EFFECTS OF A SCHOOL-BASED PHYSICAL ACTIVITY MODEL ON CARDIOVASCULAR DISEASE RISK FACTORS IN CHILDREN: ACTION SCHOOLS! BC

by

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ABSTRACT

Background: The prevalence of CVD risk factors in children is high. Physical activity is linked with cardiovascular health but 50% of children are not considered active enough to maintain good health.

Objectives: The primary objectives were to; i) evaluate the prevalence of established and novel CVD risk factors in elementary school children, and ii) assess the effect of a school-based physical activity model on selected CVD risk factors.

Research design: A 16-month cluster-randomized controlled school-based intervention with the research questions addressed in 6 sub-studies. Sub-studies 1- 4 are cross sectional analyses of baseline data. Sub-studies 5 and 6 are results from 1-school year of the randomized controlled trial.

Methods: Ten schools were randomized to intervention (INT) or control (CON) groups. Children (n=268, aged 9-11 years) from 8 schools took part in Healthy Hearts measurements. The trial aimed to provide children with 150 minutes of moderate-to-vigorous physical activity per week. Anthropometry, physical activity, cardiovascular fitness, blood pressure, arterial compliance, heart rate variability and serum factors were assessed at baseline and final.

Results: Study 1: I developed a Healthy Heart Score to assess potential CVD risk. Girls had a more favourable Healthy Heart Score than boys. 47% of girls and 68% of boys had at least one CVD risk factor. Study 2: Fitness level of Canadian children at the 50th percentile in 2004 was equivalent to the fitness of Canadian children at the 19th percentile in 1981. Study 3: A significant relationship exists between cardiovascular fitness and arterial compliance in boys and girls. Study 4: Racial differences in heart rate variability exist between Asian- and Caucasian-Canadian children. Sub-study 5: INT children had a 20% greater increase in fitness compared with CON children. Children deemed at higher risk for CVD showed large improvements in blood pressure and serum factors. Sub-study 6: INT boys demonstrated a 25% greater improvement in large artery compliance than CON boys.

Conclusions: There was a relatively high prevalence of CVD risk factors in this cohort of children. Action Schools! BC offers promise as a simple, inexpensive strategy for enhancing cardiovascular health in similar children.

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GLOSSARY OF TERMS AND ABBREVIATIONS

TERM	DEFINITION
Apolipoprotein	Protein component of the lipoprotein complex. Five types are recognized (A,B,C,D and E)
Arterial compliance	A measure of stiffness of the arterial system. Units are measured as ml blood per mmHg
Blood pressure	Pressure in the arterial system, either when the ventricles are contracting (systolic) or re-filling (diastolic), measured in mmHg
Cholesterol	A lipid-protein complexes that transport lipids through the plasma
C-Reactive Protein	A general indicator of tissue damage, which can be used to indicate damages to blood vessels that may precede heart attacks or stroke
Ethnicity	A quality or affiliation resulting from racial or cultural ties
Exercise	Exercise is deliberate exertion of the muscles with a specific goal or aim. The aim of exercise is usually to achieve a beneficial level of fitness and health
Fibrinogen	A protein determinant of blood viscosity
FITNESSGRAM	A trademarked system of testing physical ability in children
Gender	A social distinction, describing ones sexual identity, especially in relation to society/culture
Homocysteine	An amino acid, end product of protein metabolism
Leger's 20m Shuttle Run	A field test to estimate aerobic fitness in children
Maturity	Physical development as assessed by secondary sex characteristics
Physical activity	Any form of exercise or movement. The term physical activity includes planned activity such as walking, running and sports, as well as unstructured activity such as household chores and playing
Physical fitness	May be cardiovascular or muscular skeletal fitness. Cardiovascular fitness denotes the capacity to utilize oxygen at tissue level. The volume of oxygen used (VO_2) is expressed in ml of oxygen, per kilogram body weight, per minute ($ml.kg.min^{-1}$). The maximum amount of oxygen an individual can utilize is the VO_2 max. It is a reflection of the functioning and efficiency of the whole cardiovascular system
Race	A biological distinction, a description of ones genealogical line. Individuals usually fall into one of 3 groups – Caucasoid, Mongoloid or Negroid. Austaloid may be added to this
Sex	The quality by which organisms are classified as female or male on the basis of their reproductive organs, a biological distinction
Tanner staging	A system devised for rating of physical maturity, from 1 (pre-pubertal) to 5 (post-pubertal).
Triglycerides	Fat storage and transport molecule found in the blood.
Z score	A statistical term describing distance from the age and sex specific mean

ABBREVIATION	DEFINITION
BMI	Body mass index: Weight in kilograms divided by height in meters squared; kg/m^2.
CPAFLA	Canadian Physical Activity, Fitness and Lifestyle Approach.
C1	Large artery compliance, measured as ml/mmHg x 100.
C2	Small artery compliance, measured as ml/mmHg x 10.
HRV	Heart rate variability. A non-invasive measure of autonomic function, assessed using change in RR interval, measured in ms.
HF	High frequency power - An HRV measure in the frequency domain. Changes in RR interval occurring between 0.15-0.4Hz, measured as ms^2.
HDL-C	High density lipoprotein - A lipoproteins with a thick dense protein shell. Function is to transport cholesterol to liver. Reported in mmol/L in this thesis.
LF	Low frequency power - An HRV measure in the frequency domain. Changes in RR interval occurring between 0.04-0.15Hz, measured as ms^2
LF:HF	Ratio of low to high frequency power. An HRV measure in the frequency domain. An indicator of sympathetic/vagal balance.
LDL-C	Low density lipoprotein- A lipoprotein with a low density protein shell. Excess amounts are deleterious to vascular health. Reported in mmol/L in this thesis.
METS	Intensity of activity may be estimated in metabolic equivalents. One MET corresponds to oxygen consumption of $3.5ml.kg.min^{-1}$, the oxygen consumption of a 40 year old, 70 kg male at rest.
MVPA	Moderately vigorous physical activity -Activity that makes one breathless and slightly sweaty. May be classified as a heart rate, a MET equivalent or a percentage of VO_2 max.
PAQ-C	Physical Activity Questionnaire for Children, a questionnaire to assess weekly and daily physical activity levels.
RMSSD	Root mean squared of the difference in successive RR intervals- An HRV measure in the time domain, measured in ms.
SDNN (or SDRR)	Standard deviation of successive RR intervals -An HRV measure in the times domain, measured in ms.
TC	Total cholesterol. Sum of very low, low and high density lipoprotein cholesterols.
VO_2 max	Maximal oxygen uptake and use by the body, a marker of cardiovascular or aerobic fitness. Usually measured relative to body weight, per unit time ($ml.kg.min^{-1}$).

PREFACE: PUBLICATIONS ARISING FROM THIS THESIS

Sections of this thesis have been published as multi co-authored manuscripts in peer-reviewed journals. These are indicated with a star (*) beside the publication. Details of the authors' contributions are provided where relevant. I agree with the stated contributions of the thesis author, as indicated below.

_____ Dr. Heather McKay (Thesis supervisor)

McKay HA, Macdonald HM, **Reed KE** and Khan KM (2003). Exercise interventions for health; time to focus on dimensions, delivery and dollars. British Journal of Sports Medicine, 37 (2) 98-99.

***Reed KE,** Warburton DE, Lewanczuk R Z, Haykowsky MJ, Scott JM, Whitney CL, McGavock JM, McKay HA, (2005) Arterial compliance in young children: the role of aerobic fitness. European Journal of Cardiovascular Prevention and Rehabilitation, 12 (5) 952-7.
Authors' contributions: Kate Reed was responsible for the original ideas behind the paper, analysis and presentation of findings and writing the original paper. Darren Warburton, Richard Lewanczuk, Crystal Whitney and John McGavock stimulated discussion of results. John McGavock provided training and guidance with measurement of arterial compliance. Darren Warburton edited the paper. Heather McKay guided the research, research questions and was the key editor of this manuscript.

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***Reed KE,** Warburton DE, Whitney CL and McKay HA, (2006) Secular changes in shuttle run performance; a 23 year comparison. Pediatric Exercise Science, 18, 364-373.
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Reed KE, Warburton DE, Lewanczuk R Z, Haykowsky MJ, McKay HA. Effects of a 9-month school-based physical activity intervention on arterial compliance in elementary school boys. Submitted to Vascular Medicine, July 2006 *Authors' contributions*: Kate Reed was responsible for the original ideas behind the paper, analysis and presentation of findings and writing the original paper. Darren Warburton stimulated discussion of findings and edited the paper. Richard Lewanczuk and Mark Haykowsky stimulated discussion of findings. Heather McKay guided the research and was key editor on this manuscript.

Abstracts and Presentations

Ahamed YA, Macdonald HM, **Reed KE**, Naylor PJ, and McKay HA (2006).Time devoted to physical activity does not compromise academic performance of elementary school children. Medicine and Science in Sports and Exercise; 38 (S5)

Reed KE, Warburton DER and McKay HA (2005) Decline in fitness of Canadian children over the past 2 decades: a retrospective analysis. Presented as thematic poster at the European Cardiovascular Society Congress, Stockholm, Sweden.

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Reed KE, Warburton DER and McKay HA (2004). The role of aerobic fitness on arterial compliance in young children. Canadian Journal of Applied Physiology; 29 (5,S1). Presented at the Canadian Society of Exercise Physiology Annual Conference, Saskatchewan, Canada.

Reed KE, Warburton DER, Whitney CL and McKay HA (2003). The effects of physical fitness and race on heart rate variability in children. Canadian Journal of Applied Physiology; 28 (5, S1). Presented at the Canadian Society of Exercise Physiology Annual Conference, Ontario, Canada.

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CHAPTER 1. INTRODUCTION, LITERATURE REVIEW, OBJECTIVES AND HYPOTHESES

1.1. INTRODUCTION

Cardiovascular disease (CVD) is Canada's leading cause of mortality and treating this disease costs the Canadian Health Care System approximately $18 billion. Factors that increase the likelihood of an individual developing CVD are known as 'risk factors'. Risk factors may be amendable (physical activity level, smoking status, diet) or non amendable (sex, age, family history). Some physiological risk factors, such as hyperlipidemia or hypertension, may be modified with relatively conservative interventions such as diet and exercise. Researchers identified many of the currently well-known CVD risk factors several decades ago [1]. These 'established' risk factors include male sex, physical activity, physical fitness, tobacco smoking, activity level, blood pressure and cholesterol levels. More recently, a number of 'emerging 'risk factors' have been identified and the role of these risk factors in CVD represents a novel area of study. Such factors include arterial compliance, C-reactive protein, homocysteine, fibrinogen and apolipoproteins. By combining new and established risk factors, a more comprehensive profile of an individual's cardiovascular health emerges.

The prevalence of CVD risk factors in children is alarmingly high. In the Bogalusa Heart Study 58% of children displayed at least one risk factor by the age of 18 years [2]. In Europe children as young as 9 years are presenting with multiple risk factors [3]. There is a significant genetic contribution to CVD risk [4], however, the majority of risk factors, such as physical activity, can be easily modified.

There is substantial evidence that regular physical activity reduces the mortality associated with coronary heart disease, and decreases the risk of stroke, colon cancer and diabetes. Longitudinal investigations, such as the Harvard Alumni Study [5] indicate that chronic, moderately vigorous physical activity protects against all cause mortality. The Centre for Disease Control (CDC) in the United States attributes 14% of all deaths to poor diet and lack of physical activity, a value preceded only by smoking (19% of deaths). This knowledge regarding the health benefits of physical activity has not been effectively translated into positive health behaviours that promote cardiovascular health. Similarly, physical *inactivity* has recently been classified as high risk behaviour and is estimated to drain $24billion annually from funds in the United States [6]. The relative cost of physical *inactivity* in Canada is $4.3 billion [7]. Physical activity is a key player in both established and emerging risk factors [8], however, the complexity of these relationships remains unclear in adults and largely unexplored in children.

For physical activity to benefit children's health, Health Canada recommends a minimum energy expenditure each day that is equivalent to 8 kcals per kg body weight per day [9]. This is approximately 30 minutes of moderately vigorous activity, plus one hour walking per day. Although the average amount of activity reported for children aged

5-12 years is relatively high, (16.5 hours per week) there remain less than 50% of children who are physically active enough to maintain good health.

In addition to the repercussions that low physical activity has on child health, physical activity in youth has been linked with adult incidence of CVD risk factors [10]. Individuals who are more physically active [10] or more fit [11] during childhood are more likely to have a healthy cardiovascular profile in adulthood . Many risk factors that are associated with physical *inactivity* track from childhood to adulthood. These include elevated serum lipids [12], hypertension [13] and obesity [14]. There is some evidence that physical activity behaviours in childhood predict adult behaviours [15, 16] , thus establishing positive profiles of physical activity patterns in youth seems important.

There is evidence to suggest that physical activity patterns differ between boys and girls and in children across ethnicities. Studies have documented sex differences in physical activity in children as young as 3 years [17]. On average, boys are more active than girls at every age, and this difference increases with advancing maturity [18-20].

Racial differences in physical activity patterns have begun to emerge. In the few studies that have addressed this, Mexican-American [21], African-American [22, 23] and Asian children [24] are reported to be less active than same age children. Investigations that have explored racial differences in cardiovascular health have focused primarily on Black and White or Hispanic and non-Hispanic differences, whilst very few studies include Asian children.

Children spend a large portion of their waking hours in the school environment and schools are able to influence a large range of behaviours In North America, schools provide the only setting that would ensure that the majority of children are provided opportunities to be physically active on a daily basis. In most jurisdictions, however, there is currently very little time allocated to physical education (PE) class. For example, teachers in British Columbia deliver 60-80 minutes of PE per week on average and few, if any meet the 150 minutes per week recommended by the Ministry of Education [25]. Specifically, less than 25% of elementary schools devote the recommended 10% of curriculum time to PE each week [25]. This lack of PE time is exacerbated by the quality of PE provided. A classic study that addressed the quality of PE, estimated that children were aerobically active for just 6 minutes, on average in PE class [26]. Further, limited access to PE is often a function of an overfull curriculum and limited resources based on budgetary restrictions.

Schools have been the site of a number of physical activity interventions and some, but not all have proved successful for increasing physical activity [27-30]. However, all but 3 school based interventions have focused on modifying PE class time. Given the size of schools, the demands of the curriculum and the few PE specialists who remain in elementary schools, alternative strategies to provide more opportunities for children to be physically active within the school day must be considered. Finally, of the school based interventions that have addressed children's health all have focused on established risk factors [27-34], but none to date have evaluated the effect of such programs on 'emerging' risk factors.

Therefore, the general aims of this thesis were to evaluate the factors that contribute to the cardiovascular health of children and to determine whether a school based model of physical activity (Action Schools! BC) was effective for ameliorating CVD risk factors. To achieve these aims I designed, implemented and evaluated a 16-month randomized controlled school-based physical activity intervention and addressed different research questions related to this trial within six sub-studies (Chapters 3-8). While each sub-study contributed to the overall aim of the thesis, the independent aims and objectives are provided in the relevant chapters.

Briefly, in **study one** I developed a 'Healthy Heart Score' for children and evaluated the clustering of CVD risk factors in the children. In **study two** I compared the cardiovascular fitness of the children in my cohort with same-age Canadian children who were evaluated using the same fitness protocol in 1981. In **study three** I assessed the relationship between arterial compliance and physical fitness and physical activity in boys and girls. In **study four** I assessed the difference in heart rate variability between children of different ethnicities. The final two studies were concerned with evaluation of change in established and emerging CVD risk factors in response to the intervention. In **study five** I assessed the change in CVD risk factors in a sample of healthy boys and girls and in a subset of children deemed 'at risk' at baseline for CVD. In **study six**, I assessed the change in arterial compliance in a sample of healthy boys.

This thesis comprises 9 chapters. Chapter 1 provides a comprehensive review of the relevant literature and introduces the aetiology of CVD, the prevalence of each CVD risk factor and their impact on cardiovascular health. Chapter 1 also highlights the role physical activity plays in modifying each risk factor. Chapter 1 also outlines my research aims, objectives and the hypotheses specific to each sub-study. In Chapter 2 provides the methods common across sub-studies that I used to conduct my research. I also provide detailed methods for each sub-study within the relevant chapter (Chapters 3-8). Chapter 9 provides a discussion that integrates all parts of the thesis and presents the meaning of this work as an integrated whole, to children's cardiovascular health. In Chapter 9 I also discuss the limitations of my research and suggest future research directions.

1.2. LITERATURE REVIEW

In this section I begin with a description of CVD aetiology then introduce the role of physical activity in the prevention of CVD. I also explore the relationship between physical activity and CVD risk factors in both adults and children. I conclude the section by discussing other relevant risk factors for CVD.

1.2.1. CVD: definition, aetiology and risk factors

CVD is an umbrella term for a variety of diseases affecting the heart and vasculature. Diseases include acute myocardial infarction, ischemic heart disease, peripheral vascular disease, hypertension, arrhythmia, aneurysm, valve disease and stroke. Damage to a blood vessel is the main cause of cardiovascular disease and the likelihood of damage to a vessel is increased in the presence of several physiological variables or risk factors. Individuals with a high number of risk factors are more likely to experience damaged vessels, resulting in atherosclerosis.

The burden of CVD is high, both in terms of economic cost and suffering. In Canada, an estimated $18 billion (CAD) is spent annually on treating CVD. In the US, this expenditure is $471 billion, and in the United Kingdom the expenditure is $53 billion. The burden extends into the work place because of lost days of work, and into the home, because of the informal care required by many sufferers.

Atherosclerosis is a disease of muscular arteries where the inner layer of the blood vessel is disrupted by fatty deposits and fibrous tissue. This condition frequently involves coronary and cerebral vessels, leading to myocardial infarction and stroke respectively. As a result, atherosclerosis is responsible for the majority of deaths in the Western Society [35]. CVD is responsible for more than 1 in 3 deaths in North America [36].

1.2.2. Development of atherosclerosis

The inner layer of a blood vessel, closest to the lumen, is known as the intima, the middle layer is the media, and the outer layer the adventitia. The intima is a single layer of epithelial cells laying on connective tissue and, aside from providing a smooth surface for blood flow, it is responsible for many metabolic and signalling functions that help maintain integrity of the vessel wall. The media is comprised of smooth muscle in a matrix of collagen, elastin and proteoglycans. It is bound on either side by elastic laminae through which cells can pass. It stretches during systole then recoils during diastole such that the blood is pumped forward in a continuous manner. It also plays a role in regulation of blood pressure. The adventitia contains fibroblasts, nerves and lymphatic vessels to service the artery, but has no direct role in blood flow.

Fatty streaks in the vessel wall represent the earliest visible lesion in the development of atherosclerosis. They appear as patches approximately 1-2mm wide and up to 1cm long. At this early stage, they do not protrude into the lumen or disrupt blood flow. Microscopy shows the fatty deposits to be comprised of "foam cells" derived from macrophages, filled with intracellular lipid. Fibrous plaques are more advanced lesions and are the cause of clinical symptoms. The fibrous plaques often contain a core of cell debris, foam cells and cholesterol. These frequently project into the lumen and disrupt blood flow. A fibrous cap, comprising connective tissue and embedded with smooth muscle fibres, covers the plaque.

Fibrous plaques are most frequently found in the abdominal aorta, the coronary arteries, popliteal arteries, the descending thoracic aorta, the internal carotid artery and the Circle of Willis. Aside from disruption of lamellar blood flow, the fibrous plaque may undergo changes that result in further complications, namely:

1. calcification of the plaque creating rigidity in the vessel wall
2. rupture releasing thrombogenic material into the blood (may cause local occlusion of the vessel resulting in infarction)
3. rupture releasing fragments of the disrupted atheroma into the vessels and cause embolism at distal sites
4. weakening of the vessel wall as pressure from the plaque causes atrophy of the smooth muscle and loss of elastin fibres.

Observational and experimental studies have identified several factors that increase the likelihood of individuals developing atherosclerosis and subsequent CVD. Whilst some of these factors cannot be modified (increasing age, male sex, race), several risk factors are amendable. Amendable risk factors include physical activity, diet, body weight, uncontrolled diabetes, cholesterol level, hypertension, tobacco use, excess alcohol consumption and stress [35, 37].

1.2.3. CVD risk factors

In adults, other well established risk factors for development of CVD include elevated serum cholesterol levels, cigarette smoking, hypertension, obesity and diabetes. Risk stratification using these 'traditional' risk factors has been extensively studied and they will be discussed only briefly in this section. Several novel or emerging risk factors have been more recently identified, and will be discussed in more detail.

It is becoming more commonplace to undergo screening for elevated levels of serum factors such as fibrinogen, homocysteine and C-reactive protein. Further, development of more sophisticated technology allows accurate assessment of arterial compliance or endothelial function to determine vascular health. It is also now possible to utilize heart rate variability (HRV) analysis to assess the autonomic nervous system and its effect on the myocardium.

Poor outcomes for many of these variables precede elevation of the traditional risk factors, thus earlier diagnosis and treatment of individuals at risk of CVD is possible.

The prevalence of single and multiple CVD risk factors is high. In the United States, between 1991 and 2001, the prevalence of hypertension, high cholesterol, diabetes and obesity all increased (by 2.8%, 3.5%, 2.6% and 8.8% respectively) [38]. The numbers of individuals with no known risk factors is decreasing annually. In 1991 42% of the adult population had no reported risk factors; 10 years later this number was 36%. As a result, the economic, social and emotional burden of heart disease and stroke is expected to increase.

In children elevated serum lipid levels, hypertension and type II diabetes are becoming commonplace at the elementary school level. Freedman et al [39] determined that 28% of children had one or more CVD risk factors by the age of 11 years. If overweight is added as a risk factor, then this value becomes 35%. Post-mortem studies show that fatty streaks are evident in the arteries of 50% of all 2-15 year olds and their severity has been shown to correlate with the number of ante-mortem CVD risk factors present [2].

The following sections discuss both well-established and emerging CVD risk factors in adults and children. I examine the specific relationship of each with physical activity and, where relevant, sex and race.

1.2.3.1. Defining physical activity and physical fitness

One key difference in methodologies examining cardiovascular health is whether physical *activity* or physical *fitness* is assessed, and it is important to distinguish between them. Physical *activity* is a description of behaviour. It is any activity that requires your body to work at a level above resting metabolic rate. It consists of athletic, recreational or occupational activities that require physical skills and utilize strength, power or endurance. Physical *fitness* is a physiological measurement and serves as an indicator of cardiovascular health. It may be measured as an absolute value, such as time to complete a 1 mile run, or as a relative value, such as oxygen uptake per kg body weight ($ml.kg.min^{-1}$). Tests of fitness that allow researchers to assess cardiovascular capacity objectively in large population based studies include the 9-min run [27], cycle ergometry task [28], the 1-mile run [29] and the 20-m shuttle run test [40]. Many phrases are used interchangeably to describe fitness; physical fitness, cardiovascular fitness, aerobic capacity, maximal exercise capacity. I will use the terms 'physical fitness' in this thesis.

Physical activity can potentially *modulate* cardiovascular health. Physical activity can also potentially modulate physical fitness. In children, there is a moderate correlation (estimates of between r=0.17 and r=0.66 have been suggested) between physical activity and physical fitness [41, 42]. However, there are a number of other factors that contribute to fitness level, including a genetic contribution. The genetic contribution is not fully determined, but may account for 30-40% of the variance in fitness levels [43].

Studies have addressed the relationship between both physical activity and physical fitness to cardiovascular health in children. Whether fitness or activity is selected as the primary outcome variable is based on the research question. For example, the Childhood and Adolescent Trial for Cardiovascular Health study intervened with a school based (PE) model of physical activity and assessed whether the general physical activity level of children improved as well as whether changes in physical activity altered children's physical fitness [27].

The choice of using physical activity or physical fitness as predictors of cardiovascular health depends on the research question. Using measures of physical fitness, which are objective, potentially eliminates the recall bias introduced by subjective measures of physical activity assessed by questionnaire. Further, the strength of the adult relationship between physical activity and cardiovascular health is stronger than the relationship between physical activity and cardiovascular health [44], especially if physical activity is self-report. Because of this, in many studies physical *fitness* and rather than physical *activity* has been identified as the independent variable for prediction of CVD risk factors in physical activity trials. Physical fitness is also more commonly used as an independent predictor of CVD. I review intervention and cross sectional studies that address both physical activity and physical fitness as outcomes, as well as studies that evaluate the relationship of both these variables to, and their predictive value for, cardiovascular disease risk factors in children.

1.2.4. Physical activity and CVD

In this section I examine the *general* influence of physical activity on CVD in both adults and children, i.e. how physical activity acts as an independent modifiable risk factor. I also examine the relationships between physical activity in childhood and incidence of CVD risk factors in later life, and tracking of physical activity habits from childhood to adulthood. In subsequent sections I explore the specific relationship between physical activity and other modifiable risk factors.

1.2.4.1. The role of physical activity in adult CVD

There is abundant evidence in adults to support the positive role of physical activity as a key prevention strategy for CVD [45]. As the focus of this thesis is childhood, I provide only a brief overview of these studies. Morris' famous studies of London bus drivers and bus conductors in the mid 20th century showed that vigorous physical activity is associated with lower risk of coronary heart disease [46]. Since then, numerous studies have supported this finding [5, 47, 48]. One meta-analysis that explored the relationship between physical activity and heart disease determined a relative risk of death from coronary heart disease of 1.9 for sedentary compared with physically active individuals [8]. Research in recent years has targeted the intensity and duration of activity that has the greatest cardioprotective effect and the mechanisms by which this protection is conferred. Results from the classic Harvard Alumni study [1] demonstrated a dose response relationship. Risk of death from CVD becomes progressively lower as the total amount of physical activity increased. Other authors suggest that the intensity of physical activity is crucial to provide cardioprotective effect. Lee and colleagues [5] noted that for exercise to play a preventive role in development of coronary heart disease, individuals must exercise at an intensity of 6 METS or more.

The mechanism by which physical activity influences cardiovascular health is neither simple, nor fully established. Physical activity can mediate hypertension [49], blood lipids [50], obesity [51], glucose metabolism [52] and endothelial function [53] in adults. The mechanism by which physical activity influences individual risk factors is examined in more detail in the later sections.

1.2.4.2. The relationship between physical activity and CVD risk factors in childhood

In children, studies have focused on the prevalence of cardiovascular risk factors in relation to the amount of physical activity undertaken. Cross sectional studies suggest that physically active children had lower body fat [41, 54], more favourable lipid profiles [54-56], lower blood pressure [54, 55] and better endothelial function [57] compared with non active peers. Intervention studies showed that increasing physical activity levels improved risk profiles in previously lower active children [28, 31, 58].

1.2.4.3. The relationship between childhood physical activity and CVD in adulthood

A number of retrospective studies have explored the link between the amount of physical activity during childhood and the incidence of CVD risk factors in adult life. The results of these studies have been equivocal. Although some researchers found that subjects who were more active during childhood had fewer risk factors in adulthood [10] a substantial number found no such relationship [11, 59]. The lack of agreement between studies is due, in part, to the variety of methods used to assess previous physical activity and the accuracy of subjects' recall. Equivocal results due to methodological differences highlight the need for detailed, longitudinal prospective studies that explore the relationship between childhood physical activity and adult CVD risk factors.

