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The effect of a child-specific high intensity games intervention on physiological responses in normal weight and obese children

Submitted by Nicole Westrupp to Massey University Wellington as a thesis towards the degree of Master of Health Science with Sport and Exercise Science (February, 2013)

"I certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has previously been conferred upon me

…………………………………….."

Dr James Faulkner

Dr Danielle Lambrick

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Abbreviations

EX- Exercise

CON- Control

NW- Normal weight

OB - Obese

pre-INT- pre intervention

post-INT - post intervention

$\dot{V}O_2$ - oxygen consumption

$\dot{V}O_2$peak - peak oxygen consumption

$\dot{V}O_2$max - maximal oxygen consumption

%$\dot{V}O_2$peak - percent of $\dot{V}O_2$peak in proportion to peak value

$\dot{V}_E$ - minute ventilation

$\dot{V}_E$peak- peak minute ventilation

%$\dot{V}_E$peak - percent of minute ventilation in proportion to peak value

VT - ventilatory threshold

40% delta - 40% of the difference between VT

GXT- graded exercise test

%BF - body fat percentage

BMI - body mass index

HR – heart rate

HRpeak – peak heart rate

%HRpeak – percent of heart rate peak in portion to peak value

HDL – high density lipoprotein cholesterol

LDL - low density lipoprotein cholesterol

VLDL - very-low density lipoprotein cholesterol

TC - total cholesterol

TG - triglycerides

VAT - visceral adipose tissue

SAAT - subcutaneous abdominal adipose tissue

FFM - fat free mass

MM - muscle mass

BMR - basal metabolic rate

RPE - ratings of perceived exertion

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Abstract

To date, little is known about the use of child- specific high-intensity games- based exercise to improve body composition, cardiovascular indices, musculoskeletal health, psychological and social well-being. Past research in children has predominantly focused on the effect of laboratory or games based moderate intensity exercise interventions on the aforementioned markers of health (Janssen & LeBlanc, 2010). Therefore, the aim of this investigation is to assess the effect of a 6 week high-intensity games-based intervention on the physiological responses and physical parameters in normal and overweight or obese children aged 8 to 10 years. Twenty eight children were randomized into an exercise group (EX; 9.3 ± 0.9 y, 1.40 ± 0.10 m, 41.0 ± 12.4 kg, 20.5 ± 4.4 $kg{\cdot}m^2$) and 27 children into a control group (CON; 9.3 ± 0.8 y, 1.40 ± 0.09 m, 39.0 ± 11.3 kg, 19.5 ± 4.1 $kg{\cdot}m^2$). All participants completed two, pre-intervention (pre-INT) exercise tests on a treadmill i) discontinuous graded exercise test (GXT) to peak oxygen consumption ($\dot{V}O_2$peak) and ii) a submaximal exercise test at running speeds equivalent to moderate (ventilatory threshold [VT]) and heavy (40% delta [difference between $\dot{V}O_2$peak and VT]) intensity exercise for a total of 6 minutes. The EX group took part in 2 x 40 minute high-intensity child-specific games-based exercise sessions per week for 6 weeks. Follow-up assessments identical to the pre-INT were completed thereafter for all participants. The EX group from pre to post intervention (post-INT) demonstrated a significant increase in absolute $\dot{V}O_2$peak and running speed for the GXT test (P < .05); and demonstrated a significant increase in their running speed at VT (7.8 ± 0.9 vs. 8.2 ± 0.8 $km{\cdot}h^{-1}$) and 40% delta (9.4 ± 1.0 vs. 9.9 ± 1.1 $km{\cdot}h^{-1}$; $P < .05$) when compared to the CON group. A significant decrease in $\dot{V}O_2$ at VT and 40% delta was also observed for the EX group in comparison to the CON group ($P < .05$), thus demonstrating an improvement in exercise efficiency. In conclusion, a short duration (6 week) child-specific high intensity games intervention may improve maximal functional capacity and exercise efficiency, independent of body mass in children aged 8 to 10 years. An increase in the oxygen carrying capacity of blood, and capillary and mitochondrial density within the skeletal muscle are potential mechanisms for the aforementioned outcomes. Findings from this study provide important information concerning the practical application of physical activity within school or clinical-based programmes to improve health and physical fitness.

1. Introduction

Physical activity is critical for an individual's health and well-being by improving cardiovascular and musculoskeletal health, psychological well-being and cognition (Hillman, Erickson, & Kramer, 2008; Van Cauwenberghe, De Craemer, De Decker, De Bourdeaudhuij, & Cardon, 2012). In children, adolescents and adults, physical activity participation and physical fitness levels continues to decline (Eiholzer et al., 2010; WHO., 2013). Coinciding with this information, an alarming number (~48%) of both adults and children in New Zealand fail to meet the basic minimum physical activity requirements (MoH., 2013). Children who are sedentary and present with low levels of physical fitness are at risk of early development of several chronic diseases (Hillman, et al., 2008). For example, in conjunction with decreasing levels of physical activity and fitness observed in children, the prevalence of children who are overweight or obese has risen substantially in recent years (WHO., 2013) . However, there is strong evidence that advocates the importance of regular physical activity participation in reducing incidences of cardiovascular disease, type 2 diabetes, cancer, obesity, depression and premature death (Warburton, Nicol, & Bredin, 2006). In fact, regular and intense physical activity during early childhood has been shown to improve physical fitness in later life (Baquet, Guinhouya, Dupont, Nourry, & Berthoin, 2004). As such, physical activity interventions are an effective way to target both poor cardiorespiratory fitness levels and obesity in children.

There have been a number of studies that have evaluated the utility of physical activity interventions on cardiovascular fitness, metabolic markers and body composition in children and adolescents. Maximal oxygen consumption ($\dot{V}O_2$peak), submaximal $\dot{V}O_2$, and submaximal heart rate, are shown to improve following participation in an exercise intervention in several (Park et al., 2012; Resaland, Andersen, Mamen, & Anderssen, 2011) yet not all research studies (Gutin et al., 1995; McManus, Cheng, Leung, Yung, & Macfarlane, 2005). Furthermore, contradictory evidence also exists concerning metabolic markers (insulin, glucose, cholesterol etc) and body composition (body fat percentage, body weight, fat-free mass etc), with inconsistent findings frequently reported in the literature (Bell et al., 2007; Carrel et al., 2005; Chang, Liu, Zhao, & Yu, 2007; Howe, Harris, & Gutin, 2011; Nassis et al., 2005).

The methodologies between physical activity interventions differ quite extensively within the literature. For example, the length of the exercise intervention ranges from as little as 3 weeks (Kalak et al., 2012) to as long as 2 years (Resaland, et al., 2011). Physical activity interventions typically implement between 2 (Baquet et al., 2003; Lazaar et al., 2007) and 5 sessions per week (Barbeau et al., 2007; Meyer, Kundt, Lenschow, Schuff-Werner, & Kienast, 2006). Furthermore, an exercise duration ~30 to 40 minutes per session appears to be the most efficacious and frequently implemented within exercise interventions (Howe, Freedson, Alhassan, Feldman, & Osganian, 2012; Kang et al., 2002; Park, et al., 2012). An observational study revealed that children’s habitual physical activity patterns are highly intermittent and characterized by rapid changes from rest to vigorous physical activity (Bailey et al., 1995). As such, high-intensity exercise sessions may be more advantageous with children. However little research has employed this intensity and many have repeatedly utilized continuous and aerobic exercise sessions (Kalak, et al., 2012; Watts et al., 2004). In addition, methodological variations in participant demographics are apparent, for example, gender (male vs. female), body weight (normal vs. overweight/obese) and ethnicity (Caucasian vs. African-American/Asian) differ frequently within the literature. As such, conclusive guidelines and recommendations are difficult to establish.

Research is yet to amalgamate the aforementioned information and implement appropriate physical activity interventions that may mimic children's habitual physical activity patterns; as well as consider the enjoyment and attractiveness of the programme to this population. Additionally, children's physiological makeup is found to be more favourable to intermittent type exercise and as such, further improvements in cardiovascular fitness are likely with exercise of this nature (Barkley, Epstein, & Roemmich, 2009). More importantly, physical activities in children should be age-appropriate, motivating and engaging to uphold adherence and positive behavioural patterns (Baquet et al., 2010; Barkley, et al., 2009). Accordingly, the present study will assess the effect of child-specific high intensity games intervention on the physiological responses and physical parameters of normal weight and obese children aged 8 to 10 years.

2. Review of the Literature

2.1. Physical activity in adults

In 2008, approximately 31% of the world's adult population did not meet the recommended physical activity requirements of 150 minutes of moderate physical activity for one week (WHO., 2013). In New Zealand, only about half (52%) of the adult population are physically active for the minimum amount advocated (30 minutes of exercise on 5 or more days a week; MoH., 2013). In light of these statistics it is not surprising that physical inactivity is the fourth leading risk factor for mortality and accounts for approximately 6% of deaths worldwide (WHO., 2013).

Physical inactivity is a major modifiable risk factor for the development of cardiovascular disease (i.e., early atherosclerosis), type 2 diabetes, cancer (colon and breast), obesity, hypertension, osteoporosis, depression and premature death (Meyer, et al., 2006; Warburton, et al., 2006). Regular physical activity participation is considered to be effective in the primary and secondary prevention of the aforementioned diseases and conditions (Warburton, et al., 2006). Evidence has shown that individuals who are physically active have a ~50% reduced risk of death from cardiovascular disease, hypertension, type 2 diabetes, cancer (breast & colon), obesity, osteoporosis and hypercholesterolemia (Warburton, et al., 2006). Furthermore, in individuals with established cardiovascular disease, physical activity[1] and improved fitness is beneficial at attenuating or reversing the disease process (Warburton, et al., 2006). Physical activity improves total cholesterol, triglyceride and blood pressure levels, while increasing the

[1] Physical activity is defined as any bodily movement produced by skeletal muscle that requires energy expenditure (WHO., 2013). Physical fitness is a set of characteristics that allows one to meet the demands of physical activity or provide the basis for sport performance (Warburton, et al., 2006)

overall quality of life in this population group, and similar findings are also observed in patients suffering from cancer (Taylor et al., 2004). Exercise interventions improve glucose homeostasis (through a decrease in glycosylated haemoglobin concentrations) and reduce diabetes related mortality by 42% in patients with type 2 diabetes (Boule, Haddad, Kenny, Wells, & Sigal, 2001; Taylor, et al., 2004). In individuals who are overweight or obese, routine physical activity augments body composition and weight control (Taylor, et al., 2004). For further information concerning the benefits of physical activity in adults see Warburton et al. (2006).

2.2. Physical activity in children

Physical activity improves cardiovascular health, body weight regulation, musculoskeletal health and fitness, psychological and social well-being, and cognition in children (Bell, et al., 2007; Goran, Reynolds, & Lindquist, 1999; Janssen & Leblanc, 2010). Regular or habitual physical activity reduces fat stores, increases glycogen synthase and GLUT-4 protein and improves muscle capillary density in both children and adults alike (Taylor, et al., 2004). Importantly, research has shown that physical activity in early childhood strongly influences physical fitness in adulthood and creates positive physical activity habits (Carrel, et al., 2005; Goran, et al., 1999; Howe, et al., 2011; Nassis, et al., 2005). Therefore, encouraging the development of physical activity habits in children is warranted, not merely for the obese child, but also in reducing the risk of the early development of cardiovascular disease, (i.e. atherosclerosis), type 2 diabetes (i.e. hyperinsulinemia), hypercholesterolemia, unhealthy lifestyle behaviours, anxiety, depression, self-esteem, withdrawal and early morbidity and mortality (Deckelbaum & Williams, 2001; Goran, et al., 1999; Watts, Jones, Davis, & Green, 2005). As more than

95% of children (5 – 17 years) are enrolled in school, school-based physical activity interventions are an ideal setting to improve the health and fitness of normal weight and overweight or obese children (Goran, et al., 1999; Howe, et al., 2012; Wang et al., 2008). Not only do schools provide access to children (including those at risk of developing chronic diseases, i.e. cardiovascular disease, obesity, type 2 diabetes etc), but also families by providing information and support to the parents and siblings, and teachers through knowledge about the physical environment and promotion of behaviour change within the classroom (Goran, et al., 1999).

2.3. Overweight and obesity in children

Over the last two decades, the prevalence of people who are overweight or obese has increased rapidly in developed countries and has now reached epidemic proportions (MoH., 2013). An overweight or obese condition has been described as the 5th leading cause of death worldwide with approximately 2.8 million adults dying as a result of this condition (WHO., 2013). In 2010, the World Health Organization (2013) established that 43 million children worldwide were estimated to be overweight or obese. This accounted for a 6.7% prevalence of childhood overweight and obesity worldwide (WHO., 2013). In 2006/2007 it was reported that 20% of New Zealand’s children were classified as being in an overweight condition, with 8.3% inflicted with obesity (MoH., 2013).

For children, being overweight or obese can lead to many health consequences including type 2 diabetes, ischemic heart disease, ischemic stroke and several common cancers (endometrial, breast and colon), increased breathing difficulties, increased risk of fractures, as well as low self-esteem and self-confidence, and an increase in depression and anxiety (Chang, et al., 2007; Ferguson et al., 1999; Goran et al., 1999; WHO, 2013).

Becoming overweight or obese is most commonly caused by an energy imbalance whereby energy intake (i.e. food consumption) exceeds that of energy output (i.e. physical activity; Barbeau et al., 2007; Veugelers & Fitzgerald, 2005; Watts, et al., 2005). Childhood obesity increases the risk of early onset of disease, disability and even mortality during adulthood (Bell, et al., 2007; Chang, et al., 2007; Watts, et al., 2004), through the increased risk of many physiological and psychological implications mentioned previously. In addition, being overweight or obese during childhood has been suggested to track into adulthood and may be a leading contributor to the adult obesity epidemic (Deckelbaum & Williams, 2001; Wang, et al., 2008). Although fatal episodes are most likely to occur later in life, the early pathological manifestations of cardiovascular disease and type 2 diabetes are evident during childhood and as such early-implementation of physical activity interventions are urgently warranted to reduce the incidences and consequences of childhood obesity (Ferguson, et al., 1999; Gutin et al., 2002). Physical activity interventions aimed at maintaining a healthy weight should concentrate on exercise rather than dietary restriction as modifying the eating habits of children may lead to adverse effects of inappropriate eating patterns and eating disorders (Goran et al., 1999; Watts, et al., 2004)

2.4. Children's habitual exercise

An observational study by Bailey et al. (1995) revealed that children's habitual physical activity patterns are highly intermittent and characterized by rapid changes from rest to vigorous physical activity. The authors observed that ~ 95% of children's vigorous intensity bouts were less than 15 seconds (Bailey, et al., 1995). More recently, high-frequency accelerometry monitoring established children's physical activity patterns to be highly transitory and intermittent (Baquet et al. 2007). Dencker et al., (2006) observed that in total, 92% of boys and 86% of girls performed 20 minutes of vigorous activity per day (Dencker, et al., 2006). In addition, as the intensity increases, the activity becomes more sporadic (Rowlands, Pilgrim, & Eston, 2007). It is possible that children find high-intensity intermittent exercise to be more reinforcing compared to continuous and constant intensity physical activity (Barkley, et al., 2009). Children are more likely to participate in activities that they find reinforcing as this represents the motivational processes that increase the likelihood of further engaging in that particular behaviour (Barkley, et al., 2009). The greater reinforcing value of this type of physical activity may in part be a result of children's physiology (Barkley, et al., 2009). Unlike adults, children exhibit smaller muscle mass, lower muscle concentrations of glycolytic enzymes and stored glycogen, greater phosphocreatine resynthesis, quicker recovery time and reduced hydrogen concentrations (Barkley, et al., 2009). Therefore, children's unique muscle metabolism would favour intermittent type exercise, while limiting their ability to perform continuous constant load exercise (Barkley, et al., 2009).

2.5. Summary physical activity interventions

Tables 2.1 and 2.2 below summaries the physiological responses, short term (ST) v long term (LT) interventions, exercise programming and prescription (frequency, intensity, duration, type) and participant demographics (weight, gender & ethnicity). This will be further discussed within the body of the literature review.

Table 2.1 Summary of short term intervention studies

Study	n	Age (y)	Gender	Body Composition	Ethnicity	Length	Frequency (n/week)	Type	Duration	Intensity	Child specific Games	Effect ($p < 0.05$)
Baquet et al. (2010)	63	8-11	M & F	Normal 18.0 kg·m^2	NS	7 weeks	3	Intermittent vs. Continuous running vs. control	18 min vs. 39 min	100 -190% MAV 80 – 85% MAV	No	↑ $\dot{V}O_2$peak, MAV *NC* Peak $\dot{V}_E$, HR max
Baquet et al. (2004)	46	8-11	M & F	Normal 18.0 kg·m^2	NS	7 weeks	2	Intermittent running vs. control	30 min	100-130% MAV	No	↑ SBJ, MAV *NC* SAR, SHR, SUP
Baquet et al. (2002)	53	8-11	M & F	Normal 18.2 kg·m^2	NS	7 weeks	2	Intermittent running	30 min	100-130% MAV	No	↑ $\dot{V}O_2$peak, MAV, (submax), (submax), % $\dot{V}O_2$peak, % HR max, *NC* Peak $\dot{V}_E$, HRmax, $\dot{V}O_2$ (submax), HR (submax), energy cost of running,
Baquet et al. (2001)	503	11-16	M & F	Normal 19.7 kg·m^2	NS	10 weeks	1	Intermittent running	1 hour	100- 120% MAV	No	↑ SBJ, MAV, D7 *NC* SAR, SUP ↓ SHR
Bell et al. (2007)	14	9-16	M & F	Obese 31.6 kg·m^2	NS	8 weeks	3	Circuit based (aerobic & resistance exercises)	1 hour	65 – 85% HR max	No	↑ Height, Insulin sensitivity *NC* Body weight, Hip circumference, BP, Total lean mass, Total fat mass, BF%, TC, HDL, LDL, TG ↓ BMI, Waist circumference, HR (submax)

Gutin et al. (1995)	25	7-11	F	Obese 27.4 $kg \cdot m^2$	African-American	10 weeks	5	Aerobic exercises	30 min	60-80% HR max	No	↑ Height, Fat free mass, Fat free soft tissue, Bone mineral content *NC* Body weight, HRpeak, $\dot{V}O_2$peak, fat mass, Waist circumference, Waist/hip ratio ↓ BMI, HR (submax) %BF, Skinfolds, Hip-circumference
Howe et al. (2012)	27	7-9	M & F	Normal & Overweight/ Obese (BMI % ≥ 85%)	NS	9 weeks	5	Structured games	30 min	NS	Yes- Dragon's tail, couple tag etc	↑ MVPA
Kalak et al. (2012)	51	18	M & F	Normal 22.0 $kg \cdot m^2$	NS	3 weeks	5	Continuous running	30 min	NS	No	↑ Sleep time & quality, psychological functioning
McManus et al. (2004)	45	9-11	M	Normal 18.3 $kg \cdot m^2$	Chinese	8 weeks	3	Interval vs. Continuous cycling	20 min	75-85% $\dot{V}O_2$peak /85% HRmax	No	↑ $\dot{V}O_2$peak, Watts, O_2 pulse, $\dot{V}O_2$peak (submax), O_2 pulse (submax) *NC* Peak $\dot{V}_E$, HR max, HR (submax) % $\dot{V}O_2$peak
Nassis et al. (2005)	19	9-15	F	Overweight/ Obese 26.9 $kg \cdot m^2$	Greek	12 weeks	3	Sports games	40 min	HR > 150 bpm	Yes Running, bench stepping, stair climbing, skipping, basketball, volleyball & handball	↑ Height, Lower limb fat free mass, Bone mineral content, Waist circumference, *NC* Body weight BMI. %BF, Total body fat free mass, skinfolds, VAT, Insulin, Glucose, Adioponectin, C-reactive protein ↓ HR (submax), RER (submax)

Park et al. (2012)	29	12-13	M & F	Overweight/ Obese 24.0 $kg \cdot m^2$	NS	12 weeks	3	Aerobic & Resistance	30 min	50-70% HRR	No	↓ Body weight, BMI, Waist circumference, IMT *NC* Blood pressure ↑ $\dot{V}O_2peak$, % $CD34^+$ cells, % $CD133^+$ cells
Stergioulas et al. (1998)	18	10-14	M	Normal 19.9 $kg \cdot m^2$	NS	9 weeks	4	Continuous cycling	1 hour	70% Working capacity	No	↑ W, HDL ↓ 6-keto-PGF1a
Watts et al. (2004)	14	9	M & F	Obese 29.9 $kg \cdot m^2$	NS	8 weeks	3	Continuous physically active games	1 hour	HR (140-180 bpm)	Yes Dodge and tag, jogging, soccer etc	*NC* Body weight, BMI, Waist circumference, Skin folds, TC, LDL, HDL, TG, Glucose, BP, mean arterial pressure. HR (submax) ↑ FMD ↓ Resting HR

* D7- maximal covered Distance during 7 minute running test, F- Female, M- Male, MAV – maximal aerobic velocity, MVPA- Moderate-Vigorous Physical Activity, NC- No change, NS – Not Stated, SAR- Sit- and-reach, SBJ- Standing Broad Jump, SHR- shuttle run, SUP- Sit-ups, W- Working capacity

*BF %- Body fat percentage, BMI – Body Mass Index, FMD- Flow Mediated Dilation, HDL- High-density lipoprotein, HRR- Heart Rate Reserve, IMT- Carotid Intima-Media Thickness, LDL- Low-density lipoprotein, TC- Total cholesterol, TG- Triglyceride VLDL- Very low- density lipoprotein

