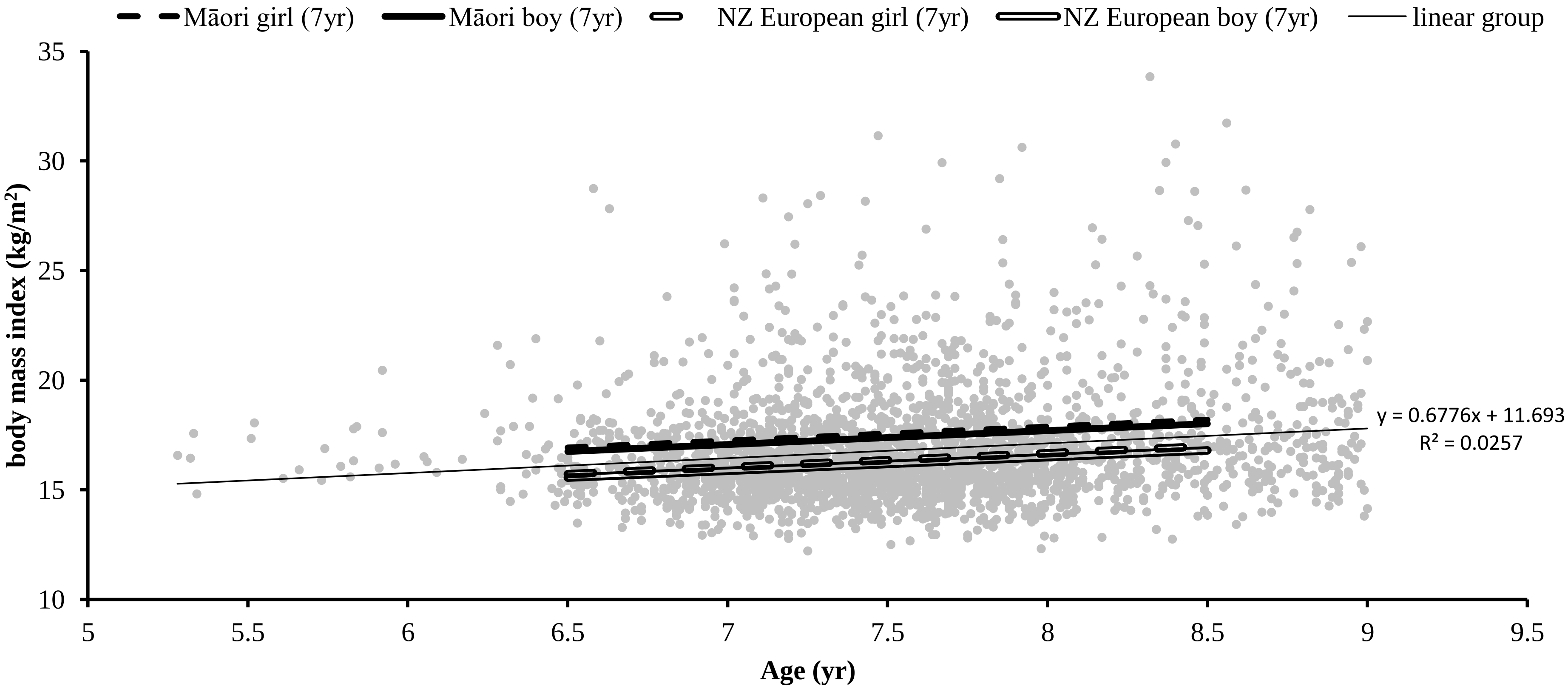



**Figure L3 (a)** Multiple regression of body mass index by age adjusted for ethnic group and gender (7-yr olds). As age increases waist circumference increases and is different among ethnic groups. Therefore in children standardised growth charts are essential for accurate body mass index risk screening.