McMurray supports the use of fitness rather than physical activity as a predictor of CVD risk in children [60]. His study of 1140 youths showed only low correlations between physical activity and blood pressure ($r = -0.04$ to 0.11) but stronger correlations between fitness and blood pressure ($r = -0.33$). Similarly, the Northern Ireland Young Hearts Project ascertained that whilst modest relationships existed between physical fitness in adolescence and total cholesterol, high density cholesterol and body fat in adulthood, there was no relationship between physical activity and any CVD risk factor [59]. The Amsterdam Growth and Health Longitudinal Study found that whilst physical fitness during adolescence was positively related to adult CVD risk factors (sum of skin folds, waist circumference and total serum cholesterol), physical activity was not [11]. Relationships between physical fitness and risk factors were also shown in the 5-year Muscatine Study involving 125 children aged 10.5 years at baseline [61]. The researchers determined that changes in fitness over the 5 years explained up to 11% of variance in cholesterol levels. Further to this, changes in fitness and muscular strength explained 15% of the variability in total body and abdominal adiposity at age 15 years.

1.2.5. Overweight and obesity

Childhood obesity has become a worldwide epidemic with significant medical and economic consequences. The association between excess body weight and CVD is well established [62] and overweight and obesity are classified as a major risk factors for coronary heart disease, along with smoking, physical inactivity and high total cholesterol.

Currently, in Canada, nearly 30% of children between the ages of 7 and 13 are overweight, with a further 9.5 % classified as obese [63]. Despite a reduced intake of calories from fat between the 1960's (42% of total calorie intake) and the 1990's (34%), the incidence of obesity is increasing in both adults and children [62]. Numerous other investigations have shown a similarly increasing trend in prevalence of obesity in both adults and children [64-66]. One longitudinal study showed that the greatest increases in weight occurred in individuals who were already in the upper weight percentiles at baseline [66]. This suggests a trend toward an increase in the severity of obesity.

Using normal values produced by the US Centre for Disease Control [67], children above the 85th or 95th body mass index (BMI) percentile for age and sex are viewed as overweight or obese respectively (now frequently defined as 'at risk of overweight' and 'overweight'). Although BMI is insensitive to body composition, it is easy to measure and commonly used to define healthy or unhealthy body mass in relation to stature. More sophisticated techniques that allow for determinations of body composition include underwater weighing, dual x-ray absorptiometry or skinfold measurement. From these the relative contribution of fat mass and muscle mass can be assessed. Recommended upper levels of percent body fat in children are less well established, but a cut off point of 33% body fat has been suggested [68].

Obese individuals frequently present with insulin resistance, elevated blood pressure, dyslipidemia and increased left ventricular mass [69], elevated haemostatic factors [70] and higher C-reactive protein [71]. The relationship between abdominal adiposity and C-reactive protein may be particularly relevant to CVD risk. It is well accepted that coronary heart disease has an inflammatory component and that its related markers, such as C–reactive protein, predict coronary events [72].

Although total fat percentage is a risk factor for CVD in adults, weight distribution or 'fat patterning' is of equal or perhaps even greater importance. Distribution of body fat, although only recently studied in children, is an independent correlate of CVD risk [73, 74]. In children a high central, or android, deposition of fat is associated with elevated serum cholesterol, lipoproteins, blood pressure [75], left ventricular mass [76], increased levels of the haemostatic agent, fibrinogen [70] and C-reactive protein [72]. Such changes may be due to metabolic alterations resulting in high circulating insulin levels and subsequent insulin resistance. This would result in greater delivery of fatty acids to the liver and interference with metabolism of high-density lipoprotein cholesterol. The effect of trunk obesity on blood pressure is possibly related to the role of insulin on sodium balance and the impact of insulin on the sympathetic nervous system.

Childhood weight and BMI track into adulthood [13, 77, 78] and predict a number of other risk factors. For example, obese children are up to five times more likely to develop hypertension than their normal weight peers [77]. Increased prevalence and severity of obesity is associated with increased prevalence type 2 diabetes, hyperlipidemia, hypertension [39] sleep apnea and left ventricular hypertrophy [79] . Freedman and colleagues determined that 58% of obese 5-10 year olds have at least one risk factor. They also calculated that the odds ratio of having 2 or 3 risk factors were 9.7 and 43.5 respectively [39]. Given these established links, maintaining healthy body weight in childhood should be a priority.

1.2.5.1. The relationship between physical activity and overweight/obesity

On a basic level, if energy input is greater than energy expended, then excess adipocyte storage will occur. Evidence suggests that physical activity increases energy expenditure, both acutely and on a more chronic level, by increasing basal metabolic rate [80].

Sedentary behaviour was positively associated with overweight and obesity in children in both cross sectional and longitudinal level studies [16, 41, 55]. Obese children reportedly choose sedentary behaviours, such as television watching, over physical activity behaviours and work harder to gain access to sedentary activities compared with non-obese individuals [81].

Negative relationships between current physical activity and body fat or BMI in children have been frequently assessed. Commonly, moderate negative correlations are reported [41, 51, 55]. Rowlands et al [41] investigated the relationship between physical activity levels and body fat in 8-10 year old children. Body fat was measured by the skinfold method. Physical activity was measured by Tritrac accelerometer and pedometers, which the children wore for up to 6 days. Results showed that physical activity correlated negatively with body fat (r= - 0.42). Similar results were reported in the Oslo Youth Study [55] where subjects were divided into quartiles according to level of physical activity. Subjects in the highest quartile of activity had significantly lower triceps skinfold thickness than subjects in the remaining quartiles. It must be noted that in Oslo Youth Study physical activity was self-report, suggesting a lower level of evidence in this study.

Longitudinal studies have shown similar findings. The Young Finns Study [16], followed 3,500 children and adolescents over 6 years. This study demonstrated that persistent physical activity was associated with reduced skinfold thickness. Subjects were categorized according to maturity across 5 groups and in each maturity group higher physical activity levels were associated with lower BMI and lower skinfold thickness.

Sedentary activities, particularly television watching, also correlate with obesity in children. A 7-year prospective study examined this relationship in 106 children aged 4-years at baseline [82]. Television watching was an independent predictor of change in BMI and triceps skinfold. Ma et al [83] grouped children according to television-viewing time per day (< 1 hour, 1-2 hours, 2-3 hours and > 3 hours) and the prevalence of obesity in each group was 10.9%, 11.8%, 13.2% and 15.1% respectively. Each hourly increment of television viewing was associated with a 1-2% increase in the prevalence of obesity. The association of body fat with television viewing and physical activity has also been shown. Janz et al [84] measured physical activity with accelerometers and body composition with dual energy X-ray absorptiometry. Children in the lowest quartile for vigorous physical activity had body fat percentages that were 4% higher than children in the highest quartile for vigorous physical activity. Children in the highest television viewing quartile had on average 3% higher body fat than children in the lowest quartile.

Inclusion of a physical activity component into childhood obesity prevention or treatment intervention is highly recommended [85]. This was highlighted in a meta-analysis that examined the contribution of various components to the success of the intervention programs [86]. The components included nutritional advice, dietary intervention and inclusion of family members. It was determined that including a physical activity component in addition to a nutrition component conferred an effect size of 0.45 compared with a nutrition intervention alone.

1.2.5.2. The influence of race on overweight and obesity

Incidence of obesity is not evenly distributed among racial groups. The Bogalusa study [2] and the Coronary Artery Development in Young Adults study [87] reported a high prevalence of obesity in African-Americans, especially girls. Incidence of obesity is also high in Native American Indian children [88], Mexican-American children [89], Latino children [29, 90] and South Asian children living in the U.S. [91]. A study of boys from three ethnic groups in one town found that, despite a lower BMI, South Asian boys had higher percent body fat and higher waist to hip ratio than Caucasian and East Asian boys, respectively [92].

A few studies have demonstrated that fat distribution varies between races. Morrison [74, 93] and Hill [94] have both shown Black children tend toward increased abdominal fat deposits compared with Caucasians, even after controlling for total body fat. Morrison however, found this difference only in girls, whilst Hill found the difference only in boys.

1.2.6. *Hypertension*

Both systolic and diastolic blood pressures have a strong, graded, independent relationship with CVD incidence in adults [95]. Chronic hypertension has been associated with carotid arterial stenosis [96], subarachnoid haemorrhage [97], cardiac arrhythmia [98], carotid wall thickening, left ventricular hypertrophy [99] and accelerated atherosclerosis [100].

Blood pressure (measured as millimetres of mercury, mmHg) is a product of cardiac output and peripheral resistance. Blood pressure assessment provides a systolic and a diastolic value, which indicate the upper and lower pressures that occur in the vessel. Normal values are age dependent and children on average have lower blood pressure than adults. Hypertension in adults is defined as blood pressure above 140/90mmHg. In a 9 year old child, a blood pressure of 120/80mmHg represents the 95th percentile [101]. One major study reported that the prevalence of adult hypertension in Europe was 44% and 28% in the US [102]. Two recent studies indicated that in Canada prevalence of hypertension in adults was lower (13% [103] and 13.9% [104]). Prevalence of hypertension in children is not well established, although values of 17% [105] and 21% [31] have been reported.

An increase in blood pressure occurs when there is an increase in peripheral resistance, without a concomitant reduction in cardiac output. Damage to the vasculature, resulting in reduced lumen diameter and/or reduced vessel compliance will increase peripheral resistance and results in increased blood pressure. However, whether damage to the vasculature results in hypertension [106] or whether hypertension causes damage to the vasculature [107] is a matter of debate.

In adults, hypertension is a known risk factor for CVD and the long-term effects of exercise on blood pressure are established. In children, however, the short-term and long-term effects of hypertension, and the impact that physical activity can have, are less well known.

1.2.6.1. The relationship between hypertension and physical activity

Blood pressure aggregates within families and there is evidence to suggest that a significant proportion of the familial aggregation is due to the effect of genes [104]. However, hypertension can be ameliorated by physical activity and is exacerbated by increased body weight. Sedentary adults have a 20-50% higher risk of developing hypertension than their active peers. Approximately 30-40 minutes of moderately vigorous physical activity reduced blood pressure in a previously inactive individual [108].

The mechanism by which physical activity reduces blood pressure is thought to be via reductions in sympathetic activity. With chronic exercise there is an increase in intravascular volume. Elevated intravascular volume causes an increased discharge from the atrial baroreceptors resulting in withdrawal of sympathetic vasomotor tone. This reduces total peripheral resistance, and thus blood pressure, to a chronically lowered level [49]. Some researchers suggest that arterial baroreceptors may be permanently reset to a lower pressure, resulting in a reduction in sympathetic nerve activity [109].

There are several randomized controlled trials that demonstrated the beneficial effect of physical activity and blood pressure in adults. For example, the dose response relationship between blood pressure and exercise was examined in 207 mildly hypertensive subjects over an 8-week intervention [110]. Clinically relevant changes in pressure occurred in the group undertaking the lowest amount of activity (30-60min/wk) and were similar to those in the higher (61-90 min/wk) exercise groups. It appears that a certain threshold of activity is required, beyond which salutary effects are not increased.

Cross sectional investigations in children frequently highlight the negative relationship between blood pressure and physical fitness or activity [55, 111, 112], but not all researchers find this to be the case [113]. Even in randomized controlled trials, providing a higher level of evidence, results are still equivocal. The relationship between fitness, physical activity and blood pressure has been addressed in several school-based interventions. The majority of investigations which reported a change in physical *fitness* reported a concomitant change in systolic or diastolic blood pressure [28, 31, 114]. For example, the Cardiovascular Health in Children (CHIC) study intervened with an 8-week program of moderately intense physical activity (30-min 3 times per week). They reported reduced systolic (4.3%) and diastolic (8.1%) blood pressures in intervention compared with control schools [115]. Conversely, the CATCH study, implemented a less intense (90-min per week during PE class) physical activity intervention over 2.5 years in elementary schools. They did not show a decrease in blood pressure despite an increase in physical activity levels of children [27]. This suggests that intensity of activity may be as important as amount of activity in determining change in blood pressure in children.

The relationship between childhood physical activity and adult hypertension is not well-established and long term studies that investigate this are needed. That said, as childhood blood pressure has been shown to track into adulthood [13], achieving and maintaining a healthy blood pressure early in life is advisable.

1.2.6.2. The influence of race on hypertension

Hypertension in adults has been frequently linked to ethnic origin. Blacks, in particular Afro Caribbeans, have the highest prevalence of hypertension [116-118], followed by South Asians and Caucasians [117-119]. Traditionally, East Asians do not demonstrate a high prevalence of hypertension, but this may be changing.

The prevalence of hypertension in China has increased dramatically over the last few decades, more than tripling between 1960 and 1990. Currently, 27% of Chinese adults (in China) are hypertensive [120]. The emergence of CVD as the leading cause of mortality in China is linked, in part, to rapid economic growth and associated socio-demographic change. Hypertension is still low in Japan compared with the U.S., England and India [119].

In some studies, African-American children had higher blood pressure than age-matched Caucasians [121-123], although other researchers have failed to show this race difference [124-126]. Alpert and colleagues [127] conducted a meta-analysis of literature published that compared blood pressure between youths of different races. They concluded that no racial group had consistently higher blood pressure compared with African- Americans. Only one study in the meta-analysis showed higher blood pressures in Caucasians than African-Americans [128]. One study found that blood pressure of Asian children was higher than Caucasian and Hispanic children [122]. Another showed higher pressures in Hispanics compared with Caucasians [129].

As hypertension in adults is most common amongst African-Americans and Afro-Caribbeans, children from other ethnic groups are not frequently studied. Thus, there is limited research on blood pressure in children from Asia, India, and Latin America. However, to understand disease aetiology, it is important to study both populations with low incidence of a disease and those with high incidence of a disease.

1.2.7. Serum factors

Conventional risk factors such as dislipidemia and hypertension cannot account for all the cases of CVD or changes in vessel structure [130]. Therefore, traditional serum measures, such as cholesterol and triglycerides, are complimented by more recently discovered factors for cardiovascular disease, including apolipoproteins, homocysteine and C-reactive protein. A more comprehensive risk profile may enhance the clinicians risk stratification. I describe each of the serum factors believed to influence CVD below. I also discuss the influence of physical activity and race on the risk factors assessed in this study.

1.2.7.1. Serum lipids: cholesterols, lipoproteins and triglycerides

Although both cholesterol and triglycerides are vital for normal physiological function, excess amounts are deleterious to health. If exogenous (i.e. dietary) lipids are insufficient, the liver is able to synthesize cholesterol and triglycerides. Dietary triglycerides and cholesterol are transferred to the liver where they are processed along with phospholipids and protein to form lipoproteins. Lipoproteins are lipid-protein complexes that transport lipids through the plasma. They are comprised of a core of cholesterol or triglyceride surrounded by a coat of phospholipids and proteins (called apolipoproteins).

Lipoproteins are categorized according to the thickness of the protein shell that surrounds the lipid; very low density; low density; high density (VLDL-C, LDL-C, or HDL-C). On the outer surface of the LDL-C is the protein apolipoprotein B (Apo B). Apo B increases the carrying capacity of cholesterol, in the LDL-C molecule, so increasing cholesterol deposits in the artery wall. The endothelium, which contains Apo B receptors, can engulf the entire LDL-C molecule. By this mechanism, LDL-C can enter the endothelial lining of an artery. Once inside the lining, monocytes engulf the now oxidized cholesterol, forming a foam cell.

High-density lipoproteins are involved in repackaging cholesterol and transporting it to the liver. With the assistance of an apolipoprotein located upon its surface, free cholesterol is esterified, allowing removal of cholesterol from the plasma and tissues. For this reason, a high ratio of HDL-C to LDL-C (or a high ratio of HDL-C to total cholesterol is thought to be beneficial to cardiovascular health. Apolipoprotein A (Apo A) is a polypeptide found primarily on the surface of the HDL-C molecule. Its role is to activate the enzyme lecithin cholesterol acetyl transferase within the HDL-C complex. This enzyme catalyzes the esterification of cholesterol, which increases its solubility, which in turn increases the carrying capacity of HDL-C. For this reason, Apo A is a marker of the cholesterol clearing capacity of blood.

The exact role of triglyceride in the development of atherosclerosis (hardening and narrowing of the artery) remains equivocal. Increased levels of triglyceride often occur when LDL-C is elevated and HDL-C is depressed. Although its role may be less potent than other serum lipids in atherogenesis, it is an independent risk factor for coronary heart disease. Often the predictive value of triglyceride loses its value after adjustment for HDL-C. Durstine [131] describes the relationship between triglycerides and coronary disease as 'somewhat positive' and goes on to state that levels of triglyceride may be of particular importance in some groups, such as people with diabetes.

Although the exact physiological functioning of lipoprotein (Lp) (a) is unclear, it has been labelled as an atherogenic and thrombogenic molecule. It is believed to have an independent role in the development of atherosclerosis. Structurally it is similar to LDL-C, but contains a unique apoprotein, apoprotein (a). It is predominantly genetically determined and less responsive to changes in diet and drug therapy than other lipoproteins. Lp (a) binds to both LDL-C and HDL-C and interferes with the functioning of the clot inhibiting molecule plasminogen, which is found on the endothelial lining. Lp (a) competes with plasminogen for binding sites on fibrinogen, resulting in formation of clots. At low to moderate levels, Lp (a) may play a role in normal repair of the arterial wall, but becomes atherogenic at levels above 30mg/dL. The risk of developing CVD is twice as high in an individual with an Lp (a) concentration >30mg/dL compared with a concentration of 5mg/dL. The long-term effects of elevated Lp (a) in children are not yet determined.

1.2.7.2. The relationship between serum lipids and physical activity

Although I will refer to some adult physical activity literature during in this section, I will focus primarily on pediatric literature.

There is a fairly extensive body of literature that has examined the relationship between physical activity and serum factors related to CVD in adults. The results may explain the reduced risk of CVD associated with lifelong physical activity. One meta-analysis of 66 training studies found that the average exercising adult had a reduced total cholesterol (10mg/dL), lower triglycerides (15.8mg/dL), lower LDL-C (5.1mg/dL) and greater HDL-C levels (1.2mg/dL) than non exercisers [50].

Findings in youth and children have shown a similar relationship. The Young Finns Study [51] attempted to determine indices of physical activity, body composition, blood pressure, serum lipids, apolipoproteins and insulin in 3500 individuals aged 9-24 years. The study, with both cross-sectional and longitudinal components, showed that whilst inverse relationships between physical activity and total cholesterol, LDL-C and insulin existed in males, these relationships were not apparent in females. Only triglyceride levels were associated with high physical activity levels in both genders. Highly active males were also shown to have more favourable HDL-C to total cholesterol ratio. As physical activity level was self-assessed, however, results may be subject to bias. A relationship was found between LDL-C and physical activity (self-report) in 49 girls aged 8-11 years [56]. This cross sectional study reported that the intensity of activity was of greater influence on LDL-C than the total amount of activity.

Not all interventions, however, have resulted in significant positive changes in cholesterol levels. The Cardiovascular Health in Children (CHIC) study [28] was a 30-minute, 3 times per week PE based intervention lasting 8 weeks. Although there were increases in physical activity levels, changes in total cholesterol were not significant. The Child and Adolescent Trial for Cardiovascular Health (CATCH) [27], another PE based intervention, was aimed at children in grades 3 to 5. The intervention was physical activity and knowledge based, with an aim of increasing the amount of vigorous activity during PE classes. However, despite a significant fall in fat intake, and increased moderately vigorous activity during PE class, CATCH failed to result in a significant change in total cholesterol levels in these children.

Studies examining the relationship between physical activity and apolipoproteins are scarce. A positive relationship of physical activity with Apo A and a negative relationship with Apo B was found in the Young Finns Study [132]. Investigators concluded that apolipoproteins tracked similarly to their low or high-density lipoprotein pair. Similarly, in a cross sectional study involving girls aged 8-14 years, higher levels of physical activity correlated with low levels of Apo B [56]. No relationship, however, between physical activity and Apo A levels was found.

Studies in adults show that the effects of physical activity and diet on Lp (a) are relatively small. The Northern Ireland Health and Activity Survey [133] was a cross sectional study on 1,600 adults. A negative relationship was found between Lp (a) concentrations and *past* physical activity, but not *recent* physical activity. In another cross sectional study of 119 adult males there was no significant difference in Lp (a) concentration between runners and sedentary control [134]. Differences were found between runners and non-runners for other lipoproteins (HDL-C and LDL-C), but the relationships between Lp (a) and any other lifestyle, training or anthropometric variable were not significant.

In children, only cross sectional investigations concerning Lp (a) have been conducted. Suter et al [135] investigated the relationship between physical activity, body fat, diet and lipid profiles in 97 10-15 year old boys and girls. They reported significant correlations between physical activity, body fat and a number of serum lipids, including total cholesterol, HDL-C and triglycerides, but no relationship was found with Lp (a). Conversely, Taimela et al [136], as part of the Young Finns Study, found a negative correlation between Lp (a) concentration and physical activity. Median serum Lp (a) was 45% lower in subjects in the highest 5^{th} percentile of physical activity compared with subjects in the lowest 5^{th} percentile of physical activity. However, results of associations from cross sectional reports should be interpreted with caution.

Few intervention studies have assessed change in Lp (a) in response to exercise and these are limited to adults. Two exercise intervention studies have shown change in Lp (a) concentration as a result of an intervention, one conducted with dietary manipulation [137, 138]. Conversely, Hubinger et al [139] conducted a 12-week study and intervened with a program of relatively vigorous exercise with previously sedentary adult males. There was no change in Lp (a) level at the end of the trial. These conflicting results may be due to small sample sizes or the nature of the intervention, or it may be that Lp (a) does not respond to exercise training. There may not be a straightforward dose-response relationship between Lp (a) and physical activity level. The role of exercise for the cardiovascular health of both adults and children, with normal and elevated levels of Lp (a) warrants further investigation.

1.2.7.3. C-Reactive Protein

C-reactive protein is a general indicator of tissue damage and therefore reflects damage to blood vessels that may precede a heart attack or stroke. C-reactive protein is believed to influence monocyte chemotaxis during atherogenesis and increase the production of adhesion molecules. Adhesion molecules are involved in T-cell and B-cell interactions and promote immune and inflammation response.

The relationship between C-reactive protein and other physiological parameters related to cardiovascular risk was explored as part of a cross sectional investigation into early arterial changes in 79 healthy children aged 9-11 years [140]. An elevated C-reactive protein level was related to two markers of early atherosclerosis: reduced flow mediated dilation and increased carotid intima-media complex thickness. Researchers concluded that C-reactive protein might affect arteries by disturbing endothelial function and promoting thickening of the intima-media. The results of this study highlight the potential role of C-reactive protein in the pathogenesis of early atherosclerosis.

1.2.7.4. The relationship between C-reactive protein and physical activity

In adults, several prospective studies have demonstrated a link between C-reactive protein levels and CVD development. One study involving 1,172 men showed positive associations between C-reactive protein levels and numerous risk factors including age, cigarette smoking, BMI, blood pressure, total cholesterol, triglycerides, lipoprotein (a), apolipoprotein B, D-dimer, homocysteine and fibrinogen [141]. Inverse relationships between physical activity levels, HDL-C and apolipoprotein A were also found, supporting the hypothesis that C-reactive protein is a marker of pre-clinical cardiovascular disease.

In children, a strong relationship was found between C-reactive protein levels and BMI [142]. These assessments were made as part of the Third National Health and Nutrition Examination Survey (NHANES III) in the US between 1988 and 1994. Among children with a BMI below the 15^{th} percentile, only 6.6% of boys and 10.7% of girls had elevated C-reactive protein levels (>2.1mg/L). Prevalence was 24.2% in boys and 31.9% in girls with a BMI above the 95th percentile. It was concluded that excess body weight is likely associated with a state of chronic low-grade inflammation in children. Another cross-sectional investigation enrolled approximately 700, 10-11 year old children and reported similar findings. Children with a high Ponderal index (weight/height^3) or a lower physical activity level [71] had higher C-reactive protein levels. The Columbia University BioMarkers Study, involving 205 children and young adults aged 6-24 years, also positively linked physical fitness and C-reactive Protein level [143]. Investigators found a low, but significant, negative correlation between physical fitness and C-reactive protein.

1.2.7.5. Homocysteine

Homocysteine is an amino acid, thought to promote oxidation of cholesterol and clot formation. Homocysteine results from protein metabolism – particularly proteins of animal origin. It is then usually rapidly re-metabolized in pathways requiring vitamin B12 (a remethylation) or vitamin B6 (transulfuartion) to prevent build up. Without this re-metabolization, homocysteine can promote vascular disease in a number of ways; by generating superoxide dismutase and hydrogen peroxide which are known to damage endothelial linings; by preventing small arteries from dilating; by altering coagulation factor levels so promoting clot formation by causing platelets aggregation. The relationship between CVD and homocysteine in adults is positive and linear. For example, one meta-analysis of adult studies showed that for every 5μmol/L rise in homocysteine, there was a 1.34 fold increase in coronary artery disease risk [144].

1.2.7.6. The relationship between homocysteine and physical activity

In adults, elevated plasma homocysteine levels have been linked with lifestyle factors, including coffee consumption, alcohol consumption, folate intake, smoking and physical inactivity [145]. The Hordaland Homocysteine Study evaluated more than 16,000 adults aged 40-62 years and showed a strong negative correlation between physical activity and homocysteine level [146].

In children there are very little data so the relationship between homocysteine and risk factors for CVD is not clear. Cross-sectional studies in children demonstrated ethnic and lifestyle influences on homocysteine [147, 148], but few attempted to determine the relationship between homocysteine and physical activity. Gallistl and colleagues [149] conducted a 3-week exercise intervention with 32 obese children aged 10-14 years. They determined that change in lean body mass was the only variable associated with homocysteine level. Physical activity did not have an independent effect on homocysteine.

1.2.7.7. Haemostatic markers

'Haemostatic markers' is an umbrella term for a collection of serum factors (fibrinogen, plasminogen activator inhibitor and D–dimmer) that contribute to the clotting process. Fibrinogen, a soluble plasma protein synthesized by the liver, is the precursor to fibrin. Plasma fibrinogen is a major determinant of blood viscosity and, therefore, plays a pivotal role in the clotting mechanism. Fibrin is an insoluble protein that forms a mesh of fibres that allows the aggregation of platelets, creating a clot. D-dimer is a fibrin degradation fragment. Elevations of D-dimer are seen when clot break down occurs, such as when thrombotic disease (deep vein thrombosis or pulmonary embolism) is present. Clots created by fibrin are broken down by plasmin (plasminogen in the inactive form). The protein plasminogen activator inhibitor can inhibit this breakdown. In this way, plasminogen activator inhibitor contributes to thrombus formation. The relationship between these factors is depicted in below (Figure 1.1).