Table 2.2 Summary of long term intervention studies

Study	n	Age (y)	Gender	Body Composition	Ethnicity	Length	Frequency (n/week)	Type	Duration	Intensity	Games	Effect ($p < 0.05$)
Barbeau et al. (2007)	201	8-12	F	Normal & Overweight	African-American	10 months	5	Split into Skills, moderate-vigorous sport games, toning & stretching vs. control	80 min	HR > 150 bpm	Yes Basketball, tag, softball, relay races etc	↑ BMI, Waist circumference, Fat mass, bone mineral content, bone mineral density, VAT, SAAT, $\dot{V}O_2$peak *NC* Fat free soft tissue ↓ BF %
Carrel et al. (2005)	50	11-14	M & F	Overweight/ Obese 31.0 kg·m^2	NS	9 months	2-3	Lifestyle focused activities vs. control	42 min	NS	No	*NC* BMI, Glucose ↑ $\dot{V}O_2$ peak ↓ %BF, Insulin
Chang et al. (2007)	65	12-14	M & F	Obese 27.3 kg·m^2	Chinese	9 months	2-5	Aerobic mostly	30 – 90 min	3-7 METS 145-160 bpm	Y/N Running, basketball, standing long jump, skipiing, taekwondo, push-ups, sit-ups, swimming, mountain climbing	↑ Height, Body weight, Endurance performance, upper and lower limb strength & flexibility ↓ BMI, TG, Insulin, Glucose *NC* %BF, Waist Circumference, TC, LDL, HDL, Speed performance

Ferguson et al. (1999)	73	7-11	M & F	Obese 28.6 kg·m^2	Black & White	4 months	5	Aerobic exercise (machines & continuous team games) cross-over design	40 min	HR > 150 bpm	Y/N ½- treadmill, cycles, rowers etc, ½ - group games	*NC* TC, HDL, LDL, TG, Lipoprotein, Glucose ↓ Insulin, %BF, HR (submax)
Gutin et al. (2002)	80	13-16	M & F	Obese 34.4 kg·m^2	Black & White	8 months	5	Moderate vs. High-intensity vs. Control machine & team games	Individually based in order to expend 1045kJ depending on group	55-60% $\dot{V}O_2$peak & 75-80% $\dot{V}O_2$peak	Y/N ½ - treadmill, cycles, rowers, steppers etc, ½ - basketball, badminton, kickball, aerobic slide	↑ $\dot{V}O_2$peak, $\dot{V}O_2$- 170, Bone mineral content, Bone mineral density ↓ VAT, %BF *NC* SAAT, Fat mass, Fat-free soft tissue, Habitual Moderate exercise, Habitual vigorous exercise
Gutin et al. (1999a) Gutin et al. (1999b)	73	7-11	M & F	Obese 28.6 kg·m^2	Black & White	4 months	5	Half machines half active games, cross-over design	40 min	HR > 150 bpm	Y/N ½ - treadmill, cycles, rowers, steppers etc, ½ - basketball, badminton, kickball, aerobic slide	↑ Body weight, Bone mineral density ↓ %BF, Fat mass, Insulin, Leptin *NC* Fat-free mass, HR (submax), Habitual vigorous exercise

Hamlin et al. (2002)	148	5-12	M & F	Normal 17.0 $kg \cdot m^2$		4 months	3	Moderate – vigorous activities	15 min	NS	Y/N Skipping, continuous running, aerobics circuit, obstacle course, games, relays, interval exercises, exercise to music	↑ Body weight, broad jump ↓ Sit and reach *NC* BMI, sum of skinfolds, 550m run
Hansen et al. (1991)	69	9-11	M & F	Normal (Hypertensive vs. Control) 18.1 $kg \cdot m^2$	Danish	8 months	3	Extra ordinary PE lessons	50 min	NS	Y/N Extra lessons of an ordinary Physical Education programme	↓ Systolic BP, Diastolic BP ↑ $\dot{V}O_2peak$
Howe et al. (2011)	106	8-12	M	Normal & Overweight/ Obese 20.2 $kg \cdot m^2$ 47.4 % classified as overweight/ obese	African-American	10 months	5	Split into- Skills, moderate vigorous sports games, toning & stretching	80 min (25 min skill, 35 min games, 20 min toning & stretching)	HR > 150 bpm	Yes Basketball, tag, softball, relay races etc	*NC* BMI, Waist circumference, Fat mass, Fat free mass, Relative $\dot{V}O_2$-170 ↓ BF % ↑ Bone mineral content, Bone mineral density, Absolute $\dot{V}O_2$-170, Habitual moderate exercise

Kang et al. (2002)	80	13-16	M & F	Obese $34.4\ kg{\cdot}m^2$	Black & White	8 months	5	Moderate vs. High intensity vs. control	43 min & 29 min	55-60% $\dot{V}O_2peak$ & 75-80% $\dot{V}O_2peak$	Y/N ½ - treadmill, cycles, rowers, steppers etc, ½ - basketball, badminton, kickball, aerobic slide	↓ %BF, VAT, TG, VLDL, Diastolic BP ↑ $\dot{V}O_2peak$ *NC* TC, HDL, LDL, Lipoprotein, Adipoctein, Glucose, Insulin, Systolic BP
Lazaar et al. (2007)	18	6-10	M & F	Normal & Obese $15.6\ kg{\cdot}m^2$ & $20.4\ kg{\cdot}m^2$	NS	6 months	2	Continuous aerobic	1 hour	70% HRpeak	Yes traditional games, focused on skill, technique, posture, balance & coordination	*NC* BMI ↓ Waist circumference, Sum skinfolds ↑ Fat free mass
Meyer et al. (2006)	96	11-16	M & F	Obese $30.4\ kg{\cdot}m^2$	German	6 months	3	Continuous aerobic Obese exercise vs. Obese control &normal control	1 hour	HR between 140-180 bpm	Y/N Swimming, aquatic training, walking, & sports games	↓ BMI, Waist/hip ratio, Insulin, Insulin Resistance, TG, LDL, Fibrinogen, C-reactive protein *NC* %BF, HDL, LDL/HDL ratio
Owens et al. (1999)	73	7-11	M & F	Obese $28.4\ kg{\cdot}m^2$	Black & White	4 months	5	Half machines half active games vs. control	40 min	70-75% HR max	Y/N ½ - treadmill, cycles, rowers, steppers etc, ½ - basketball, badminton, kickball, tag etc	↑ Body weight, Fat free mass *NC* Total fat mass, VAT, SAAT ↓ %BF, HR (submax)

Resaland et al. (2011)	256	9	M & F	Normal 17.2 kg·m^2	Norwegian	2 years	5	Exercise intervention vs. control	55 min	Moderate to vigorous	Yes Running, relay, obstacle course, football, basketball, gymnastics	*NC* Body weight, BMI, HR peak ↑ $\dot{V}O_2$peak, running time
Walther et al. (2009)	188	11-12	M & F	Normal & Overweight/ Obese 18.1 kg·m^2 11.9 % Classified as Obese	NS	1 year	5	Normal PE + Continuous running	1 hour	NS	Y/N Extra ordinary Physical Education lesions (45 min) + endurance running (15 min)	↓ % Obese children, Leukocytes ↑ $\dot{V}O_2$peak, Max workload, HR max *NC* HDL, BP, Fat free mass, total body water content, LDL, TC, TG

* F- Female, M- Male, NC- No change, NS – Not Stated, $\dot{V}O_2$-170 - $\dot{V}O_2$ at a heart rate of 170 bpm,

*BF %- Body fat percentage, BMI – Body Mass Index, FMD- Flow Mediated Dilation, HDL- High-density lipoprotein, HRR- Heart Rate Reserve, IMT- Carotid Intima-Media Thickness, LDL- Low-density lipoprotein, SAAT- subcutaneous abdominal adipose tissue, TC- Total cholesterol, TG- Triglyceride, VAT- Visceral Adipose Tissue, VLDL- Very low- density lipoprotein

2.6. Physiological responses to physical activity interventions

2.6.1. Cardiovascular fitness

An improvement in maximal oxygen consumption ($\dot{V}O_2$peak) and submaximal $\dot{V}O_2$ is evident in both children and adolescents following participation in a physical activity intervention (see Table 2.1 & 2.2; see Figure 2.1; 2002; Baquet, et al., 2010; Barbeau, et al., 2007; Carrel, et al., 2005; Gutin, et al., 2002; Hansen, Froberg, Hyldebrandt, & Nielsen, 1991; McManus, et al., 2005; Park, et al., 2012; Resaland, et al., 2011; Walther et al., 2009). For example, Walther et al. (2009) demonstrated a 29% improvement in $\dot{V}O_2$peak (37.9 to 48.8 $mL \cdot kg^{-1} \cdot min^{-1}$) in children who took part in a year-long exercise intervention that included a total of 5 (compared to 2) Physical Education lessons and continuous running sessions per week. (Gutin, et al., 1995). In both children and adolescents, improvements in cardiorespiratory fitness have also been observed through reduced heart rate (3 - 6 %) at a given submaximal exercise intensity following regular participation in physical activity (Bell, et al., 2007; Ferguson, et al., 1999; Gutin, et al., 1995; Nassis, et al., 2005; Owens et al., 1999; Park, et al., 2012). Bell et al. (2007) found that children participating in an aerobic and resistance based circuit intervention for 8 weeks decreased submaximal heart rate from 165 $b \cdot min^{-1}$ to 155 $b \cdot min^{-1}$. Similar findings have also been reported in a 8 month, cross-over design exercise intervention (see Figure 2.2). Improvements in $\dot{V}O_2$peak following participation in physical activity is strongly linked to an increase in cardiac output and ateriovenous oxygen difference at the skeletal muscle (Bassett & Howley, 2000) In addition, the oxygen carrying capacity of blood, and skeletal muscle capillary and mitochondrial density are also enhanced to further improve aerobic and anaerobic capacity (Bassett & Howley, 2000; Watts, et al., 2005). The mechanism for the observed improvements in submaximal heart rate is suggested to be primarily due to an increase in stroke volume which results in an increase in cardiac output (Baquet, et al., 2010). A decrease in systolic and diastolic blood pressure has also been observed following regular (8 months) physical activity participation (Hansen et al. 1991; Kang et al. 2002). Mertens and Van Gaal (2000) proposed that physical activity decreases extracellular fluid volume, sympathetic nervous activity, and normalizes the rennin-angiotension-aldosterone system which are some of the mechanisms that may reduce blood pressure.

Despite the results observed previously, $\dot{V}O_2$peak was not altered in children following a 10-week aerobic exercise intervention (Gutin, et al., 1995). Similar findings were reported when considering the submaximal heart rate response (Baquet, et al., 2002; Gutin & Owens, 1999; McManus, et al., 2005; Watts, et al., 2004). Interestingly, of the present literature reviewed, none have found any influence of the exercise intervention on minute ventilation (Baquet, et al., 2002; Baquet, et al., 2010; McManus, et al., 2005). This may be due to the short duration of the exercise intervention as utilized in the aforementioned studies.

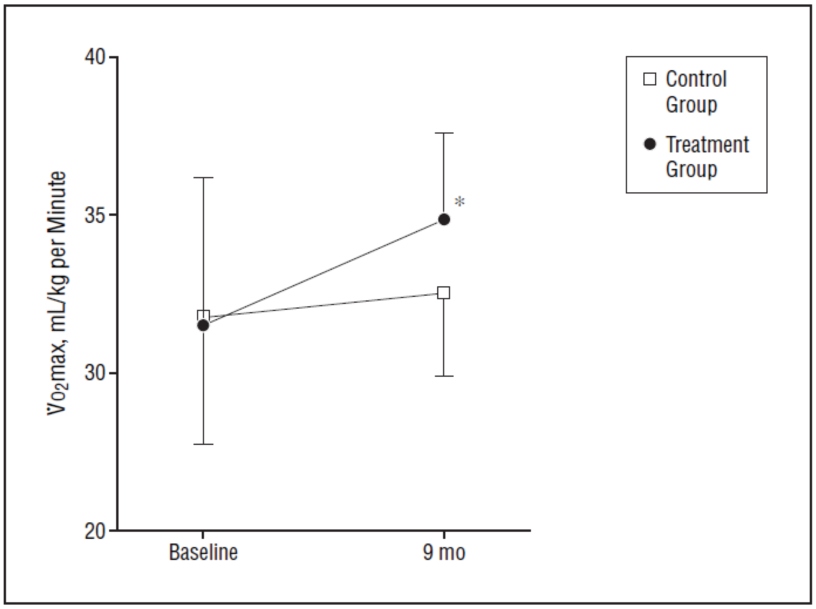

Figure 2.1 Mean ± SD change in fitness levels as indicated by $\dot{V}O_2$max after a 9-month school year, the change was greater in the treatment group compared to the control (* $P < .05$). As noted in Carrel, et al., (2005). Improvement of fitness, body composition, and insulin sensitivity in overweight children in a school-based exercise program: a randomized, controlled study. *Archive of Pediatric and Adolescolescent Medicine*, *159*(10), 963-968.

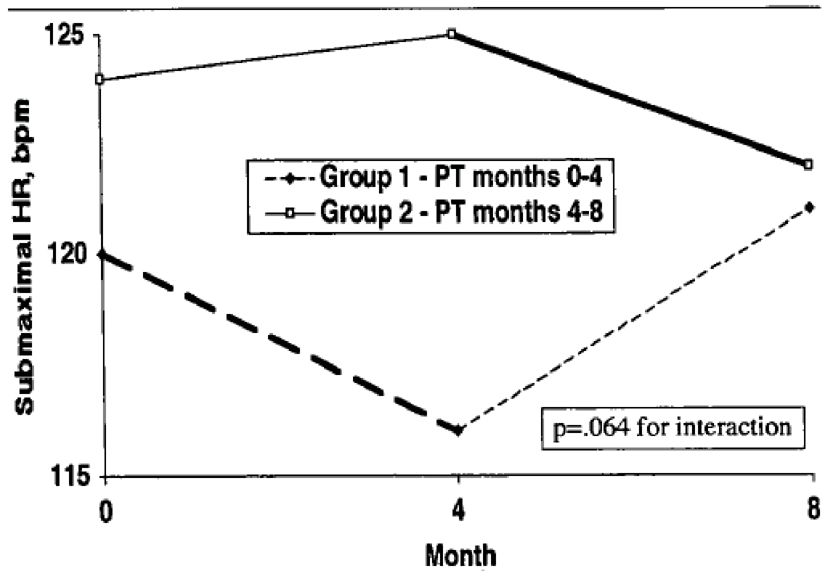

Figure 2.2. Least square means for submaximal HR. Standard errors for the six means ranged from 1.5 bpm to 1.7 bpm. As noted in Gutin, B., Owens, S., Okuyama, T., Riggs, S., Ferguson, M., & Litaker, M. (1999). Effect of physical training and its cessation on percent fat and bone density of children with obesity. *Obesity Research, 7*(2), 208-214.

2.6.2. Metabolic markers

In general, physical activity in children and adolescents has been shown to reduce blood insulin (see table 2.1 & 2.2; Carrel, et al., 2005; Chang, et al., 2007; Ferguson, et al., 1999; Meyer, et al., 2006); blood glucose (Chang, et al., 2007), triglyceride concentration (Chang, et al., 2007; Kang, et al., 2002; Meyer, et al., 2006) and high-density lipoprotein (HDL) cholesterol (Stergioulas, Tripolitsioti, Messinis, Bouloukos, & Nounopoulos, 1998) by between 16 and 23 %. Smaller changes in low-density lipoprotein (LDL) cholesterol (Meyer, et al., 2006) and very LDL cholesterol (5 % & 6 %, respectively) have however been observed (Kang, et al., 2002). The most significant changes in these metabolic markers occurred in a study by Chang et al. (2007). A significant decrease in fasting insulin levels 29.2 to 18.5 mU·L^{-1} (~ 37%), fasting glucose levels 5.2 to 4.0 mmol·L^{-1} (~ 23%) and triglyceride concentrations 1.3 to 0.9 mmol·L^{-1} (~ 31%) was observed upon completion of this 9-month aerobic exercise intervention (Chang, et al., 2007). Regardless of the above findings on metabolic markers, some exercise interventions have also found no beneficial changes to fasting insulin (Kang, et al., 2002; Nassis, et al., 2005), fasting glucose (Carrel, et al., 2005; Kang, et al., 2002; Nassis, et al., 2005; Watts, et al., 2004), triglycerides (Bell, et al., 2007; Ferguson, et al., 1999; Walther, et al., 2009; Watts, et al., 2004), LDL cholesterol (Bell, et al., 2007; Chang, et al., 2007; Ferguson, et al., 1999; Kang, et al., 2002; Walther, et al., 2009; Watts, et al., 2004) and HDL cholesterol (Bell, et al., 2007; Chang, et al., 2007; Ferguson, et al., 1999; Kang, et al., 2002; Meyer, et al., 2006; Walther, et al., 2009; Watts, et al., 2004). In addition, no evidence of improved total cholesterol upon completion of an exercise could be found (Bell, et al., 2007; Chang, et al., 2007; Ferguson, et al., 1999; Walther, et al., 2009; Watts, et al., 2004).

As skeletal muscle is the primary target tissue for insulin action, exercise training may enhance the action of insulin and therefore decrease overall concentrations through an increase in muscle mass (Nassis, et al., 2005). In addition, exercise has been shown to increase concentrations of the GLUT-4 protein enzyme in skeletal muscle and improve insulin-regulated glucose transport into the cell, therefore, decreasing overall insulin and blood glucose concentrations in both children and adults (Nassis, et al., 2005; Taylor, et al., 2004). Exercise training also reduces the concentration of triglycerides by improving the clearance of triglycerides through plasma lipoprotein lipase (Ferguson, et al., 1999). Kang et al. (2002) established a significant association between visceral adipose tissue (VAT) and total cholesterol, triglyceride and VLDL cholesterol. It is suggested that VAT further develops lipolysis, thus further releasing free fatty acids into the portal vein, which in turn stimulates hepatic synthesis and release of lipid-rich lipoproteins (Kang, et al., 2002). It is also possible that physical activity leads to an overall decrease in the production of triglycerides hence reducing plasma concentration (Ferguson, et al., 1999).

As previously discussed, exercise training increases muscle capillary density, which in turn results in improved glucose delivery to the muscle reducing overall glucose and insulin concentrations (Taylor, et al., 2004).

2.6.3. Body composition

Physical activity improves body composition by increasing energy expenditure and therefore improving energy balance in overweight or obese populations (Owens, et al., 1999; Potter, Zakrzewski, Draper, & Unnithan, 2013; Watts, et al., 2005). In normal weight individuals, regular physical activity helps to maintain a healthy body composition by producing a balance in energy consumption and expenditure (Watts, et al., 2005). Physical activity interventions of varying length (10 weeks to 10 months) have demonstrated a significant decrease in body fat percentage of both children and adolescents (3 - 15%; see table 2.1 & 2.2; see Figure 2.3; Barbeau, et al., 2007; Carrel, et al., 2005; Ferguson, et al., 1999; Gutin, et al., 2002; Gutin, et al., 1995; Howe, et al., 2011; Kang, et al., 2002; Owens, et al., 1999). Nevertheless, limited changes in body weight have also been observed (2 %) following participation in an exercise intervention (Park, et al., 2012). Supporting this observation is an increase in fat-free mass of 3 to 11 % upon completion of a physical activity intervention in children and adolescents (Gutin, et al., 1995; Howe, et al., 2011; Owens, et al., 1999), and as such potentially explains why limited research has observed a decline in body mass in this population. A 13% decline in VAT also contributes to the overall improvement in body composition after exercise (see Figure 2.4; Gutin, et al., 2002; Kang, et al., 2002). This is caused by increased utilization of free-fatty acids from VAT, decreasing VAT and improving body fat distribution (Ramsbottom, Williams, Fleming, & Nute, 1989).

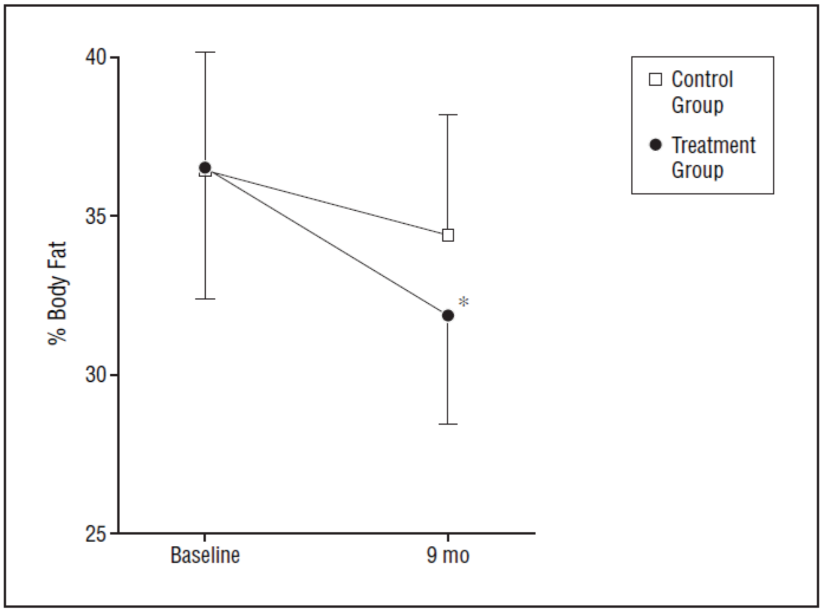

Figure 2.3. Mean ± SD decrease in percentage body fat after a 9-month school year, the decrease in the treatment group was greater compared to the control (* *P* < .05). As noted in Carrel, et al., (2005). Improvement of fitness, body composition, and insulin sensitivity in overweight children in a school-based exercise program: a randomized, controlled study. *Archive of Pediatric and Adolescolescent Medicine*, *159*(10), 963-968.