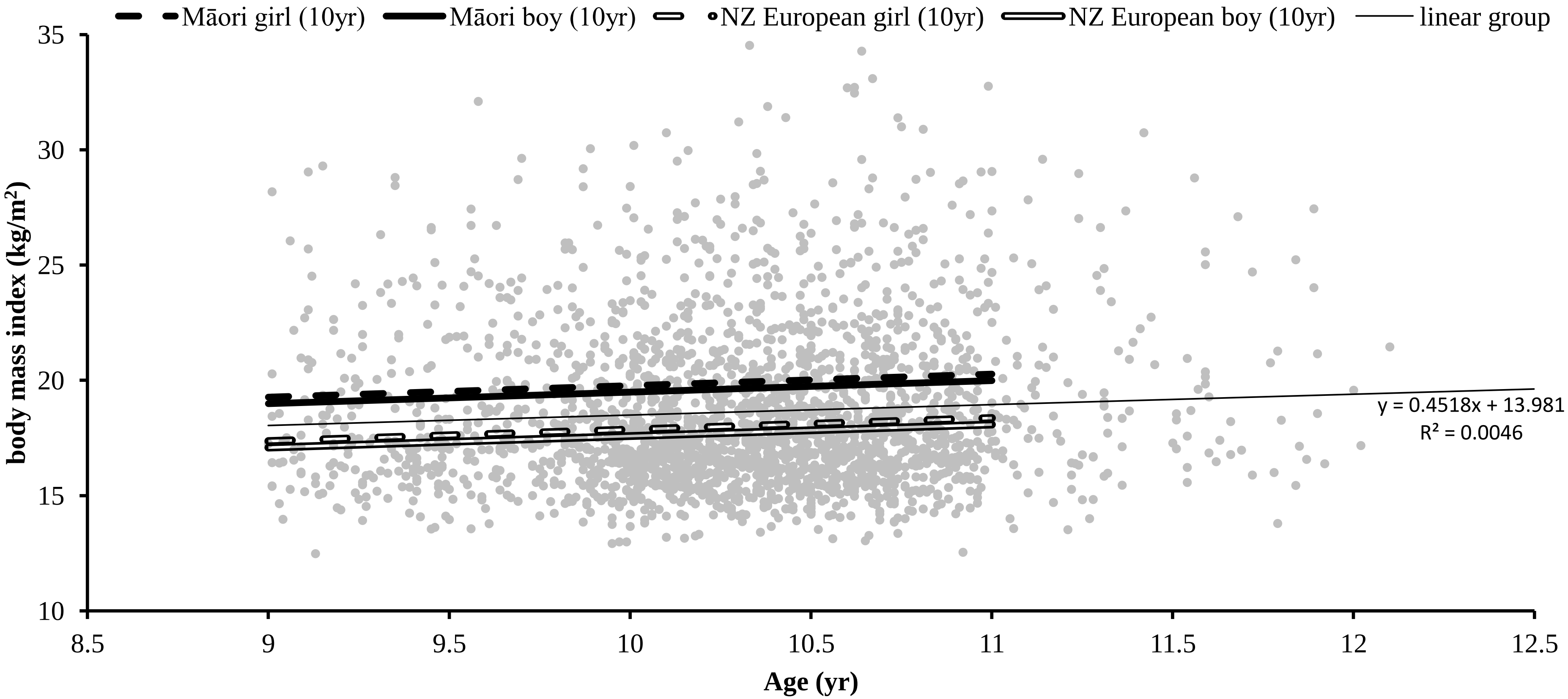



**Figure L3 (b)** Multiple regression of body mass index by age adjusted for ethnic group and gender (10-yr olds). Pattern follows that of the 7-yr old group.