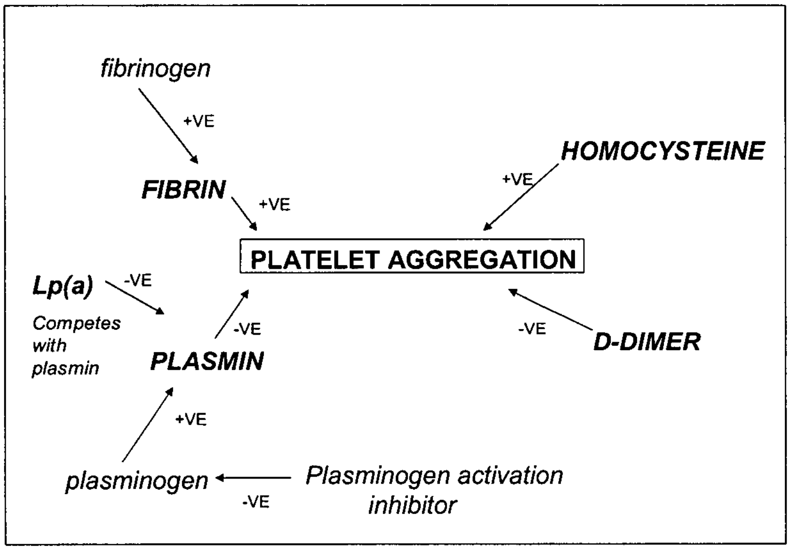

Figure 1.1 Factors contributing to (+ve) or inhibiting (-ve) clot formation. Precursors to serum factors affecting clot formation are written in lower case.

1.2.7.8. The relationship between haemostatic markers and physical activity

In adults, the response of fibrinogen levels to physical activity has been studied. A cross sectional study of inflammatory markers in relation to physical activity level showed a negative correlation between chronic physical activity and fibrinogen levels [150].

Similar results have been found in children. Barbeau and colleagues [151] conducted an 8 month physical activity intervention on 74 obese teenagers. They found that although baseline levels of fitness (initially low) and adiposity (initially high) were associated with higher levels of haemostatic markers, the intervention did not influence any serum factors. However, the researchers note the low compliance to the program may have affected results. The Columbia University Biomarkers Study was a cross sectional study that assessed 193 children and youth aged 4-25 years (68% Hispanic) [143] designed to examine relationships between serum factors and fitness (not physical activity). Researchers found that fitness levels were inversely associated with plasma fibrinogen levels.

The effects of short term energy restriction combined with physical training on haemostatic risk factors were observed in a short term intervention involving 56 obese children aged 10-13 years [149]. Researchers found that after 3 weeks participation in the program, all haemostatic risk factors decreased significantly. However, as change in risk factors was correlated with change in body composition, the direct and independent effect of the exercise was not clear.

As results from the few investigations involving children that attempted to change fibrinogen levels have varied, longitudinal studies that address this question are vital.

1.2.7.9. The influence of race on serum factors

In adults there are well known racial differences in mortality and morbidity from coronary heart disease and stroke. One large investigation of adults examined the causes of death in six ethnic groups in the U.S. [152]. The investigation used proportional mortality ratios (PMR) to explore the incidence of vascular related deaths in adult Caucasian, Mexican-American, African-American, East Asian and Asian Indian populations. Asian Indians experienced the highest PMR for coronary heart disease, followed by Caucasians. The highest PMR for stroke was seen in Asian-American women, followed by Chinese and Japanese individuals and, finally, African-American women.

Race influences a number of serum factors in adults. For example, Lp (a) levels are frequently high in African-Americans [153], low in American-Indians [154] and Mexican-Americans [155]. An investigation of more than 2000 African-American and Caucasian subjects found that the likelihood of having raised Lp (a) levels was nearly three times higher in African-American compared with Caucasians [155]. However, compared with Caucasians, African-American have higher levels of HDL-C [156], lower triglyceride levels, less of the small atherogenic lipoprotein molecules [153] and lower Apo B concentrations [156]. Fibrinogen levels are significantly higher in Asian women living in the United Kingdom than British Caucasian women [157], whilst South Asian adults living in Canada have higher total cholesterol, LDL-C, Lp (a), triglycerides, fibrinogen and homocysteine but lower HDL-C than European-Canadian or Chinese-Canadian adults [158].

Children of different racial backgrounds have different serum profiles. A comprehensive review of blood lipids and lipoproteins reported mean serum values for young people (3-18 years) from 26 countries [159]. The review determined that children from European countries had the highest total cholesterol level, with Australian, Japanese and North American children having slightly lower values. Children from Pakistan and the Philippines also had lower levels. Black African children showed the lowest level. HDL-C cholesterol as a percentage of total cholesterol did not follow a similar pattern, however. Children from Japan and Spain had the highest (most favourable) HDL-C percentage whilst children from Pakistan and the Philippines had the lowest (least favourable) percentage.
In separate studies African-American children exhibited lower triglyceride, higher Lp (a) and higher HDL-C levels than Caucasians [160], whilst Mexican-American children had higher total cholesterol level than Caucasian children and higher LDL-C cholesterol levels than both African-American and Caucasian children [126]. The National Heart

Lung and Blood Institute's Growth and Health Study examined various serum factors in a bi-racial cohort of 2379 young girls aged 9-10 years [161]. Researchers determined that African-American girls had a median Lp (a) concentration three times that of Caucasian girls.

Levels of the haemostatic factors also differ between races. Black South African children had higher homocysteine levels than white South African children [147]. The CATCH study enrolled 96 elementary schools in the US and assessed a number of serum factors in 3524 children aged 13-14. Boys had higher homocysteine levels than girls and African-Americans had higher levels than both Caucasians and Mexican-Americans. NHANES III demonstrated similar findings [162]. Boys had higher serum homocysteine than girls at all ages and across all races. They reported that African-American children had the highest mean homocysteine level followed by Caucasians and Mexican-Americans.

There are several important issues related to serum factors, physical activity and race that have not yet been evaluated in children. Most studies to date have been cross-sectional. It is important to assess both cross-sectional differences and the prospective response of children from different racial backgrounds so that targeted interventions can be effective. Further, by investigating children of different races who live in similar geographic and economic environments, the more specific role of race and other lifestyle differences can be delineated.

1.2.8. Heart rate variability

The clinical relevance of heart rate variability (HRV) was first noted in the mid 1960s when it became apparent that fetal distress was immediately preceded by variations in beat rhythm [163]. This change in rhythm occurred before any change of actual heart rate. From this initial observation, physicians developed techniques to observe the beat-by-beat fluctuations in the heart rate of patients, initially those with diabetic neuropathy. A decade or so later, it was confirmed that HRV was a strong predictor of mortality after infarction [164]. Since then, physiologists and physicians have developed sophisticated techniques to allow accurate assessment of beat-by-beat cardiovascular control and HRV has joined a number of more traditional screening tools to provide accurate CVD risk stratification [165].

The nervous system is divided into the somatic and autonomic divisions, both comprising afferent (sensory) and efferent (motor) nerves. Somatic nerves are under voluntary control and allow movement of the body. The autonomic nervous system (ANS) consists of a separate group of afferent and efferent neurons that control the automatic, or visceral, functions of the body such as blood pressure, digestion, blood circulation and respiratory activity. There are two major divisions of the ANS through which the body transmits all autonomic impulses: the sympathetic nervous system, which originates in the thoracic and lumbar regions - and the parasympathetic nervous system, which originates in the brain stem and sacral regions.

Although the heart has an intrinsic rate of around 100 beats per minute, this rate is also controlled by the action of the ANS (sympathetic and parasympathetic branches) on the sinoatrial node. The parasympathetic branch acts upon the heart via the vagus nerve, and dominates at rest. This system is frequently referred to as the vagal system. Heart rate at rest results from the combination of the excitatory action of the sympathetic system and the inhibitory effect of the parasympathetic system. Removal of cardiovascular inhibition (by inactivating the vagus nerve) results in a sharp rise in heart rate. In general, a healthy heart has a relatively high variability of beat-to-beat intervals (R-R, taken from the traditionally labelled P QRS T of an electrocardiogram (ECG), with the P was representing atrial depolarization, the QRS complex representing ventricular depolarization and the T wave representing ventricular repolarization). This reflects an active vagal system.

Heart rate variability is an umbrella term for a variety of measures that assess the autonomic influence on the heart and in turn reflect cardiac health. In a normal ECG, the interval between each normal QRS complex is determined, as is the RR interval. This is shown in below (Figure 1.2).

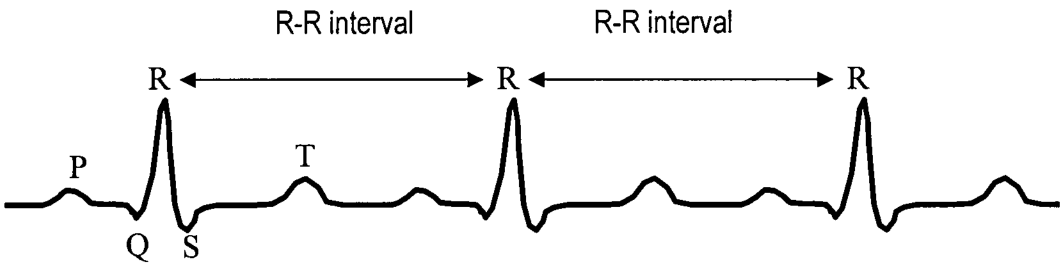

Figure 1.2 Schematic diagram of an ECG trace. The P, Q, R, S and T are labelled, and the RR intervals highlighted.

Measures are separated into either time domain or frequency domain components and recordings generally fall into long term (24 hour) or short term (2-5-min) categories. Although 24 hour recording allows for a greater array of analyses, HRV in adults is influenced excessively by changes in environment and the physical and mental state of the patient. Whilst a long-term recording is often warranted in clinical settings, a short-term (5-min) recording provides a fast and stable measure of autonomic activity [165].

In adults, impaired variability (low HRV) was been found in patients with myocardial infarction [166], chronic heart failure, and left ventricular dysfunction [167]. In infants, low HRV values have been associated with the likelihood of sudden infant death syndrome [168] and atrial septal defects [169]. Recently pediatric norms for HRV were established [170] showing that children have a greater variability than adults [171, 172]. Gender also influences HRV [171, 173], although the exact nature of these gender differences are not yet fully understood.

Martini and colleagues [174] investigated the relationship between body weight and HRV in children and concluded that obese subjects had significantly lower HRV parameters (i.e. more sympathetic, less vagal activity) than their normal weight counterparts. Alterations in autonomic function in relation to obesity have previously been reported.

The increased activation of the sympathetic system in obese subjects is a response to an increased food intake and the resultant rise in the metabolic rate [175]. Body fat distribution also influences the sympatho-vagal balance. Greater sympathetic activity was observed in subjects with high levels of visceral, as opposed to subcutaneous, fat deposits [174, 176]. Increased sympathetic activity would manifest as an elevated low to high frequency power ratio (LF: HF). However the elevated LF:HF ratio in the Martini et al study was not due to a higher sympathetic activity (as would be indicated by an elevated LF) but rather to a reduced parasympathetic, or vagal, activity (indicated by a reduced HF) [174]. The mechanisms that describe the relationship between obesity and altered autonomic function in children have yet to be fully determined.

1.2.8.1. The relationship between HRV and physical activity

Long-term aerobic exercise positively influences HRV by reducing chronic sympathetic neural flow to the sinoatrial node. A 12-week training program in 19-45 year old recreational runners resulted in an increase in spectral power and in high frequency power, indicating an elevated vagal input to the heart [177]. Autonomic adaptations were also seen in previously sedentary subjects following an 8-week training program [178]. During the moderate training period (2 months) HRV increased, with a shift in the autonomic nervous system towards vagal dominance. Interestingly, 7 weeks after the end of the intervention all values had returned to pre-training levels, indicating the reversible nature of the change.

In children, whilst an increase in variability was shown after a high intensity 13-week training program (3 x 1hr per week), researchers failed to find a change in the relative contribution of sympathetic and vagal activity [172]. The longest study to date was carried out on obese children, who underwent 4 months of training [179]. Using short-term recordings, the intervention group experienced favourable changes in time and frequency domains compared with controls, demonstrating positive effects on the sympathetic-vagal balance.

There are few long term or intervention studies investigating HRV in healthy children. It is apparent that physical activity can influence the autonomic nervous system, but the magnitude and exact nature of this influence is not clear. Body fat and fat distribution contribute to HRV. Exercise interventions aimed at modulating HRV must therefore take these variables into account.

1.2.8.2. The influence of race on HRV

Recently, ethnic differences in HRV have become apparent. There are differences in variability between African-American and Caucasian adult men, with African-American men having lower sympathetic activity [180, 181]. Results of previous studies exploring ethnic differences in youth have been equivocal. Whilst one investigation found that African-American adolescents displayed less favourable HRV measures (time and frequency domains) than age-matched Caucasians [182], another found a lower (more favourable) ratio of sympathetic to vagal modulation on heart rate in African-Americans [183].

There have been few prospective investigations in children and none with duration of more than 4 months. Few have explored gender or ethnic differences. Some investigations that explored racial differences have compared Caucasian with African-American individuals, whilst none explored HRV differences between East Asian, South Asian or Mexican-American individuals. These are all areas that require further research to better understand the full effect of physical activity on HRV.

1.2.9. Arterial compliance

The arterial system has been equated to a series of elastic conduits and high resistance terminals that, combined, constitute a hydraulic filter. This filtering converts the intermittent output of the heart to a steady flow through the capillaries.

The stroke volume is discharged from the left ventricle into the aorta relatively rapidly, and the energy is dissipated in part by forward flow of the blood through the capillaries. The remainder of the energy is stored as potential energy and is absorbed by the elastic arterial walls. During diastole, elastic walls recoil pushing blood along the artery. It is the elastic nature of the artery walls, therefore, that allows blood flow to be continuous rather than intermittent. This 'hydraulic filtering' reduces work load on the heart i.e. less work is required to pump a flow steadily rather than intermittently. Compliance is partially determined by the elastic properties of the artery and, in turn, contributes to the pressure-volume relationship.

The relationship between volume and pressure in the aorta of subjects in different age ranges is depicted below (Figure 1.3). In the youngest age group the sigmoid curve highlights the ability of the aorta to undergo a large increase in volume with a fairly minimal change in pressure. In older individuals, however, a relatively slight increase in volume results in a large increase in pressure. At any point, the slope represents compliance of the artery – (dV/dP).

In younger adults, the compliance tends to be highest over the normal range of pressures, and least at the extremes of pressure. As age increases there is a general decrease in compliance, especially at pressures above 80mmHg. This is due to progressive changes in the collagen and elastin content of the artery wall resulting in stiffness (atherosclerosis). As individuals age there is an increase in elastic modulus (Ep) of the artery.

The elastic modulus of an artery is defined as:

$Ep = \Delta P/(\Delta D/D)$

Where:

ΔP = pulse pressure (difference between systolic and diastolic pressure in an artery);

D = diameter of the aorta during the cardiac cycle;

ΔD= the maximum change in diameter during systole;

The fractional change in aortic diameter reflects a change in volume; the elastic modulus of an artery is inversely proportional to arterial compliance. A small change in pressure for large change in blood volume, as normally seen in healthy young individuals is, therefore, usually indicative of a large arterial compliance and a small elastic modulus.

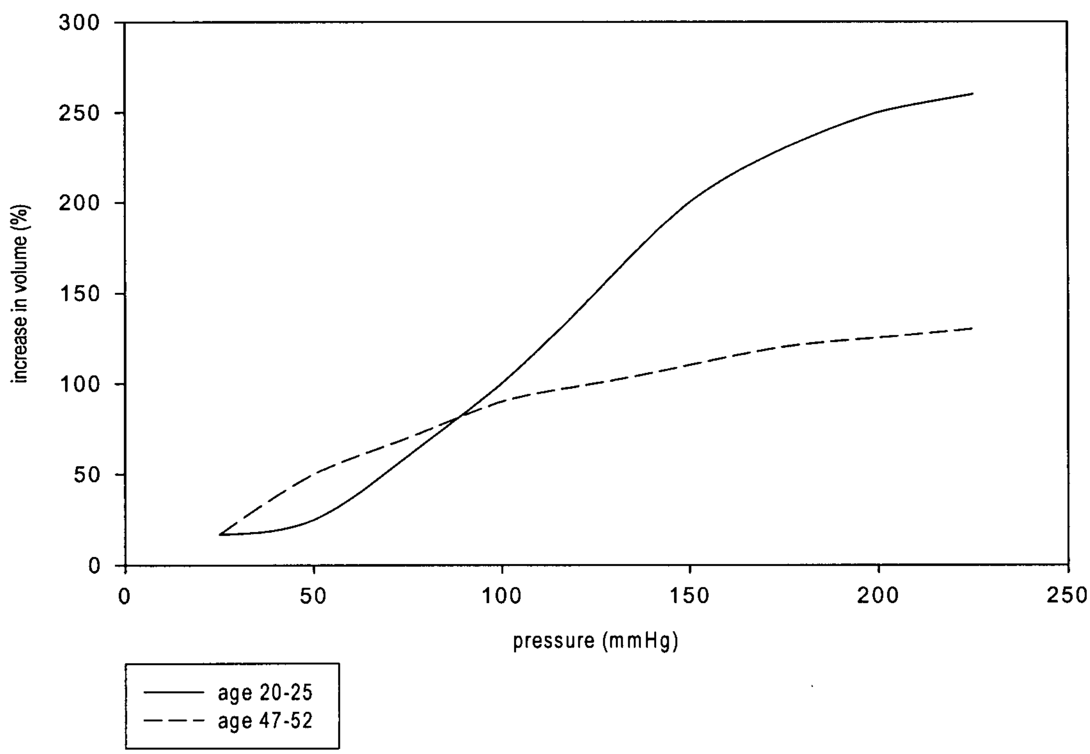

Figure 1.3 A schematic diagram of the volume: pressure relationship of an artery of a young adult (solid line) and an older adult (dotted line) adapted from Berne and Levy [184].

The Atherosclerosis Risk in Communities Study [106] indicated that increased arterial stiffness *preceded* hypertension. Dysfunction of the endothelium results in structural and functional alterations in the vessel wall. The normal endothelium maintains vessel tone, mainly via nitric oxide release. Besides altering smooth muscle tone in the vessels, nitric oxide protects the artery wall from lipid infiltration and from platelet aggregation. Disruption in the endothelium is frequently seen first in the smaller conduit vessels and then in the small arteries, partly because nitric oxide has a greater role here than in the larger arteries. The structural and functional changes result in the widened pulse pressure (the difference between systolic and diastolic pressure) characteristic of reduced arterial compliance (a precursor of atherosclerosis). However, other researchers have postulated that arterial stiffness occurs as a consequence of hypertension [107]. Hypertension accelerates atherosclerosis, collagen synthesis, smooth muscle hyperplasia and hypertrophy. These changes would all increase arterial stiffness.

After controlling for body size, arterial compliance in children is high. This compliance begins to decline after just a few months of life [185]. Arterial stiffness progressively increases with age in normotensive, healthy adults, but it may be moderated by a variety of factors.

1.2.9.1. The relationship between arterial compliance and physical activity

Physical activity positively influences arterial compliance in adults [186, 187] . The increased blood flow that occurs as a result of exercise increases sheer stress. The higher intra-luminal forces stimulate nitric oxide release from the endothelium to cause dilation. Chronic increases in sheer stress result in remodelling of the lumen (an increase in diameter and a decrease in smooth muscle tone) to reduce repeated increases in sheer stress. Further to this, a post-exercise induced decrease in sympathetic output may result. Immediately following a bout of physical activity there is a reduction in both the responsiveness of adrenergic receptors to catecholamine and reduced sympathetic nerve activity [109]. It is also proposed that physical activity, via both an anti-inflammatory and an anti-thrombotic role, preserves the properties of the endothelium.

Indirectly, physical activity may affect parameters such as fat mass, HDL-C level and blood pressure that are often covariates of arterial stiffness. The effect of physical activity on coronary arterial stiffness and compliance may be mediated by a number of factors, both locally and systemically. In children, arterial compliance was influenced by obesity, especially android fat distribution [188]. However, in adults, the effect of exercise on compliance of the peripheral arteries, such as the brachial or femoral artery, was independent of changes in other risk factors [186].

Two studies showed that an intensive exercise intervention caused significant improvement in endothelial function (measured by pulse wave velocity) among obese children [189, 190]. Watts and colleagues [190] conducted an 8-week intervention with 14 obese children aged 9 years. Endothelial function increased by 7% in response to the intervention. Woo and colleagues [189] conducted a 6-week intervention with 82 obese children aged 9-12. They too reported significant increases in endothelial function. There have been no longitudinal studies investigating the relationship between arterial compliance and physical activity, or interventions involving normal weight, healthy children.

1.2.9.2. The influence of race on arterial compliance

Few studies have explored racial differences in arterial compliance and stiffness. Arterial stiffness (measured by pulse wave velocity) was shown to be higher (less favourable) in Asian adults [191] compared to Caucasian adults. Similarly, Afro-Caribbean men with diabetes had an accelerated age-related decline in compliance compared with their diabetic Caucasian peers [192]. In children, only one study has looked at inter-racial differences and similar findings were observed. Black children (10-15 years) in South Africa had lower arterial compliance than White and Indian children from nearby towns [193]. Further investigations into the ethnic differences need to be carried out; not only to determine racial or ethnic specific norms, but also to explore the effect of combined risk factors on these populations.

1.2.10. Physical fitness: an independent risk factor and a modifier of other risk factors

'Physical fitness' refers to a set of physiological (such as maximal oxygen uptake) that reflects a person's exercise capacity. Pediatric studies show a low (r=0.17) [42] to moderate (r=0.66) [41] correlation between physical activity and physical fitness. Genetics is believed to explain 25-40% of the variance in fitness [41, 43]. Nevertheless, there is evidence to suggest that fitness is associated with physical activity levels in children and the contribution of genetics is thought to be of lesser importance than variations due to environmental factors [44].

During the past 2 decades physical fitness has become a well established predictor of CVD and all cause mortality in adults. Fitness can be measured accurately in a number of ways and is a strong and independent predictor of health outcomes [194]. Numerous studies support the notion that higher levels of fitness confer cardioprotective effects, even in the presence of other risk factors [194-199]. Longitudinal cohort studies in adults generally show the magnitude of mortality is reduced substantially with increasing fitness. A large number of studies have demonstrated at least a 50% lower mortality rate in high physically fit compared with low physically fit individuals [195, 197, 198].

In children, a similar pattern emerges. The most fit children demonstrate lower levels of individual risk factors and clustered risk factors than lower fit children [200]. Higher levels of fitness are associated with lower levels of fibrinogen [143], C-reactive protein [201], blood pressure [31, 111], vascular stiffness [202] and body fat [31, 41]. A recent report from the Quebec Family Study showed higher physical fitness was related to lower clustering of risk factors in youth [200]. Surprisingly, only recently has the clustering of CVD risk factors been examined in children. Eisenmann and colleagues [200] studied the association between fitness and mass, and the individual and combined influence these have on other CVD risk factors in children. Importantly, they are the first to determine a composite CVD risk profile for children using a number of risk factors including age adjusted blood pressures, total cholesterol, LDL-C, HDL-C, glucose and triglycerides. They reported that both physical fitness and BMI are independently associated with CVD risk score in youth. Not surprisingly, the most fit individuals with the lowest BMI had the most favourable CVD risk profile. Figure 1.4 demonstrates this relationship in girls (age 9-18 years). Boys showed a similar pattern across groups.

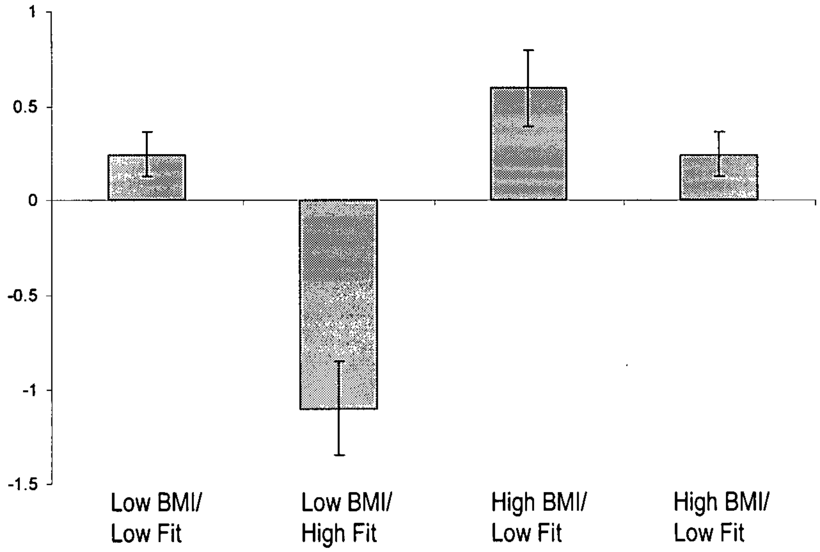

Figure 1.4 Differences in composite risk score across body mass index and aerobic fitness among young girls. Values are mean and SE. Girls in the Low BMI/High Fit group have a significantly lower composite risk score than girls in other groups. Adapted from Eisenmann [200].

Although it is essential that these early results utilizing composite CVD risk scores be replicated in other studies, these early findings support the overwhelming evidence from adult studies [194-199], that suggest a strong link between physical fitness and cardiovascular health.

1.2.11. Childhood physical activity

This section begins with an overview of the methods currently used to assess physical activity. This is followed by a discussion of current physical activity levels in children.

1.2.11.1. Measurement of physical activity

Reliable and valid measurement of physical activity is difficult to achieve in all ages and populations. Measurement of physical activity in a large-scale project requires a relatively low cost method. A wide range of methods has been employed in an attempt to measure physical activity. Problems inherent in many types of measurement are greater in children due, in part, to their inability to accurately recall past activity. In addition to this, the sporadic or transitory nature of their activity makes it difficult to quantify and record their energy expenditure and physical activity level [203]. Children are often intensely active for very short periods of time. In one investigation the median duration of moderate intensity activities of children was six seconds [204]. A researcher observing a child's activity every 10-15 seconds may not obtain valid or reliable data. In adults, measurement focuses on extended periods of activity, such as a 15-20 minute exercise session. This type of activity is not common in children, so measuring activity using adult criteria and measurement techniques is inappropriate.

Energy expenditure and physical activity are not synonymous. Energy expenditure refers to the amount of energy in the form of calories that the body is using and thus, continues at rest. Physical activity refers to *voluntary* movement. Methods used to estimate physical activity frequently estimate energy expenditure. Accelerometers, for example, can supply information regarding duration and intensity of movement, and give an estimation of the energy required to carry out this activity. Conversely, tools used solely to estimate energy expenditure, such as doubly labelled water, cannot describe or estimate physical activity in terms of duration or intensity.