Such findings are not conclusive to all exercise interventions implemented in children and adolescents. Other research studies have found no significant difference upon completion of the exercise intervention in body mass (Bell, et al., 2007; Nassis, et al., 2005; Resaland, et al., 2011; Watts, et al., 2004), body mass index (BMI; Carrel, et al., 2005; Howe, et al., 2011; Nassis, et al., 2005; Resaland, et al., 2011; Watts, et al., 2004), or body fat percentage (Bell, et al., 2007; Chang, et al., 2007; Meyer, et al., 2006; Nassis, et al., 2005). It is possible however, that body composition measures were not altered due to an increase in the participant's height. This has been suggested when analysing participants BMI and body weight status (Carrel, et al., 2005; Nassis, et al., 2005). In addition, the methodologies for obtaining accurate body composition measures, such as using BMI or bioimpendence analysis, may have influenced the accuracy of the aforementioned outcomes (Bell, et al., 2007). Furthermore these and the previously mentioned non-significant findings in cardiorespiratory fitness and metabolic markers may be in part due to the study design (duration, intensity, type) and the length of the intervention itself.

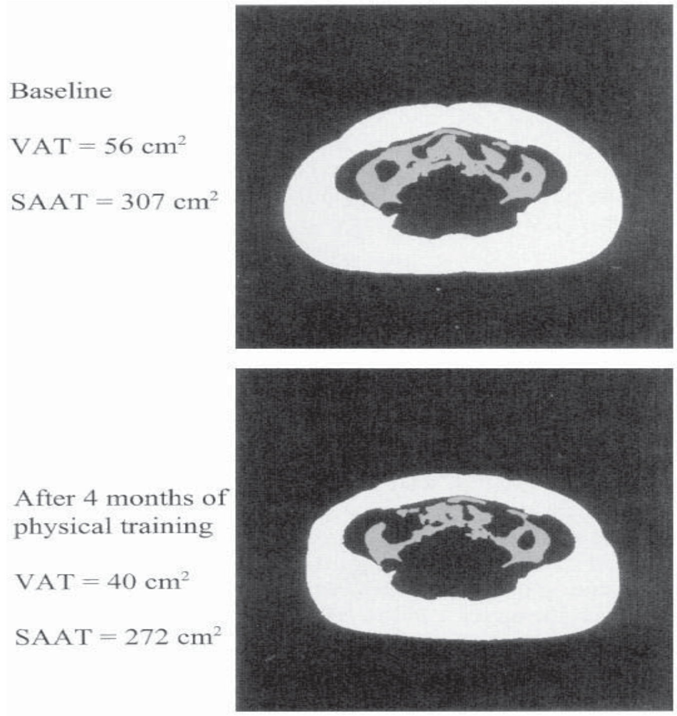

Figure 2.4. MRI scans obtains at L4 showing VAT (grey) and SAAT (white) from a 9-year old white female before and after 4 months of physical training. As noted in Owens, et al., (1999). Effect of physical training on total and visceral fat in obese children. *Med Sci Sports Exerc, 31*(1), 143-148.

2.7. Length of intervention

2.7.1. Short term exercise interventions

Exercise intervention studies (<3 months in duration; see table 2.1) have shown beneficial effects on $\dot{V}O_2$peak, submaximal heart rate, body fat percentage, BMI, fat-free mass, carotid intima-media thickness (IMT) and sleep quality. Of the research reviewed for this thesis, a seven to eight week intervention was most commonly applied (Baquet, et al., 2002; Baquet, et al., 2010; Baquet, et al., 2004; Bell, et al., 2007; McManus, et al., 2005; Watts, et al., 2004). Limited research has, to date, been conducted on assessing the efficacy of an exercise intervention that is less than seven weeks in length (Kalak, et al., 2012). In general, there is a similar amount of short (< 3 months) and long term studies (> 3 months) conducted (see table 2.1 & 2.2). On average, an increase of 5 to 11 % in $\dot{V}O_2$peak (Baquet, et al., 2002; Baquet, et al., 2010; McManus, et al., 2005) and a 5 to 6% decrease in submaximal heart rate (see 2.5.1 Cardiovascular fitness; Bell et al., 2007; Gutin et al., 1995) has been observed in exercise interventions of seven to eight weeks. Body fat percentage and fat-free mass both improved by 3% which corresponded to a 1.4% decrease in body fat percentage and a 0.8 g increase in fat-free mass from participation in the exercise intervention (Gutin, et al., 1995). Park et al. (2012) revealed a decrease in carotid intima-media thickness from 0.43 to 0.39 mm after 12 weeks of exercise. The above information gives evidence that short term interventions are beneficial in improving body composition and physiological parameters in children and adolescents.

However, some studies have observed no differences in $\dot{V}O_2$peak (Gutin, et al., 1995), submaximal heart rate (Baquet, et al., 2002; McManus, et al., 2005), body fat percentage (Bell, et al., 2007; Nassis, et al., 2005) and fat-free mass (Nassis, et al., 2005) following completion of exercise interventions that are less than 3 months in duration. Furthermore no significant improvements in fasting glucose, fasting insulin, triglyceride, LDL cholesterol and HDL cholesterol have been shown in short term interventions (see Table 2.1; Bell, et al., 2007; Watts, et al., 2004). This perhaps suggests that more time is required to positively influence these metabolic markers and longer study durations may be more effective, in addition, intensity, type and frequency are also influential.

2.7.2. Long term exercise interventions

The more prolonged exercise interventions employed have incorporated exercise interventions ranging from 4 months to 2 years (see table 2.2), with the majority of these studies applying interventions between 8 to 10 months (Barbeau, et al., 2007; Carrel, et al., 2005; Chang, et al., 2007; Ferguson, et al., 1999; Gutin, et al., 2002; Gutin & Owens, 1999; Hansen, et al., 1991; Howe, et al., 2011; Kang, et al., 2002; Lazaar, et al., 2007; Meyer, et al., 2006; Owens, et al., 1999; Resaland, et al., 2011; Walther, et al., 2009). Body composition, and in particular body fat percentage, significantly decreased on average by 3 to 15% in exercise interventions of 4 months (Ferguson, et al., 1999; Owens, et al., 1999), 8 months (Gutin, et al., 2002; Kang, et al., 2002), 9 months (see Figure 2.4; Carrel, et al., 2005) and 10 months (Barbeau, et al., 2007; Howe, et al., 2011). For example, Walther et al. (2009) notably reduced the prevalence of children classified as overweight or obese from 13% to 7% following their one year exercise intervention. Contradictory to short-term interventions, this length of intervention appears to be highly successful in reducing fasting insulin levels as evident in exercise programmes of 4 months (see Figure 2.2; Ferguson, et al., 1999; Gutin et al., 1999), 6 months (Meyer, et al., 2006) and 9 months (Carrel, et al., 2005; Chang, et al., 2007). On average, these studies produced a reduction in fasting insulin levels by 10 to 37%; triglyceride (6, 8 and 9 months) and glucose (9 months) concentration levels were also improved (see 2.5.2 Metabolic Markers). Cardiorespiratory fitness, in particular $\dot{V}O_2$peak, increased by 2 to 29% in 4-month (Ferguson, et al., 1999; Gutin, et al., 1999), 8-month (Gutin, et al., 2002; Kang, et al., 2002), 9-month (see Figure 2.1; Carrel, et al., 2005) and 10-month interventions (Barbeau, et al., 2007; Howe, et al., 2011), and a 3% decrease in submaximal heart rate was observed after 4 months of exercise training (Ferguson, et al., 1999).

Diverse outcomes on the effect of exercise interventions on body fat percentage, fasting insulin, fasting glucose, triglycerides and submaximal heart rate are evident in the literature. Research of four (Ferguson, et al., 1999), eight (Kang, et al., 2002) and nine months (Carrel, et al., 2005) in duration failed to improve fasting glucose concentrations which directly contradicts the study by Chang et al. (2007) mentioned above. Likewise more prolonged exercise interventions also failed to have any beneficial effect on insulin (Kang, et al., 2002), triglycerides (Ferguson, et al., 1999; Walther, et al., 2009), body fat percentage (Chang, et al., 2007) and submaximal heart rate (Gutin & Owens, 1999). Consequently, in the reviewed studies the length of the programme does not appear to be a decisive factor to improve body composition, and physiological variables in children and adolescents. More importantly, the frequency, duration, intensity and type of exercise interventions may be considered more pertinent factors in improving the health and fitness of children and adolescents.

2.8. Exercise prescription and programming

2.8.1. Exercise frequency

In the research reviewed no more than 5 exercise sessions were implemented each week, regardless of the length of the exercise intervention (Table 2.1 & 2.2), and 3 or 5 sessions per week were most frequently implemented (~ 32% & 35% of literature reviewed in this thesis). Research studies that incorporated 5 sessions per week into their training programme found an improvement in $\dot{V}O_2$peak (Barbeau, et al., 2007; Gutin, et al., 2002; Kang, et al., 2002), submaximal $\dot{V}O_2$ (McManus, et al., 2005), fasting insulin (Ferguson, et al., 1999; Gutin, et al., 1999) and body fat percentage (Barbeau, et al., 2007;

Gutin, et al., 2002; Gutin, et al., 1995; Gutin & Owens, 1999; Howe, et al., 2011; Kang, et al., 2002; Owens, et al., 1999). In overweight or obese children and adolescents, body fat percentage was shown to decrease, while an increase in fat free mass was evident; occasionally this occurred irrespective of a change in total body mass (Barbeau, et al., 2007; Gutin, et al., 2002; Gutin, et al., 1995; Howe, et al., 2011; Kang, et al., 2002; Owens, et al., 1999).

Interestingly, similar findings in $\dot{V}O_2$peak (Baquet, et al., 2002; Walther, et al., 2009), fasting insulin (Meyer et al., 2006), and fat-free mass (6.4% increase; Lazaar, et al., 2007) were observed when fewer exercise sessions (2-3) were implemented each week. Baquet et al. (2003) concluded that only 2 sessions per week may be needed to improve $\dot{V}O_2$peak in children and adolescents (Baquet et al., 2003). Based on this information, conclusive recommendations for the number of training sessions per week required to produce beneficial effects on body composition and physiological responses in children and adolescents are lacking. As such other relevant factors may be more efficacious in physical activity interventions.

2.8.2. Exercise duration

Of the reviewed studies, the duration of the training sessions ranged from 18 minutes (Baquet, et al., 2010) to 90 minutes (Chang, et al., 2007). Over half (~ 54%) of the research studies were 30 or 40 minutes in duration (Ferguson, et al., 1999; Howe, et al., 2012; Kang, et al., 2002; Owens, et al., 1999; Park, et al., 2012; Walther, et al., 2009). The remaining research employed exercise durations of 20 minutes or less (~11%; Baquet, et al., 2010; McManus, et al., 2005; Walther, et al., 2009), 50 minutes (~7%; Hansen, et al., 1991; Resaland, et al., 2011) 60 minutes (~21%; Baquet, Berthoin, Gerbeaux, & Van Praagh, 2001; Bell, et al., 2007; Lazaar, et al., 2007; Meyer, et al., 2006; Stergioulas, et al., 1998; Watts, et al., 2004) or greater than 60 minutes (~7%; Barbeau, et al., 2007; Howe, et al., 2011). Difficulties were however encountered when calculating the exercise duration of certain studies due to a lack of methodological information (Barbeau, et al., 2007; Howe, et al., 2011; Lazaar, et al., 2007; Meyer, et al., 2006; Nassis, et al., 2005; Park, et al., 2012; Resaland, et al., 2011; Watts, et al., 2004). In these aforementioned studies, although total exercise time was reported (40 – 80 minutes), the actual time children and adolescents were physically active was not noted. For example, although Watts et al. (2004) reported 60-minute exercise sessions, pre- and post-stretching and the time to deliver exercise instructions were included within this period of time.

The exercise interventions that did include sessions between 30 and 40 minutes (the ACSM (2013) recommendation for structured physical activity) established positive results in body weight (2%), BMI (3 - 5%) body fat percentage (2 - 15%), fat free mass (3 - 6%), maximal and submaximal exercise responses ($\dot{V}O_2$peak [5 -11%], heart rate [4 - 5%]) and fasting insulin (10 - 37%), fasting glucose (23%) and triglycerides (6 - 31%; Baquet et al., 2010; Baquet, et al., 2002; Carrel, et al., 2005; Ferguson, et al., 1999; Gutin, et al., 1995; Gutin & Owens, 1999; Kang, et al., 2002; Owens, et al., 1999; Park, et al., 2012). In addition, a literature review by Baquet et al., (2003) on the effect of exercise training in enhancing $\dot{V}O_2$peak in children and adolescents demonstrated that exercise durations from 30 minutes to 1 hour were the most efficacious.

2.8.3. Exercise intensity

Heart rate, as expressed as an absolute value (Barbeau, et al., 2007; Chang, et al., 2007; Ferguson, et al., 1999; Gutin & Owens, 1999; Howe, et al., 2011; Meyer, et al., 2006; Nassis, et al., 2005; Watts, et al., 2004) or as a proportion of a maximal value (%HRmax; Bell et al., 2007; Gutin, et al., 1995; Lazaar, et al., 2007; McManus, et al., 2005; Owens, et al., 1999; Park, et al., 2012), are most frequently used to prescribe exercise intensity in children and adolescent studies. When prescribing exercise based on absolute heart rate, intensities greater than 150 $b \cdot min^{-1}$(Barbeau, et al., 2007; Ferguson, et al., 1999; Gutin, et al., 2002; Howe, et al., 2011; Nassis, et al., 2005), or between 140 and 180 $b.min^{-1}$ (Chang, et al., 2007; Meyer, et al., 2006; Watts, et al., 2004) have typically been used. When expressed as a %HRmax intensities have ranged from 50 to 85 % (Bell, et al., 2007; Gutin, et al., 1995; McManus, et al., 2005; Owens, et al., 1999; Park, et al., 2012). As absolute heart rates are not individualised to the participant, it is difficult to categorize the prescribed intensities as either low-, moderate- or high- intensity in these aforementioned studies. Alternatively, other studies have prescribed exercise based on percentage of $\dot{V}O_2peak$ (55 - 80%; Gutin, et al., 2002; Kang, et al., 2002; McManus, et al., 2005) and as a percentage of maximal aerobic velocity (80 - 190 %; Baquet, et al., 2002; Baquet, et al., 2001; Baquet, et al., 2010; Baquet, et al., 2004).

Furthermore, some research studies do not state the intensities prescribed within their physical activity intervention (Carrel, et al., 2005; Hansen, et al., 1991; Howe, et al., 2012; Kalak, et al., 2012; Walther, et al., 2009). The main protocol of these studies was to provide supplementary exercises to their everyday scheduled or habitual physical activity. For example, Hansen et al. (1991) applied three additional ordinary physical education lessons per week to the exercise intervention children and Howe et al. (2012) included structured and enjoyable games to the exercise intervention children during ordinary recess time. Consequently, these research studies cannot be included in this particular section as the intensity has not been clearly identified.

Both moderate and high-intensity exercises elicit favourable changes in body composition, cardiorespiratory fitness and blood lipids, yet, verifying whether one is more advantageous than the other can be problematic. The influence of moderate and high intensity exercise on cardiovascular fitness ($\dot{V}O_2$peak, $\dot{V}O_2$-170- [$\dot{V}O_2$ at heart rate of 170 b.min^{-1}]), body composition (%BF, fat-mass, VAT, subcutaneous abdominal adipose tissue), insulin resistance markers (Insulin glucose, LDL, HDL, VLDL, TC, TG etc) and habitual exercise (moderate, vigorous – using 7-day recalls) in obese adolescents, established superior effects of the high-intensity protocol in most of the aforementioned variables (Gutin, et al., 2002; Kang, et al., 2002). Baquet et al. (2003) considers the intensity to be a key factor in a training design and an intensity higher than 80 %HRmax is required to improve $\dot{V}O_2$peak. In addition, high intensity exercise may be more appealing to children as it more closely reflects that of their habitual physical activity (see 2.4 for further discussion) and therefore enhances adherence (Gutin, 2008). However a combination of both intensity (moderate versus high) and type (intermittent versus continuous) of exercise protocols need to be considered collectively. This is especially relevant if the aim is to reflect the nature of children's habitual physical activity (typically high- intensity and intermittent).

2.8.4. Exercise type

Continuous type protocols account for the vast majority of the exercise interventions employed in this thesis review. Beneficial improvements in body composition, submaximal and maximal exercise parameters and blood lipid profiles have been demonstrated following the prescription of continuous, aerobic based (i.e. cycling, running etc) exercise protocols (Gutin, et al., 1995; Kalak, et al., 2012; McManus, et al., 2005; Stergioulas, et al., 1998). Similar findings have been observed following continuous circuit type training (exercise including 1 minute cycle followed by 1 minute resistance exercises non-stop; Bell, et al., 2007) and after regular participation in physical education classes or other game sessions (Barbeau, et al., 2007; Hansen, et al., 1991; Howe, et al., 2012; Howe, et al., 2011; Lazaar, et al., 2007; Nassis, et al., 2005; Resaland, et al., 2011; Walther, et al., 2009; Watts, et al., 2004). These sessions incorporated lessons on skills, technique, coordination and predominantly sports games. To date, treadmill, cycle, cross trainer and sports games have been most frequently used modalities to prescribe continuous exercise. (Ferguson, et al., 1999; Gutin, et al., 2002; Gutin & Owens, 1999; Owens, et al., 1999).

Fewer studies have implemented an intermittent exercise protocol, with running and cycle sprints being the most common form of high-intensity exercise (Baquet, et al., 2002; Baquet, et al., 2001; Baquet, et al., 2010; Baquet, et al., 2004; McManus, et al., 2005). Baquet et al. (2010) compared continuous and interval aerobic running training on cardiovascular fitness in children and found that both protocols were equally effective in improving $\dot{V}O_2$peak (5% & 7%, respectively) and maximum aerobic velocity (7% & 8%, respectively). However, McManus et al. (2005) established that high-intensity interval training may elicit a greater change in the ventilatory threshold and oxygen pulse than continuous exercise. This has been supported by a brief investigation which established that children found intermittent cycling more reinforcing, motivating and stimulating than continuous at exercise intensities above and below the ventilatory threshold (see 2.4 for further discussion; Barkley, et al., 2009). It is possible that children have unique characteristics of muscle metabolism (see 2.4 for a list of these characteristics) thus increasing their ability to perform repeated bouts of short duration, high-intensity physical activity (Barkley, et al., 2009). Additionally, children's habitual activity is more closely correlated to interval training than continuous (see 2.4 for further information). It has been recognized that activities need to be age-appropriate, as such, younger children prefer games that involve stop and go movements rather than exercising on machines at constant loads (Gutin, 2008). This again may promote adherence and reduce participant dropout from the exercise intervention. It has been speculated that high-intensity intermittent exercise is better suited to the transitory nature of children's habitual physical activity and therefore is more efficient at improving their cardiorespiratory system (Baquet, et al., 2010). In addition, intermittent training improves both the central (cardiac output) and peripheral (arteriovenous difference, capillary density, oxidative enzymes) components of $\dot{V}O_2$peak (Baquet, et al., 2010).

2.9. Demographics information

2.9.1. Gender

In adults, differences between males and females during exercise are evident (Ariens, van Machelen, Kemper, & Twisk, 1997; Helgerud, Storen, & Hoff, 2010). It is suggested that these variations are in part due to a lower haemoglobin content (Daniels, Krahenbuhl, Foster, Gilbert, & Daniels, 1977) and smaller cardiac output in females compared to males (Woo, Derleth, Stratton, & Levy, 2006). This therefore decreases their oxygen carrying capacity and cardiac function. However, as there is no evidence to suggest that male and female children respond differently to exercise interventions, it is suggested that physiological gender differences are not yet present in prepubertal children (Rowland et al., 1997).

The majority of the literature reviewed here included both male and female participants in their exercise programme (see table 2.1 & 2.2). Several studies completed preliminary statistical analysis and established no gender effect (Baquet, et al., 2002; Baquet, et al., 2010; Baquet, et al., 2004; Gutin, et al., 2002; Kang, et al., 2002; Owens, et al., 1999). When results were presented separately between boys and girls, significant differences were not apparent in $\dot{V}O_2$peak, blood pressure and habitual moderate-vigorous physical activity, upon completion of the exercise intervention (Hansen, et al., 1991; Howe, et al., 2012; Resaland, et al., 2011). Pre-pubertal boys and girls have relatively little variation in muscle mass and as such, it is not surprising that when $\dot{V}O_2$peak is expressed relative to body weight that no differences are revealed (Rowland, et al., 1997). Given the limited evidence, gender does not appear to be a key factor in the influence of an exercise intervention in children and adolescents.