**Appendix M Body mass index verses waist to height ratio in children 6 to 11 years old.**

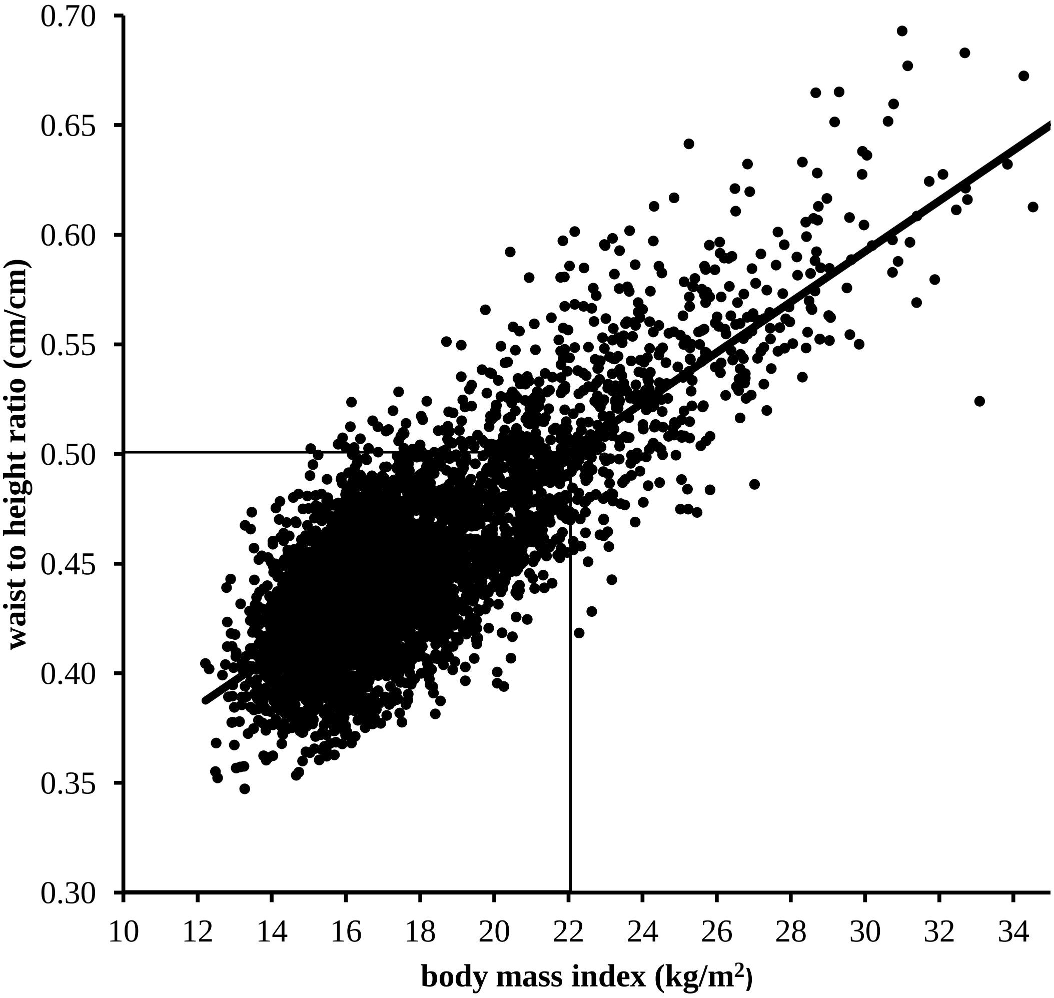



**Figure M1**.In children 6 to 11 years old, for every 1 kg/m$^2$ increase in body mass index, waist to height ratio increased 0.013 (95% CI 0.013) cm/cm adjusted by age and gender (R = 0.86, P < 0.0001) **or** 0.012 cm/cm (95% CI 0.011, 0.012) independent of age and gender (R = 0.80, P < 0.0001).

**Appendix N Initial stepwise multiple regression analysis – Body size adjusted for fat mass %, age, gender and school decile.**

**Table N1 Percentage change in time to run 550m in association with increase in body fat measures, gender, age and school decile.**

| | **WHtR (0.01cm/cm)** | **FM% (1%)** | **Gender girls†** | **Increasing age in years** | **Decile low<sup>Ψ</sup>** | **Decile medium<sup>Ψ</sup>** |
|---|---|---|---|---|---|---|
| 7 year olds[A] | 1.1% (0.8%, 1.4%) | 0.7% (0.6%, 0.8%) | 4.0% (2.9%, 5.1%) | -4.9% (-5.7%, -4.0%) | 6.7% (5.3%, 8.1%) | 3.8% (2.6%, 5.2%) |
| 10 year olds[A] | 1.2% (0.9.%, 1.5%) | 0.8% (0.6%, 0.9%) | 6.1% (5.0%, 7.2%) | -4.2% (-5.1, -3.2%) | 6.8% (5.4%, 8.2%) | 3.6% (2.3%, 4.9%) |
| | **BMI ($1kg/m^2$)** | **FM% (1%)** | **Gender girls†** | **Increasing age in years** | **Decile low[Ψ]** | **Decile medium[Ψ]** |
| 7 year olds[B] | 0.9% (0.6%, 1.2%) | 0.8% (0.6%, 0.9%) | 3.5% (2.4%, 4.6%) | -5.5% (-6.3%, -4.6%) | 6.7% (5.3%, 8.1%) | 3.8% (2.5%, 5.1%) |
| 10 year olds[B] | 1.1% (0.9%, 1.3%) | 0.8% (0.6%, 0.9%) | 5.5% (4.4%, 6.6%) | -5.0% (-5.9, -4.1%) | 6.5% (5.1%, 7.9%) | 3.7% (2.4%, 5.0%) |
| | **WaistC (1 cm)** | **FM% (1%)** | **Gender girls†** | **Increasing age in years** | **Decile low[Ψ]** | **Decile medium[Ψ]** |
| 7 year olds[C] | 0.3% (0.2%, 0.4%) | 0.8% (0.7%, 0.9%) | 3.6% (2.5%, 4.8%) | -5.8% (-6.6%, -5.0%) | 6.7% (5.6%, 8.4%) | 3.9% (2.6%, 5.2%)* |
| 10 year olds[C] | 0.4% (0.3%, 0.5%) | 0.8% (0.7%, 1.0%) | 5.8% (4.6%, 6.9%) | -5.2% (-6.1, -4.3%) | 7.0% (5.6%, 8.5%) | 3.8% (2.5%, 5.1%)* |

A = WHtR (constant) of 151 run seconds (7 year olds), 136 run seconds (10 year olds). B = BMI (constant) 190 run seconds (7 year olds), 172 run seconds (10 year olds). C = Waist circumference (constant) = 188 run seconds (7 year olds), 167 run seconds (10 year olds)

* 95% confidence interval for percentage change in time to run 550m.

† Girls were slower than boys. As children aged run time decreased.

Ψ Low (decile 1-3) and medium (decile 4-7) deciles are slower than higher (decile 8-10) deciles.

WHtR = waist to height ratio, FM% = fat mass percent. BMI = body mass index. WaistC = waist circumference.