The combined use of objective and subjective measures provides the researcher with a broad view of activity so that pattern, type and amount of physical activity can be assessed. Common methods used to estimate physical activity/energy expenditure in children are summarized (Table 1.1). Many of the objective measures are inappropriate for large scale field research projects due to high costs and potential for subject reactivity. Further it is difficult to determine the most appropriate method for researchers as many objective methods have not been validated against the gold standard measure [205]. In choosing a physical activity measurement method one must consider the strengths and weaknesses of each method, the size and characteristics of the study cohort and the specific research objectives. Ultimately, the method chosen should be valid, reliable and nonreactive [206]. Self report instruments are most commonly used to assess children's physical activity [207]. This is likely due to the low costs, low researcher burden, quick administration time and therefore, the ability of measure large numbers of children in a short time period [208]. This thesis uses one physical activity recall questionnaire (PAQ-C)

The PAQ-C is a multi-item questionnaire, designed to assess habitual moderately vigorous physical activity in children. It was developed through a multi step process that included item modification based on feedback from students, research assistants and item analysis. The final questionnaire consisted of 10 items, nine of which are used to calculate a summary activity score. The other question assesses whether the child was sick in the previous week or was prevented from normal activity as a result of other events. Within each PAQ-C item, physical activity is described as 'sports games or dance that make your legs feel tired or make you sweat' All items are scored on a 5-point scale (1=low activity to 5=high activity). The PAQ-C has been modified to include an estimate of time per activity session (item 1) as well as involvement in extracurricular activities (sports, music clubs etc), the number of nights per week spent in organized activities and the number of television hours watched and computer games played. The PAQ-C has been validated against various instruments (including other self-report questionnaires and motion sensors) with values of r=0.39 to 0.63 [208]. The moderate correlation between the PAQ-C and accelerometers (r=0.39) is similar to correlations found with other self report and interviewer administered questionnaires [209]. The lack of strong association in validation studies of self report is attributed to limitations in memory and recall, especially in children less than 10 years, overestimation of physical activity and bias due to social desirability [210]. A further limitation of the PAQ-C is that it does not discriminate between vigorous and moderate physical activity. Despite these limitations, it is a cost effective and time effective tool that is useful in large scale studies. Reliability (test re-test with a one week interval) of the measure was shown to be high in both girls (r=0.82) and boys (r=0.75) aged 9-14 years [208].

Other recall methods include the Baecke questionnaire [211], the Tecumseh questionnaire [212] and the Minnesota Leisure Time Physical Activity questionnaire [213]. Although these have been well validated in adults, they are inappropriate for children because of the duration of recall or the nature of the activities included. Questionnaire and recall methods have clear advantages when used in large or epidemiological studies but may be less valid or reliable than other measures of physical activity or energy expenditure. The important consideration is to use the tool that is most appropriate for the cohort being investigated and the research question being asked.

The majority of previous school-based physical activity interventions have relied on participants' self –report, however, some have successfully used objective measures. The Childhood and Adolescent Trial for Cardiovascular Health (CATCH) project successfully used a direct observation tool (SOFIT) during PE classes over many years [214]. Similarly, the Middle School Physical Activity and Nutrition (MSPAN) study used SOFIT to observe changes in the intensity of physical activity during PE class [215]. The MSPAN study extended its observation of children from PE classes alone to include recreation time as well. Researchers used an adapted version of SOFIT – the System for Observing Play and Leisure Activities for Youth (SOPLAY). This enabled the observation and recording of the activity of children at recess, lunch and after school, to gain a broader picture of the children's activity level.

The Sport, Play and Recreation in Kids (SPARK) project used accelerometers to assess differences between groups after a 2-year intervention period [29]. Unfortunately, no baseline data were collected using this measurement tool, so change could not be analyzed. Similarly, the Promoting Lifestyle Activity for Youth (PLAY) [30] study assessed physical activity levels by pedometer at only one time point. Cross sectional results showed that children involved in the intervention group took significantly more steps than children in the control group. Importantly, SPARK, PLAY and MSPAN used measurement tools that enabled the researchers to ascertain whether total physical activity had increased, whereas CATCH only assessed physical activity during scheduled PE classes.

Table 1-1 Common methods of assessing energy expenditure and physical activity, including advantages and disadvantages of each.

Instrument	Method of data collection	Validity and Reliability	Advantages	Disadvantages
Doubly Labelled Water	Ingestion of radio labelled isotope, excreted in as water and CO_2 over 4-20 days	Gold standard for estimating TEE	Subject is free living unlike chamber calorimetry No reactivity by the subject No interference with every day tasks	Isotopes are expensive. Affected by diet. No daily or hourly patterns can be seen and cannot distinguish exercise from TEE Requires at least 3/4 days
Direct observation	Researchers observe activity several times each minute	**Validity:** against VO_2 r=0.61– 0.91, against HR, r=0.36-0.69 (depending on activity level [210] [216] **Reliability** : 84 to 99% agreement between observers [216]	All activity, even sporadic, is recorded No subject bias	Time consuming for observers. Behaviour may be affected by observation
Heart rate monitoring	Chest strap worn and heart rate recorded over one or more days	**Validity:** against 1 day TEE. HRM overestimated TEE by 14% [217]. Low correlations against accelerometer (r=0.28) **Reliability:** ICC =0.91, [218]	Intensity/duration and frequency of physical activity is shown Can record several days	HR affected by non-physical variables such as excitement Expensive
Pedometers	Worn on waistband, counts steps taken – records movement in vertical plane	**Validity**: High correlation with DO (r=0.87-0.97) [219]. **Reliability:** ICC=0.81-0.91 [205] although validity and reliability vary with site (waist vs. ankle) [220]	Inexpensive and objective	Only measures one plane, no upper body work. Provides no detail regarding intensity or frequency. Can be easily tampered with.

Table 1-1 cont.				
Instrument	Method of data collection	Validity and Reliability	Advantages	Disadvantages
Accelerometers	Worn like a pedometer but device records movement in 1, 2 or 3 dimensions	**Validity:** against DLW (r=0.73) [221]. **Reliability**: over several days ICC=0.76 [218]	Records most activities and can include intensity and duration	More expensive than pedometers. Can be easily tampered with.
Self-report questionnaire	Participant recalls activity over last 24 hours, 7 days or other set period	**Validity:** Recall high as 0.98 (ICC) but underestimated calorie expenditure by 14%. Correlated with HRM r=0.53 [209] and with accelerometry r=0.76 [218] **Reliability**: Questionnaire specific, PAQ-C r=0.075 (boys), r=0.82 (girls) with 1-wk interval	Can distinguish high and low active groups in large group measurements. Patterns and trends of activity are shown. Inexpensive	Becomes less accurate with increasing time span. Frequently requires adaptation for different ages, cultures, seasons

TEE= (total) energy expenditure, HRM=heart rate monitoring, ICC=intra class correlation

Despite the well-accepted difficulty in measuring physical activity in children, several researchers have attempted to quantify activity levels, both cross-sectionally and longitudinally. The majority of studies have reported a decline in physical activity during adolescence [161, 222] and have suggested a number of reasons for this. These include environmental determinants such as socio-economic status (SES), coming from a single parent home and levels of parental education, as well as genetic determinants such as gender and racial background [223, 224].

1.2.11.2. Influence of gender

Sex differences in the amount and change in physical activity have been fairly well documented in both cross-sectional and longitudinal studies, in children as young as 3 years old [17]. There is consistent evidence that boys are more active than girls, with this difference increasing with advancing maturity as assessed by both self-report and objective assessment [18-20, 225].

The Muscatine Study tracked physical activity of boys and girls over five years [18]. Between the ages of 10 and 15 boys increased their self-reported level of vigorous activity, whilst girls typically reported a decrease in activity level. Girls showed more instability in their behaviour. However, this may be a positive factor as antecedents are not firmly rooted and so behaviour is modifiable [222].

Gortmaker and colleagues [20] found that an educational-based intervention resulted in increased physical activity and decreased obesity in girls, but not in boys. They suggested that girls might be more attuned to issues of diet and physical activity and are, therefore, more receptive to interventions. This notion is further supported by data from a twin study [226]. Four hundred and eleven twins aged 12-25 years completed the Baecke questionnaire to determine sports participation and leisure time physical activity. Quantitative genetic modelling was used to show that genetic influences of sports participation and leisure time physical activity were greater in males, whilst females were more influenced by environmental factors.

1.2.11.3. Influence of race

Several studies have assessed racial or ethnic differences in physical activity patterns. A meta-analysis utilizing 108 studies concluded that Caucasian children are generally more active than children from other ethnic backgrounds (including children of African-American, Asian, and Mexican-American decent). This difference became more apparent as children matured [227]. Similarly, the Cardiovascular Health in Children (CHIC) project measured changes in activities of children as they moved from 3rd to 11th grade and a clear racial difference was found [23]. Boys of all races displayed similar activity levels until grade 6, when Caucasian boys began reporting higher levels of physical activity than African-American boys. African- American girls reported fewer vigorous activities than

Caucasian or 'other' race girls at all ages. By high school, race was a significant predictor of physical activity level. A ten-year study of girls showed large ethnic differences in the age-related decline in activity of girls from 9-19 years [22]. Physical activity decreased by nearly 100% among the African-American girls but only by 64% among the Caucasian girls [22]. A comparison of African-American, Caucasian and Mexican-American children reported ethnic differences in levels of physical activity and sedentary activities [228]. Levels of moderately vigorous and vigorous physical activity were lower and inactivity was higher in African-American and Mexican-American children compared with Caucasians. Asian-American children are also less physically active than age and maturity-matched Caucasian peers [229]. The 1996 National Longitudinal Study of Adolescent Health represents more than 14,000 American children and showed that Asian-American and African-American females had lower physical activity levels than Caucasians. Similarly Canadian data, showed that physical activity in Asian-Canadian children (boys and girls) was lower than in Caucasians at several maturity levels [24, 230].

1.2.12. Measurement of fitness

This section refers to measurement of cardiovascular or aerobic fitness. Direct measures of fitness, such as a maximal oxygen uptake test, are usually conducted in laboratory by trained personnel. This makes their use much less common in large scale setting. Indirect measures or field tests usually estimate fitness from performance or a dependent variable, such as heart rate. The most frequently used measures are described below.

1.2.12.1. Direct measures

The 'gold standard' for measuring fitness is a test of maximal effort where oxygen uptake and carbon dioxide produced are measured. The subject is fitted with a face mask and inspired and exhaled gases are monitored. From these values, maximal oxygen uptake (VO_2 max) is estimated. This is the volume of oxygen (ml) used to support metabolic events per unit time (min), and per unit body weight (kg). Such tests are usually performed on a treadmill where speed or incline (or both) are increased every 1-3 minutes. In children a modified Baulke protocol is commonly used whereby children run at a constant velocity (5.6km/h) with a 2% increase in incline each 1 minute, starting at an incline of 6%. The test duration is 9 minutes. A stationary bicycle may also be used for a maximal fitness test. During this test the child cycles at a regular cadence and flywheel resistance increases at 2-3 minute intervals. For these procedures, the test terminates when the subject reaches volitional exhaustion or when the criteria for achieving VO_2 max have been satisfied. For children this is achieving 85% age determined maximal heart rate, a respiratory exchange ratio of >1.0 and a plateau in VO_2 with an increased workload). Although direct assessment of VO_2 is a reliable method of fitness assessment in children [231] it is not always feasible. Frequently, children fail to meet the criteria for achieving VO_2 max [232]. For many children using a treadmill with a steep incline or wearing a face mask may be too difficult [233]. Further, direct assessment of oxygen uptake is time consuming and requires specifically trained personnel. Thus, it is seldom a feasible option in a large scale trial.

1.2.12.2. Indirect measures

Several tests that *estimate* or *indirectly assess* physical fitness in children are available. These include running tests that are frequently used for children due, in part, to the familiarity with the activity. However, a major limitation is the extent to which body weight influences performance [234]. Rowland [235] estimated that body weight (specifically body fat) may account for up to 31% of the variance in performance in a running task. A bicycle test may, therefore, be preferable for children whose mass has too great an influence on results during a body weight supported task.

A commonly used test is the 20-m incremental shuttle run test. I describe this procedure in Methods (Chapter 2). Briefly, this test involves continuously running between 2 lines 20-m apart (one lap), in time to an audible 'beep'. The time between recorded beeps decreases each 1 minute (1 stage). There are several versions of the 20-m shuttle test, but the most commonly used is that devised by Leger and Lambert [40]. The test begins with subjects running at 8.5km/h, and increasing in speed by 0.5km/h each stage. It is a maximal test, that provides a reliable (r=0.91) and valid (r=0.76-0.85 against direct VO_2 max measures) estimate of fitness in children [236, 237] . Oxygen uptake can be estimated using a regression equation based on number of laps completed [238], but many researchers chose to report the absolute number of laps completed. The test is suitable for use with large groups, is a familiar (and fun) activity for children and requires no special equipment. One attractive feature of Leger's test is the availability of age and sex specific normative values, making between cohort comparisons possible. One potential limitation of Leger's shuttle test is subjects' motivation, which may vary between trials or measurement occasions. This effect can be minimized by strictly standardized training of the measurement personnel to provide uniform motivation at each testing session.

Another indirect measure of physical fitness is the 1-mile test where children attempt to run 1-mile in as short a time as possible. This procedure is reliable in young children (r=0.70-0.83) [239], but the validity of the test compared with a VO_2 max test is lower than the 20-m shuttle (r=0.65-0.75) [240]. Variations include the 6-, 9- and 12- minute tests, where children attempt to cover as much distance as possible in a given time. Although reliable, these measures are less valid (compared with VO_2 max) than the 20-m shuttle test. The 6-minute test correlated with VO_2 max at r=0.63 [241]. The 9-minute test produces values more closely related to a gold standard VO_2 max test (r=0.71-0.82) [242], as does the 12-minute test (r=0.70-0.82) [242]. Reliability of the 9-minute test is lower than that of the 20-m shuttle test, but similar to the 1-mile test in same age children (r=0.69-0.89)[243]. The reliability of the 12-minute run is higher (r=0.84-0.89) and more similar to that of the 20-m shuttle test [240]. Given the known relationship between body weight and performance in running tasks [235], and the increasing levels of childhood obesity [244], it may be prudent for researchers to re-examination of the validity of the 9- and 12-minute run tests.

Step tests are less common procedures for assessing physical fitness in children compared with adults. Examples of step tests include the Queen's College Step Test, the Chester Step Test and the Canadian Aerobic Fitness Test. The step test is a submaximal procedure that predicts maximal aerobic fitness from heart rate recovery, based on known relationships calculated using a nomogram or regression equation. Hui and colleagues [245] compared children stepping at rates of 22, 26 and 30 steps per minute with a direct measure of VO_2 max. Validity varied between r=0.72 and r=0.78. Reliability of step tests in adults is high [246], but is not frequently examined in children. Further, normative data is often available only for older youth and adults. For example the Queen's Step Test only reports normative data for individuals of 13 years or older [247]

Finally, physical work capacity at a heart rate of 170bpm (PWC170) provides alternative, submaximal test to assess physical fitness in children. This procedure is usually conducted on a bicycle ergometer. Children cycle at a set cadence at increasing resistance until a heart rate of 170bpm is achieved. Maximal oxygen uptake is estimated from work capacity (Watts per kg body weight). The validity of the PWC170 was similar to that of the 20-m shuttle run (PWC170 r=0.84 against measured VO_2 max) but researchers stated that constraints of time and tester expertise favour the 20-m shuttle test for the assessment of aerobic capacity in the field. [237] However, a submaximal test such as the PWC170 or a stepping task may be preferable to a maximal test for some children.

In summary, a number of laboratory tests and field tests are currently used to assess children's physical fitness. The preferred method will be based on the procedure reliability and validity, it's appropriateness for the cohort being measured (i.e. age and body mass), time constraints, facility constraints and tester expertise. Among these, Leger's 20-m shuttle run performed at least as well as other methods and thus, will be used in the current study.

1.2.13. School-based physical activity interventions

This section describes school-based physical activity interventions aimed at improving cardiovascular health in children. Over the last 2 decades, researchers have targeted health status and behaviour through school-based interventions. Reviews and meta-analyses have shown that interventions that included a physical activity component were more successful than those that were solely education based [248]. In this section I describe only population based interventions that included a physical activity component, utilized a control group, and had a main aim of improving cardiovascular health. I describe interventions that had change in physical activity or change in physical fitness (via increasing physical activity) as a primary outcome. Studies where change in physical activity was only self-report [34, 222] are not included, due to potential bias. Only one major paper from each intervention is outlined, unless the intervention was repeated in a modified form. For example, the CHIC intervention, initially implemented in grade 3-4 children, was repeated in older children and another intervention arm was added.

In randomized school-based interventions the school (cluster) is usually the unit of randomization and the children are the unit of analysis. This design is advantageous as it prevents contamination that would occur if the intervention and control children attended the same school. This means however, that children can no longer be regarded as independent observations and as a result the effective sample size is less than the total number of participants [249]. The reduction in sample size depends on the average cluster size and the degree of correlation between clusters. The correlation between clusters is the intra-cluster correlation coefficient (ICC) and is the proportion of the total variance of the outcome that can be explained by the variation between clusters. Not all studies have accounted for the within school variance, either a priori or in adjusted their data. Failing to account for this variance increases the likelihood of making a type 1 error (i.e. incorrectly rejecting the null hypothesis).

Four well designed studies that accounted for cluster effects, provided clear details on intervention, conducted a comprehensive evaluation of change in risk factors and provided adequate results are detailed below. Seven other studies, that are less clear in their description or did not account for cluster effects are summarized in Table 1.2, along with specific results from the first 4 studies.

A 1-school year intervention with a comprehensive evaluation program was conducted in Australia [58, 114, 250]. Children were allocated to one of six groups; fitness, fitness + school nutrition, school + home nutrition, school nutrition, home nutrition or control. Participants were 1147 children aged 10-12 years. Researchers accounted for the cluster effect in the statistical analysis by using school (the unit of randomization) as a random effect in the analysis of variance. Cardiovascular fitness was assessed by Leger's 20-m shuttle run and by 1.6km run time. Blood pressure, body fat and cholesterol were also measured before and after the 1-school year intervention. The exercise component of the intervention was progressive and designed to include 15 minutes of physical activity per day [114]. It was a set program of activities that included jump rope and aerobic dance. The greatest number and magnitude of changes were seen in the fitness and the fitness + school nutrition groups. Physical activity was not measured.

The SPARK (Sports, Play and Recreation for Kids) project was a 2-year school-based intervention in 955 children in grades 5 and 6 in seven schools [29]. Researchers accounted for the within school variance by utilizing the ICC. One of the major differences with SPARK was the method of intervention delivery. PE specialists, as well as classroom teachers, carried out health related PE classes. The PE classes were conducted 3 times per week for 30 minutes, with 15 minutes of health related fitness (such as aerobics or jogging) and 15 minutes of skill related fitness (such as basketball or Frisbee). There were improvements in both experimental groups (PE specialists and generalist classroom teachers) compared with control groups. However, children taught by PE specialists showed significantly greater gains in cardiovascular fitness (1-mile run time) and abdominal strength gains compared with those taught by the generalist teachers. Physical activity was measured by recall and by accelerometry. Baseline accelerometer scores were not collected, but between-school comparison was carried out using data gathered at the final time point. There were no significant differences between intervention and control groups in this objective measure of physical activity.

The Cardiovascular Health in Children (CHIC) [28, 60] study was based on an 8-week intervention that assessed change in a number of CVD risk factors in children in grades 3 and 4 and in grades 6-8. The researchers accounted for the cluster effect in the statistical analysis by using school (the unit of randomization) as a random effect in the analysis of variance. In the first study, delivered to grade 3-4 children, schools were randomized to either an exercise and education intervention or a control group. The exercise component involved training for 30 minutes, 3 days per-week for 8 weeks. Each session included 20 minutes of aerobic activity such as soccer, tag or circuits, and 10 minutes of warm up and stretching. Most schools had to adapt their timetables to accommodate the 3 sessions of PE per week. The weekly education component introduced curriculum based lessons on nutrition, smoking and activity. There were no statistical changes in the biological variables assessed [28]. The study was extended to assess the effect of the same intervention on 6-8th grade students in rural areas [60]. Researchers utilized a factorial design to include; an exercise only group (ExO), an education only group (EdO), an exercise and education group (EE) and a control group. Favourable changes were seen in the intervention groups for systolic and diastolic blood pressure (2.8mmHg and 4.8mmHg less in ExO), sum of skinfolds (3.1mm less in EE) and in aerobic capacity (0.8ml.kg.min^{-1} in ExO group). Despite the fairly large sample size and an ethnic mix of students, there was no report of analysis by gender or ethnicity.

The Childhood and Adolescent Trial for Cardiovascular Health (CATCH) [27, 251] was a larger series of studies aimed at a greater range of children (age 8-15 years) that included an intervention of 2.5 years duration. It was a multi-site trial and statistical analysis included both site (fixed effect) and school (random effect) as in the analysis. The intervention was both knowledge and physical activity based and success was measured on both a school level (dietary fat intake and change in amount of moderately vigorous physical activity [MVPA] undertaken in PE classes) and on an individual level (9-minute run and serum cholesterol). The physical activity goal was to increase MVPA to 40% of class time during the 90-mins per week dedicated to PE class. Teachers were provided with training and resources (such as videos, jump ropes, and step-benches) to enable them to increase physical activity during PE class. Changes were shown at the school but not the individual level. However, changes in MVPA were fairly modest, with increases of 6 minutes per PE class reported in the intervention schools (using SOFIT monitoring).

1.2.13.1. Insights from previous studies

By reviewing the available literature on school-based physical activity interventions aimed toward improving CVD risk profiles in children a number of valuable insights into developing a successful model can be gained.

Firstly, the intervention must be of sufficient duration for changes in CVD risk factors to become apparent. Durations of 12 weeks or less, while resulting in increases in physical activity, have failed to change any physiological outcomes (fitness, cholesterol or BMI for example) [28, 252]. Interventions of one school year duration [114, 253] have shown significant increases in many outcome variables. Interventions of longer duration do not necessarily show further improvements in risk factors [27, 29, 254].

Interventions that have provided increased physical activity several times per week (i.e. not focused on changing PE class) were most successful in changing risk factors. Those studies that increased the frequency of physical activity [29, 33, 114] had more success than interventions where physical activity was provided on a less frequent basis [27]. Interventions where brief periods of physical activity were delivered on a *daily* basis [33, 114] were as successful as interventions where the total amount of physical activity delivered per week was similar, but in fewer sessions [29, 31].

The SPARK [29] study highlighted the importance of the mode of delivery in the success of the intervention. Change in fitness was highest in the groups where the physical activity was delivered by specifically trained teachers (PE specialists) compared with classroom teachers.

Finally, interventions which included nutrition or education components [27, 114] consumed more time and resources, but did not necessarily achieve greater results than interventions (or components of interventions) that were solely physical activity orientated [29, 114].

Table 1-2 School-based physical activity interventions aimed at reducing CVD risk factors. Studies are in order of publication date. Data are mean (SD) or mean (95%CI)

First author	Subjects & Duration	Intervention, primary outcome variables & statistical approach	Results of change in primary outcomes. * significantly different from control group
Dwyer [33]	Grade 5 10.3 years 7 schools n=231 14 weeks	INT group: 1¼ hours day. Intervention details not stated beyond 'aim to raise heart rate' CON group: usual PE, 3x30min per week *Primary outcomes*: fitness (PWC 170), skinfolds, TC Included teacher as a random effect in statistical design	**INT**: increase fitness 2.42 (0.1) Kpm/min/kg* **CON** : increase fitness 1.2 (0.1) Kpm/min/kg
Simons-Morton [214]	Grades 3-4 7-9 years 4 schools n=not provided 2 years	INT group: Education, school lunch program and provision of resources to increase MVPA in PE class (duration not stated) CON group: usual PE classes (2x wk), no education or change to lunch program *Primary outcome*: increase MVPA in PE class by DO Did not account for cluster effect	**INT:** 3^{rd} grade 11.7 (7.5) mins MVPA* **CON** : 3^{rd} grade 2.9 (3.5) mins MVPA **INT** : 4^{th} grade 20.0 (15.0) mins MVPA* **CON**: 4^{th} grade 1.0 (4.0) min MVPA
Arbeit [31]	Grades 4-5 4 schools n=556 12 weeks	INT schools: School lunch program, 12 extra health knowledge classes and aim of 'increasing activities during PE class that would improve fitness' CON schools: Normal PE class (2x wk) *Primary outcome*: fitness (1 mile run) Did not account for cluster effect	Change in fitness compared to **CON** **INT**: 4^{th} grade boys 1.4% decrease 4^{th} grade girls: 7.3% increase* 5^{th} grade boys 15% increase* 5^{th} grade girls 14% increase * No variance around mean provided
Vandongen [114]	Age 10-12 years 30 schools n=1147 1 school year	INT schools: Fitness, Fitness + Nutrition Education or Nutrition Education alone. Fitness groups had 15 mins MVPA such as jump rope or dance each week day (goal HR 150-170bpm) CON schools: Regular PE classes (2x wk) *Primary outcome*: fitness (20-m shuttle) and total cholesterol Accounted for cluster effect in model design and statistical analysis	20-m laps at final shown **INT** (fitness) girls: 47.5 (43.8, 57.1)*, boys: 57.3 (43.4, 61.3)* **INT** (fitness + nutrition) girls: 51.5 (48.0, 55.0)*, boys: 61.6 (57.3, 65.9)* **CON** girls: 41.0 (37.2, 44.9) boys: 54.5 (50.3, 58.7)

Table 1-2 cont			
First author	Subjects & Duration	Intervention, primary outcome variables & statistical approach	Results of change in primary outcomes. * significantly different from control group
Harrell [28]	Grade 3 and 4 12 schools n=1274 8 weeks	INT schools: 30 min x 3 per week PA to include 20 minutes of aerobic activity and weekly education. CON schools: usual PE (2x wk) *Primary outcome*: change in fitness (PWC170) Accounted for cluster effect in model design and statistical analysis	Change in fitness **INT** schools: 8.3% (0.8) increase fitness **CON** schools: 4.4% (0.6) increase in fitness
Hooper [252]	Grades 2 and 4 N=97 1 school 10 weeks	INT: 10 weeks of fitness class 4 x 30 min/wk of non competitive games and dance. Plus, 2x 30 min/wk education on nutrition. At home PA encouraged with a 'parent pack' of ideas provided. CON: usual PE (frequency not stated) *Primary outcome*: Fitness (1 mile run) Did not account for cluster effect or control for baseline fitness	Change in fitness **INT**: 34 seconds (4.6% slower than baseline) **CON** 29 seconds (4.4% slower than baseline)
Leupker [27]	Grades 3-5 n= 5106 56 INT schools 40 CON schools 2.5 years	INT schools: Education and 'enhanced' PE to increase MVPA time CON schools: usual PE (2x wk) *School outcome*= increased MVPA in PE class measured by DO *Individual outcome* = total cholesterol , 9 minute run Multi-centre trial, accounted for cluster effect in model design and statistical analysis	**INT** schools: Increased MVPA (6 minutes) from 37.4% to 51.9% during PE class*. Change in cholesterol **INT:** -1.3mg/dL **CON**: -0.9mg/dL Distance ran in 9 minutes at follow-up **INT**: 1521 (SE10) yards **CON**: 1503 (SE11) yards
Manios [254]	Grade 2 n=831, 24 INT schools 16 CON schools 6 years	INT: 2 x 45 minutes per week during PE class (details not provided) Plus health education lessons CON : Not stated *Primary outcome*: MVPA outside of school (self report) and fitness (20-m shuttle) School included as a random effect in statistical design	Change fitness (20-m shuttle stages) (mean(SE) **INT** : 2.5 (0.1)* **CON** : 1.2 (0.1) Change in MVPA (min/week) **INT**: 281 (22)* **CON**: 174 (27)

Table 1-2 cont			
First Author	Subjects & Duration	Intervention, outcome variables & statistical design	Results of change in primary outcomes. * significantly different from control group
Sallis [29]	Grades 4 and 5 n=955 5 INT schools 2 CON schools 2 years	INT schools: Health related PE taught by 1) PE specialists or 2) classroom teachers , 3x 30 min/wk CON schools: usual PE (2x wk) *Primary outcome:* PA using accelerometry (final only), fitness (1 mile run) Accounted for cluster effect using ICC in statistical analysis	Increase fitness **INT 1)** boys 36%* girls 27% * **INT 2)** boys 8% girls 13% **CON** boys 18% girls 20% Accelerometer counts (hours) 1 weekday **INT 1)** boys 8.4 (7.7, 9.0) girls 6.9 (6.5, 7.4) **INT 2)** boys 7.8 (7.4, 8.2) girls 7.6 (6.9, 8.2) **CON** boys 8.2 (7.7, 8.7) girls 7.9 (7.3, 8.4)
Van Beurden [255]	7-10 year olds n=1045 9 INT schools 9 CON schools I school year	INT schools: increase physical skills and PA in PE class time. Teachers received training and a limited budget to purchase new equipment. Frequency of PE not stated. CON: Usual PE *Primary outcomes*: Increase physical skill, increase MVPA & VPA during PE class Non randomly assigned, school as random variable to account for cluster effect	Change in PA **INT** schools: 4.5% increase in MVPA compared with CON (equates to 1 minute per PE class) **INT**: 3.3% increase in VPA compared with CON
Pangrazi [30]	Grade 4 n=606 29 INT schools 6 CON schools 12 weeks	PLAY : 15 minute activity break each school day of semi structured activity PE: Regular school PE class CON: No intervention and no PE class *Primary outcome*: steps per day measured with pedometer Did not account for clustering effect in statistical approach	Step count **INT**: Play and PE 12,763 (3,832) steps/day* Play only 12,598 (4,026) steps/day* PE only 12,401 (3,919) steps/day* **CON:** 11,180 (4,261) steps/day

NSD= no significant difference, * significantly different to control group at P<0.05
INT =intervention group, CON = control group, PA=physical activity, MVPA=moderately vigorous physical activity, VPA= vigorous physical activity, PWC= physical work capacity, HR=heart rate, DO = direct observation .