2.9.2. Body weight

As demonstrated in table 2.1 and 2.2, overweight or obese children (BMI $\geq$ 25 kg·m^2; BMI percentile $\geq$ 85%; $\geq$ 32 %BF) and adolescents responded in a similar manner to exercise interventions as normal weight children (BMI 18.5 – 24.9 25 kg·m^2; BMI percentile 5 – 85%; 14 – 31 %BF), with improvements in $\dot{V}O_2$peak, (Carrel, et al., 2005; Gutin, et al., 2002; Kang, et al., 2002; Park, et al., 2012; Walther, et al., 2009) submaximal heart rate (Gutin, et al., 1995; Nassis, et al., 2005; Owens, et al., 1999), body fat percentage (Barbeau, et al., 2007; Carrel, et al., 2005; Gutin, et al., 2002; Gutin, et al., 1995; Gutin & Owens, 1999; Howe, et al., 2011; Kang, et al., 2002; Owens, et al., 1999), body weight (Park, et al., 2012), BMI (Gutin, et al., 1995; Meyer, et al., 2006; Park, et al., 2012), fat free mass (Howe, et al., 2011; Owens, et al., 1999), VAT (Gutin, et al., 2002; Kang, et al., 2002), fasting insulin (Carrel, et al., 2005; Chang, et al., 2007; Meyer, et al., 2006), fasting glucose (Chang, et al., 2007), triglycerides (Chang, et al., 2007; Kang, et al., 2002; Meyer, et al., 2006), and endurance performance (Chang, et al., 2007) observed.

During exercise (treadmill walking/running) overweight or obese children elicit a higher $\dot{V}O_2$peak or proportion of their $\dot{V}O_2$peak compared to their normal weight counterparts (Goran et al., 2000). The greater body weight, higher body fat percentage and reduced muscle tone in overweight and obese children elicits a higher $\dot{V}O_2$ response due to an elevated demand for ATP (Katch, Becque, Marks, Moorehead, & Rocchini, 1988). However, both the normal weight and overweight or obese children elicit a similar improvement in $\dot{V}O_2$peak (5 - 11%) following regular exercise participation (Baquet, et al., 2002; Carrel, et al., 2005; McManus, et al., 2005; Park, et al., 2012). In addition, both normal weight and overweight or obese children equally, improved their habitual moderate-vigorous physical activity upon completion of the games-based exercise intervention (Howe, et al., 2012). From the literature reviewed, submaximal heart rate appears to only be improved in studies that included overweight or obese participants (Bell, et al., 2007; Ferguson, et al., 1999; Owens, et al., 1999) with no significant changes in the normal weight counterparts (Baquet, et al., 2002; McManus, et al., 2005). It is possible that the initially high cardiorespiratory fitness level of the normal weight children impaired the likelihood of further improvements, compared to the overweight or obese children (Baquet, et al., 2002). The body weight status (i.e. normal weight cf. overweight/obese) of children and adolescents does not appear to be a limiting factor to the beneficial effects of an exercise intervention on cardiorespiratory fitness.

As expected, overweight or obese children and adolescents produce advantageous modifications in body composition measures after participation in an exercise programme. Meyer et al. (2006) reported that obese children in the exercise intervention group (3 x 1 hour exercise sessions per week for six months, see table 2.1 & 2.2 for further information) obtained significant improvements in BMI (9%), waist-to-hip ratio (6%), fasting insulin (19%), insulin resistance (21%), TG (28%), LDL (5%), fibrinogen (9%) and C-reactive protein (58%), compared to obese control and lean control children. Similar findings were observed by Kang et al. (2002). The magnitude of these observed changes most likely corresponds to physical activity reducing fat stores (TG), increasing glycogen synthase and GLUT-4 protein and improving muscle capillary density to a greater extent in obese subjects (see 2.5.2 for further information; Taylor, et al., 2004). As mentioned by Lazaar et al. (2007) physical activity positively enhances fat oxidation and fat balance through the promotion of a decline in fat mass and maintenance of lean mass.

2.9.3. Ethnicity

Limited research has assessed the influence of ethnicity on body composition and the physiological responses to an exercise intervention. Only 5 studies considered the effect ethnicity may have on the responses to an exercise intervention (Ferguson, et al., 1999; Gutin, et al., 2002; Gutin & Owens, 1999; Kang, et al., 2002; Owens, et al., 1999). Kang et al. (2002) is the only study that revealed differences between African-American and Caucasian adolescents following an exercise intervention. It was shown that the Caucasian children had significantly higher change in scores for VLDL cholesterol and the African-American adolescents had significantly higher scores for insulin levels (Kang, et al., 2002). The remainder of these studies included participants who were classified as

Caucasian, African-American or Asian. However, preliminary statistical analysis did not draw any inference concerning the differences in ethnicity. Although research is required to assess the effect of an exercise intervention on physiological markers in different ethnicities this area of interest will not be examined in the present thesis.

2.10. Rationale

Given the current evidence on children's habitual physical activity (see 2.4 for further discussion), only a few studies have incorporated high-intensity interval protocols into their interventions (Baquet, et al., 2002; Baquet, et al., 2001; Baquet, et al., 2010; McManus, et al., 2005). However, these studies have largely employed structured running and cycling sprint training (i.e. 7 x 30 second maximal sprints on a cycle ergometer) and have failed to consider the 'fun' aspect or the attractiveness of the exercise programme to the children or adolescents (Baquet, et al., 2004; Gutin, 2008). Of the studies that have incorporated games into their exercise intervention (and as such considered the enjoyment factor of the programme with this population), the majority have based their interventions on skills, sport specific games, and have been continuous and aerobic in nature (Barbeau, et al., 2007; Howe, et al., 2011; Lazaar, et al., 2007; Nassis, et al., 2005; Watts, et al., 2004). Yet, this fails to represent the features of children's habitual physical activity as largely intermittent with short bursts of vigorous activity, as reported by Bailey et al. (1995). Howe et al. (2012) is currently the only study thus far to consider an exercise intervention that included child specific games. The intervention utilized structured enjoyable games during recess and the main focus was to increase aspects of habitual moderate-vigorous physical activity, as such other measures (i.e. $\dot{V}O_2$peak, %BF, blood lipids) were not included in their analysis. Nevertheless, there still appears to be a lack of amalgamation between exercise interventions that include high-intensity intermittent protocols and child specific games. The enjoyment of an activity has been reported as the most important factor affecting participation in physical activity among children (Howe, et al., 2012), and yet, most interventions have not considered the enjoyment of activities that have been implemented. Exercise programmes also need to be age-appropriate for the given population as this will not only enhance the attractiveness of the programme but will also create conditions for progress and enhanced motivation (Baquet, et al., 2010). This is of particular importance if the overall aim of the exercise intervention is to improve body composition in overweight or obese children, as this will increase adherence and the likelihood of continual participation in this particular behaviour (Barkley, et al., 2009). Accordingly, the study team considered a short term intervention of approximately 6 weeks, as potentially more favourable at maintaining motivation, enjoyment and adherence during the exercise intervention.

2.10.1. Purpose

Therefore the primary purpose of this study was to assess the effect of a high-intensity games- based exercise intervention that is specifically designed for children (i.e. child-specific games) on the physiological responses in both normal weight and obese children.

2.10.2. Hypotheses

- Children randomised to the exercise intervention would elicit significantly greater improvements in the maximal and submaximal physiological responses then those randomised to the control group.

- Improvements in the maximal and submaximal physiological responses would occur irrespective of body weight status (i.e. normal weight cf. overweight or obese)

3. Methods

3.1. Participants

Fifty five children, aged 8-10 years, volunteered to take part the study. Participants were recruited from two schools in the Wellington region. All children were asymptomatic of illness, disease and pre-existing injuries, as assessed by a standardised health screening questionnaire, which was completed by parents or guardians (appendix A). Prior to participation, parent or guardian provided informed consent (appendix B) and child assent (appendix C) was obtained. This research was conducted in agreement with the guidelines and policies of the Massey University Human Ethics Committee: Southern A (appendix D).

Children and their parents or guardians completed a Physical Activity Questionnaire (appendix E). All children participated in Physical Education lessons on Tuesday afternoons (approximately 1.30pm) for 1 hour. These sessions typically involved sports games and skill development.

3.2. Procedure

All participants took part in 4 laboratory-based exercise sessions (pre [pre-INT] & post intervention [post-INT]); 2 maximal graded exercise tests (GXT) to volitional exhaustion ($\dot{V}O_2$peak) and 2 sub-maximal exercise protocols, within a thermoneutral environment (21.1 ± 1.8 °C; 36.8 ± 4.6 % [humidity]; 755.4 ± 6.2 mmHg [air pressure]).The initial session consisted of anthropometric measures. Standing and seated stature, was measured to the nearest 0.1cm (SECA scales, Hamburg, Germany), while body mass, fat-free mass (FFM), muscle mass (MM; all to the nearest 0.1kg), body fat percentage (%BF) and basal metabolic rate (BMR) were all measured using a bioelectrical impedance analyser (InBody Biospace 230, Los Angeles, USA). In accordance with the ACSM (2013) participants' waist, hip, forearm, biceps, quadriceps and calf girth measures were also taken (Lufkin W606PM, Apex Tools Group, Maryland, USA), all on the right side of the body. During the initial session participants completed a GXT (pre-INT) to maximal functional capacity on a motorized treadmill (True 825, Fitness Technologies, St Louis, USA). Measures peak oxygen uptake ($\dot{V}O_2$peak), peak heart rate (HRpeak), minute ventilation ($\dot{V}_E$), respiratory exchange ratio (RER), speed achieved at peak, and the ratings of perceived exertion (RPE), were taken to gain peak physiological, physical and perceptual values.

Following a minimum 48-hour recovery from the initial laboratory-based GXT (test 1) participants completed a sub-maximal exercise test (test 2). The sub-maximal exercise protocol required the participants to complete two individually determined exercise intensities (jog, run) for 6 minutes interspersed with a 5 minute recovery bout. Following these 2 exercise tests participants were randomly allocated to either an exercise intervention (EX) or to a control (CON) group. The exercise intervention was 2 x 40 minute sessions of discontinuous exercise in the form of child-specific game activities for 6 weeks. These sessions were scheduled outside of the children's normal Physical Education (P.E.) lessons and were therefore considered as supplementary exercise. Upon completion of the exercise programme (~3-4 days), participants completed post-intervention (post-INT) assessments. This incorporated a follow-up GXT (post-INT) to maximal functional capacity (test 3) and a submaximal exercise test (test 4). These testing procedures were identical to test 1 and test 2. The CON group continued to attend their weekly P.E classes, but no additional exercise sessions were included.

In accordance with Jones and Doust (1996), the treadmill belt for all laboratory-based exercise tests was set at 1% gradient. On-line respirtatory gas analysis was measured via a breath-by-breath automatic gas exchange system (Sensormedics, USA). Volume and gas calibration was performed prior to the exercise tests in accordance with manufacturer's guidelines. Repeated measures were implemented to produce a 1% error against the known concentration of gases (4% carbon dioxide, 16% oxygen). During all of the exercise sessions (test 1, 2, 3 and 4) a paediatric facemask was worn to allow respiratory variables ($\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}_E$ & RER) be recorded throughout the exercise tests. A paediatric wireless chest strap telemetry system (Polar Electro T31, Kempele, Finland) was used to record heart rate throughout all exercise tests.

3.2.1. Graded exercise test to $\dot{V}O_2$peak (test 1 & 3)

Prior to commencement of the first GXT (test 1), all participants were familiarised to a range of treadmill speeds (4 $km \cdot h^{-1}$, 6 $km \cdot h^{-1}$ & 8 $km \cdot h^{-1}$), and the testing equipment (facemask, heart rate monitor etc.). Children were encouraged to walk or run on the treadmill until they felt comfortable and the lead researcher was confident with their ability. The GXT to maximal functional capacity followed a discontinuous incremental protocol similar to Lambrick et al. (2011) to ascertain $\dot{V}O_2$peak and peak heart rate (HRpeak). Children commenced the test at 4 $km \cdot h^{-1}$ (walk) for one minute. The treadmill speed was then slowed to a stop to allow a 1 minute recovery, before increasing again to a speed of 6 $km \cdot h^{-1}$ for a further one minute. A one minute recovery was implemented following each minute of active exercise. Speed was increased by 1 $km \cdot h^{-1}$ until a speed of

8 km·h^{-1} was accomplished. Thereafter, running speeds were increased by 0.5 km·h^{-1} (8.5, 9, 9.5, 10, 10.5 km·h^{-1} etc) until volitional exhaustion (see Figure 3.1).

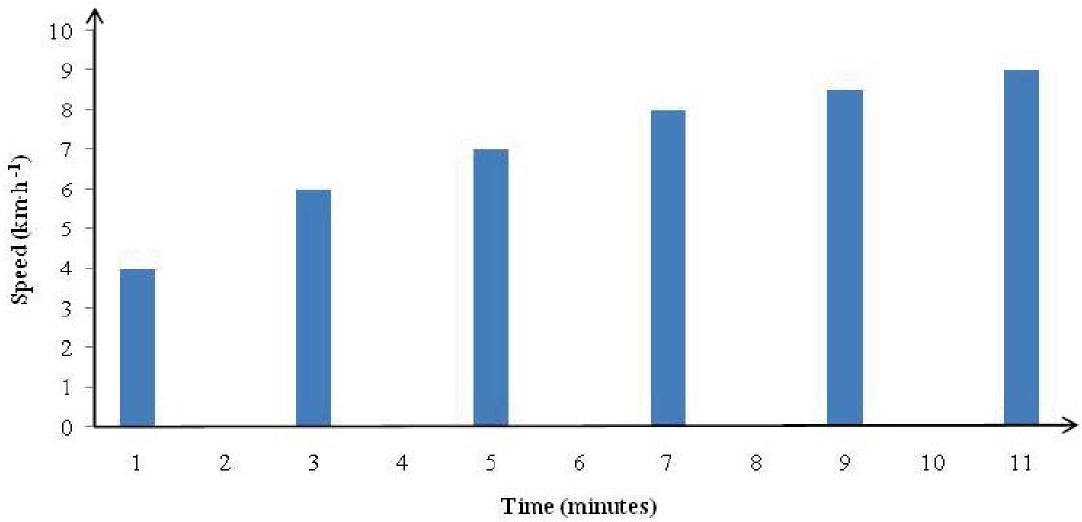

Figure 3.1 Example of the GXT discontinuous protocol

The GXT test was used primarily to determine each child's $\dot{V}O_2$peak, peak speed and ventilatory threshold (VT). A discontinuous protocol has been suggested to be more effective in eliciting maximal levels of exertion in children, perhaps because it may reflect the intermittent activity pattern of children's play (Eston & Parfitt, 2007). Criteria for test termination was based on volitional exhaustion, a HR max of 200 b·min^{-1} and RER $\geq$ 1.00. A plateau in $\dot{V}O_2$, or subsequent increase in $\dot{V}O_2 < 2.1$ ml·kg^{-1}·min^{-1} in the final stage of exercise test was typically not obtained due to the discontinuous procedure (Barker, Boreham, van Praagh, & Rowlands, 2009). Research has suggested that two criteria are substantial when determining $\dot{V}O_2$max and $\dot{V}O_2$peak in children (Carrel, et al., 2005; Figueroa-Colon et al., 2000; Howe, et al., 2011). The GXT enabled the calculation of appropriate relative exercise intensities for the submaximal exercise tests (test 2 and 4).

3.2.2. Calculation of VT and 40% delta

The V-slope method (Beaver, Wasserman, & Whipp, 1986) was used to analyse the slopes of $\dot{V}O_2$ and $\dot{V}CO_2$ volume curves from the initial GXT to determine the running speed equivalent with VT. As the determination of the lactate threshold in children can be problematic, VT was used as it is a non-invasive procedure and provides an estimation of the lactate threshold (Barker, et al., 2009). Using the $\dot{V}O_2$ values reported at VT and $\dot{V}O_2$peak, the running speed equivalent to 40% delta (difference between VT and $\dot{V}O_2$peak) was calculated (Figure 3.2). This was used to reflect the upper limit of heavy intensity, steady state exercise (Carter, Pringle, Jones, & Doust, 2002; Williams, Dekerle, McGawley, Berthoin, & Carter, 2008) and ensured that participants were exercising at an equivalent physiological intensity. The VT and 40% delta exercise intensities (i.e. running speeds) were verified by three independent researchers and were used for the subsequent exercise economy test.

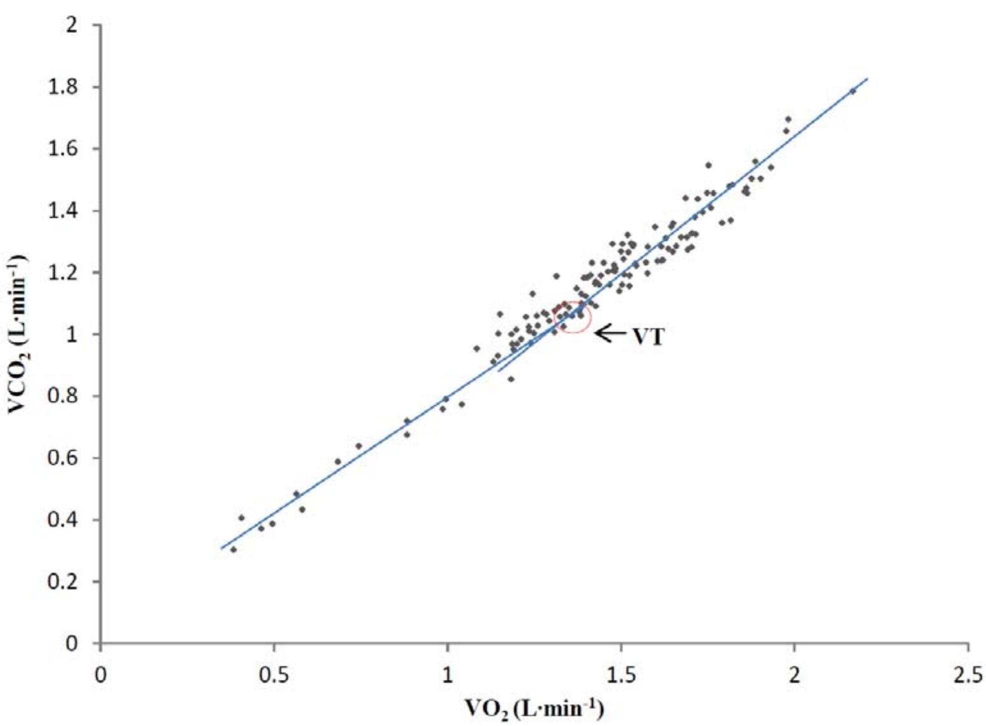

Figure 3.2. Example of the V slope method used to determine VT

3.2.3. Submaximal exercise test (test 2 & 4)

Following the GXT, participants returned to Massey University and completed submaximal exercise test at a moderate and heavy exercise intensity. This protocol included a warm-up at 4 km·h^{-1} (walk), and speeds equivalent to VT (moderate) and 40% delta (heavy) which were ascertained from the GXT. Prior to exercise, resting measures for $\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}_E$, RER and HR were obtained for five minutes. Participants ran for six minutes at each intensity to ensure that the oxygen cost for a given running speed would be at a steady-state oxygen consumption (Figueroa-Colon, et al., 2000). A five minute recovery period was implemented between each exercise bout (see figure 3.3).

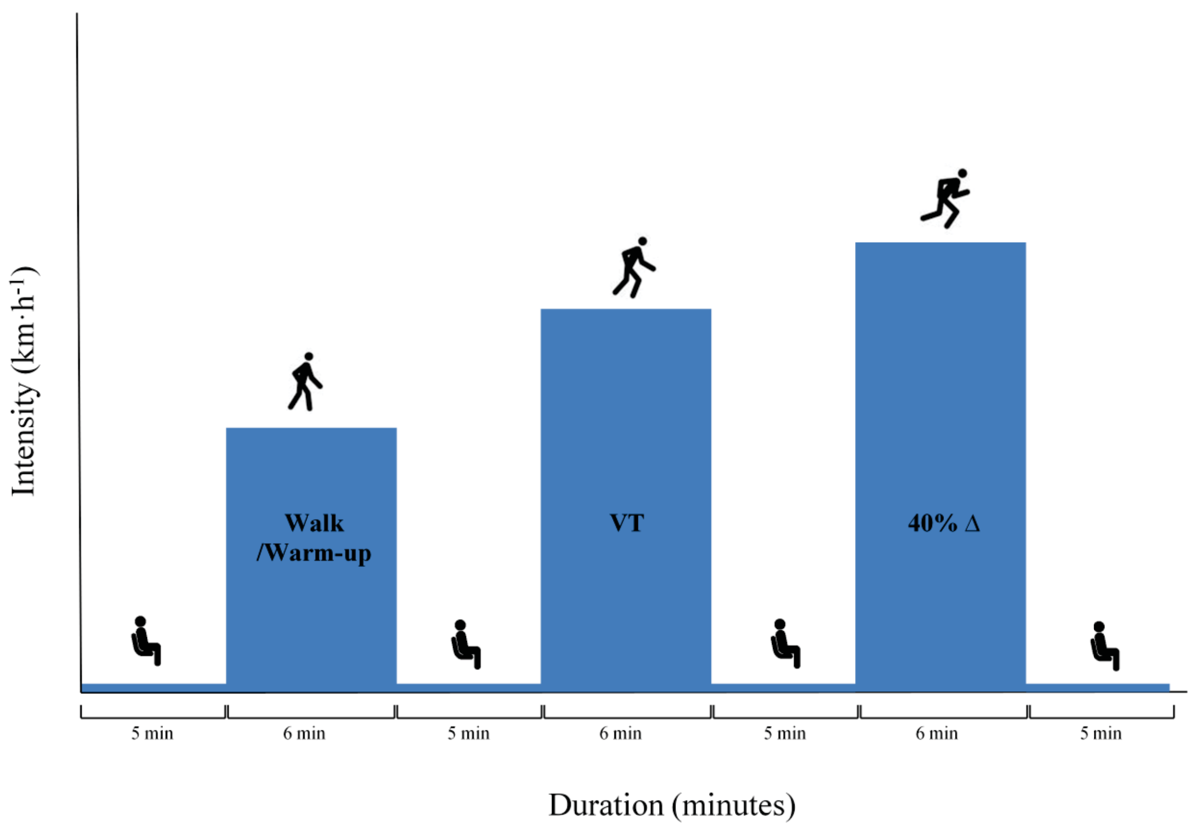

Figure 3.3 Schematic diagram of the submaximal exercise protocol

3.2.4. Perception of exertion

During the laboratory-based exercise session, individual's subjective perception of exertion (RPE) was determined upon completion of each stage using the Eston- Parfitt (E-P) scale (appendix I). The E-P scale is a curvilinear 0-10 scale suggested to be more familiar and appropriate to children than the Borg 6-20 scale often used for adults (Eston, Lambrick, & Rowlands, 2009). The E-P scale employs pictorial cues to produce a curvilinear relationship between RPE and exercise intensity. All physical and physiological outputs were concealed from the participants. In addition, during the exercise intervention, RPE values were obtained upon completion of a 6-minute games session (further detail see 3.2.6).