1.2.14. Rational for future studies

The literature review highlights a unique opportunity to evaluate key areas in childhood cardiovascular health and physical activity that are, as yet, unexplored. These include questions related to the relationships between cardiovascular risk factors and race, physical fitness and physical activity and importantly, the changes that can occur in risk factors in response to a physical activity intervention.

1.2.14.1. Assessment and modification of risk factors

Levels of physical activity are low in many Western children, and Canadian children are no exception. Recently, low levels of physical fitness in children have also become apparent. In adults the relationship between physical fitness and CVD is established. In children, a low physical fitness is associated with an increased number of CVD risk factors. Investigating the level of fitness in young Canadian children is warranted. The high prevalence of potentially modifiable CVD risk factors suggests the economic and social burden of CVD could be reduced through programs that address risk factor modification. A randomized controlled trial of physical activity, aimed toward reducing multiple CVD risk factors has not been conducted in Canadian children. Thus, such an intervention, assessing change in modifiable CVD risk factors in a representative sample of the population is called for.

1.2.14.2. Physical activity, fitness and novel risk factors in children

Although several authors observed the relationship between physical activity and prevalence of emerging cardiovascular risk factors [51, 71, 132, 136], these observations were mainly cross-sectional. Few researchers have attempted to influence the more novel CVD risk factors by lifestyle intervention [143, 149, 179] and as many of these interventions included both diet and exercise components, the independent effect of exercise was not always clear. Second, interventions have been frequently targeted toward high-risk individuals, especially obese children, and population based interventions are sparse. No single study explored the effects of a long duration, physical activity intervention on emerging serum, neural and vascular factors combined. Given the synergistic relationship between the autonomic nervous system, the vasculature and the blood, there is an urgent need to assess change in all these components.

1.2.14.3. Race and novel risk factors in children

There is a paucity of data regarding differences in cardiovascular risk factors in children from a variety of racial backgrounds The effect of race on many established CVD risk factors has been explored [67, 126] but the influence of race on many of the emerging risk factors is not fully determined [160, 161]. The influence of Asian race on many factors, including C-reactive protein, Lp (a), apolipoproteins, haemostatic factors, arterial compliance and heart rate variability is unknown.

1.2.15. Rationale behind the development of Action Schools! BC

The success of school-based interventions has been linked to a number of key variables - outlined below.

Classroom based focus of physical activity: The majority of interventions take place during school PE class, but as many students only engage in PE once per week, and rarely more than twice, relatively little time is available for increasing fitness and reducing the cardiovascular health risks in children. In some programs [28] schools had to alter their timetable to fit in enough PE sessions, something that is unlikely to continue after completion of the intervention.

Adequate teacher training and support: The classroom teacher leads PE classes in many elementary schools. Many teachers feel inadequately equipped to make large changes in the PE session without external assistance or advice. This was highlighted in the SPARK [29] study, where it was found that results from PE specialists were greater than results obtained by the classroom teachers.

Inclusive activities: Interventions need to be inclusive, with age and gender being focal points within program design. A variety of options must be available to the students to prevent staleness and lack of enthusiasm. "Variation in activities by race within gender suggest that establishing activity patterns in youth may be race specific as well as gender specific and must be accounted for in designing physical activity interventions' [23]

Comprehensive assessment: A greater array of physiological measurements is now available, and their importance relative to CVD risk is becoming clearer [70, 130, 143] . Physical activity interventions affect children in a variety of ways – physically, emotionally and perhaps academically. An important strategy is to assess both independently and in combination with one another in order to observe the full impact of the program. The response of various subgroups - gender, ethnic and age- to physical activity interventions may differ and should be explored [20, 30, 215]. The nature of the intervention is likely to evoke different responses from different groups and results appear to be dependent upon the subgroup in question.

We have addressed these factors in the design of the Action Schools! BC model of school-based physical activity. We developed the model using a socioecological approach. Ecological models of health promotion are increasingly being promoted. In this model we acknowledge that behaviour is a consequence of actions among many levels of influence; personal interaction, organizational, community and policy. Interdependency within these levels is recognized. Socioecological models target change strategies through one or more of these levels, directly or indirectly.

1.3. AIMS, OBJECTIVES AND HYPOTHESES

The core of this thesis is a cluster randomized controlled trial of school-based physical activity that aims to enhance cardiovascular health in young boys and girls. There are 6 studies that comprise the thesis, all of which utilize core data to evaluate the physical activity and cardiovascular health in children. Here, I provide a brief rationale, the aims and hypotheses for each of the 6 studies.

1.3.1. Determining CVD risk in elementary school children.

Prevalence of individual risk factors and clustering of risk factors are high in children [3, 256]. Studies examining prevalence of risk factors in children have used a single cut off point to assign 'risk', but in adult risk score algorithms the extent of the elevated risk factor is also considered [257]. The aim of this study was to create a cardiovascular "healthy heart" score for children using established risk factors that can easily be assessed within a school environment.

My primary objective was to create a CVD risk score for a child that was independent of both age and sex and could incorporate both number and severity of CVD risk factors. Studies reporting sex differences in clustering of risk factors in children are equivocal, but currently in BC, obesity levels are higher in boys than in same age girls. Thus, my secondary objective was to compare the clustering of risk factors between young girls and boys.
Hypothesis: Girls would have a significantly better Healthy Heart Score than age-matched boys.

1.3.2. Secular changes in shuttle run performance.

Several studies have reported declining fitness in children over the past 2-3 decades [258, 259]. One meta-analysis examining studies from 55 countries reported that fitness, measured by running performance, has declined by 0.43% per year since 1980 [260]. Data on Canadian children are sparse. The aim of this study was to challenge the notion that children today are less aerobically fit than children were 20 years ago.

My primary objective was to compare the aerobic fitness of Canadian boys and girls, aged 9-11 years, measured in 2004, with the aerobic fitness of same age and sex Canadian children measured in 1981.
Hypothesis 1: Children's aerobic fitness assessed in 2004, using Legers 20-m shuttle run will be similar to aerobic fitness values reported in 1981.

1.3.3. Arterial compliance in young children: the role of aerobic fitness

The influence of physical activity on vascular health in childhood has been briefly explored [57]. Studies show that arterial compliance is related to fitness in adults [202, 261] but the contribution that fitness can make to arterial compliance in children is not established. Further, sex differences in arterial compliance measured using radial artery tonometry have not been explored. The aim of this study was to evaluate the factors influencing arterial compliance in girls and boys.

My objectives were to; 1) describe the relationships between arterial compliance and physical activity and cardiovascular fitness in elementary school children, and 2) describe sex differences in arterial compliance.
Hypothesis 1: There will be a strong positive relationship between physical activity and fitness and arterial compliance.
Hypothesis 2: Girls would have a lower arterial compliance than same-age boys.

1.3.4. Differences in heart rate variability between Asian and Caucasian children

Racial differences in many CVD risk factors are apparent [116-118, 181, 262]. Such differences may suggest the need for both race specific norms and clinical cut points or the need for targeted interventions. The aim of this study was to investigate differences in heart rate variability between Asian-Canadian (AC) and Caucasian-Canadian (CC) children living in the geographic proximity.

My primary objective was to evaluate differences in HRV between Asian-Canadian and Caucasian-Canadian elementary school aged boys and girls. My second objective was to evaluate differences in HRV between pre-pubertal boys and girls.
Hypothesis 1: AC children have lower levels of the time domain variables (standard deviation of RR intervals [SDRR] and root mean square of successive RR intervals, [RMSSD]) accompanied by greater sympathetic predominance, evidenced by a higher LF:HF ratio in the frequency domain compared with same age and sex CC children.
Hypothesis 2: Girls will have altered HRV profiles, (specifically lower variability with 5-min recording), compared with age-matched boys.

1.3.5. Do children at risk for CVD achieve a greater benefit from a school-based physical activity intervention than children not at risk?

It is widely accepted that the atherosclerotic process begins in childhood and progresses through adulthood [2]. The rise in sedentary behaviour, increasing levels of obesity and the presence of multiple risk factors in young children is cause for concern. This trend has both short term and long term health implications [78, 263, 264]. The aim of this study was to evaluate whether a physical activity intervention (Action Schools! BC) was an effective model for decreasing CVD risk factors in children.

My primary objective was to evaluate the effects of a 9-month school-based physical activity intervention on selected CVD risk factors in elementary school boys and girls. My second objective was to evaluate the effects of a 9-month school-based physical activity intervention on selected CVD risk factors in elementary school boys and girls deemed 'at risk' for future CVD.

Hypothesis 1: At the end of the 9-month intervention, boys and girls randomly assigned to the physical activity intervention group would have significantly improved CVD risk profile than boys and girls randomly assigned to the control group.

Hypothesis 2: At the end of the 9-month intervention, boys and girls randomly assigned to the physical activity intervention group and deemed "at risk" at baseline would have significantly improved CVD risk profiles than boys and girls in the same group not deemed "at risk".

1.3.6. Effects of a school based physical activity intervention on arterial compliance in healthy children.

Studies in adults have shown that increasing physical activity can improve vascular health [187, 261, 265]. This relationship has not yet been explored in children. The aim of this study was to evaluate the effects of a school-based physical activity intervention on arterial compliance in healthy elementary school children.

My objective was to assess the influence of a 9-month school-based physical activity intervention on arterial compliance.

Hypothesis: At the end of the 9-month intervention, boys randomized to the physical activity intervention would have a greater arterial compliance than boys randomized to the control group.

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CHAPTER 2. METHODS[1]

In this section I describe the methods used for my core study. First I describe the study design, school recruitment process, inclusion and exclusion criteria and randomization processes. Next, I describe the Action Schools! BC (AS! BC) model, provide an overview of the data collection protocol and describe the measurement procedures. I conclude with an overview of the statistical analyses and data storage procedures. Methods specific to each sub-study are briefly repeated within each individual paper.

2.1. STUDY DESIGN

This was a cluster, randomized controlled trial of physical activity. Participants were children aged 9-11 at baseline, from 10 schools in the Richmond and Vancouver Schools Districts. The total study time was 16 months, including 2 intervention phases of 3 and 9 months, separated by the summer vacation. The study timeline is shown in Figure 2.1.

Children from 10 schools selected undertook the AS! BC program. Four schools were randomly selected for full in-school cardiovascular measurement. In addition, children who consented to participate in the CVD Risk Factors sub-study were included in the cardiovascular measurement component (Figure 2.2), thus children from 8 schools were involved in Healthy Hearts measures.

Ethical approval for the study was obtained from the University of British Columbia Clinical and Behavioural Sciences Research Ethical Review Board. Ethics approval forms are provided (Appendix A). Parents and participating students also consented for all parts of the study. Consent forms are provided (Appendix A). Children and their parents provided separate consent for the blood draw to assess blood lipids and serum factors.

[1] A version of this chapter is published as Naylor PJ, Macdonald HM, Reed KE and McKay HA, (2006) Action Schools! BC: a socioecological approach to modifying chronic disease risk factors in elementary school children. Prevention of Chronic Disease, 3 (2) A60

Figure 2.1Time-points for recruitment, data collection and program initiation. Measurements, location and time-points are summarized below.

2003

Jan	Feb	Mar	April	May	June
Recruitment		**Baseline measurement CV measures and blood draw**	Phase I: Program starts in schools		**Questionnaires**

July	Aug	Sept	Oct	Nov	Dec
School summer break		**CV Measures Arterial compliance**	Phase II: Program continues in schools		

2004

Jan	Feb	Mar	April	May	June
CV Measures	Phase II: Program continues in schools			**Final measurement CV measures and blood draw**	

Measurement number	Measurement in schools	Measurement at VGH	Measurement at BCCWH
Time 1, Baseline February 2003- March 2003	CV, Heart rate variability	Bone Health Measures Questionnaires	Lipids and hormones (March–April)
Time 2 June 2003	Questionnaires Pedometers		
Time 3, New school year baseline September 2003	CV, Arterial compliance Questionnaires, Pedometers		
Time 4 January 2004	CV, Questionnaires Pedometers		
Time 5, Final June 2004	CV, Arterial compliance, Pedometers	Bone Health Measures Questionnaires	Lipids and hormones

2.2. PARTICIPANTS

Several meetings to facilitate school, Principal, teacher and student participation in the study were conducted.

2.2.1. School Recruitment

After obtaining permission from the Vancouver and Richmond District School Boards, we delivered presentations to Principals and Vice-Principals at District (Richmond) and Area (Vancouver) meetings (October-November 2002). During these sessions we outlined the aims and objectives of the study and responsibilities of the Action Schools! BC schools. Principals were given the opportunity to discuss with their teaching staff the opportunity to become involved in the program. They were asked to contact the AS! BC administrator to arrange a second meeting if they wished to participate.

The Action Schools! BC component that required the largest sample size was Bone Health (requiring approximately 300 students). We estimated that we could achieve this number of students if 10 schools were recruited into the study. Twenty schools (out of 103 in the Districts = 19%) volunteered for the study in the first week. These schools were then evaluated against our inclusion criteria. The AS! BC evaluation team utilized results of the 2002 Ministry of Education Satisfaction Survey [1] to determine which schools were *already* participating in a physical activity program or initiative. This survey, which was given to students in grades 4-7 and their parents, contained questions such as

"At school, does your child get exercise? (For example, physical activity or sports)".

Responses were on a 1-5 scale, with 1= at no time, 2= few times, 3=sometimes, 4=many times and 5= all of the time. Schools with a mean score of 3 or less (i.e. those schools we believed to be not already participating in a physical activity intervention beyond the normal school activities) were invited to participate in the study. Of the 20 volunteer schools, 11 were selected on the basis of the survey. We closed recruitment once we had the required number of schools. One school Principal withdrew his consent prior to randomization after realizing his school could be randomly selected as a control school. Thus 10 schools were randomized for the study.

2.2.2. Student recruitment

To recruit students for the study, I gave a presentation at each of the 10 schools to all students in grades 4 and 5. I explained the nature of the study, in terms of participation in the intervention and the evaluation and allowed time for questions. At the end of the presentation, children were asked to take home a consent form and a health history questionnaire for their parent / guardian to complete. These forms were available in English, Punjabi, Chinese and Vietnamese. All children in classrooms where teachers volunteered to participate in delivering the AS! BC model participated in the AS! BC activities. I obtained consent from those children who wished to participate in the evaluation.

2.2.3. *Recruitment for CVD Risk Factors sub-study*

After gaining permission from the Principals, we sent a letter directly to the home address of those children whose parents consented to participate in Action Schools! BC (n=514). In this letter we described the blood draw procedure in detail and enclosed a consent form for parents to sign and return if they and their child wished to participate in this sub-study.

2.2.4. *Incentives*

We provided incentives for intervention schools and teachers to participate, including the provision of resources for the classroom, field trips for the students and advice and assistance from two AS! BC facilitators who were elementary school physical education specialists. Usual Practice (control) schools received the same resources, training and facilitation as the intervention schools at the end of the 16-month evaluation program. Incentives for children to participate in the measurement included two trips to the Bone Health Research Laboratory at Vancouver General Hospital (VGH) and in school sessions for cardiovascular measurement and questionnaires. Children were also given Action Schools! BC stickers, Frisbees, socks, pens, juice boxes and snacks during and after data collection.

2.2.5. *Inclusion and exclusion criteria*

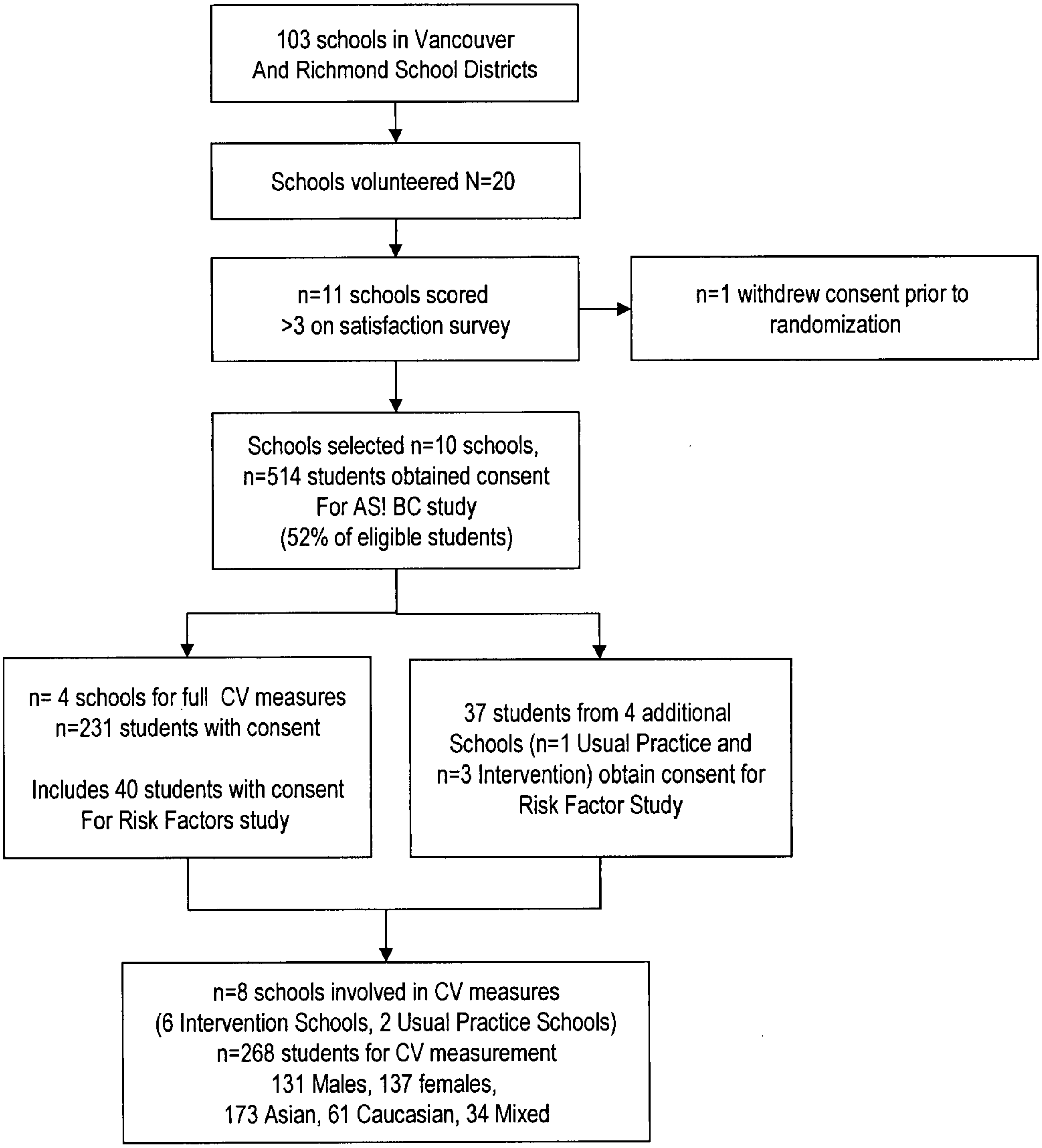
All children who participated in regular school activities and returned a signed consent form and a Health History Questionnaire were invited to participate in measurement. Children unable to participate in normal physical activity or those with a current illness or history of illness or medication that might affect cardiovascular performance were excluded from the analyses.

2.2.6. *Classification of ethnicity and race*

The Health History Questionnaire was completed by parents on behalf of their child (Appendix B). Ethnicity was classified according to parents' place of birth or grandparents' place of birth. If both of the parents, or all four grandparents, were born in North America or Europe, the child was classified as Caucasian. If both of the parents, or all four grandparents, were born in China, Japan, Korea, Vietnam, Philippines, India, Pakistan or Korea, the child was classified as Asian. Asian children were sub-classified as South Asian (originating from India or Pakistan) or East

Asian (originating from other Asian countries). Children were classified as 'Mixed' if parents were of two different races (e.g. Asian and Caucasian) or African origin.

Figure 2.2 A flow diagram showing recruitment of schools and students in February 2003.
Flow diagram showing student numbers in February 2003, September 2004 and June 2004 is provided (Appendix C)



After school and student recruitment was complete, schools were randomized to one of three arms. Schools were stratified based on size (greater or less than 300 students) and school district (Vancouver or Richmond). Randomization was conducted remotely by an individual not otherwise involved in the trial (Patti Jansen). Treatment allocation is illustrated (Figure 2.3). As previously mentioned, the study was a clustered randomized controlled trial where the school was the unit of randomization and the individual student was the unit of analysis. The clustered model was not taken into account in the power calculation, but was accounted for in the statistical analysis.

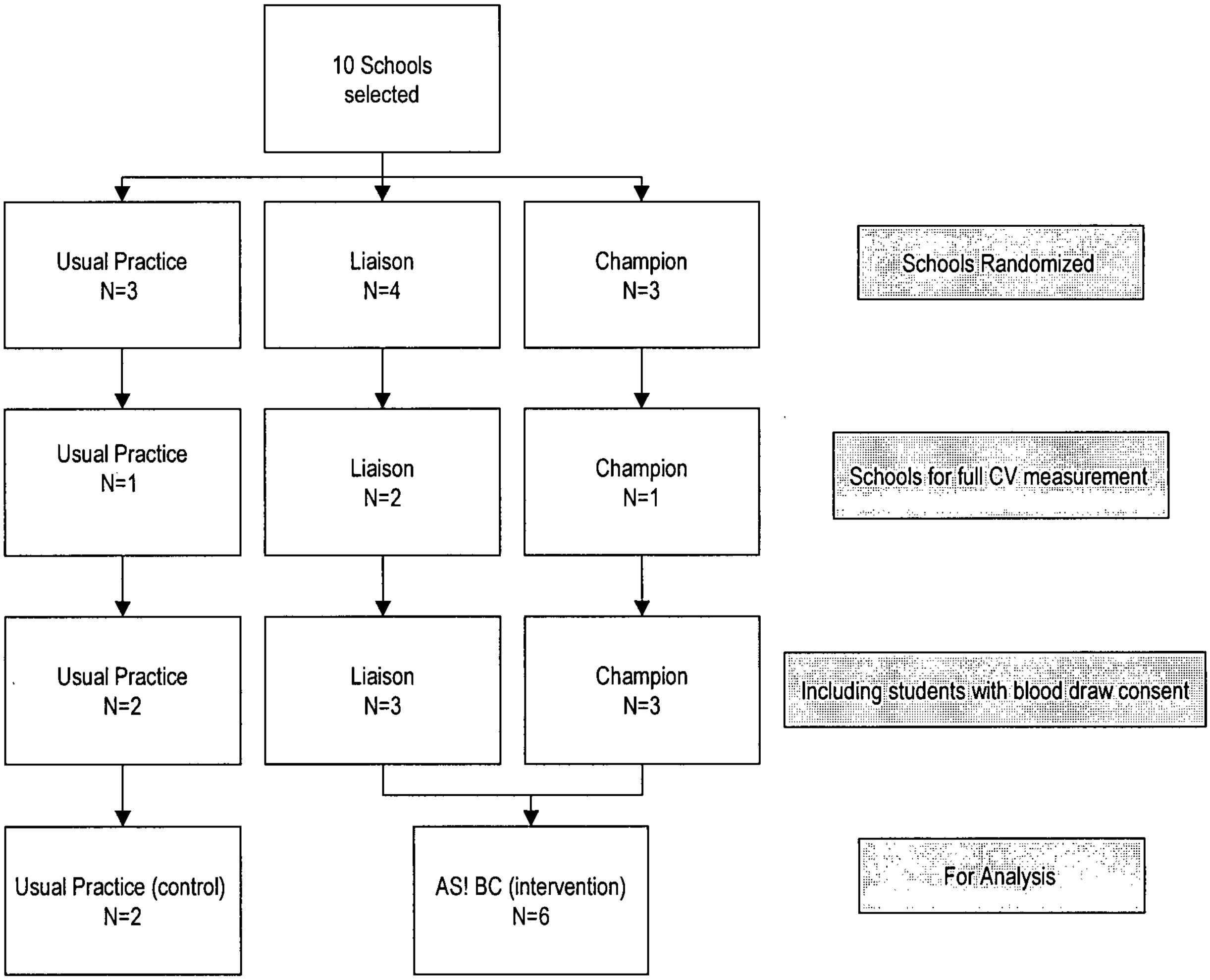


Figure 2.3 A schematic that illustrates the random allocation of the 10 Action Schools! BC schools into the three treatment arms; Liaison, Champion and Usual Practice. Schools involved in the cardiovascular testing component are shown. Liaison and Champion schools were collapsed for all analyses in this thesis.

2.3. THE ACTION SCHOOLS! BC INTERVENTION

2.3.1. Development of the intervention

Actions Schools! BC is a flexible framework for action. The Action Schools! BC model is defined as a "best practices physical activity models designed to assist elementary schools in creating individualized action plans to promote healthy living". We conducted a comprehensive Internet, direct contact, print media and scientific literature review of programs and activities delivered in Vancouver, British Columbia, Canada and worldwide. From this we created a user-friendly compendium (Action Pages) of physical education resources, resource agencies, programs, support organizations, and specific network contacts. The component of the final intervention model for cardiovascular health was determined in consultation with the multi-disciplinary investigation team. For this component specifically, input was obtained from Dr Heather McKay, Dr Darren Warburton and Dr PJ Naylor.

2.3.2. Organizational Structure of Action Schools! BC

An organizational structure for the management and delivery of Action Schools! BC was developed under the direction of Dr. McKay, the Principal Investigator for the overall study. My role was Director of the cardiovascular component of AS! BC. The organizational structure is provided below (Figure 2.4). A list of membership on all committees shown in the Organizational Structure Chart is provided (Appendix D). I briefly describe the role of each of these committees below.

Advisory Committee: This group, which comprised government, education, health and community stakeholders, had the task of guiding the development and implementation of the AS! BC model. Specifically, the committee comprised members from organizations including: BC Ministry of Health; BC Ministry of Tourism; Sports and Arts; BC Ministry of Education; BC Parks and Recreation; BC School Trustees; BC Principals Association; 2010 Legacies Now and BC's Provincial Health Services Authority.

Technical Team: This team comprised schoolteachers and principals, University of British Columbia and University of Victoria Professors and Physical Education Consultants with experience and expertise in delivering sports and physical activity in school and community settings. Their role was to assist the Support Team in delivery and modification of the AS! BC program.

Support Team: Specialists from JW Sporta were the mainstay of this team. This team oversaw the design of the AS! BC program, drawing on years of experience in delivering the Premier Sports Awards Program to 70% of BC schools. The Support Team liaised with the AS! BC Facilitators (Debbie Keel and Judy Howard), the elementary school teachers who delivered the program and trained the classroom teachers.

School Action Team: The success of AS! BC lies in the ownership of the program by the schools. At initial planning meetings with the school principals and teachers, the support team assisted in identifying teachers willing to 'champion' the Action Schools! BC program. The School Action Team was comprised school principals, 'Champion' teachers, an AS! BC Facilitator and supportive parents. The role of this group was to customize a program that reflected the personality and perceived needs of the school and promote these activities within the school (the Action Plan).

Evaluation Team: The evaluation team comprised directors representing each of the measurement components; Healthy Hearts (myself), Healthy Bones (Heather Macdonald), Healthy Self (Ryan Rhodes), Healthy Eating (Ryna Levy-Milne), Academic performance (Kadriye Ercikan), Healthy Weight (Jean-Pierre Chanoine and Kerry MacKelvie O'Brien) and Process Evaluation (PJ Naylor and Janelle Zebedee). Measurement scheduling and other administration tasks were conducted by the AS! BC administrators (Connie Waterman and Josie McKay). I was involved in the design of the cardiovascular component of the AS! BC program (specifically determination of intensity and duration of the cardiovascular activities) and was responsible for training and supervising the CV measurement team. I was present for every cardiovascular measurement and conducted all of the heart rate variability measures personally. I also collected or supervised all of the arterial compliance measures.

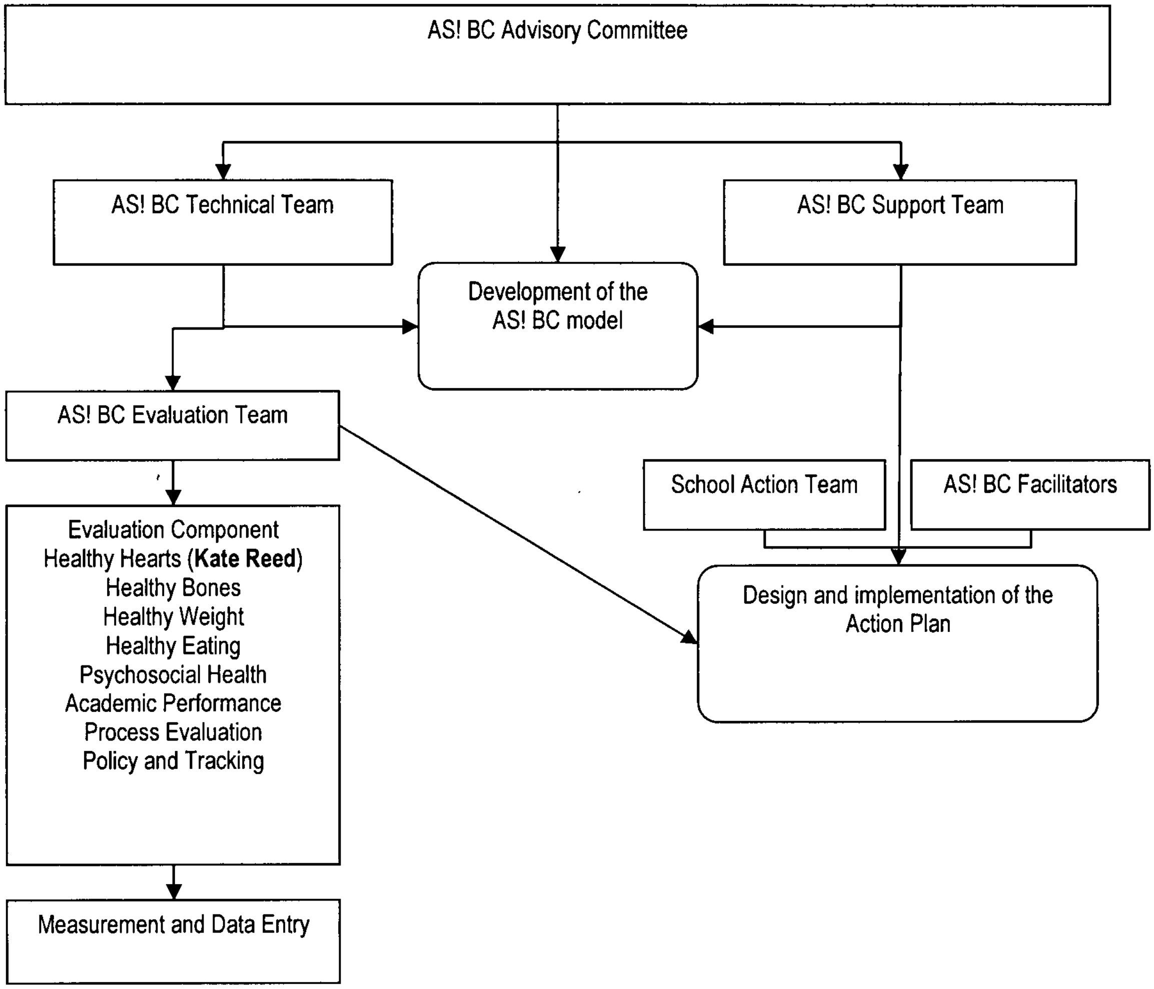


Figure 2.4 Flowchart showing the organizational structure of Action Schools! BC.

2.3.3. *Action Schools! BC: Components*

The overall goal of Action Schools! BC was to provide children with 150 minutes of moderate to vigorous physical activity per week across 6 Action Zones: School Environment, Scheduled Physical Education, Classroom Action, Family and Community, Extra-curricular and School Spirit. Within each zone, the Action Schools! BC model provides Action Ideas with options to create their individualized Action Plans. I provide a description of each and an example of activities that a school may adopt in each Action Zone.

School Environment: This action zone identified opportunities to educate students, staff and families about the importance of physical activity and to promote a healthy school environment. Activities might include assemblies or pep rallies and presentations at Parents Advisory Committee or staff meetings.
Scheduled Physical Education: In this zone we encouraged schools to deliver the recommended Ministry of Education Instructional Resource Package (IRP) of 150-min of physical education.
Classroom Action: This was a novel feature and a mandatory zone within the AS! BC model. Teachers were asked to complete 15 extra minutes of classroom based physical activity each school day (15 X 5). Activities included hip-hop dance (Energy Blast video provided), exercises with Therabands and short playground circuits.
Family & Community: In this zone we identified opportunities to promote the benefits of physical activity within the community with family and friends. One example is a partnership program with district community centres that offered Action items in their community programming. Another example is visits from community centre staff to schools to deliver dance, games or other programs to students.
Extra-curricular: In this zone we encouraged teachers to provide extracurricular activities for students. These included walk or cycle to school days.
School Spirit: In this action zone the whole school was encouraged to participate in events and activities such as the walking school bus, school conga line or Sneaker Club.

2.3.4. *Unique aspects of Action Schools! BC*

The Action Schools! BC model is comprised of several unique elements:

- It capitalizes on best practices for physical activity
- It links community based programs with school-based programs
- It establishes partnerships across sectors of government and between community, school and stakeholders
- It provides a framework for action that encourages a diverse program of activities, opportunities and resources
- It utilizes and nurtures established relationships with schools, educators and school boards.
- Individualized Action Plans are created that are tailored to specific school needs, demographics, current resources and goals.
- It is geared to every child, regardless of skill level

2.4. ACTION SCHOOLS! BC IMPLEMENTATION

The Action Schools! BC intervention was comprised of 2 treatment arms (Liaison and Champion) and a control arm (Usual Practice). I describe these below.

Usual practice. Schools continued their normal program of school-based physical activity and we did not intervene with school environment at all.

Liaison Schools. Schools randomized to the Liaison arm were assisted in delivery of the program by an AS! BC Facilitator. The Facilitator worked with the School Action Team to devise the individualized Action Plan and to provide support and assistance with logging of activity. In addition, the Facilitator conducted workshops to introduce the various components of the program. The Facilitator also provided and updated the resources (Classroom Action Bin) required by each classroom teacher. The Facilitator worked with one self-appointed person from each school to schedule meetings, workshops and assist in inventories of space and equipment. The Facilitator visited on a weekly basis, to provide assistance and observe delivery of the program. This usually took between 2 and 4 hours per school, per week.

In addition, the Support Team met with principals on several occasions to discuss school health policy and provide assistance and ideas with regard to creating a healthier school environment (e.g. organizing a walking school bus or a jump-rope day).

Champion Schools: The major distinction between the intervention arms is creation of an in-school 'Champion', as opposed to the AS! BC Facilitator. In Champion schools, a self-appointed individual (teacher, principal or parent) took on the role of the AS! BC Facilitator. The Support Team guided creation of the Action Plan, provided workshops and the same Classroom Action Bin. Although contact time with the external AS! BC Facilitator was usually ½ - 1 hour per school per week, advice and assistance could be sought by contacting the Support Team.

NOTE: As the frequency, intensity, type and duration of physical activity delivered in the Liaison schools and the Champion schools were the same, the two intervention arms are collapsed for data analysis.

2.4.1. *Creating an Action Plan*

The Action Plan served to outline and clarify the Action Schools! BC program for the teachers. Action Plans were made for each individual class participating and for the whole school. The Action Plan was made by the School Action Team in conjunction with members of the AS! BC Support Team. The plan was based on goals set within each of the 6 Action Zones. From the goals identified by classroom teachers (with assistance from the School Action Team), a set of Action Ideas was decided upon using ideas from the Action Pages 'best practices' compendium. Once the Action Plan was created, individualized Classroom Action Bins were provided (one for each class participating – classes in grades 4 and 5 for Phase I and grades 5 and 6 for Phase II) supplying resources required and schedules of activities for individual classes. By creating an individualized Action Plan, activities were chosen that fulfilled the Healthy Hearts component (described later). An example of an Action Plan is provided (Appendix E)

We provided two training workshops for teachers (Spring 2003 and Fall 2003) in both Liaison and Champion schools to facilitate delivery of the Action Plan. This was arranged at the discretion of the principal to accommodate the teaching schedule. Workshops were, on average, 3- 5 hours in duration and teacher on-call services were provided for substitute teachers. The aim of these workshops was to introduce teachers to the resources, share ideas about different kinds of activities, introduce pedometers and specifically, to train teachers to deliver the activities that comprised their Action Plan. In the Liaison schools the workshops were conducted by Debbie Keel, and in the Champion schools, by Judy Howard.

During the second workshop (Fall 2003) teachers who were new to the intervention (because of teacher rotation within a school or movement between schools) received full training.

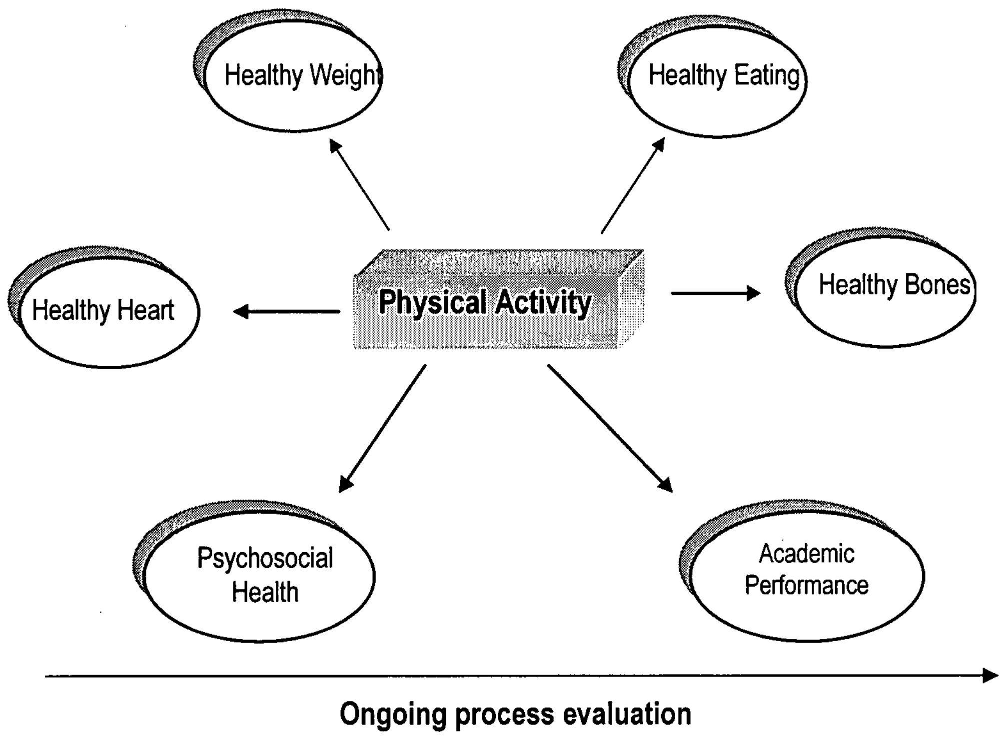
2.4.2. *The Classroom Action Bin*

Liaison and Champion Schools were provided with an Action Bin that was stored in the classroom (Appendix E). In Liaison schools the bin contained physical activity resources to support their Action Plan. These ranged from information booklets and dance videos to skipping ropes and exercise bands. Champion schools received only a basic bin. This comprised items selected by the Support Team that were sufficient to engage in a variety of activities, but not as many resources as provided to the Liaison schools. One bin was provided to each grade 4 and 5 classroom teacher who chose to participate in the study. The AS! BC Support Team provided instructions on how to use the available resources at the teacher workshops.

2.5. CARDIOVASCULAR HEALTH COMPONENT OF ACTION SCHOOLS! BC

The cardiovascular health component of the AS! BC was mandatory. Options were presented as a 'menu' from which the teacher selected a variety of physical activities that provided the children with an additional 75 minutes per week of moderate to vigorous physical activity (MVPA), in addition to normal PE class (2 x40-min/wk) for a total of 150 minutes per week MVPA (Appendix E). Moderately vigorous physical activity (MVPA) may be classified in a number of ways; achieving and sustaining a heart rate above 130 bpm [2], above 120bpm, or at 75% above resting heart rate [3]. The cardiovascular health component was delivered in the Classroom Action Zone. These 15-minute physical activity sessions were designed to increase heart rate to moderate levels.

Figure 2.5 Evaluation components of Action Schools! BC
This schematic illustrates the multiple health outcomes evaluated in the Action Schools! BC study. My thesis focuses on the cardiovascular component.



2.6. DATA COLLECTION

2.6.1. Data collection overview

Data collection took in the schools in February/March 2003, September 2003, January 2004 and May/June 2004, and at Vancouver General Hospital (VGH) in February/March 2003 and in May/June 2004. Blood draw took place at BC Children's and Women's Hospital (BCCWH) in March 2003 and May/June 2004.

For measurements at VGH each child was released from school for 2.5- 3 hours and driven to the hospital in a minivan. Children travelled in groups of 6, with one driver plus a chaperone. For in-school measurements, children were released from class in groups of 6 for 40-45 minutes. Testing took place in schools gyms or lunchrooms. Sensitive measurements (arterial compliance and heart rate variability) were taken in a nearby quiet room, such as a library. For the blood-draws, a parent or guardian escorted children to BCCWH and this procedure required approximately 30 minutes.

Data collection time-points and locations are summarized in Figure 2.1

2.6.2. Data collection personnel and training of the measurement team

The measurement team consisted of a full time research coordinator and graduate students from the University of British Columbia. Two weeks prior to the first data collection session measurers undertook a one-day training session to learn how to administer questionnaires and physical measurements. Prior to each subsequent data collection, new measurers (as applicable) were trained on a one to one basis.

I collected all heart rate variability data and collected or supervised applanation tonometry measurements (assistance from Jessica Scott and Ben Esch). A trained nurse (Mable Tang) conducted the blood draws and samples were prepared by a trained laboratory technician (Alfred Wong). One trained technician at St Paul's Hospital (Margaret Henderson) analyzed all serum samples for lipids, fibrinogen, C-reactive protein and homocysteine.

2.7. MEASUREMENT PROCEDURES

In the current study we utilized a physical activity intervention model and assessed its influence on our primary outcome measure (physical fitness) as well as selected secondary outcome measures (HRV, blood pressure, arterial compliance, BMI, serum factors) (Appendix F). Physical fitness was selected as the primary outcome variable based on its large independent effect on cardiovascular health and its positive impact on other CVD risk factors [247, 193]. Further, we were able to obtain reliable and valid measures of physical fitness of our relatively young cohort using Leger's 20-meter shuttle run in a field setting. Data collection forms are provided (Appendix B). I provide an illustration of the stations through which the children rotated at VGH (Figure 2.6) and during the in-school testing sessions (Figure 2.7).

Figure 2.6 Flow diagram showing movement of students through testing stations at VGH measurement sessions

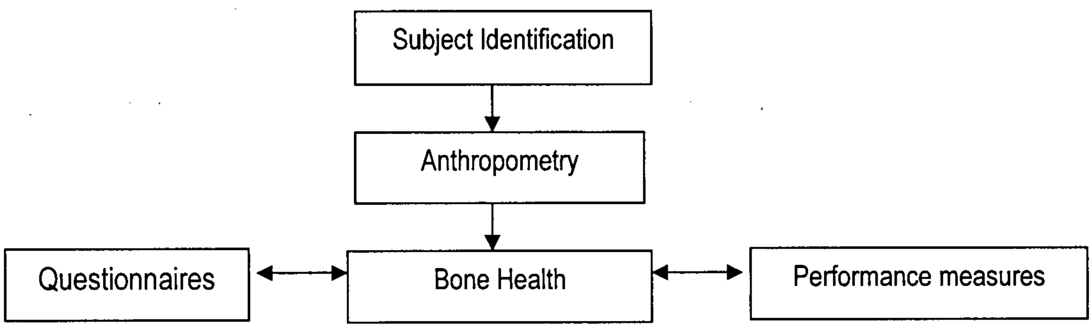
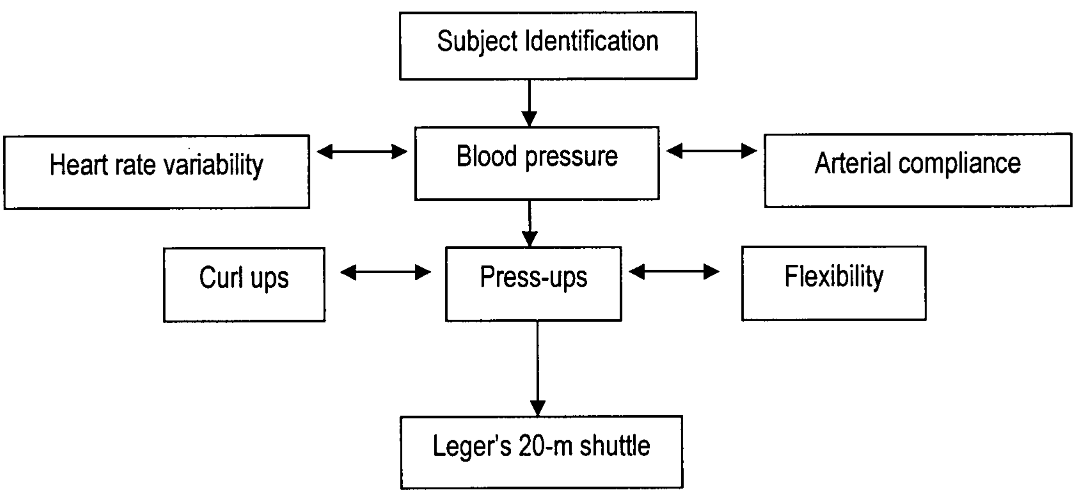


Figure 2.7 Flow diagram showing movement of students through stations during in-school testing



2.7.1. Measurements

2.7.1.1. Anthropometry

We obtained duplicate measures of standing height (stretch stature without shoes) to the nearest 1mm using a wall-mounted stadiometer. Stretch stature was measured by the standard method, applying gentle upward traction on the base of the mastoid process. We measured body mass, in light clothing, on an electronic scale (SECA) to the nearest 0.1kg. Two measures of height and mass were taken, unless measurements differed by more than 4mm or 0.2kg, in which case a third measure was taken. The average of the two values or the median of 3 values was used for analysis. Body mass index was determined using the equation kg / (m^2).

2.7.1.2. Physical activity questionnaire

We assessed physical activity by questionnaire at 5 points throughout the intervention. The Physical Activity Questionnaire for Children (PAQ-C) [4] is a self administered 7-day recall questionnaire that has been validated against various instruments (including other self-report questionnaires and motion sensors) with values of r=0.39 – 0.63 [4]. Details of the PAQ-C have been provided in Chapter 1. In brief, the PAQ-C is composed as:
item 1 is a specific activity recall from a list of common activities;
items 2-7 focus on physical activity throughout different parts of the day (recess, lunch time, PE class, after school, evening) and weekend;
item 8 asks the child how much television they watched the previous week;
item 9 asks how often the child was active on each day of the previous week;
item 10 asks whether the child was prevented from normal physical activity;
item 11 asks the children to select statements which best describes his/herself from low to high active.

The original PAQ-C has been extended in two ways. First, to estimate time spent in each of the activities indicated in the first section (item 1) and second, to describe extra curricular activities, such as Chinese school or soccer club (item 12). The questionnaires were analyzed to determine average activity scores (PA score: low active =1, high active =5 on a continuum) and average activity time (min/day: minutes per day of general physical activity). Each child completed the PAQ-C with the assistance of a research assistant.

2.7.1.3. Maturity

Each child was asked to self assess physical maturity using line drawings and description of pubic hair (boys and girls) and breast stage (girls) based on Tanner Staging [5] (Appendix B). Tanner stages are numbered 1 to 5. Stage 1 represents pre-puberty, stages 2 and 3 represent early-middle puberty, stage 4 represents late puberty and stage 5 represents post puberty. Self assessed Tanner stage agrees well with physician ratings [6]. There were separate forms for girls and boys. The girls' form also required them to indicate whether menarche had been reached. Each child was taken to a private room, shown the form by a same sex investigator then left alone in the room to check the appropriate picture. Children ticked the picture that most closely resembled their stage of development and were provided with an envelope in which to seal the form before returning it to the investigator.

2.7.1.4. Cardiovascular Health and physical performance

We assessed cardiovascular and musculo-skeletal fitness using FITNESSGRAM (The Cooper Institute in Dallas, Texas). Developed in 1982, the battery of measurements was designed to increase awareness of children's fitness levels. Students are assessed in three general areas of health-related fitness. Each of the test items was selected to assess important aspects of a student's health related fitness, not skill or agility.

Aerobic capacity: Aerobic capacity was assessed using Legers 20-m shuttle run [7]. This is a progressive aerobic endurance test, in which subjects repeatedly run 20-m laps in time with a clearly audible 'beep' until fatigue. The test in is stages, with stage one starting at 8.5 $km.hr^{-1}$. Each stage is one minute in duration and increases in speed by 0.5 km.hr-1.

A 20-m distance was measured and marked out. After simple instructions regarding the test, participants lined up in groups of 4-6 and the test began. One tester ran, to set pace, with the participants. Participants were verbally encouraged throughout the whole test. Subjects continued running until volitional exhaustion or until the tester's direction if the subject failed to reach the 20-m marker on 2 consecutive occasions. Using a hand held counter, we recorded numbers of laps completed by each participant. Validity in relation to maximal oxygen uptake (VO_2 max) was reported to be moderately high (r=0.72) and test-retest reliability has been reported as 0.93 (ICC) [8].

Curl up: To assess endurance of the abdominal muscles, each student was asked to lay supine, knees bent to 90°, hands on the floor, and lift their upper body so fingers slide 10 cm forward on the floor. A textured mat allowed students to determine range of movement. Curl ups were conducted at a pace of 20 per minute (a metronome was audible to ensure correct pace) until fatigue or if technique became poor.

Press-ups: To assess upper body strength each student was asked to lay prone, with hands under the shoulder and then extend their arms to lift their body (only hands and feet are touching the floor). The student then lowered their body back toward the floor, keeping their back straight. Press-ups were conducted at a pace of 20 per minute until fatigue or if technique became poor.

Sit and reach test: To assess hamstring and lower back flexibility, each student was instructed to sit with feet flat against a box, legs straight, arms extended and fingers touching a sliding block. Keeping their legs straight, the student slowly leaned forwards, pushing the block as far as possible. Score was the number of centimetres the block was pushed forward.

2.7.1.5. Serum factors

Children were brought to the BCCWH by their parent or guardian between 7:00 AM and 9:00 AM after a 12-hour fast. We applied local anaesthetic (Ametop, Smith and Nephew) and a hot water pack to the back of one hand. This remained in place for 10-15 minutes. After this time, the nurse drew 20mL of blood using a single venipuncture whist the child remained in a recumbent position. Samples were immediately placed on ice, then centrifuged (within 2 hours) at 3200rpm, 4°C for 15 minutes. Serum was then drawn from the samples, sealed in Eppendorf tubes, and frozen at -83°C. When all samples were collected, serum was analyzed using routine assay techniques at St Paul's Hospital, Vancouver, BC.