3.2.5. Randomisation

Children were assigned randomly to either an exercise (EX) or control (CON) group. Randomization was also stratified by bodyweight to ensure and even representation of normal weight (NW) and overweight or obese (OB) children in both the EX and CON groups. Twenty eight children were randomized into an EX group (9.3 ± 0.9 y, 1.40 ± 0.10 m, 41.0 ± 12.4 kg, 20.5 ± 4.4 kg·m^2) and 27 children into a CON group (9.3 ± 0.8 y, 1.40 ± 0.09 m, 39.0 ± 11.3 kg, 19.5 ± 4.1 kg·m^2). BMI percentiles were used to categorize children into an appropriate body weight status (Cole, Bellizzi, Flegal, & Dietz, 2000). Participants were categorized as being in either a normal weight (5th to <85th), overweight (> 85th) or obese (≥95th percentile) condition (C.D.C. 2013; Cole, et al., 2000). Mean (± SD) BMI percentiles were reported for the EX group (NW: 52.1 ± 23.4% & OB: 94.7 ± 3.1%. respectively) and for the CON group (NW: 54.7 ± 23.8% & OB: 92.1 ± 5.2%, respectively). Ethnic diversity was evident in both the EX and the CON groups (table 4.1).

3.2.6. Exercise intervention

The participants in the exercise intervention group completed a supervised high-intensity, child specific, discontinuous games programme for 6 weeks. This included 2 sessions per week scheduled outside of their normal Physical Education lessons (as mentioned previously). The exercise sessions were programmed for 90 minutes, and children spent approximately 40 minutes of that time in physical activity. Sessions were undertaken at the local schools, as a school-based exercise intervention is viewed as a key environment for implementing physical activity strategies in children (Howe, et al., 2012; Wang, et al., 2008). In addition, structured physical activity sessions are associated with higher levels of physical activity and lower sedentary levels in children (Van Cauwenberghe, et al., 2012).

To date, accurate representation on the most effective exercise intervention length (i.e. 7 weeks to 2 years) is yet to be concluded (as mentioned in 2.6.1 & 2.6.2). Research has revealed that exercise interventions lasting 7 weeks are advantageous in improving $\dot{V}O_2$peak in children, but little is known about interventions of 6 weeks in length. As such, this study implemented a child-specific games based exercise intervention for 6 weeks. After a 2 week pilot study and collaboration with the Physical Education teacher at the local school, a protocol of 6 minutes of active exercise followed by 2 minutes of recovery was implemented, in accordance with previous literature (Barbeau, et al., 2007; Howe, et al., 2012; Howe, Freedson, Feldman, & Osganian, 2010; Howe, et al., 2011). Within each exercise session, different games were used for each 6-minute exercise period to increase motivation, enjoyment, adherence, and to ensure children took part in each game at a high-intensity. The 2-minute recovery period was used to provide instructions concerning the proceeding game activity. In addition, a child-specific circuit was implemented for a total of 4 minutes, this included the following exercises: ladder running, step-ups, skipping, star jumps, hopscotch hoops, zig zag, high knees, shuttle runs, jumping jacks (similar to jump squats) and lateral jumps. A total of 14 games were completed throughout the 6-week intervention. Most of these are similar to those previously utilized in Howe et al., (2010) and include: Rob the nest, couple tag, dodgers and markers, modified dodgeball, Simpson game, poison tag, tail tag, octopus, rats and rabbits, corners, stuck in the mud, scatter ball, keep the bucket full and monsters (see appendix F for more details of these games). Throughout the exercise intervention HR was continuously recorded using a Polar $Team_2$ system (POLAR, Oulu, Finland). Refer to appendix G for the heart rate values for each exercise session during the intervention. Upon completion of the physical activity intervention a questionnaire was employed to determine whether the children enjoyed and gained any benefit from their participation in the intervention (appendix H).

3.3. Data analyses

3.3.1. $\dot{V}O_2$ values used in statistical analysis

In accordance with previous research (Volpe Ayub & Bar-Or, 2003), submaximal $\dot{V}O_2$ values were reported as the net difference in $\dot{V}O_2$ between the actual $\dot{V}O_2$ reported during VT and 40% delta, and the resting $\dot{V}O_2$ values reported prior to each exercise intensity. This was expressed in both $L \cdot min^{-1}$ and $mL \cdot kg^{-1} \cdot min^{-1}$. The $\dot{V}O_2$, $\dot{V}_E$, HR and running speed during VT and 40% delta were also expressed as a proportion of their peak values (%$\dot{V}O_2$peak, %$\dot{V}_E$peak, %HRpeak, peak running speed, respectively).

3.3.2. Statistical analysis

A series of independent sample t-tests were used to compare pre-INT anthropometric variables (i.e. stature, body mass, % BF) between EX and CON groups. Levene's test for equality of variance was used to assess the variance in values between conditions. A similar analysis was conducted to compare anthropometric markers at pre-INT for OB (EX vs. CON) and NW (EX vs. CON) participants.

A series of 3-factor repeated measures ANOVA; Test (pre-INT, post-INT) x Condition (EX, CON) x Weight (OB, NW) were used to compare $\dot{V}O_2$peak, HRpeak, $\dot{V}_E$peak RER, RPE and running speed from the GXT to maximal functional capacity. A similar analysis was applied to compare physiological, physical and perceptual markers from the moderate (VT) and heavy (40% delta) intensity sub-maximal exercise tests. In the preceding analyses, if Mauchly's test of sphericity was violated a Greenhouse-Geisser correction factor was employed. Where a significant interaction was located, a Tukeys honestly significant difference (HSD) test was implemented. The Tukeys HSD calculates the minimum raw score mean difference that must be attained to declare significance between any two groups (Vincent, 1999). Alpha was set at 0.05. All data was analysed using the statistical package SPSS for windows, PC software, version 20.0.

4. Results

4.1. Physical activity status

Prior to participation in the exercise programme parents or guardians rated their child's physical activity levels as excellent (16%), very good (34%), good (30%) and fair (16%). The most common physical activities reported by the children included swimming (22%), walking (14%), soccer (11%), netball (8%), bike riding (7%), running (7%) and rugby (7%). Activity sessions were typically of 30 minutes (32%) and 60 minutes (36%) in duration.

4.2. Participant descriptives

Participants' characteristics are presented in table 4.1. Excluding the waist-to-hip ratio ($t_{(53)} = -2.4$, $P < .05$), there were no significant differences for all other anthropometric variables between the EX and CON groups at the pre-INT assessment ($P > .05$). Similar findings were revealed when comparing anthropometric markers for NW participants between EX and CON groups, and for OB participants ($P > .05$).

When comparing OB and NW children, seated stature, body mass weight, BMI percentile, hip, waist, all girth measures, muscle mass, fat mass and BMR, were all higher for OB children ($P < .05$; see appendix J).

Table 4.1. Descriptives for Exercise (EX) group and Control (CON) group at pre-intervention (pre-INT)

		Exercise Group			Control Group		
		NW	**OB**	**Total**	**NW**	**OB**	**Total**
Gender (n)		8 M, 5 F	10 M, 5 F	18 M, 10 F	9 M, 7 F	3 M, 8 F	12 M, 15 F
Age (years)		9.2 ± 0.7	9.3 ± 1.0	9.3 ± 0.9	9.2 ± 0.8	9.4 ± 0.8	9.3 ± 0.8
Ethnicity	European	5	5	10	7	1	8
	Maori	0	1	1	3	3	6
	Pacific Island	2	6	8	4	4	8
	African	4	1	5	1	3	4
	Asian	1	0	1	1	0	1
	Middle Eastern	1	2	3	0	0	0
Stature (cm)		136.7 ± 9.7	143.3 ± 9.2	140.3 ± 9.9	138.2 ± 8.3	143.6 ± 8.7	140.4 ± 8.7
Seated Stature (cm)		116.3 ± 4.6	120.8 ± 4.1	118.7 ± 4.8	117.2 ± 4.3	120.3 ± 4.9	118.6 ± 4.7
Body mass (kg)		31.2 ± 5.7	48.9 ± 11.0	40.7 ± 12.5	32.0 ± 5.5	46.7 ± 11.2	37.9 ± 11.0
BMI ($kg \cdot m^2$)		16.9 ± 1.7	23.7 ±3.6	20.5 ± 4.4	17.0 ± 1.5	23.2 ± 3.8	19.5 ±4.1
BMI Percentile (%)		52.1 ± 23.4	94.7 ± 3.4	74.9 ± 26.8	54.7 ± 23.8	92.1 ± 5.2	70.0 ± 26.2
Body fat (%)		16.8 ± 5.7	33.7 ± 7.1	25.9 ±10.7	18.0 ± 6.1	30.4 ±8.6	23.1 ± 9.4
Muscle Mass (g)		13.4 ± 3.2	16.6 ± 3.4	15.0 ± 3.6	13.2 ± 2.4	17.7 ± 3.0	14.9 ± 3.4
Fat Mass (g)		4.8 ± 1.8	15.9 ± 5.9	10.6 ± 7.1	5.5 ± 2.2	15.9 ± 7.6	9.4 ± 7.0
Basal Metabolic Rate (calories/day)		930 ± 115	1044 ± 125	989 ± 131	925 ± 85	1083 ± 107	984 ± 120
Hip (cm)		66.1 ± 7.1	82.9 ± 9.4	75.1 ± 11.9	69.2 ± 5.6	81.6 ± 9.7	74.3 ± 9.7
Waist (cm)		57.2 ± 4.3	73.2 ± 10.2	65.8 ± 11.3	56.1 ± 5.1	70.8 ± 10.2	62.0 ± 10.4
Waist:Hip Ratio		0.87 ± 0.06 †	0.88 ± 0.06	0.88 ± 0.06*	0.81 ± 0.04	0.87 ± 0.08	0.83 ± 0.06
Forearm (cm)		18.6 ± 1.6	22.1 ± 2.3	20.5 ± 2.7	19.4 ± 1.6	22.1 ± 2.5	20.5 ± 2.4
Biceps (cm)		19.3 ± 1.8	25.0 ± 3.0	22.4 ± 3.8	19.9 ± 2.0	24.4 ± 2.8	21.7 ± 3.2
Quadriceps (cm)		36.7 ± 4.0	46.6 ± 5.6	42.0 ± 7.0	38.8 ± 4.4	46.4 ± 5.0	41.9 ± 6.0
Calf (cm)		26.8 ± 3.1	32.5 ± 3.7	29.9 ± 4.4	27.4 ± 2.2	33.1 ± 3.3	29.7 ± 3.9

*Significant difference between EX and CON groups at pre-INT ($P < .05$)

† Significant difference between EX and CON group participants at the pre-INT ($P < .05$)

4.3. Graded exercise test

4.3.1. Peak running speed

There was a significant test main effect for peak running speed ($F_{(1,51)} = 6.2$, $P < .05$), with a higher value reported post-INT compared to pre-INT (11.7 ± 1.6 vs. 11.4 ± 1.7 $km \cdot h^{-1}$, respectively). There was also a Test by Condition interaction ($F_{(1,51)} = 7.0$, $P < .01$). Post-hoc analysis using Tukeys HSD demonstrated a greater change (increase) in peak running speed between pre-INT and post-INT during the GXT for children in the EX compared to CON group (Table 4.2). However, following a significant Test by Condition by Weight status interaction for the peak running speed ($F_{(1, 51)} = 6.1$, $P < .01$), Tukeys HSD only revealed a significant change in speed during the GXT between pre-INT and post-INT for NW participants randomised to the EX group ($P < .01$; Figure 4.1). Furthermore, post-hoc analysis revealed the post-INT running speed for the NW EX group to be significantly higher than all other conditions ($P < .01$; Figure 4.1).

Table 4.2. Pre- and post- INT results from GXT for Exercise (EX) group and Control (CON) group

	Exercise Group			**Control Group**		
	Pre	**Post**	**Total**	**Pre**	**Post**	**Total**
Speed ($km \cdot h^{-1}$)	11.3 ± 1.6	11.9 ±1.6*~	11.6 ±1.5	11.4 ± 1.6	11.4 ± 1.6	11.4 ±1.6
Heart rate ($b \cdot min^{-1}$)	197 ± 11	197 ± 13	197 ±11.2	196 ± 11	196 ± 11	196 ± 11
VO_2peak ($L \cdot min^{-1}$)	2.0 ± 0.4	2.2 ± 0.4	2.1 ± 0.4	2.2 ± 0.4	2.3 ± 0.5	2.3 ± 0.4
VO_2peak ($ml \cdot kg \cdot min^{-1}$)	51.4 ± 8.5	53.2 ± 9.4	52.7 ± 6.6 +	57.7 ± 9.3	57.8 ± 8.0	56.9 ± 6.7
V_E ($L \cdot min^{-1}$)	62.0 ± 15.0	66.4 ± 14.9	63.7 ± 13.7	64.9 ± 15.2	69.0 ± 19.8	68.4 ± 16.5
RER	0.91 ± 0.05	0.93 ± 0.05	0.92 ± 0.05	0.89 ± 0.06	0.90 ± 0.06	0.90 ± 0.05
RPE (E-P)	8.9 ± 2.0	8.9 ± 1.7	8.9 ± 2.2	8.1 ± 2.9	8.0 ± 2.9	8.1 ± 2.2
Stride frequency	95 ± 6	95 ± 7	95 ± 6	94 ± 7	94 ± 7	93 ± 6

*Significant interaction between EX and CON groups at pre-INT and post-INT ($P < .05$)

~ Significant interaction between Test, Condition and Weight status ($P < .05$)

+ Between Condition (EX vs. CON) main effect ($P < .05$)

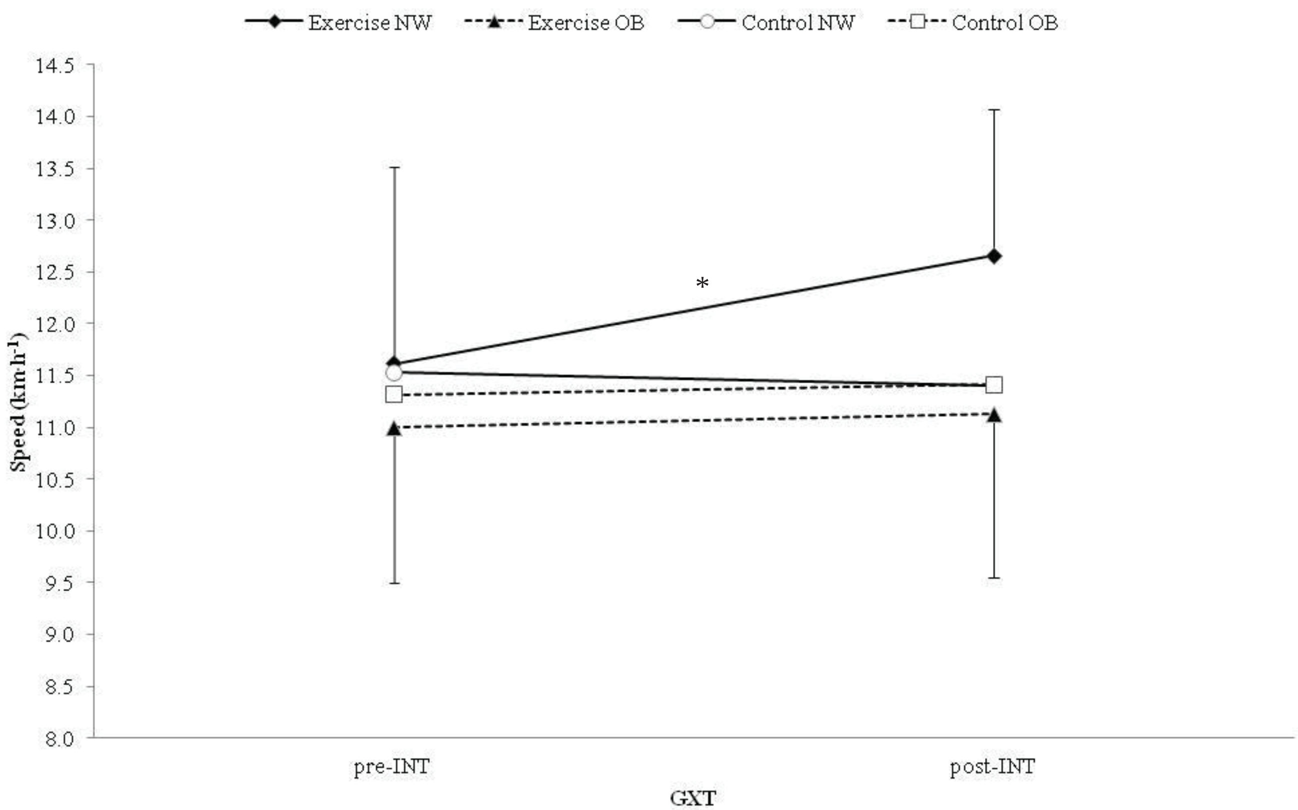

Figure 4.1 Pre- and post-INT peak running speed from GXT between Condition (EX, CON) and Weight status groups (NW, OB)

*Significant interaction between Test, Condition and Weight status (*P* < .05). Rate of change in running speed for the NW EX significantly different than all other groups.

4.3.2. $\dot{V}O_2$ peak ($L \cdot min^{-1}$ & $mL \cdot kg^{-1} \cdot min^{-1}$)

A significant Test main effect (pre-INT vs. post-INT) for the GXT was reported for $\dot{V}O_2$peak (2.1 ± 0.4 vs. 2.2 ± 0.3 $L \cdot min^{-1}$, respectively; $F_{(1,51)}$ = 13.1, P < .01). A main effect for Weight status was revealed for both absolute ($F_{(1,51)}$ = 18.4, P < .001) and relative ($F_{(1,51)}$ = 32.0, P < .001) $\dot{V}O_2$peak. A significantly higher absolute $\dot{V}O_2$peak was revealed for OB children (2.4 ± 0.6 vs. 2.0 ± 0.5 $L \cdot min^{-1}$, respectively), although a higher relative $\dot{V}O_2$peak was observed for NW children (59.9 ± 6.7 vs. 49.7 ± 6.7 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively). A Condition main effect was also established for relative $\dot{V}O_2$peak ($F_{(1,51)}$ =

5.3, *P* < .05; Table 4.2). The $\dot{V}O_2$peak was significantly lower in the EX group compared to the CON group.

There were no Test by Condition, Test by Weight status or Test, by Condition by Weight status interaction for both absolute and relative $\dot{V}O_2$peak (both *P* > .05; table 4.2).

4.3.3. $\dot{V}_E$ ($L \cdot min^{-1}$)

A significant Test main effect (pre-INT vs. post-INT) was observed for maximal $\dot{V}_E$ (63.8 ± 13.9 vs. 68.2 ± 16.0 $L \cdot min^{-1}$, respectively; $F_{(1,51)} = 10.0$, $P < .05$). A Weight status main effect was also seen ($F_{(1,51)} = 17.8$, $P < .001$), with a higher maximal $\dot{V}_E$ for OB compared to NW children (73.9 ± 13.8 vs. 58.2 ± 13.7 $L \cdot min^{-1}$, respectively). There was no main effect for Condition (*P* > .05).

There were no Test by Condition, Test by Weight status or Test, by Condition by Weight status interaction for $\dot{V}_E$ (*P* > .05; Table 4.2).

4.3.4. *Heart rate*

There were no main effects (Test, Condition, Weight status) or Test by Condition, Test by Weight status or Test by Condition by Weight status interactions for heart rate (all *P* > .05; Table 4.2).

4.3.5. RER

There were no main effects (Test, Condition, Weight status) or Test by Condition, Test by Weight status or Test by Condition by Weight status interactions for RER (all $P > .05$; Table 4.2).

4.3.6. RPE

There were no main effects (Test, Condition, Weight status) or Test by Condition, Test by Weight status or Test by Condition by Weight status interactions for RPE (all $P > .05$; Table 4.2).

4.3.7. Stride frequency

A Weight status main effect was observed for stride frequency ($F_{(1,51)} = 11.6$, $P < .01$). The OB children had a lower stride frequency compared to the NW children (92 ± 6 vs. 97 ± 6, respectively).

There were no other main effects (Test, Condition) or Test by Condition, Test by Weight status or Test by Condition by Weight status interactions for stride frequency (all $P > .05$; Table 4.2).