2.7.1.6. Arterial compliance

We measured arterial compliance by applanation tonometry, using the HDI/Pulsewave CR 2000 System (Eagan, Minnesota, U.S.). The device consists of an oscillometric blood pressure component and a non- invasive arterial pulse wave sensor.

Each child lay supine on a padded surface and a rigid plastic wrist stabilizer was placed on the right forearm to prevent excess movement. The sensor was positioned over the radial artery, immediately proximal to the wrist at the point of maximum pulsation, and held in place with a plastic component and Velcro straps. Correct horizontal and vertical positioning was achieved by fine tuning placement of the sensor. This allowed adequate pressure to be applied to the artery, but not so much as to occlude the vessel. The sensor was moved and pressure exerted on the vessel until an adequate signal was obtained. An appropriate sized compression cuff was placed on the left upper arm. This cuff was attached to the computer to allow calibration of pressure. After inputting the child's height and mass, the cuff was inflated then subsequently deflated to determine systolic and diastolic pressures. Once the cuff had deflated, arterial waveform was recorded for 30 seconds then analyzed. This procedure was repeated twice on each subject and the mean value used for analysis.

Analysis of the waveform: The waveform is produced by change in pressure in the artery in relation to change in blood volume. Immediately after the steep increase in pressure (in response to rapid ventricular ejection), the pressure in the artery reduces as the volume decreases. This is seen as decay of the waveform. The 'dicrotic notch' becomes apparent in decaying portion of the curve and depicts the closure of the aortic valve. As there is no longer a continual forward flow of blood leaving the ventricle, a slight increase in pressure occurs in the artery, reflecting the small backflow of blood. The decay of blood pressure prior to the next beat is dependent on the stiffness of the artery. Compliance is determined via an algorithm (which incorporates body size and cardiac output) for the small vessels and the larger vessels. In the arterial system, larger vessels serve (in part) to act as 'buffers' and alter the flow from an intermittent state to a continuous state. For this reason, compliance in these vessels can be referred to as 'capacitive arterial compliance'. Given a more compliant small artery, backflow of blood after the aortic valve closes will be less and more delayed. For this reason, compliance in the small vessels can be referred to as 'reflective arterial compliance'.

Validity of Pulse Waveform Analysis was found to be high when compared with other measures of compliance; calculation from stroke volume and pulse pressure (r=0.92) and MRI- based carotid artery distension (r=0.75) [9] and by invasive measurement of compliance (r=0.82) [10].

2.7.1.7. Heart rate variability

A Polar S810 Heart Rate Monitor (Polar Electro, Oy, Finland) was placed around the chest and the sensor dampened to aid skin contact. Children were asked to lay supine on a padded surface and remain completely still with their eyes closed for 7-8 minutes in a quiet room. Data recording began immediately. Data were downloaded into Polar analysis software and then analyzed in the time and frequency domains at 500Hz, using HRV analysis software (Biomedical Signal Analysis Group, Kuopio, Finland) (Appendix H). After discarding the first minute of data and the automatic removal of anomalies, only data sets with at least 256 RR intervals were included. Data with more than 6% errors were discarded. Fast Fourier Transformation was applied to the data sets. Frequency domain HRV parameters were set according to the proposal of the Task Force [11] . Frequencies were set as; low frequency VLF (0.01-0.04Hz) low frequency (LF) (0.04-0.15Hz) or high frequency (HF) (0.15-0.5Hz).

2.8. SAMPLE SIZES

Sample size for the entire cohort was calculated by estimating change in the primary outcome variable, physical fitness as assessed by Leger's 20-m shuttle run. The power to show a main effect for the intervention was calculated based on a 10% increase in Leger's 20-m run performance in the intervention group. Similar school-based interventions have shown increases in physical fitness to be as much as 90% greater [12], whereas others have shown a 13% [13] and an 8% [14] increase in aerobic performance. A mean of 36 laps ±8 [15] was estimated as a baseline to determine power and sample size. Therefore to show a 10% increase in physical fitness as measured with a 20-m incremental shuttle run, with alpha set at 0.05 and power at 0.8, a total sample size of approximately 166 was needed. For statistical analysis purposes, I collapsed the two intervention arms into one group. With a yearly attrition rate of 20%, approximately 200 subjects were required to show a main effect.

2.9. STATISTICAL METHODS

Statistical methods appropriate for each individual study are provided in each section. For all analyses, data were checked with box plots and scattergrams to detect outliers. The distribution of the data was checked for normality and appropriate transformations applied. The type of transformation depended on the extent and the nature of skew.

Where appropriate, the cluster design of the intervention was considered by adjusting the test statistic and the confidence intervals by the variance inflation factor (VIF). This is calculated as 1+ (m-1) ICC, where m=adjusted mean cluster size and ICC is the intracluster co-efficient. The ICC is calculated as BMS-WMS/BMS + (m-1) WMS, where BMS is the Between-clusters Mean Squared and WMS is the Within-clusters Mean Squared. Results for ICC and VIF used are provided (Appendix G)

2.10. OTHER DATA ISSUES

All measurers and data entry personnel were blinded to treatment allocation at baseline. One person (Ryland Haggis) entered data at all time points. Data were stored in the central database and were password protected.

Data stored in the central database was password protected and access granted by the Principal Investigator only. Hardcopies of data were stored in a locked cabinet and only research personnel involved in the study were allowed access. To maintain patient confidentiality participants were referred to by ID number only.

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CHAPTER 3. DETERMINING CARDIOVASCULAR DISEASE RISK IN ELEMENTARY SCHOOL CHILDREN: DEVELOPING A HEALTHY HEART SCORE[2]

3.1. INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality for both men and women in most developed countries. In Canada alone, treatment of the disease demands $18 billion of the annual health care budget [1].

It is widely accepted that the atherosclerotic process begins in childhood and progresses through adulthood [2]. The Bogalusa Heart Study determined that as the number of CVD risk factors increases, so did the severity of both coronary and aortic atherosclerosis in young people [3]. Risk factors for development of CVD include hypertension, smoking, low physical activity, diabetes, obesity, low ratio of total to high-density cholesterol and a family history of heart disease. As many as 50% of children may exhibit one or more CVD risk factor [4] and some studies report higher clustering (presence of more than one risk factor) in boys [5, 6]. Reports that noted the clustering of risk factors in children frequently classified a risk factor as elevated if the level was above the 75^{th} percentile for that measure. Unlike adult based investigations, the severity of a risk factor is not normally assessed in pediatric populations.

Odds ratio calculations that predict the likelihood of developing coronary heart disease in adults have commonly used a variety of biological or lifestyle factors. The Framingham Heart Study used biological and lifestyle factors to create several algorithms, that predicted risk of coronary heart disease [7]. In these models, the time course and probability of an event was calculated using risk ratios derived from adult levels of risk factors that may have been present for some time. However, using adult-specific algorithms is inappropriate for predicting cardiovascular disease risk in children.

It is not yet possible to predict an adult cardiac event from childhood risk factor clustering. Despite this, the presence of risk factors in youth is associated with the extent of arterial wall damage [3] and intima-media thickness in adulthood [8]. Furthermore, relative rank is maintained from childhood to adulthood for many CVD risk factors, including blood pressure, obesity, total cholesterol, physical fitness and physical activity [9, 10]. Thus, it is possible and likely important to assess the modulation of CVD risk factors during childhood. The prevalence of risk factors in children is widespread [4-6]. This suggests that a population-based prevention approach may be most effective, compared to methods that solely target those individuals deemed to be at higher risk for CVD. The Committee on

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Atherosclerosis, Hypertension and Obesity in Youth (AHOY) recently issued a statement concerned with cardiovascular health promotion for children. It emphasized that schools were important stakeholders in population-based health promotion and risk-reduction efforts [11].

Consequently, the primary aim of this study was to create a cardiovascular "Healthy Heart Score" for elementary school children using established risk factors that can easily be assessed within a school environment. We aimed to i) create a score that was independent of both age and sex, and that could incorporate both number and severity of CVD risk factors and ii) correlate the Healthy Heart Score with various serum lipids. Our secondary aim was to use the Healthy Heart Score to compare the difference in risk factor clustering and severity between young girls and boys. As previous studies have shown a higher incidence of clustering of risk factors in boys, we hypothesized that girls would have a significantly better Healthy Heart Score than age-matched boys.

3.2. METHODS

3.2.1. Rationale for cardiovascular risk factors used in the profile

There were a number of criteria that risk factors needed to satisfy to be included in the profile.
First, they were easily measured by a school nurse or trained classroom teacher. Thus, factors such as total cholesterol or high-density lipoprotein (HDL-C) concentration, despite their relationship with CVD, were not included. Second, we selected those risk factors that were established in adults, such as systolic blood pressure and diastolic blood pressure [7]. Childhood blood pressure is a strong predictor of adult blood pressure, and explains up to 25% of the adult variance in this index [12]. Body mass index (BMI) is associated with several important CVD risk factors in both adults and children, such as left ventricular hypertrophy, insulin resistance and endothelial dysfunction [13]. Cardiovascular fitness is also associated with several important CVD risk factors indicators, such as HDL-C, which has recently been identified as an independent risk factor for CVD [14]. Poor cardiovascular fitness during youth and young adulthood is associated with the development of diabetes, hypertension and metabolic syndrome in later life [15]. Finally, regular physical activity in childhood is also associated with several cardiovascular disease risk factors including a healthy serum lipid profile [16], endothelial function [17]. Despite the association between cardiovascular fitness and physical activity, we included both in the score. Although fitness [18] during youth is a stronger predictor of cardiovascular health in adulthood than physical activity [19, 20], activity in childhood, and change in activity during youth, are also related to cardiovascular disease risk profiles in adulthood [21]. In adults it is difficult to detect whether physical fitness or physical activity is the better predictor of health status so it is important that both are assessed [22].

3.2.2. *Subjects*

Subjects were 252 children (127 boys, 125 girls) aged 9-11 years attending elementary schools in the Greater Vancouver and Richmond School Districts. All children were participants in Action Schools! BC, a school-based model designed to assess the role of physical activity on multiple health outcomes. Measurements for the Healthy Heart Score took place in September 2003. Children were included in the present study if they participated in normal school physical education class and were free of disease, and were not taking medications that influenced their cardiovascular health. Health screening was assessed by a questionnaire that was completed by each child's parent. The University of British Columbia's Clinical Research Ethics Board gave ethical approval for the study. Parents of all children provided written informed consent, and all children gave verbal and written assent.

3.2.3. *Measurements*

Detailed methods are provided in chapter 2, but summarized below.

Cardiovascular fitness: Cardiovascular fitness was assessed using Leger's 20-m incremental shuttle run, designed for use with children [23] . The tool is a valid and reliable measure of aerobic fitness in children [24].
Anthropometry: Standing height (stretch stature without shoes) was measured to the nearest 1mm using a wall mounted digital stadiometer (Seca Model 242, Hanover, MD). Mass in light clothing was measured using an electronic scale (Seca Model 840, Hanover, MD) to the nearest 0.1 kg. BMI was determined using the equation mass (kg) / height $(m)^2$.
Blood pressure: After 5-10 minutes quiet rest, we obtained duplicate measurements on the left arm in the seated position using an automated sphygmomanometer and an appropriately sized cuff (VSM MedTech, Canada).
Physical activity: We administered the Physical Activity Questionnaire for Children (PAQ-C) [25]. We used question 1 from the PAQ-C, and asked children how long they spent on each activity, to determine total minutes of moderately to vigorous physical activity (averaged over 7-days to provide minute of physical activity per day).
Blood collection: We obtained intravenous blood samples between 8.00 AM and 9.30 AM from the antecubital vein of a small subset of children (n=77, 40 boys and 37 girls) who had fasted overnight. Samples were later analyzed for TC, HDL-C and LDL-C and triglyceride concentration (TG) at St. Paul's Hospital Laboratory, Vancouver.

3.2.4. *Determining cardiovascular disease risk level*

In step 1 we created age and sex appropriate percentile scores for each risk factor
Unlike adult levels of many risk CVD risk factors, recommended ranges of physiological variables change as children mature and grow in stature. Therefore, we converted biological risk factors (systolic and diastolic blood pressure and BMI) to age and sex appropriate percentiles.

We used sex specific Centre for Disease Control (CDC) growth charts to convert BMI to a percentile [26]. We used normal values from the National High Blood Pressure Education Program to convert systolic and diastolic blood pressures to age, sex and height appropriate percentiles [27].

Cardiovascular fitness score was determined according to age and sex appropriate criterion values from FITNESSGRAM [28]. Physical activity "risk level" was determined based on whether children met the suggested guidelines (60 minutes per day) provided by the American Alliance for Health [29].

In step 2 we determined the Healthy Heart Score for each child. We adopted a similar approach to the Framingham group to reflect varying levels of hypertension in our participants. In adults, hypertension is frequently defined as a yes/no variable, however, the Framingham group has shown that additional blood pressure categories are important in predicting CHD risk [7]. Thus, the Framingham CHD risk factor prediction algorithm uses both continual and (5) categorical values for blood pressure value. We assigned systolic and diastolic blood pressure scores of 1 to 4; score 1=<75^{th} percentile, score 2=76^{th}-85^{th} percentile, score 3=86^{th}-95^{th} percentile and score 4=>95^{th} percentile. Body mass index was allocated a score of 1 to 4 based on standard definitions of 'obese' (BMI >95^{th} percentile) (score 4) and 'overweight' (BMI between 85^{th}-95^{th} percentile) (score 3) [18]. We also created BMI categories between the 75-85^{th} percentile (score 2) and BMI <75^{th} percentile (score 1). We allocated fitness score based on whether children were above (score 1), within (score 2) or below (score 3) criterion based aged and sex appropriate values [28]. Our rationale was based on the reported relationship between adult fitness quartile and relative death risk. Although this had not been established in children, fitness tracks fairly well from childhood to adulthood [30]. For physical activity, children were assigned a score of 1 if they undertook >60 min of physical activity/day (PA/d), a score of 2 for 30-60 minutes PA/d and a score of 3 if they were active for < 30 minutes per day.

Thus, Healthy Heart Scores could range between 5 and 18 and lower scores represented a more favourable CVD risk factor profile.

3.2.5. *Data analysis*

Descriptive data are mean (SD). Healthy Heart Scores are also given as a median. Mean Healthy Heart Scores was negatively skewed, therefore Healthy Heart Score were compared using non-parametric 2 sample tests (Mann Whitney). Statistical significance was set at $p<0.05$. We used Pearson's Product Moment Correlation to assess the relationship between Healthy Heart Scores and serum factors.

3.3. RESULTS

Table 3.1 provides descriptive data for the 252 children, 125 girls and 127 boys who participated in the study. Mean Healthy Heart Score was calculated for the whole group and for girls and boys separately. The group mean Healthy Heart Score was 8.2 (2.2) with a range of 5-16. Girls' mean Healthy Heart Score was 7.6 (2.1) with a median of 7. Boys' Healthy Heart Score (mean 8.6 (2.2) median 8) was significantly higher than girls' Healthy Heart Score ($Z=3.9$, $P<0.01$). The distribution of Healthy Heart Score by sex is shown (Figure 3.1). The number of children assigned to each scoring category is shown (Table 3.1). Data for the whole group and then for boys and girls are provided.

Forty two percent of children had no elevated risk factors (blood pressure above 75th percentile, obesity or overweight, fitness less than age recommended level or less than 30 minutes physical activity per day). The percentages of children with 2, 3, 4 or 5 elevated risk factors were 29, 17, 9 and 3, respectively.

The Healthy Heart Score was found to correlate with TC: HDL-C ($r = 0.30$, $p = 0.01$), HDL-C ($r = -0.32$, $p = 0.01$) and triglyceride concentration ($r = 0.23$, $p = 0.05$)

3.4. DISCUSSION

We created a composite cardiovascular disease risk profile that encompasses both biological and lifestyle risk factors. Unique to this study, we allocated a score based on the severity of five known risk factors for CVD. We found that the majority of children (58%) presented with at least one elevated risk factor. We showed that, in a subgroup of children, Healthy Heart Score and several serum lipid and lipoprotein concentrations (TC:HDL-C, HDL-C level and triglycerides) were significantly correlated. Although these relationships do not formally validate the score, they provide evidence that the non-invasive measures used in the study are associated with well known lipid and lipoprotein concentrations that are related to cardiovascular health.

It was disconcerting that by 10.7 years, on average, 58% of children had elevated levels of at least one CVD risk factor. The presence of CVD risk factors in young people is associated with damage to the aorta and the coronary vessels [3]. The Bogalusa Heart Study [3] correlated ante-mortem risk factors with post-mortem level of fatty streaking and plaque deposits in blood vessels from youth aged as young as 2 years. Children with 0, 1, 2, and 3 or 4 risk factors were found to have 19%, 30%, 38%, and 35% of the aorta covered in fatty streaks, respectively. The comparable figures for fatty streaks in the coronary arteries were 1.3 %, 2.5%, 7.9 % and 11% of the vessels being affected.

The presence of CVD risk factors in our study correspond with reported trends of declining physical activity and fitness and increasing prevalence of overweight in children [31] [32] [33]. A recent meta-analysis of 55 studies from 11 countries, showed that fitness has been declining in children by, on average, 0.5% per year over the last 2 decades [31]. In Canada the decline has been 0.75% per year. Similarly, researchers in Europe found that the average fitness level of children in 2002 was 1.2 SD below the recommended population mean [34]. Fitness levels of 20% of the children in our study failed to meet standards set for health [28]. Interestingly, poor fitness was more prevalent in boys, with 33% of boys failing to meet criterion standards. Lower levels of acceptable fitness differed for boys and girls. For example, a 10 year old boy needs to complete 23 laps of the 20-m shuttle test to have acceptable fitness, but a 10 year old girl needs to complete only 15 laps to be classified as equally fit. In this study, girls and boys performed the similarly on the 20-m shuttle test (28 laps and 29 laps, respectively). However, a greater number of boys scored 'low' for fitness because the criterion level for boys was set higher (34% boys and 8% of girls completed a lower number of 20-m shuttles than their age and sex specific criterion value). Blair [35] reported a significantly higher risk of all-cause morbidity and mortality in adults resulted from being in the lowest quintile for fitness. The FITNESSGRAM standards were established so that the lowest desirable value corresponds to the lowest 20% of the adult population (39ml.kg.min^{-1} for males and 34ml.kg.min^{-1} for females).

The prevalence of children meeting the guidelines for physical activity levels either inside or outside of school was relatively low. Approximately 24% of children engaged in less than 30 minutes of physical activity per day and this value was similar for boys and girls. The Canadian Fitness and Lifestyle Research Institute reported that only 44% of girls and 53% of boys aged 6-12 years participated in sufficient daily physical activity for optimal health and growth [36]. The U.S. National Institute of Child Health and Human Development reported typical physical activity levels for elementary school children during physical education class [37]. In that report, children accrued only 4.8 minutes of very active and 11.9 minutes of moderate to vigorous physical activity during a typical physical education class. Leisure time physical activity is also decreasing outside school hours. In England, there was a 20% drop in active commuting to school between 1970 and 1991 and now more than 50% of children in elementary school are driven less than 1 mile to school [33].

Conversely, BMI has been increasing by an average of 0.6% per year in children since 1990 [32]. According to Third National Health and Nutritional Examination Survey (NHANES III), the percentage of *obese* children (BMI >95th percentile) has tripled since the 1960s and is now approximately 14% [38]. In Canada, between 1981 and 1996, the prevalence of *overweight* increased among boys from 15% to 28.8% and among girls from 15% to 23.6%. Over the same time period, the prevalence of obesity increased from 5% to 14% among boys and to 12% among boys [39]. In the present study, 15.2% of children were in the highest risk category (>95th percentile) for BMI. As with fitness, a greater percentage of boys were in the highest risk category for BMI compared with girls (24% and 4%, respectively).

The prevalence of single or multiple CVD risk factors in children is high. In Europe, at least 50% of children aged 8-15 years have at least one biological risk factor for cardiovascular disease [4]. Children with low levels of physical activity have an increased likelihood of having an additional elevated risk factor for cardiovascular disease. Investigators reported that those children in the lowest quartile for physical activity had an odds ratio of 1.5 or 1.8 (for boys and girls, respectively) for presence of 2 or more CVD risk factors. Similarly, Andersen and colleagues [34] randomly selected 1020 children aged 9-15 years old. They found that 8-9 times as many children as expected from a random distribution had 5 CVD risk factors and 3 times as many children had 4 CVD risk factors. Our results extend these findings as we included both low cardiovascular fitness and low physical activity as risk factors. Inclusion of these variables had a large impact on the number of children allocated to the higher risk categories. The percentages of children with elevated BMI and elevated blood pressure is similar to levels reported in several other studies [11, 38, 40].

3.5. LIMITATIONS

We acknowledge that our study has a number of limitations. The indirect methods we used to assess cardiovascular fitness and physical activity may have greater variability compared with direct measures such as oxygen uptake for fitness or direct observation or accelerometers for physical activity. We strove to reduce this limitation be using tools that were valid and reliable for evaluating fitness and physical activity in children [24]. Further, one of our criteria for assessment was that teachers or health care professionals could undertake measurements in the school. With these field-based fitness assessments we were able to measure several children at one time on the school premises. Importantly, all of our measurement team were trained to provide uniform encouragement to students during each testing session, as motivation could potentially confound the results of the 20-m shuttle test.

We also acknowledge that we assessed a relatively small sample of Canadian children, and cannot extrapolate our findings beyond a sample of children living in the Vancouver area. Importantly, these children had been volunteered for a school-based physical activity intervention. Schools had been selected for the intervention based partially on their current physical activity program. Schools where the physical activity opportunities were low [41] (as assessed by parents and students) had been selected to take part in the intervention. Thus, these children may not have been representative of all elementary school children in Vancouver. Children from schools that provided a fuller physical activity curriculum may have had better cardiovascular risk profiles and therefore better Healthy Heart Scores.

Finally, we do not know whether a Healthy Heart Score of 3 for BMI, for example, is as potentially detrimental to adult cardiovascular health as a Healthy Heart Score of 3 for blood pressure. Unlike adult indices, tools created for children, such as this so not 'weight' the risk factors. Until the long term risks of elevated CVD risk factors in children are fully understood, weighting scores in children will be difficult. The Healthy Heart Score was created as a pilot tool, designed to provide an indication of cardiovascular disease risk, not as a valid tool to predict the occurrence of a future cardiac event. A scoring method that utilized continual data, rather than categorical data could potentially result in a more precise measure. Converting continual data to 3 or 4 categories (as in the Healthy Heart Score) results in a loss of precision.

3.6. CONCLUSION

The prevalence of cardiovascular disease risk factors in children has increased substantially over the last 15 years, and in this study we showed 58% of children had at least one elevated risk factor. We extended previous risk scores by determining a Healthy Heart Score using five known CVD risk factors. We created a cardiovascular risk profile for children that accounted for the severity of each risk factor, using variables that can be assessed in a school setting. We found in a subgroup of children the Healthy Heart Score was significantly associated with a number of serum lipid and lipoproteins related to CVD risk. We supported our hypothesis that girls would have a better (lower Healthy Heart Score than same age boys). This occurred despite similar group means and is likely linked to criterion standards. In particular, boys' scores for fitness and BMI were substantially worse than girls' scores. Given that many CVD risk factors are present in childhood and track through adolescence and into adulthood, it is important that cardiovascular disease risk be assessed early. Further, there is a need for effective interventions that target reduction of CVD risk factors beginning at an early age.

Table 3-1 Data for Healthy Heart Score assessment. Descriptive data (mean, (SD)) are shown in column one in bold. Numbers (*% in parentheses*) of children assigned to each category for each risk factor measured are shown in the remaining columns (n=252).

	Score and risk level:	Score 1 'low'	Score 2 'moderate'	Score 3 'mod-high'	Score 4 'highest'
	Mean (SD)				
BMI	**19.1 (3.5)**	148 *(59)*	27 *(10)*	42 *(17)*	35 *(14)*
Boys	**20.3 (3.9)**	64 *(50)*	14 *(11)*	19 *(15)*	30 *(24)*
Girls	**17.9 (2.7)**	84 *(68)*	13 *(10)*	23 *(18)*	5 *(4)*
SBP	**104.8 (9.5)**	191 *(78)*	22 *(7)*	26 *(10)*	13 *(5)*
Boys	**105.7 (9.7)**	89 *(71)*	15 *(11)*	16 *(12)*	7 *(6)*
Girls	**103.9 (9.2)**	102 *(84)*	7 *(4)*	10 *(7)*	6 *(5)*
DBP	**62.3 (7.9)**	204 *(83)*	23 *(8)*	20 *(7)*	5 *(2)*
Boys	**62.4 (8.0)**	101 *(80)*	14 *(11)*	11 *(8)*	1 *(1)*
Girls	**62.1 (7.9)**	103 *(86)*	9 *(5)*	9 *(6)*	4 *(3)*
Fitness	**28.6 (13.2)**	22 *(8)*	176 *(70)*	54 *(22)*	
Boys	**29.2 (12.7)**	3 *(3)*	80 *(63)*	44 *(34)*	
Girls	**28.0 (13.8)**	19 *(14)*	96 *(78)*	10 *(8)*	
PA	**73.9 (40.2)**	171 (69)	53 *(20)*	28 *(11)*	
Boys	**73.9 (40.8)**	91 (73)	24 *(18)*	12 *(9)*	
Girls	**73.8 (39.6)**	80 (65)	29 *(23)*	16 *(12)*	

BMI = body mass index (kg/m^2), SBP= systolic blood pressure and DBP = diastolic blood pressure (mmHg), Fitness (20-m shuttles completed), PA= physical activity (min/day)

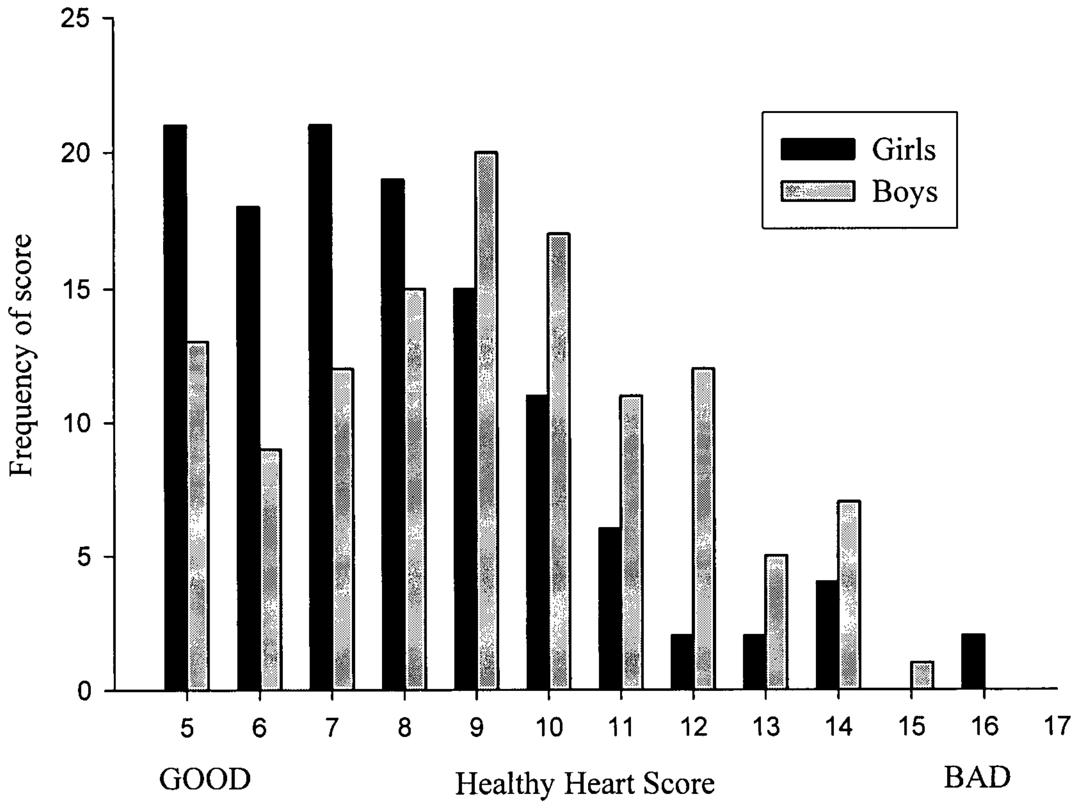

Figure 3.1 Distribution of Healthy Heart Scores by sex. Scores could range from 5 to 18, with a lower score indicating a more favourable Healthy Heart Score (n=252).