4.4. Submaximal exercise test: Moderate intensity (VT)

4.4.1. Physiological

A significant Test main effect was only revealed for %$\dot{V}O_2$peak ($F_{(1,50)} = 5.3$, $P < .05$) and %$\dot{V}_E$max ($F_{(1,50)} = 5.0$, $P < .05$). A significant decline between pre-INT and post-

INT was observed for both %$\dot{V}O_2$peak (63 ± 10 vs. 60 ± 10, respectively) and %$\dot{V}_E$max (77 ± 12 vs. 73 ± 11 %, respectively). A Test by Condition interaction was established for absolute and relative $\dot{V}O_2$ (L·min^{-1}; mL·kg^{-1}·min^{-1}), %$\dot{V}O_2$peak (%), $\dot{V}_E$ (L·min^{-1}) and %$\dot{V}_E$ max (all $P < .05$). Each of the aforementioned physiological variables were lower post-INT compared to pre-INT for the EX group (table 4.3).

A main effect for Weight status was also established for $\dot{V}O_2$ (L·min^{-1}; mL·kg^{-1}·min^{-1}) and $\dot{V}_E$ (all $P < .05$). On average OB children elicited a higher $\dot{V}_E$ (55.0 ± 10.0 vs. 42.9 ± 9.9 L·min^{-1}, respectively) and absolute $\dot{V}O_2$ (1.5 ± 0.3 vs. 1.2 ± 0.3 L·min^{-1}, respectively), but a lower relative $\dot{V}O_2$ (31.2 ± 5.2 vs. 35.8 ± 5.1 mL·kg^{-1}·min^{-1}, respectively) than NW children. There were no Test by Weight status, or Test by Condition by Weight Status interactions for all physiological markers (all $P > .05$).

4.4.2. Physical

Although a Test main effect was observed for the running speed at VT between the pre- and post-INT (7.9 ± 0.8 vs. 8.2 ± 0.8 km·h^{-1}, respectively; $F_{(1,50)} = 17.1$, $P < .001$), when expressed in proportion (%) to the peak running speed from the GXT, there were no differences (70 ± 6 vs. 71 ± 6 %, respectively; $F_{(1,50)} = 0.4$, $P > .05$). ANOVA also revealed a Test by Condition interaction for the running speed at VT ($F_{(1,50)} = 7.5$, $P < .05$). As demonstrated in Table 4.3 a significant increase in the running speed (between pre-INT and post-INT) was only observed for the EX group. However, when expressed as a proportion of maximal running speed, a Test by Condition interaction was not observed ($P > .05$; Table 4.3).

There were no further main effects (Condition or Weight status) or interactions (Test by Weight status, Test by Condition by Weight status) for absolute and relative running speeds (all $P > .05$). However, when considering the stride frequency at VT, a Weight status main effect was established ($F_{(1,50)} = 9.2$, $P < .05$), with NW children eliciting a higher stride frequency compared to their OB counterparts (92 ± 8 & 86 ± 8, respectively). There were no further main effects or interactions for stride frequency (all $P > .05$).

Table 4.3. Submaximal exercise test at VT for pre-INT and post-INT between EX and CON groups

	Exercise Group			Control Group		
	Pre	**Post**	**Total**	**Pre**	**Post**	**Total**
Speed (km·h^{-1})	7.8 ± 0.9	8.2 ±0.8*	8.0 ±0.8	8.0 ± 0.8	8.1 ± 0.8	8.1 ±0.8
% peak Speed	70 ± 6	70 ± 5	70 ± 5	71 ± 5	72 ± 7	71 ± 5
Heart rate (b·min^{-1})	181 ± 12	182 ± 15	181 ±13	180 ± 14	179 ± 14	180 ± 13
% HRpeak	92 ± 5	92 ± 4	92 ± 5	92 ± 6	91 ± 6	92 ± 5
VO_2 (L·min^{-1})	1.3 ± 0.4	1.2 ± 0.3 *	1.2 ± 0.3 +	1.3 ± 0.3	1.4 ± 0.4	1.4 ± 0.3
VO_2 (ml·kg·min^{-1})	32.8 ± 6.4	30.1 ± 6.6 *	31.7 ± 5.1 +	34.9 ± 5.1	36.1 ± 5.8	35.3 ± 5.2
%VO_2peak	64 ± 11	57 ± 10*	61 ± 8	61 ± 7	63 ± 9	63 ± 9
V_E (L·min^{-1})	48.0 ± 12.5	45.2 ± 10.1*	46.2 ± 9.9 +	48.9 ± 11.0	52.7 ± 14.2	51.9 ± 10.0
%$V_E$peak	78 ± 14	69 ± 11*	74 ± 10	76 ± 9	77 ± 11	76 ± 10
RER	0.96 ± 0.04	0.94 ± 0.06	0.95 ± 0.04	0.93 ± 0.03	0.93 ± 0.05	0.93 ± 0.04
RPE (E-P)	5.5 ± 2.6	4.7 ± 2.5	5.1 ± 1.8 +	4.0 ± 1.9	3.8 ± 2.0	4.0 ± 1.8
Stride frequency	90 ± 11	90 ± 8	90 ± 8	88 ± 9	88 ± 8	87 ± 8

*Significant interaction between EX and CON groups at pre-INT and post-INT ($P < .05$)

+ Between Condition (EX vs. CON) main effect ($P < .05$)

4.4.3. Perceptual

ANOVA revealed a significant Condition ($F_{(1,50)}$ = 5.0, *P* < .05; Table 4.3) and Weight status ($F_{(1,50)}$ = 4.8, *P* < .05) main effect for the RPE. As demonstrated in table 4.3, EX group elicited a higher perception of exertion compared to CON group. With regards to Weight status, the OB children reported a higher RPE at VT than the NW children (5.0 ± 0.3 vs. 4.0 ± 0.3, respectively). There were no further main effects or interactions for RPE (all *P* > .05).

4.5. Submaximal exercise test: Heavy intensity (40% delta)

4.5.1. Physiological

A Test main effect was only revealed for %$\dot{V}O_2$peak ($F_{(1,50)}$ = 7.1, *P* < .05), %$\dot{V}_E$max ($F_{(1,50)}$ = 5.3, *P* < .05). A significantly lower value was observed during the post-INT for %$\dot{V}O_2$peak (73 ± 8 vs. 70 ± 9 %, respectively), and %$\dot{V}_E$max (93 ± 13 vs. 89 ± 14%, respectively). A Condition main effect was also reported for both absolute and relative $\dot{V}O_2$ (L·min^{-1}; mL·kg^{-1}·min^{-1}), %$\dot{V}O_2$peak, $\dot{V}_E$ (L·min^{-1}; all *P* < .05; Table 4.4), with a lower value established for EX compared to the CON group. Similar to the moderate intensity domain, a significant Test by Condition interaction was revealed for both absolute and relative $\dot{V}O_2$ (L·min^{-1}; mL·kg^{-1}·min^{-1}), %$\dot{V}O_2$peak (%) and $\dot{V}_E$ (L·min^{-1}), %$\dot{V}_E$max (%; *P* < .05). Each of the aforementioned physiological variables were lower post-INT compared to the pre-INT for the EX children (table 4.4).

A main effect for Weight status was also revealed for $\dot{V}O_2$ (L·min^{-1}; mL·kg^{-1}·min^{-1}) and $\dot{V}_E$ (L·min^{-1}; *P* < .05). On average OB children elicited a higher $\dot{V}_E$ (67.4 ± 13.5 vs.

52.5 ± 13.4 L·min^{-1}, respectively) and absolute $\dot{V}O_2$ (1.7 ± 0.3 vs. 1.4 ± 0.3 L·min^{-1}, respectively), but a lower relative $\dot{V}O_2$ (36.0 ± 5.1vs. 41.8 ± 5.1 mL·kg^{-1}·min^{-1}, respectively) than NW children during the heavy intensity exercise. Interestingly, a Test by Weight status interaction ($F_{(1,50)}$ = 6.1, P < .05) demonstrated a significantly greater reduction in %$\dot{V}O_2$peak between pre- and post-INT for OB (75 ± 8 vs. 69 ± 9%, respectively) compared to NW children (71 ± 8 vs. 70 ± 9 %, respectively; Figure 4.2).

A Test by Condition by Weight status interaction was only revealed for $\dot{V}_E$ ($F_{(1,50)}$ = 4.4, P < .05). As demonstrated in Figure 4.3, despite no changes in $\dot{V}_E$ for NW children (EX and CON) between pre- and post-INT, OB children within EX group lowered their $\dot{V}_E$ while OB children within CON increased their $\dot{V}_E$ between assessments.

Table 4.4. Submaximal exercise test at 40 % delta for pre-INT and post-INT between EX and CON groups

	Exercise Group			**Control Group**		
	Pre	**Post**	**Total**	**Pre**	**Post**	**Total**
Speed (km·h^{-1})	9.4 ± 1.0	9.9 ±1.1*	9.7 ±1.0	9.8 ± 1.0	9.8 ± 1.0	9.7 ±1.0
% peak Speed	84 ± 5	84 ± 5 ~	84 ± 5	86 ± 5	86 ± 7	86 ± 5
Heart rate (b·min^{-1})	194 ± 10	196 ± 11	195 ±10	197 ± 11	198 ± 10	198 ± 11
%HRpeak	98 ± 3	100 ± 4	99 ± 4	101 ± 4	101 ± 5	101 ± 4
VO_2 (L·min^{-1})	1.5 ± 0.4	1.4 ± 0.3 *	1.4 ± 0.3 +	1.6 ± 0.4	1.7 ± 0.4	1.7 ± 0.3
VO_2 (ml·kg·min^{-1})	36.9 ± 5.7	34.4 ± 6.9 *	35.9 ± 5.1 +	41.9 ± 5.7	42.8 ± 6.0	41.9 ± 5.1
%VO_2peak	72 ± 9	65 ± 9*	69 ± 7 +	74 ± 8	75 ± 8	74 ± 7
V_E (L·min^{-1})	56.6 ± 13.7	53.3 ± 12.0*~	54.5 ± 13.5 +	61.2 ± 15.1	66.6 ± 22.3	65.3 ± 13.5
%$V_E$peak	92 ± 16	81 ± 12*	87 ± 11	94 ± 9	96 ± 15	95 ± 12
RER	0.98 ± 0.05	0.97 ± 0.08	0.98 ± 0.05	0.96 ± 0.05	0.96 ± 0.06	0.96 ± 0.05
RPE (E-P)	7.3 ± 2.4	7.4 ± 2.8	7.3 ± 2.3	6.7 ± 2.7	7.1 ± 2.7	7.0 ± 2.3
Stride frequency	92 ± 7	93 ± 6	92 ± 5	92 ± 5	91 ± 5	91 ± 5

*Significant interaction between EX and CON groups at pre-INT and post-INT (P < .05)

~ Significant interaction between Test, Condition and Weight status (P < .05)

+ Between Condition (EX vs. CON) main effect (P < .05)

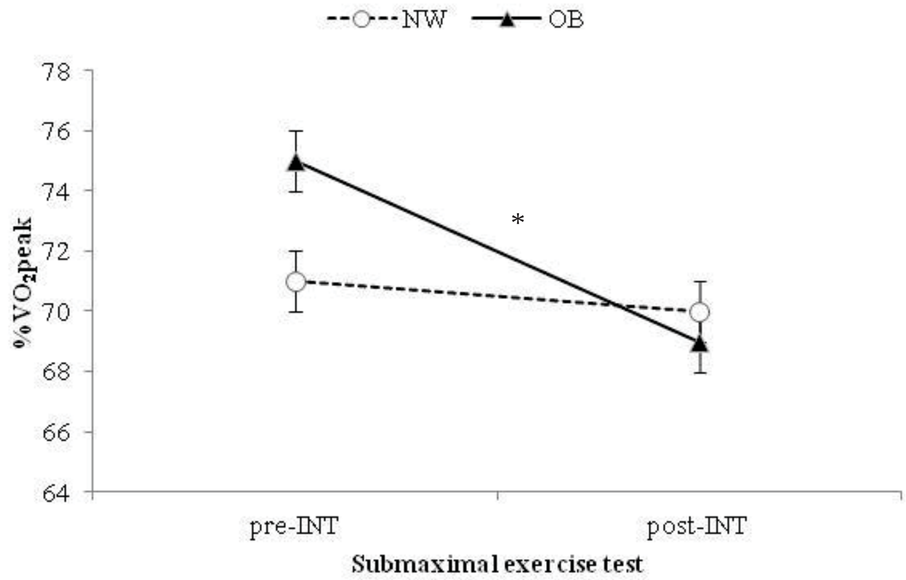

Figure 4.2 Percent $\dot{V}O_2$ at VT pre- and post-INT between NW and OB groups.

*Significant interaction between Test and Weight status (*P* < .05). A significant decrease in % $\dot{V}O_2$ for the OB children compared to the NW children.

4.5.2. Physical

Although a Test main effect was observed for the running speed at 40% delta between the pre- and post-INT (9.6 ± 1.0 vs. 9.8 ± 1.0 km·h^{-1}, respectively; $F_{(1,50)} = 18.4$, $P < .05$), when expressed in proportion (%) to the peak running speed from the GXT, there were no differences (85 ± 5 vs. 85 ± 6%, respectively; $F_{(1,50)} = 0.0$, $P > .05$). ANOVA also revealed a Test by Condition interaction for the running speed at 40 % delta ($F_{(1,50)} = 21.4$, $P < .05$). A significant increase in the running speed (between pre-INT and post-INT) was only observed for EX group (table 4.4) however, when expressed as a proportion of maximal running speed, a Test by Condition interaction was not observed ($P > .05$; Table 4.4).

Unlike VT, a Weight status main effect was observed at 40% delta ($F_{(1,50)} = 3.9$, $P < .05$), with NW children's heavy-intensity running speed being higher than OB (10.0 ± 1.0

vs. 9.5 ± 1.0 km·h^{-1}, respectively). Furthermore, when expressed as a proportion of maximal running speed, a Test by Condition by Weight status main effect was revealed ($F_{(1,50)}$ = 4.9, P < .05). As demonstrated in Figure 4.4, an increase in running speed was observed for both OB and NW children randomised to the EX group. However, when considering the stride frequency at 40% delta, a Weight status main effect was observed ($F_{(1,50)}$ = 5.4, P < .05), with NW children eliciting a higher stride frequency compared to their OB counterparts (94 ± 5 & 90 ± 5, respectively). There were no further main effects or interactions for stride frequency (all P > .05).

4.5.3. Perceptual

ANOVA revealed a significant Weight status main effect for RPE ($F_{(1,50)}$ = 5.7, P < .05). The OB children reported a higher RPE at 40% delta than the NW children (7.9 ± 2.3 & 6.4 ± 2.3 P < .05). There were no further main effects or interactions for RPE (all P > .05).

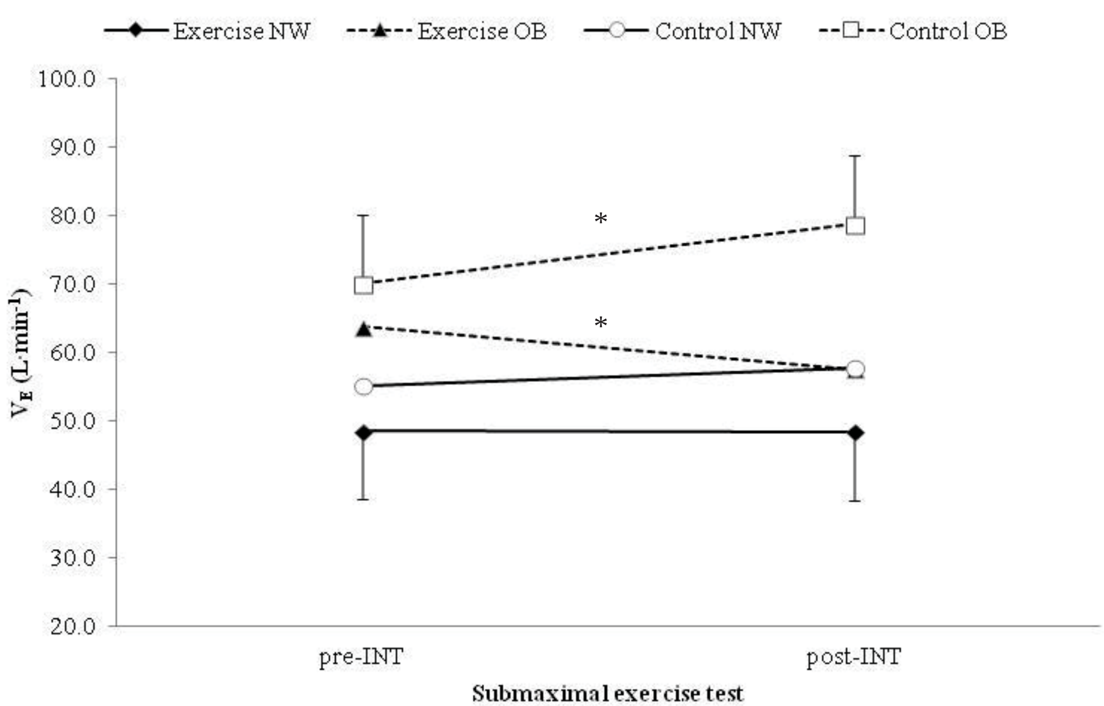

Figure 4.3 $\dot{V}_E$ during 40% delta between Condition (EX, CON) and Weight status (NW, OB) groups

*Significant interaction between Test, Condition and Weight status (P < .05). Rate of change for the OB EX (decrease) and OB CON (increase) significantly different than all other groups.

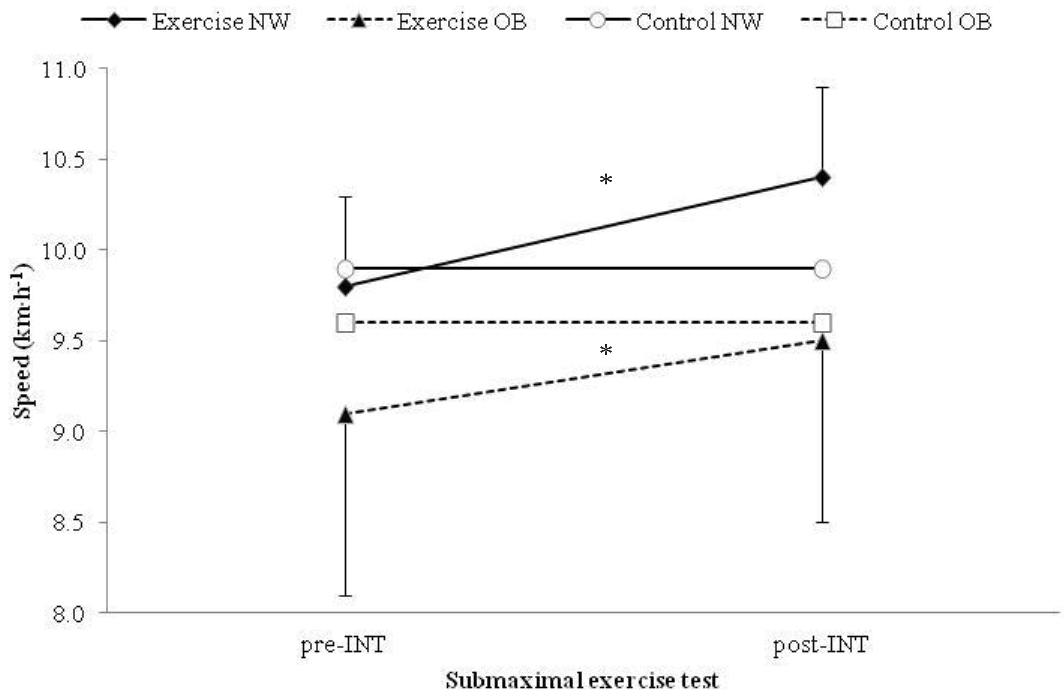

Figure 4.4 40% delta speed between Condition (EX, CON) and Weight status (NW, OB) groups

*Significant interaction between Test, Condition and Weight status (*P* < .05).Rate of change for the NW and OB EX group significantly different than all other groups

5. Discussion

The purpose of the present study was to determine the effect of a high-intensity games based exercise intervention on physiological responses in children aged 8 to 10 years. Of secondary importance, this study also assessed whether any observed changes in the aforementioned markers was moderated by body weight (normal weight [NW] vs. obese [OB]). In the present study, only the participants that were randomized to the EX group were able to run at a higher speed during the GXT to maximal functional capacity, and at both submaximal exercise intensities (moderate & heavy). Furthermore, with a lower $\dot{V}O_2$ also reported at the moderate and heavy exercise intensity domains for the EX group, this study has established that six weeks of exercise can improve a child's exercise efficiency. In addition, a greater reduction in oxygen consumption between pre- and post-INT was established for the OB children compared to their NW counterparts.

5.1. Exercise vs. Control group

5.1.1. GXT to maximal functional capacity

In the present study, the EX children significantly improved their peak running speed following participation in the 6-week exercise intervention. This finding occurred despite no changes in relative or absolute $\dot{V}O_2$peak or HRpeak. This strongly suggests an improvement in aerobic endurance capacity following participation in the exercise intervention, as the children could run for a longer duration of time (~10 min vs. ~12 min) and at a faster peak running speed. These findings appear to complement those reported by Baquet et al. (2002; 2010). In these studies, an exercise intervention of similar duration (7 week), led to significant increases in maximal aerobic velocity, irrespective of a change in maximal HR. However, unlike the present findings, these studies also reported an improvement in $\dot{V}O_2$peak following the exercise intervention. Regardless of this observation, the EX and CON groups in the current study, established greater pre-INT $\dot{V}O_2$peak values compared to previous literature (Baquet, et al., 2002; Baquet, et al., 2010). Furthermore, the post-INT $\dot{V}O_2$peak values for the EX and CON group were similar or greater (table 4.2) to those reported by Baquet et al. (2002; 2010) in children of similar age (53.6 ± 6.3, 54.1 ± 3.4 & 47.5 ± 7.2 $mL \cdot kg^{-1} \cdot min^{-1}$). Baquet et al. (2010; 2003) stated that an increase in $\dot{V}O_2$peak is unlikely in prepubertal individuals who may have an elevated level of aerobic fitness at the commencement of an exercise intervention. Therefore, the participants in the present study appear to be physically fitter than those in Baquet et al. (2010; 2003), and as such a statistical improvement in $\dot{V}O_2$peak may have been more difficult to obtain, particularly as a slightly shorter intervention (6 weeks) was implemented. In addition, an increase in the daily physical activity levels of children cannot be expected to substantially alter $\dot{V}O_2$peak as children generally have a high level of both physical activity and cardiorespiratory fitness (Resaland, et al., 2011). Although our 6-week intervention was unsuccessful at increasing $\dot{V}O_2$peak in children, a 10-week intervention in girls (7 – 11 years) also failed to have any positive influence on $\dot{V}O_2$peak (Gutin, et al., 1995). Overall, an improvement in aerobic fitness could be suggested by the overall increase in peak running speed observed in the EX children only.

It is also of interest to note that a similar HRpeak, RER and $\dot{V}_E$peak were observed pre- and post-INT, regardless of the exercise condition (EX, CON). The HR findings reported in this study are in accordance with previous research which has implemented either 7-week (Baquet, et al., 2002; Baquet, et al., 2010) or 8-week (McManus, et al., 2005) exercise interventions. McManus et al. (2005) reported comparable HRpeak values

(197 ± 5 & 193 ± 6 b·min^{-1} for pre and post assessments, respectively) upon completion of the exercise intervention as the current study. This finding suggests that exercise interventions less than 8 weeks are not likely to improve HRpeak in children (8-11 years). The only study to reveal an improvement in HRpeak was that of Walther et al. (2009) who implemented an exercise intervention for one year and established a significant increase in HRpeak of 4%. The physiological mechanism observed for the observed change in HRpeak warrants further investigation The reported findings for $\dot{V}_E$peak are in conjunction with other research implementing exercise interventions of 7 weeks (Baquet, et al., 2002; Baquet, et al., 2010), 8 weeks (McManus, et al., 2005) and 10 weeks (Gutin, et al., 1995). All of the aforementioned studies and the current research reported no significant change in $\dot{V}_E$peak following the exercise intervention.

5.1.2. Submaximal exercise test

Similar to the GXT, children in the EX group significantly increased their running speed at both a moderate and heavy intensity exercise. However, of particular interest, regardless of the condition (EX, CON), there were no differences in running speed when expressed as a proportion of maximum for the pre- and post-INT during the moderate (70 ± 6 vs. 71 ± 6 %, respectively) and heavy (85 ± 5 vs. 85 ± 6%, respectively) intensity exercise domains. This therefore indicates that the EX children were able to sustain a higher running speed at both the moderate (8.2 ± 0.8 km·h^{-1}) and heavy exercise intensities (9.9 ± 1.1 km·h^{-1}; yet remain in proportion to their maximum speed), thus indicating an overall improvement in cardiorespiratory fitness. Unlike the GXT, this finding occurred in combination with a decline in both the relative and absolute $\dot{V}O_2$ and %$\dot{V}O_2$peak during the moderate and heavy intensity exercise domains. Therefore, not only were the EX group running at a faster speed, they were also utilizing less oxygen in order to sustain the submaximal exercise (at moderate and heavy exercise intensities). The finding from the present study demonstrates that the EX group improved their exercise efficiency following participation in a 6-week child-specific intervention.

Of the reviewed studies, the influence of an exercise intervention has predominantly focused on $\dot{V}O_2$peak, and not submaximal $\dot{V}O_2$. Conflicting findings occur with the limited studies that measured submaximal $\dot{V}O_2$. Baquet et al. (2002) established no change in submaximal $\dot{V}O_2$; however, similar to the current study, %$\dot{V}O_2$peak significantly reduced following their exercise intervention. Alternatively, McManus et al. (2005) reported an increase in submaximal $\dot{V}O_2$, yet %$\dot{V}O_2$peak was not altered. The variations in the literature may be a product of training design (i.e. intensity, duration, frequency, type, length) or participant characteristics (age, weight, training status). Although an improvement in exercise efficiency is only based on inferences from a decline in submaximal $\dot{V}O_2$ and an increase in running speed at both moderate and high intensity exercise, this finding is supported by adult based literature (Beneke & Hutler, 2005; Franch, Madsen, Djurhuus, & Pedersen, 1998). For example, the improvements in exercise efficiency in this study support those reported by Franch et al. (1998). In their study they observed ~3 % improvement in running economy after 6 weeks of high intensity training due to a reduction in oxygen consumption at a given exercise intensity (12.3, 13.4 & 14.4 $km \cdot h^{-1}$). Furthermore, Ramsbottom et al. (1989) implies that an improvement in running efficiency irrespective of a change in $\dot{V}O_2$ max (similar to the present study) suggests that; "an increased rate of oxygen utilization reflected a greater oxidative degradation of metabolic substrates together with a slower rate of lactate production" (p. 171).

The observations in submaximal heart rate are in accordance with previous research. Both the present study and previous research have found no effect of the exercise intervention on altering submaximal HR in children (Baquet, et al., 2002; Gutin & Owens, 1999; McManus, et al., 2005; Resaland, et al., 2011; Watts, et al., 2004). Resaland et al. (2011), for example, reported no change in submaximal HR despite a significant improvement in running time to exhaustion following completion of their 2 year exercise intervention (5 x week). A few studies did report a decline in submaximal HR following their interventions (Ferguson, et al., 1999; Nassis, et al., 2005; Owens, et al., 1999). This indicates an improvement in cardiorespiratory fitness. However, as all participants in the aforementioned studies were obese, it is possible that initial cardiorespiratory fitness levels were lower. As the participants in the present study appear to have substantially higher levels of cardiorespiratory fitness compared to other research (mentioned previously), further improvements in submaximal HR are less expected.

A significant decline in submaximal $\dot{V}_E$ and $\%\dot{V}_E$max during both the moderate and heavy intensity exercise was only observed for the EX group. Adult based literature established a substantial decline in submaximal $\dot{V}_E$ following six weeks of high intensity exercise training (Franch, et al., 1998). This study found that exercise training decreased submaximal $\dot{V}_E$ by ~11 $L{\cdot}min^{-1}$. Interestingly, the OB children in the EX group significantly decreased their $\dot{V}_E$ between pre- and post-INT assessments (63.7 ± 5.8 vs. 57.5 ± 6.5 $L{\cdot}min^{-1}$, respectively; refer to figure 4.3), yet their CON counterparts had a significant increase in $\dot{V}_E$ (70.0 ± 6.1 vs. 78.7 ± 6.8 $L{\cdot}min^{-1}$, respectively; refer to figure 4.3). Similar to $\dot{V}O_2$, studies in the current literature review predominantly considered the effect of an exercise intervention on maximum $\dot{V}_E$. As such, comparisons of the literature concerning children are difficult to ascertain. The present study, although significant, reduced submaximal $\dot{V}_E$ by only 2.8 L·min^{-1} (moderate) and 3.3 L·min^{-1} (heavy). In children, participation in regular physical activity decreases resting $\dot{V}_E$ and improves exercise $\dot{V}_E$, thus leading to enhanced exercise efficiency (Baquet, et al., 2010). Franch et al. (1998) further suggests this finding as the decrements observed in $\dot{V}_E$ correlated with improvements in running economy, and may have accounted for 25-70% of the decrease in aerobic demand ($\dot{V}O_2$). This observation coincides with the findings of the present study.

Interestingly, the HR and $\dot{V}_E$ findings may be implicitly related. As the present study demonstrated no changes in peak HR following the exercise intervention, the observed improvement in exercise efficiency may in part be due to an increase in stroke volume, and as such, may be related to an improvement in cardiac output (Bassett & Howley, 2000). Although further research in to these cardiovascular responses following a short-term exercise intervention is necessary, it may be suggested that an increase in the ventilation perfusion ratio may underpin the improvements in exercise efficiency and the observed reduction in minute ventilation (Bassett & Howley, 2000).

The ratings of perceived exertion (RPE) were, on average, significantly higher in the EX children during the moderate exercise intensity only. This finding may be attributed to the greater exposure the EX group had with using the RPE scale. For example, during the exercise intervention (which occurred 2 time per week for 6 weeks), RPE was obtained upon completion of every game during the session, this accounted for approximately seven times per session. As such, the EX children were more familiar with the RPE scale and may better represent their perception of exertion compared to the CON children. This highlights the importance of familiarization to influence the accuracy of an individual's perception of exertion (Eston, et al., 2009).

5.2. Effect of body mass (NW vs. OB)

5.2.1. GXT

Findings in the present study established a significant increase in peak running speed for the NW children in the EX group. There were no overall differences in peak running speed between NW and OB children, nor was this altered by pre- and post-INT (figure 4.1). Aside from the NW EX children, this suggests that NW and OB children responded in a similar manner to the GXT. However, on average, the OB children demonstrated a significantly lower relative $\dot{V}O_2$peak and higher absolute $\dot{V}O_2$peak compared to NW children. This observation is in accordance with previous research that established an inferior oxygen consumption in overweight or OB children (Goran, et al., 2000; Marinov, Kostianev, & Turnovska, 2002; McMurray & Ondrak, 2011; Potter, et al., 2013). In the most recent study by Potter et al. (2013), the relative $\dot{V}O_2$ values between the NW and overweight children are both lower (NW: 43.8 ± 6.2 vs. Overweight: 35.9 ± 8.3 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively) than those reported in the current study (NW: 59.9 ± 6.5 vs. OB: 49.7 ± 6.7 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively). Comparable findings to the present study were also reported for McMurray et al. (2011), Marinov et al. (2002), and Goran et al. (2000). Although, the OB children in the current study had a lower $\dot{V}O_2$peak than the NW children, when expressed as $mL \cdot kg^{-1} \cdot min^{-1}$, it appears that the values established are higher than those reported in previous literature. As such, the OB children may have had established high cardiorespiratory fitness levels than most other overweight or OB populations.

The findings in HRpeak and RER are in conjunction with previous literature (Goran, et al., 2000). This study established no significant difference in HRpeak and RER between NW and OB children. This suggests that both the NW and OB children had a similar level of aerobic conditioning (Goran, et al., 2000). Marinov et al. (2002) supports this concept as it was reported that an elevated RER value in OB children constituted to a higher level of deconditioning and lower physical activity levels. As this was not evident in the present study it is plausible to suggest that the OB and NW children both retain comparable physical and aerobic conditioning levels.

The overall $\dot{V}_E$ of the OB children in the present study was significantly higher than the values reported for the NW children. Similar results were also established in Marinov et al. (2002) where considerably higher minute ventilation values were reported for OB when compared to their NW counterparts (62.7 ± 23.7 & 46.2 ± 15.6 $L{\cdot}min^{-1}$, respectively). It is suggested that the excess body mass observed in OB children leads to a less economical breathing pattern during exercise which contributes to a higher $\dot{V}_{E,}$ however this doesn't necessarily reflect a inferior cardiorespiratory fitness (Volpe Ayub & Bar-Or, 2003).

This present study reported that no noteworthy differences were established in the perception of exertion between NW and OB children during the GXT. Marinov et al. (2002) reported conflicting findings to the current literature, the OB children in their study produced enhanced RPE values in comparison to their NW counterparts (6.2 ± 1.2 vs. 5.2 ± 1.1, respectively). This again, may recognise the equivalent cardiorespiratory levels between NW and OB children.

5.2.2. Submaximal exercise test

For both relative (%) and absolute running speed, no differences were observed between NW and OB during submaximal exercise at a moderate and heavy intensity exercise domains. As all children were exercising at individually prescribed intensities (VT and 40% delta) that corresponded to specific metabolic markers (VT & $\dot{V}O_2$peak), the similarities in running speed between NW and OB children is of interest. This finding suggests that when appropriate intensities are prescribed for the individual (rather than pre-determined intensities used in most literature) OB children are able to exercise at comparable absolute running speeds to their NW counterparts. As such, we feel that the methodology used to compare OB and NW children in this study enables a more accurate and holistic interpretation of the effect that body mass may have on physiological responses to exercise.

Considering the aforementioned information, the OB children reported higher absolute $\dot{V}O_2$ values, yet lower relative values compared to their NW counterparts. This finding is in accordance with previous research that implemented set absolute exercise intensities (Ekelund, Franks, Wareham, & Aman, 2004; McMurray & Ondrak, 2011). While running at 8.0 km·h^{-1}, the overweight children elicited a higher absolute $\dot{V}O_2$ (1.1 ± 0.3 vs. 0.9 ± 0.2 L·min^{-1}, respectively) and lower relative $\dot{V}O_2$ (32.1 ± 5.3 vs. 35.4 ± 5.1 mL·kg·$^{-1}$min^{-1}, respectively) when compared to their NW counterparts (McMurray & Ondrak, 2011). As suggested previously, greater body weight, higher %BF, and reduced muscle tone in OB children produces a higher $\dot{V}O_2$ response and elevated demand in ATP (Katch, et al., 1988).

The present study also reported a increase in the %$\dot{V}O_2$peak values for the OB children pre-INT (figure 4.2). This finding is supported by McMurray and Ondrak et al. (2011), where the overweight children utilizing a higher %$\dot{V}O_2$max (4 – 6%) at all intensities compared to the NW children. Despite this result, upon completion of the physical activity intervention the OB children significantly decreased their %$\dot{V}O_2$peak, to comparable levels as the NW children (figure 4.2). The reduction in %$\dot{V}O_2$peak observed in the OB children is presumably created by those participants randomized to the EX group. The OB EX group reduced their %$\dot{V}O_2$peak values more than the OB CON group during both the moderate (EX: 66 ± 12 to 56 ± 10 % vs. CON: 64 ± 7 to 65 ± 7%, respectively) and heavy (EX: 75 ± 7 to 64 ± 7 % vs. CON: 76 ± 6 to 74 ± 5%, respectively) intensity exercise domains. This strongly suggests that participation in a physical activity intervention can improve cardiorespiratory indices of OB children.

Similar to the GXT, there were no apparent differences in submaximal HR between NW and OB children. A majority of studies have been ineffective in reducing submaximal HR following an exercise intervention (Baquet, et al., 2002; McManus, et al., 2005). Of the studies that have established a noteworthy reduction in submaximal HR (~3 to 4%), these have only included OB participants (Ferguson, et al., 1999; Nassis, et al., 2005; Owens, et al., 1999). As no variation was observed in the present study it could be suggested that the cardiorespirtatory fitness of the OB and NW children were comparable, and as such, no further reduction in HR could be observed with the OB children. The finding of the present study is not in conjunction with previous research. During an initial submaximal exercise test HR response was significantly higher in the OB children compared to their NW counterparts (Goran, et al., 2000; McMurray & Ondrak, 2011; Volpe Ayub & Bar-Or, 2003). Therefore, once again, as this did not occur in the current study, this could be an indicator of higher pre-established levels of cardiorespiratory fitness in the OB children.

The submaximal $\dot{V}_E$ reported during both moderate and heavy intensity exercise was significantly higher in the OB children in comparison to NW. Similar to the information previously reported (5.1.2) the OB children present with inefficient breathing patterns which causes them to breath more frequently during moderate and heavy intensity submaximal exercise (Volpe Ayub & Bar-Or, 2003).

During the submaximal exercise, the perception of exertion was on average, elevated in the OB children in comparison to their NW counterparts at both the moderate and heavy exercise intensities. Marinov et al. (2002) suggested that as OB children's "psycho-motor" capacities are lower than their NW counterparts, their ability to tolerate physical exertion may be impaired, thus increasing their perception of exertion.

5.3. Strengths and limitations

5.3.1. Strengths

One of the strengths of this study is the adherence to both the exercise intervention and the laboratory based testing sessions. Previous research has utilized enticements to ensure adherence. Ferguson et al. (1999) and Gutin et al. (2002) paid participants $1 for every session of the intervention that they attended; additionally, Gutin et al. (1995) paid participants $100 to complete at least 3 sessions per week and the post intervention assessments. Apart from 2 children from the CON group, who were removed by their teacher due to their behaviour during school time, there were no withdrawals from this study. Most importantly, all participants randomized to the EX group had 100% compliance to the intervention. All participants are aware that participation was completely voluntary and they are free to withdrawal any time without query or prejudice. Despite this information, children in the EX group attended all exercise sessions that were available to them without further enticement, and as such, adherence was a strength to the present study.

Furthermore, children in the EX group enjoyed and benefited from participation in the physical activity intervention as shown by the results of the questionnaire (appendix K). This questionnaire established that 86% (agree a lot) enjoyed it, 54% (agree a lot) and 36% (agree) got something out of it, 68% (agree a lot) and 18% (agree) found it very exciting. In addition, 93% disagreed (a lot) that it was no fun at all, and 75% (a lot) and 25% disagreed that they felt bored. The child-specific games based exercise intervention was not only effective at improving physiological responses and physical parameters to exercise, but the children also enjoyed and gained benefits from their participation in the intervention, and as such this was a significant strength to the present study.

A further strength of the present study is the methodology utilized to determine the moderate and heavy exercise intensities. Previous literature has predominately utilized absolute exercise intensities rather than standardising the exercise intensities to thresholds (VT) and maximal parameters (Ekelund, et al., 2004; McMurray & Ondrak, 2011; Volpe Ayub & Bar-Or, 2003). The present study has used a more rigorous methodology by individually standardising exercise intensity (VT, 40% delta) in order to assess the physiological responses and physical parameters to submaximal exercise. In addition, this may provide a more accurate appraisal of the influence of body mass (NW, OB) as all children are exercising at individually prescribed intensities.

5.3.2. Limitations

Despite the novel findings of the present study, certain limitations are recognised. Due to the time constraints of this thesis project (1 year), only one GXT was undertaken to determine $\dot{V}O_2$peak, pre- and post-INT. Although it is accepted that one test is adequate to establish exercise efficiency and aerobic capacity, in order to gain an accurate determination of maximal functional capacity ($\dot{V}O_2max$ or $\dot{V}O_2peak$), and thus VT, two GXT's are often recommended (Figueroa-Colon, et al., 2000).

In the present study, maximal functional capacity was referred to as $\dot{V}O_2peak$ rather than $\dot{V}O_2max$. This was largely due to the implementation of a discontinuous exercise test. The achievement of a plateau in oxygen consumption (~2 $mL \cdot kg^{-1} \cdot min^{-1}$) was unlikely due to the short exercise stages, as such, test termination was based on either the children reporting volitional exhaustion, or due to HRmax exceeding 200 $b \cdot min^{-1}$ and RER $\geq$ 1.00. Therefore, $\dot{V}O_2peak$ was utilized as a more appropriate and reliable alternative with this population (Figueroa-Colon, et al., 2000).

The maturation of the participants in this study was not measured. It is possible that children were at different tanner maturation stages whilst taking part in this study. However, this study did not have ethical approval to determine this information, as such, chronological age rather than maturational age was employed. This may have altered the physiological responses to exercise. However, Baquet et al. (2003) reports that benefits from participating in a physical activity intervention occur regardless of maturation.

Another constraint to the present study is the influence of diet. It would have been beneficial if all of the participants were in a fasted state (overnight fast) when completing both their GXT and submaximal exercise tests. This would be in accordance with previous research (Goran, et al., 2000) and could possibly remove any altering effect diet may or may not have on body weight, %BF, and the respiratory variables ($\dot{V}O_2$, $\dot{V}_E$ & RER). Although this would've been ideal, after collaboration with the local primary school teachers, it was discussed that this may not be feasible or consistent with the children of the present study.

Due to the number of participants in the present study the time between GXT and submaximal tests was not constant. This occurred as interruptions such as school holidays and other school commitments meant that a few participants may have had a little longer than 1 week between GXT and submaximal tests. Therefore, the lack of ability to control for time between tests could have influence the results and is therefore a disadvantage to the current study.

Although all children were assessed at relative physiological markers during the pre- and post-INT exercise testing, the exercise intervention was not individualized. Therefore, it is possible that some children would have been exercising above or below set intensities and this may have produced variation in the response to the exercise intervention. As such the research team recognise this as a potential limitation to the current study.

5.4. Future research

Only 4 studies of the reviewed literature have assessed the effect of detraining on body composition and physiological markers in children and adolescents (Chang, et al., 2007; Ferguson, et al., 1999; Gutin & Owens, 1999; Gutin, et al., 1999). These studies found that 3 to 4 months post-INT, significant increases in submaximal heart rate, BMI, %BF, waist circumference, TG, blood glucose and insulin were observed. In all cases, the values for the aforementioned variables were higher than those reported at baseline (Chang, et al., 2007; Ferguson, et al., 1999; Gutin & Owens, 1999). The benefits of exercise training are eradicated when participants become less active (3 to 4 months), this indicates the importance to maintain physical activity upon completion of an exercise intervention (Gutin, 2008). As research is limited in this area, future research could further explore and support the effect of exercise cessation on physiological responses to maximal and submaximal exercise. In addition, a cross-over design would be beneficial to determine whether the CON group produce similar benefits from participation in the intervention.

Of the literature reviewed, the time of day that the intervention was implemented has not been regularly noted. A few studies included after-school (afternoon) sessions (Barbeau, et al., 2007; Ferguson, et al., 1999) and others made no mention of the time that the exercise intervention was carried out. It would be interesting to determine whether the time of day may or may not influence physiological responses to exercise as well as body composition measures. Future research could employ physical activity sessions in the morning before-school, in the morning during school, in the afternoon during school (like the present study), and in the afternoon after-school. This would not only establish the time of day that is more beneficial (if any), but also which children may prefer and be more likely to adhere to. Additionally, the acute and long-term effects of physical activity interventions implemented at different times of the day and the discrepancy, if any, in cerebral oxygenation (as measured by NIRS) and cognition in children could be established. This would help determine whether there is an optimal time that physical activity should be implemented in order to enhance learning in children.

The influence of ethnicity on the physiological response to an exercise intervention is yet to be established. Although numerous studies have eliminated ethnicity as a confounding variable in their research studies, to date, none have considered the effect of the exercise intervention in New Zealand children. In particular, the differences between European descent, Maori and Pacific Island children are yet to be determined. In addition, there are currently no ethnic-specific BMI cut-off points for children. Therefore, future research is needed to identify specific BMI classifications for all children of varying ethnicities.

Further research consideration is needed for the effect of the exercise intervention on body composition. This would include a variation of body composition measures including weight, height, body fat percentage, girth measures and the utilization of DEXA scanning. Information, such as this, should more accurately establish the influence of the exercise intervention on body composition and hopefully determine favourable changes within the OB population.

Finally, the exercise intervention was only implemented for 6 weeks (2 sessions per week). It is interesting to note whether a more frequent and longer intervention could have improved body composition measures of the overweight or obese children in this study. Previous research has established that longer (> 6 weeks) and more frequent (> 3 x per week) interventions are beneficial. However to date; none have utilized the child-specific games into their methodology. Future research should aim to identify whether further advantages are achieved following participating in a child-specific games intervention performed for more than twice a week and for longer than 6 weeks.

5.5. Practical application

The findings from the present study provide practical information for schools, teachers, parents and health professionals when implementing an exercise programme. Although skill development is important for physical education lessons in schools, findings from the present study suggest that high intensity games are advantageous to the physiological responses to exercise in children. In addition, as a result of the games utilized in this intervention (appendix F), children also appear to have enjoyed the exercise intervention considerably (5.3.1). The games utilized in the present study are commonly used in physical education lessons and provide minimal skill. This is to ensure that all children are able to elicit a high intensity as the skill of the game is not a confounding factor. Most importantly, the games in the intervention provided variety and as such, the children maintained motivation and intensity. Therefore, when implementing physical activity sessions, the inclusion of a variety of high-intensity games could be perceived to be important when trying to improve the health and fitness of children aged 8 to 10 years. Furthermore, these games should not require a high skill level in order to ensure that all children can participate and benefit. It is important to note that the OB children produced similar, if not greater, improvements from this intervention. As such, this exercise programme may be considered suitable when the aim is to improve the health and fitness of all children and in particular OB children. This, and the aforementioned information on the exercise programme, maybe important for schools and teachers. As children spend a vast majority of their time within a school setting, the school and teachers themselves play a vital role in the health and fitness of children. The exercise programme can simply be utilized during normal Physical education lessons in addition to some of the skill based lessons. Furthermore, structured physical activity programmes could be implemented during the lunch break as another alternative. As children are playing games they do not perceive the exercise programme as exercise but more as structured play, therefore lunch breaks are a further option.

6. Conclusions

The present study has established that when a short child-specific high intensity physical activity intervention is utilized, beneficial changes in the physiological and physical responses to exercise occur. More specifically, children who partook in the exercise intervention significantly increased their running velocities at peak, VT and 40% delta. This occurred in conjunction with a substantial decline in their oxygen consumption at VT and 40% delta, indicating an improved exercise efficiency in the EX group. Importantly, these findings occurred irrespective of weight status (i.e. NW vs. OB). Furthermore, it is possible that heightened responses occurred for the OB children compared to the NW children in the EX group, in particular the response in $\dot{V}_E$ and % $\dot{V}O_2$peak. Unlike previous research, the present study implemented independent exercise intensities which enabled a more accurate interpretation of the results. The structured, high-intensity and child-specific games intervention implemented in the present study mimics that of children's habitual play and requires minimal skill and is a novel approach to exercise research in children. The children by and large enjoyed the intervention (as seen by the questionnaire and adherence information) and no enticements were required in order to promote adherence. Most importantly, the physical activity intervention can be implemented within school or clinical based programmes at minimal cost using common physical education games. Future research should aim to determine the effect of a cross-over design, longer study duration and implement different times of the day. The findings from the current study show that field-based structured activity designed for children is an effective method to improve the cardiorespiratory fitness of children within school systems.

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Appendices

HEALTH SCREENING FOR CHILD VOLUNTEERS (PARENTAL FORM)

Name: ....

It is important that volunteers participating in research studies are currently in good health and have had no significant medical problems in the past. This is:

1. To ensure their own continuing well-being.
2. To avoid the possibility of individual health issues confusing study outcomes.

Your answer to the questions in this questionnaire, on behalf of your child, are **strictly confidential.**

Please complete this brief questionnaire to confirm your child's fitness to participate:

1. **At present**, does your child have any health problem for which they are:
   - a. On medication, prescribed or otherwise................. Yes No
   - b. Attending a general practitioner............................. Yes No
   - c. On a hospital waiting list.. Yes No

2. **In the past two years**, has your child had any illness that required them to:
   - a. Consult your family GP... Yes No
   - b. Attend a hospital outpatient department................ Yes No
   - c. Be admitted to hospital.. Yes No

3. **Has your child ever** had any of the following:
   - a. Convulsions... Yes No
   - b. Asthma.. Yes No
   - c. Diabetes.. Yes No
   - d. A blood disorder.. Yes No
   - e. Head injury.. Yes No
   - f. Digestive problems.. Yes No
   - g. Heart problems.. Yes No
   - h. Problems with bones or joints...................................... Yes No
   - i. Disturbance of balance/coordination............................ Yes No
   - j. Numbness in hands or feet.. Yes No
   - k. Disturbance of vision.. Yes No
   - l. Ear / hearing problems... Yes No
   - m. Thyroid problems... Yes No
   - n. Kidney or liver problems.. Yes No

If YES to any question, please describe briefly on the reverse, if you wish (for example, to confirm problem was/is short-lived, insignificant or well controlled).

Thank you for your cooperation

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

School of Sport and Exercise

P O Box 756, Wellington 6140, New Zealand

The effect of a 6 week exercise intervention on exercise economy in children (8-10 years) of different body mass

Consent Form

(Parent/Guardian)

I have read the Information Sheet concerning this project and I understand what it is about. I have read the Participant Information Sheet with or to my child……………………………………...... (*Insert name*), and I am satisfied that they understand what they will be required to do. I understand that I am free to request further information at any stage.

I agree to my child taking part in this project under the conditions set out in the Information sheet.

Signed…………………………………... Date……………………......

Please Print Name…………………………...

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

School of Sport and Exercise

P O Box 756, Wellington 6140, New Zealand

The effect of a 6 week discontinuous exercise intervention on exercise economy in children (8-10 years) of different body mass

Assent form

(Participant)

I understand what I will have to do if I take part in this study. I understand that I am free to ask any questions at any stage during the study.

Please tick the box below that applies to you:

I agree to take part in this project ☐

Please Print Name: ....

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

7 May 2012

COPY FOR YOUR INFORMATION

Nicole Westrupp
4/37 Daniell Street
Newtown
WELLINGTON

Dear Nicole

Re: HEC: Southern A Application – 12/08
The effect of a 6 week exercise intervention on exercise economy in children (8-10 years) of different body mass

Thank you for your letter dated 7 May 2012.

On behalf of the Massey University Human Ethics Committee: Southern A I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

A/Prof Hugh Morton, Chair
Massey University Human Ethics Committee: Southern A

cc Dr James Faulkner
School of Sport & Exercise
WELLINGTON

Dr Danielle Lambrick
IFNHH
WELLINGTON

A/Prof Steve Stannard, HoS
School of Sport & Exercise
PN621

Prof Richard Archer, HoI
IFNHH
PN452

Massey University Human Ethics Committee
Accredited by the Health Research Council

Research Ethics Office, Massey University, Private Bag 11222, Palmerston North 4442, New Zealand
T +64 6 350 5573 +64 6 350 5575 F +64 6 350 5622
E humanethics@massey.ac.nz animalethics@massey.ac.nz gtc@massey.ac.nz
www.massey.ac.nz

Physical Activity Questionnaire

Compared to other people their age, how would you rate your child's physical activity levels at the present? *(please circle one)*

Excellent	Very good	Good	Fair	Poor	Don't know
1	2	3	4	5	6

Please fill out the following table for each physical activity (e.g. Bike riding; Netball; Swimming) that your child currently does in a typical WEEK.

Physical Activity	Monday-Friday			Saturday-Sunday		
	How many times?	Minutes per session	Total minutes	How many times?	Minutes per session	Total minutes

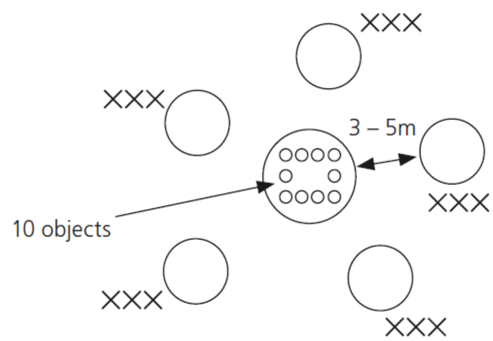
Please fill out the following table for each leisure activity (e.g. Homework, Watching TV, Playing video games) that your child currently does in a typical WEEK.

Physical Activity	Monday-Friday			Saturday-Sunday		
	How many times?	Minutes per session	Total minutes	How many times?	Minutes per session	Total minutes

Games from intervention

Rob the nest

Teacher calls a number and all players with this number run to the central nest and take 1 egg at a time back to their nests.



When all objects from the central nest have gone runners may "rob" the nests of other groups.

Changes of number can be called at any time. All eggs are returned to the central nest following a win and the game begins again. Can also do it to a certain time and everyone goes until the clock stops and the winner is the team/person with the most balls.

Couple tag

Taggers keep hands joined and chase the free players. If tagged, the free player replaces the one who tagged him.

Dodgers and markers

One child is the dodger, the other the marker. The dodger tries to get clear of the marker, who tries to stay within arm's reach of the dodger. On whistle or stop, both marker and dodger stop. The marker tries to touch the dodger. One step is allowed – if he can touch the dodger, he wins a point. Change positions. Repeat several times.

Modified Dodgeball

All children start at one end of the court. The aim is to run from one end to the other without being hit by the balls. If they are hit they join the coaches on the side to throw balls. The game continues until all are out. Then it is re-set and started again. In order to ensure that those who are out are still exercising they are in charge of racing to collect all the balls in order to be able to throw them again at their peers.

Simpson game

All children sit in a circle (if a large group then two circles). Everyone starts off as a Maggie, when Maggie is called all children run around the circle and back to their seat. The first person back becomes a Lisa (then Bart, Marge and Homer).

Poison tag

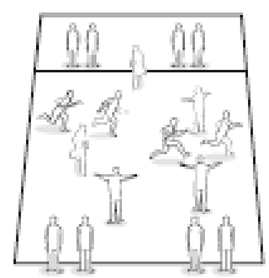
Similar to normal tag, 1 or two taggers are selected. If a person is tagged on their arm they have to hold their arm, if they get tagged on the leg they have to hop. This continues until everyone is tagged on both arms (i.e. arms are crossed) and both legs (i.e. sitting/kneeling down). Aim of the tagger(s) is to tag everyone completely in the fastest time. Once done, the game is re-set with a new tagger trying to beat that time.

Tail tag

All students start with a coloured sash tucked in the back of their shorts and hanging down behind them (tails). On "GO", all students run around trying to grab the tails from other students. It doesn't matter if they lose their tail; they still play on and try to regain a tail from another student. Play for a 2 minutes and then stop and re-set.

Octopus

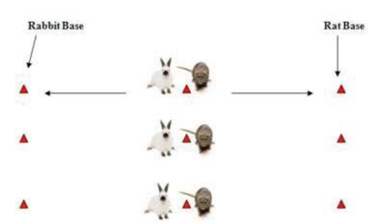
On “Go”, all children try to run across the area to the safe line on the other side. The tagger chases and attempts to catch them. If tagged, that person stands still facing the way they were when caught – these children become the seaweed and are able to tag other runners if they come close enough. Continue until all runners have been tagged. Repeat the game with a new tagger.



Rats and rabbits

When teacher calls “Rats”, the children in that team run to the safety of their own line, while the Rabbits chase them. Both teams return to central line.

When teacher calls “Rabbits”, the Rabbits team runs to their safety line chased by Rats.



Corners

Four hoops are placed in a each corner of a square. One hoop is placed in the middle of the square with a ball in it. Even numbers of children are in each corner and each team is numbered 1 -5. For example, when ‘2’ is shouted, all the 2s from each corner race into the middle to retrieve the ball. First to get the ball gains a point for their team (aka their corner).

Stuck in the mud

On “Go”, the taggers chase the runners, attempting to tag them on the back. If tagged, runners bounce on the spot until freed by another runner crawling through their legs.

Scatter ball

Two even teams are formed. Every member of Team one throws a tennis ball as far as they can then begin jogging from A to B (about 20 metres). During this time Team two are racing to collect all the balls back into the hoop. Once all the balls are in the hoop, Team one stops running and the total amount of runs from A to B is noted. Then the teams switch places.

Keep the bucket full

Thrower tosses balls out of the bucket in any direction as high and quickly as possible. Children catch or retrieve balls and return them to the bucket by running with them and placing them in the bucket. Time how long it takes them to get all the balls back into the bucket.

Monsters

Cone off both ends of the playing area with one end being ‘Jail’ and the other ‘Home Base’. The coach is the ‘Monster’ and their aim is to throw tennis balls at the children and hit them below their waist. If a child is hit below the waist they go to ‘Jail’. The only way they can be freed from jail is to be tagged by someone who has not been hit by a tennis ball. Children are ‘safe’ when they are at home. The aim of the game is for all children to get home, however the monster is trying to get all the children in jail. Warn kids when there is 20 seconds left for them to get to home base and make sure they do all get to home base.

Heart rate values for exercise session during the intervention

Session	Average HR	Maximum HR
1	176	195
2	162	191
3	160	189
4	170	189
5	166	185
6	162	182
7	165	187
8	166	188
9	162	186
10	156	189
11	161	185
12	157	186
Total	**164**	**188**

APPENDIX G

Physical Activity Enjoyment Scale

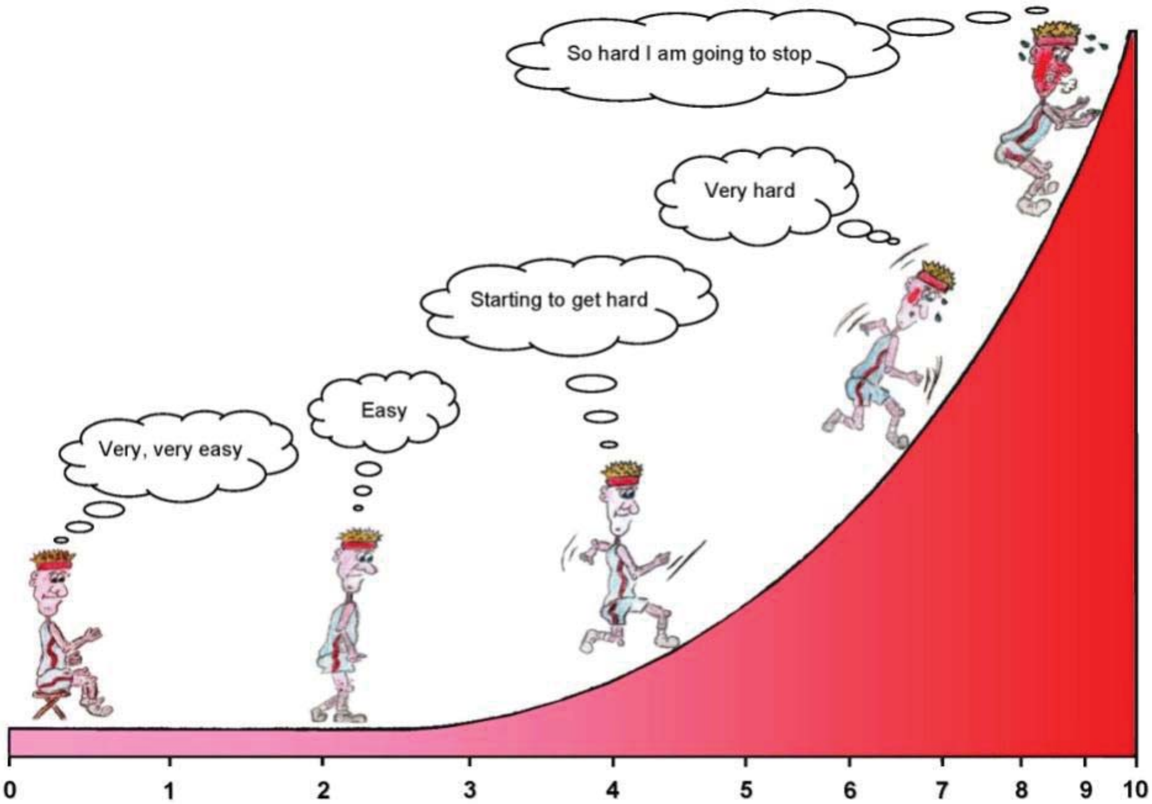
This questionnaire is **only asking you about the exercise games programme** that you took part in at your school on Tuesday and Friday afternoons. **It is not asking you about the sessions at Massey University.**

When I took part in the exercise games programme at my school...

	Disagree a lot	Disagree	Don't know	Agree	Agree a lot
1. I enjoyed it	1	2	3	4	5
2. I felt bored	1	2	3	4	5
3. I disliked it	1	2	3	4	5
4. I found it pleasurable	1	2	3	4	5
5. It was no fun at all	1	2	3	4	5
6. It gave me energy	1	2	3	4	5
7. It made me sad	1	2	3	4	5
8. It was very pleasant	1	2	3	4	5
9. My body felt good	1	2	3	4	5
10. I got something out of it	1	2	3	4	5
11. It was very exciting	1	2	3	4	5
12. It frustrated me	1	2	3	4	5
13. It was not at all interesting	1	2	3	4	5
14. It gave me a strong feeling of success	1	2	3	4	5
15. It felt good	1	2	3	4	5
16. I felt as though I would rather be doing something else	1	2	3	4	5

Thanks, Nicole

Eston-Parfitt (E-P) Ratings of Perceived Exertion Scale



Demographic details comparing NW (1) and OB (2) children

Group Statistics

	a.BMI_Condition	N	Mean	Std. Deviation	Std. Error Mean
a.Age	1.00	29	9.2069	.77364	.14366
	2.00	26	9.3077	.92819	.18203
a.Height	1.00	29	137.4966	8.78784	1.63186
	2.00	26	143.4692	8.81620	1.72900
a.Seated_height2	1.00	28	116.8000	4.40236	.83197
	2.00	26	120.5962	4.37580	.85816
a.BMI	1.00	29	16.9345	1.56964	.29147
	2.00	26	23.4615	3.61453	.70887
a.BMI_Percentile	1.00	29	53.5172	23.20964	4.30992
	2.00	26	93.6154	4.38248	.85948
a.Hip	1.00	29	67.8345	6.40565	1.18950
	2.00	26	82.3654	9.36171	1.83598
a.Waist	1.00	29	56.5828	4.70206	.87315
	2.00	26	72.1846	10.06589	1.97408
a.Hip_Waist_Ratio	1.00	29	.8367	.05656	.01050
	2.00	26	.8764	.06687	.01312
a.Forearm	1.00	29	19.0414	1.60991	.29895
	2.00	26	22.0808	2.34350	.45960
a.Bicep	1.00	29	19.6276	1.90073	.35296
	2.00	26	24.7385	2.86958	.56277
a.Quad	1.00	29	37.8586	4.30801	.79998
	2.00	26	46.5538	5.27706	1.03492
a.Calf	1.00	29	27.1000	2.58623	.48025
	2.00	26	32.7692	3.45459	.67750
a.Inbody_weight	1.00	29	31.6379	5.51630	1.02435
	2.00	26	47.9500	10.90601	2.13884
a.MM	1.00	27	13.3111	2.71170	.52187
	2.00	22	17.0273	3.25623	.69423
a.FM	1.00	27	5.2519	2.00391	.38565
	2.00	22	15.8864	6.49991	1.38579
a.Inbody_BF	1.00	29	17.4724	5.84447	1.08529
	2.00	26	32.3500	7.78805	1.52736
a.BMR	1.00	27	927.1111	96.98705	18.66517
	2.00	22	1059.5455	116.71852	24.88447

APPENDIX K

Physical Activity Enjoyment Scale Results

	Disagree a lot	Disagree	Don't know	Agree	Agree a lot
1. I enjoyed it	0%	0%	0%	14%	86%
2. I felt bored	75%	25%	0%	0%	0%
3. I disliked it	79%	14%	4%	4%	0%
4. I found it pleasurable	7%	4%	11%	21%	57%
5. It was no fun at all	93%	7%	0%	0%	0%
6. It gave me energy	4%	4%	21%	29%	43%
7. It made me sad	75%	14%	7%	0%	4%
8. It was very pleasant	0%	0%	7%	25%	68%
9. My body felt good	7%	0%	18%	11%	64%
10. I got something out of it	0%	0%	11%	36%	54%
11. It was very exciting	4%	0%	11%	18%	68%
12. It frustrated me	68%	25%	4%	4%	0%
13. It was not at all interesting	64%	14%	18%	0%	4%
14. It gave me a strong feeling of success	0%	0%	18%	29%	54%
15. It felt good	4%	4%	7%	32%	54%
16. I felt as though I would rather be doing something else	68%	7%	25%	0%	0%