3.7. REFERENCES

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CHAPTER 4. SECULAR CHANGES IN SHUTTLE RUN PERFORMANCE: A 23-YEAR RETROSPECTIVE COMPARISON OF 9-11 YEAR OLD CHILDREN[3]

4.1. INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality for both men and women in most developed countries. In Canada, treatment for CVD consumes $18 billion of the annual health care budget [1]. Traditional risk factors for development of CVD include hypertension, smoking, diabetes, obesity, low ratio of total to high-density cholesterol, a family history of heart disease and low physical activity [2]. Low physical fitness has recently been identified as an independent predictor of CVD [3], comparable in importance to diabetes [4]. Further, because physical fitness has been shown by some researchers to track from childhood into adulthood, the level of childhood physical fitness has implications for adult health status [5, 6].

Although several studies reported a decline in aerobic fitness in children and adolescents over the past 2 decades [7-9], results are equivocal as cross sectional studies from the US and Europe report that fitness levels of children have are not different [10] or are higher than previously reported [11, 12]. A recent meta-analysis evaluated 55 studies from 11 countries and reported that physical fitness, as measured by running performance, has declined by, on average, 0.43% each year since 1980 [13]. Fitness levels of Canadian boys and girls (6-17 years), declined by 0.75% per year, on average [13]. These estimates were derived by comparing data from 2 studies [14, 15]. Leger's original 20-m Shuttle Run Test was conducted 24 years ago and the other, an unpublished study conducted 15 years ago. In order to address the current status of Canadian children it is therefore important to undertake a comparison using recent pediatric fitness data that can be examined in relation to the fitness level of same age children measured 23 years ago.

Eisenmann and Malina [10] reported that maximal oxygen uptake (VO_2 max) remained stable in boys to age 18 years and in girls to age 15 years. After age 15 years, girls' VO_2 max decreased by 20%. This highlights the sex-, age- or maturity- specific nature of the decline, which may go unreported when subgroups of children are not investigated separately. Tomkinson's [13] meta-analysis pooled Canadian children ages 6-17 years, meaning it is not possible to examine trends of particular age groups using that study.

Thus, the current investigation aimed to revisit the notion that children are currently less aerobically fit than they were 2 decades ago. Our primary objective was to compare current levels of shuttle run performance and estimated VO_2 max (hereafter known as 'fitness') in Canadian boys and girls, aged 9-11 years, to same age and sex Canadian

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children measured in 1981 using the identical protocol. We aimed to assess the decline in fitness by using published data reporting the results of Leger's 20-m shuttle run test.

4.2. METHODS

4.2.1. Design

Design: We compared two distinct cohorts. A 2004 cohort and a subset of data from Leger's original 1981 cohort [15].

4.2.2. Subjects

1981 cohort: We utilized a subset of data of all 1,112 boys and 1,039 girls aged 9-11 years, who participated in a 1981 investigation of physical fitness levels of Canadian children and youth (boys; n=322,404 and 386, girls; n=322,335 and 382 for ages 9,10 and 11 respectively) [15]. Specifically, we extracted mean scores and standard deviations from the 20-m shuttle run test, by sex and age group.

2004 cohort: Participants were 252 children (125 girls, 127 boys) aged 9-11 years (33 aged 9 years, 116 aged 10 years and 103 aged 11 years) attending public elementary schools in the Greater Vancouver and Richmond areas. The schools involved in the study were all mixed-sex, racially diverse state schools with students from various socioeconomic backgrounds. Parents provided written informed consent for their child's participation, and children gave verbal consent. Parents completed a health questionnaire for their child and all children were deemed free of disease and were not taking medications known to affect the cardiovascular system. The University of British Columbia Review and Ethics Board gave approval for the study.

4.2.3. Measurements (2004 cohort)

Measurements were conducted in September by trained investigators. Running took place in the school gymnasiums,

Cardiovascular fitness: Cardiovascular fitness was assessed using Leger's 20-m Shuttle Run Test, designed for use with children [16]. Children began running at 8.5 $km.hr^{-1}$ and increased in speed by 0.5 $km.hr^{-1}$ each minute, signifying the next stage. A tester ran with the children to encourage correct pacing. Final velocity was used to estimate maximal oxygen uptake, VO_2 max, using the equation:

VO_2 max = 31.025 + (3.238*speed) - (3.243*age) + (0.1536*speed*age)[16].

Anthropometry: Two measures of standing height (stretch stature without shoes) to the nearest 1mm were taken. Mass in light clothing was measured twice using an electronic scale (SECA, Germany) to the nearest 0.1 kg

Age: Age at time of measurement was calculated and rounded down to a whole number of years.

4.2.4. Data analysis

Data from the 2004 cohort were compared with data collected from children who participated in the original (1981) investigation undertaken by Leger [15]. We converted stage number to estimated VO_2 to allow the use of parametric statistics.

First, independent t-tests were used to compare estimated VO_2 max achieved by the 1981 cohort with that of the 2004 cohort (by age and sex). Second, we used 1981 derived sex and age specific means and standard deviations, to recreate the original distribution curves. Using the frequency distribution of the original data we calculated a 1981 equivalent Z score for each child in the current (2004) study. The Z score was subsequently transformed into a percentile score. Age and sex specific percentiles were calculated for each individual. From these values we devised a mean percentile for group (girls and boys). All statistical analyses were conducted using SPSS version 12.0 for Windows (SPSS Inc, Chicago, IL). Results were considered significant at $P< 0.05$.

4.3. RESULTS

A total of 252 children completed the 2004 study with mean age10.8 (0.6) years and BMI 19.0 (3.5). This cohort comprised 127 boys (10.7 (0.6) years, BMI 20.1 (4.0)) and 125 girls (10.8 (0.6) years, BMI 18.0 (2.7)).

Comparison of estimated VO_2 max

We provide the mean estimated VO_2 max in the 20-m Shuttle Run Test for girls and boys in the current study for comparison. We compare these to sex and age matched values obtained from the 1981 cohort (Figure 4.1). We observed significantly lower aerobic fitness in both boys and girls in the 2004 cohort as compared to the 1981 cohort ($P<0.01$). We can therefore estimate that the mean VO_2 max of boys in the 2004 study is 14% less than boys in 1981, and the mean VO_2 max of girls in the 2004 study is 9% less than girls in 1981.

Comparison of relative performance

The 50th percentile in the 2004 cohort was equivalent to the 19th percentile in the 1981 cohort. That is, the mean performance of a child assessed in 2004 was approximately 30 centiles lower than the mean performance of a child assessed in 1981 (Figure 4.2). This schematic represents distributions of fitness and highlights the 50th percentile for the 2004 data.

Sex-specific comparisons showed that boys' performance in 2004 shifted further from the 1981 mean than did girls (Figures 4.3 and 4.4). The mean percentile for boys in 2004 was equivalent to the 14th percentile in 1981. For girls, the mean percentile in 2004 was equivalent to the 23rd percentile in 1981.

4.4. DISCUSSION

We addressed the question of whether Canadian children today (2004) are less fit than same-age and sex children measured 23 years ago. Our data suggest that fitness has declined significantly (30 percentiles) over the past 2 decades. Change in aerobic performance of Canadian youth was investigated only once before [13], and only using data collected until 1990. We extended these findings to examine current aerobic fitness levels compared with same age and sex children in 1981. Thus, we present a comparison of childhood aerobic fitness across 23 years.

The lower levels of fitness that we observed in the 2004 cohort (approximately 30 percentiles) suggests a more substantive decline in the last decade compared to previous reports of a 7-8% deficit for Canadian children aged 6-17 years, from 1980 to 1990 [13]. Previous estimates of change in fitness, however, were based on children across a large age range and we were unable to determine whether this trend occurred in pre-pubertal children (as in the present study). We were also unable to evaluate the acceleration of the decline (steady across 10 years or a sudden decrease) since 1990.

Our results support those of Tomkinson's meta-analysis, whereby the aerobic fitness levels of boys declined at a faster rate than that of girls. We estimated that the decline in performance levels (as measured by change in estimated VO_2 max) of boys is approximately 0.6% per year, whereas the decline in girls is approximately 0.4% per year. Current fitness of girls in our study was broadly similar to values reported in other studies [17]. However, a slightly different picture emerged for boys. Canadian boys were somewhat less fit than same age US and European boys [17]. In addition, the disparity in fitness levels of both girls and boys in the current study compared with other countries increases as children age. To illustrate, compared with same age children from the US, girls and boys in the present study performed 110 and 84%, better, respectively, at age 9 years. By age 11 years, this decrement has decreased to 83 and 77% compared with same age US girls and boys, respectively [17]. Given the known relationship between aerobic fitness and cardiovascular health [3] and knowing that fitness levels track from childhood to adulthood [5, 6], these findings are of clinical importance.

There are no clear published mechanisms that explain these apparently substantial decrements in the physical fitness of Canadian children. There are, however, numerous possible explanations. Although data are inconclusive, physical activity in children has been shown to be positively associated with physical fitness [8, 18]. Therefore, reductions in physical activity and increased non-active recreation, such as television watching, may be one mechanism by which physical fitness has declined [19]. Currently, 23% of children in the US do not engage in any free-time physical activity [20] and more than 50% of children in elementary school are driven less than 1 mile to school [21]. Reports of childhood physical activity levels, however, are most often from cross sectional data and longitudinal data that describe this decline are sparse [7]. It is therefore extremely difficult to clearly capture secular trends in children's fitness levels over the past 10 or 20 years.

Second, the school environment is one setting in which children have traditionally been provided opportunities to participate in daily physical activity. However, the amount of time allocated to physical education (PE) class for grade 6 students in Canada (assessed in Ontario) is currently 30-40 minutes, 3 times per week, on average [22]. Previous studies have shown that during each PE session, each child is likely to be aerobically active only 6% of the time, on average [23]. This provides children less than 10 minutes of scheduled school-based physical activity per week. Clearly, given the competing demands of academia, the arts and PE, schools are struggling to meet the recommended 150 minutes of PE per week [24]. Time devoted to PE in Canada, at just 50-min per week, is lower than nearly every other country they evaluated in the study [25].

Third, whether changes in physical attributes, including body mass, of children accounts for changes in physical performance is currently being vigorously investigated in Canada and around the world. Body mass and body fatness are negatively associated with running performance [8]. Changes in fatness over a 12-year period explained between 40 and 60% of the variance for change in running performance over the same 12-year time frame [8].

As in other countries, BMI has increased substantially in Canadian children over the past 15 years [26]. Although reports vary, the prevalence of overweight has tripled in boys and more than doubled in girls. The prevalence of obesity has increased from 2 to 10% in boys and from 2 to 9% in girls [26]. The BMI of urban dwelling children in this study (mean 19.0 (3.5)) is comparable with that for age-matched children in the National Longitudinal Survey of Children and Youth [26]. Tremblay et al [27] calculated that since 1981, BMI has been increasing in children by 0.1kg.m^2 annually. This increase in BMI is likely to have influenced running performance.

There is convincing evidence that fitness in childhood is associated with the presence CVD risk factors. This association is likely to persist into adolescence and beyond [28] [29]. Therefore, the promotion of physical activity to attain physical fitness during childhood may represent an effective tool for the primary prevention of CVD [30].

4.5. LIMITATIONS

We acknowledge that a limitation of the study is its generalizability beyond children aged 9-11 years in British Columbia. As noted in the previous Chapter, children in the current study were from schools that were providing only minimal physical activity opportunities. Further, our data were from children from 2 cities in British Columbia, and these regions may not be representative of the entire Canadian population. A study that compared the Quebec study with a larger Canadian sample (including children from British Columbia), however, suggested that Leger's original sample was representative of the whole of Canada [31]. Also, the ethnic background of British Columbians is diverse, with 12% of the population being of Asian origin. In the current study more than half the participants are of Asian origin, which may affect results. According to Health Canada, however, children in British Columbia are more physically active than children anywhere else in the country [32]. Whether they are aerobically fitter, we cannot say, and we are therefore unable to extrapolate our findings to draw conclusions regarding changes in fitness levels of youth across all age groups and regions. In addition, because we compared published descriptive statistics (means and SD), we were unable to compare differences in the data distribution (i.e. skew of each data set).

4.6. CONCLUSION

In summary, we provide novel evidence to suggest that fitness levels in Canadian children, measured in one urban area of British Columbia has declined substantially over the past 20 years. Currently, the fitness of children in Canada is at least as low, if not lower, than children in many other countries around the world [17]. We also provide evidence that suggest aerobic fitness of boys has declined further than has aerobic fitness of girls. The reasons for this are largely unknown. Our results support the encouragement of improving physical fitness in the school setting.

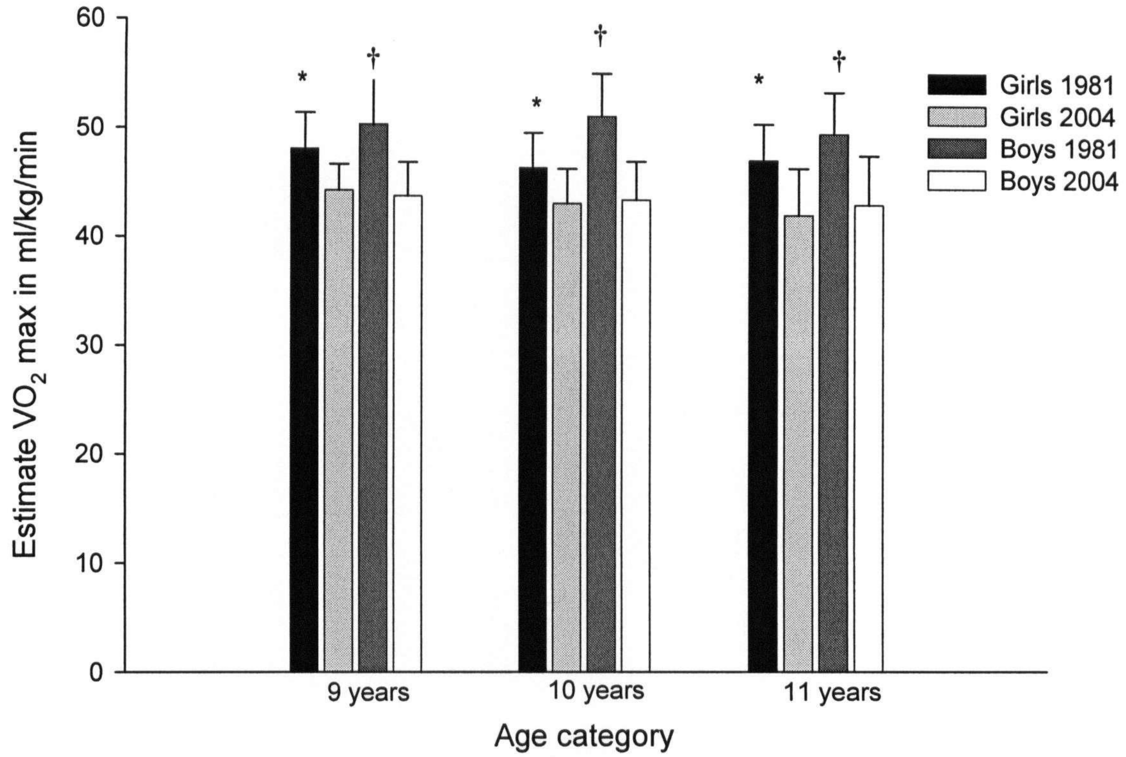

Figure 4.1 Estimated VO_2 max of children measured in 1981 and 2004. Data (mean and SD) are shown by age and gender. * significantly different to same age girls in 2004 cohort, † significantly different to same age boys in 2004 cohort, $p<0.01$.

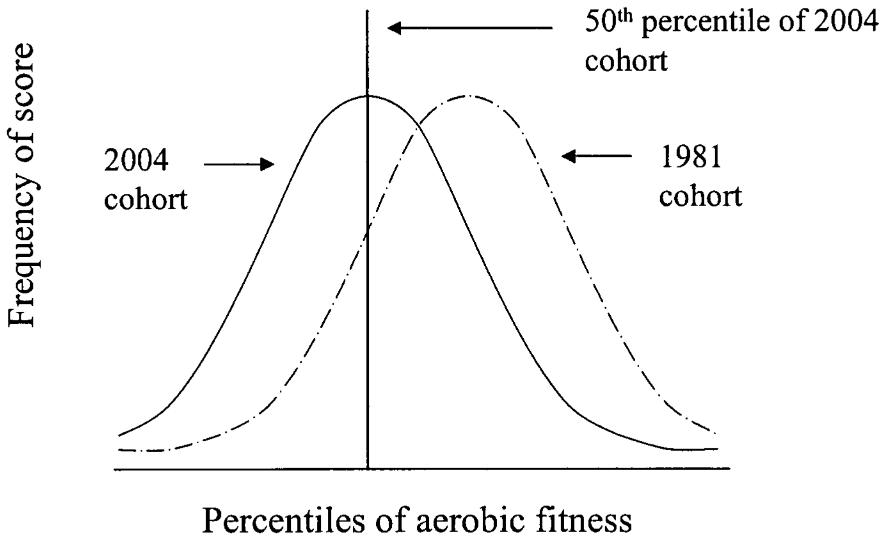

Figure 4.2 Schematic representation of distribution of physical performance scores (20-m shuttle test stages) for children measured in 1981(hashed line) and 2004 (solid line). The 50th percentile (solid vertical line) of the 2004 cohort falls at the 19th percentile of the 1981 cohort.

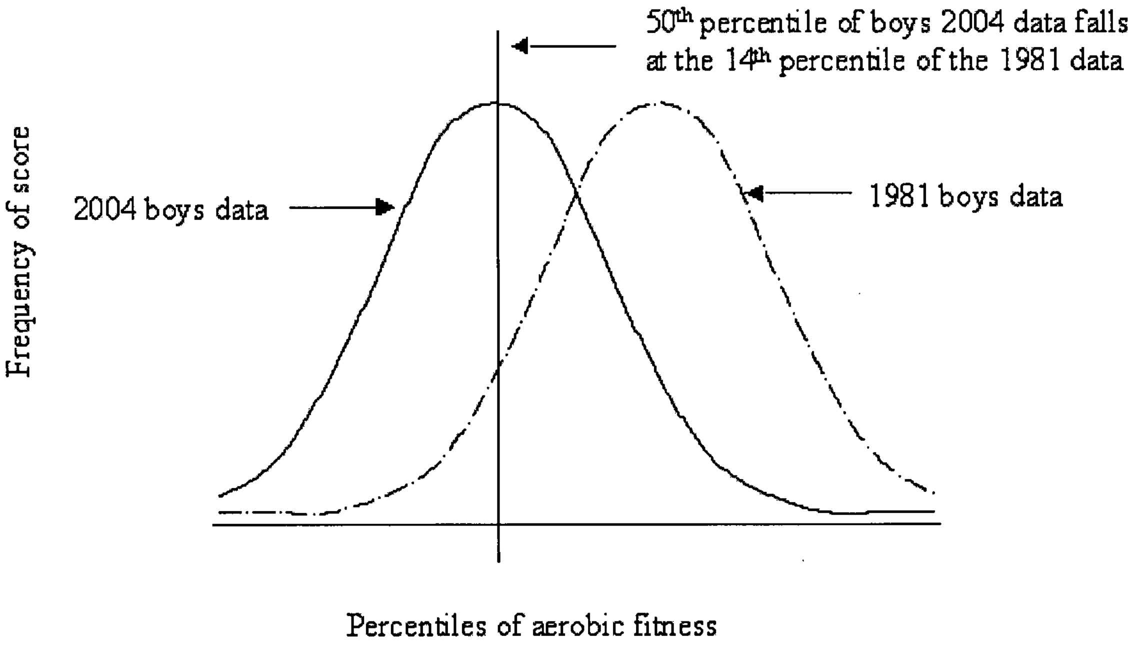

Figure 4.3 Schematic representation of distribution of physical performance scores (20-m shuttles) for boys measured in 1981 (hashed line) and 2004 (solid line). The 50th percentile (solid vertical line) of the 2004 cohort falls at the 14th percentile of the 1981 cohort.

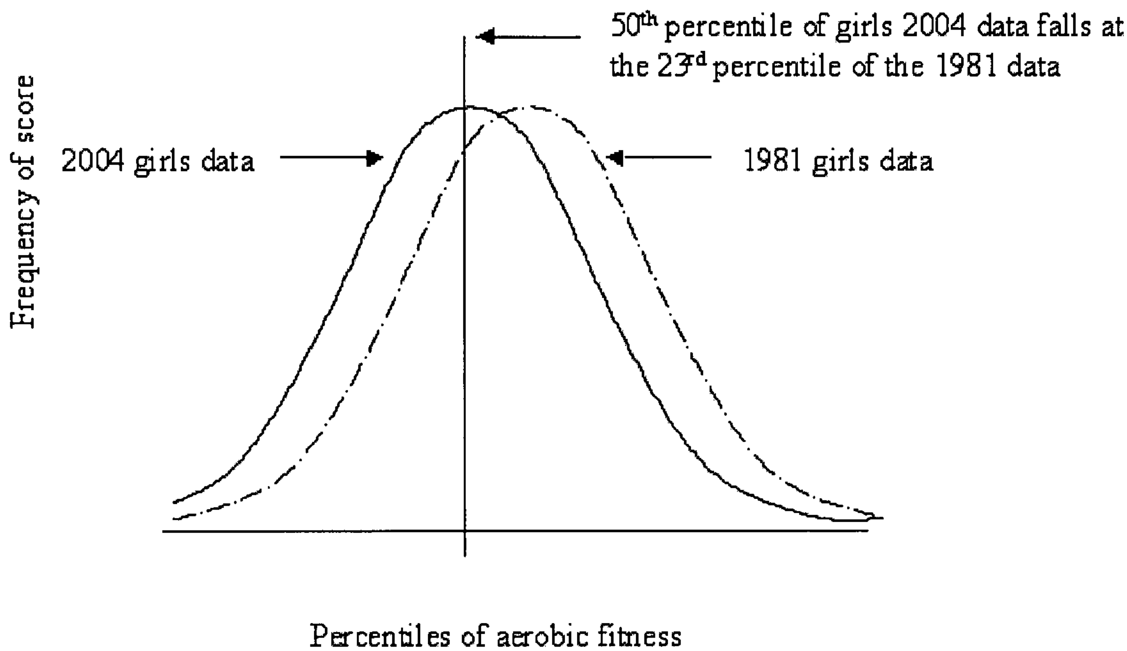

Figure 4.4 Schematic representation of distribution of physical performance scores (20-m shuttles) for girls measured in 1981(hashed line) and 2004 (solid line). The 50th percentile (solid vertical line) of the 2004 cohort falls at the 23rd centile of the 1981 cohort.

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CHAPTER 5. ARTERIAL COMPLIANCE IN CHILDREN; THE ROLE OF CARDIOVASCULAR FITNESS[4]

5.1. INTRODUCTION

Relatively new technology has allowed for the non-invasive measurement of pulse wave velocity and the arterial pulse contour to evaluate arterial compliance [1] . In the adult literature, arterial compliance is reduced in individuals with major risk factors for CVD [2] and established CVD [3]. Importantly, changes in arterial compliance precede, by years, clinical evidence of chronic disease [4]. Thus, arterial compliance is an important early predictor of the risk for chronic vascular diseases. Arterial compliance in adults is affected by multiple variables including; age [5], race [6], gender [7], arterial pressure [7] and presence of the metabolic syndrome [8]. It is also positively related to cardiovascular fitness [9-11].

In children, arterial compliance is associated with blood pressure (inversely) [12], obesity and body weight [13], gender [14] , height and race [15]. However, little is known about the relationships between arterial compliance and physical activity and cardiovascular (physical) fitness in children. For instance, Abbott and colleagues [16] found that habitual physical activity was positively related to the associated flow-mediated dilation in the brachial artery of 5-10 year old children, whilst Woo and colleagues [17] found that 6 weeks of exercise, combined with diet enhanced endothelial function in obese children. The independent relationship between arterial compliance and physical fitness in healthy children has not been quantified.

Accordingly, the first objective of this investigation was to determine the relationships between arterial compliance, physical activity and fitness in elementary school children. The second objective was to explore sex differences in arterial compliance between same age boys and girls. We hypothesize that high levels of physical activity and fitness would be associated with improved arterial compliance. Second, due to levels of sex steroids during this early pubertal period, we hypothesize that girls will have a lower arterial compliance than same age boys [14].

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5.2. METHODS

This cross-sectional investigation used radial artery applanation tonometry (HDI/Pulsewave CR2000, Eagan, MN). Applanation tonometry is a reliable method of determining large (C1) and small (C2) artery compliance [18]. Compliance values are determined using an internal algorithm based on diastolic decay features of the radial pulse contour using a modified Windkessel model. C1 is derived from an analysis of the diastolic slope decay of the waveform, whilst C2 is derived from the oscillatory component of the diastolic decay. A detailed description of the determination of compliance from the analysis of the waveform has been previously published [3]. Validity was high compared with other measures of compliance such as MRI- based carotid artery distension (r=0.75) [19] and invasive measurement of compliance (r=0.82) [3]. Coefficient of variation in our laboratory was 10% for C1 and 13.7% for C2. These estimates are highly comparable with published values [20].

5.2.1. Subjects

We examined 99 children, aged 9-11 from schools in the Greater Vancouver and Richmond School Districts, who were part of a larger study (Action Schools! BC). School and subject recruitment and exclusion criteria are detailed in Chapter 2 (Methods). All children participated in normal school physical education class and were free of disease. Children were selected from the larger group involved in the study using stratified random sampling, with the first 2 children from each testing group (6 children per group) chosen for arterial compliance assessment. Children Health status was assessed by a questionnaire, completed by each child's parents. The University of British Columbia's Clinical Research Ethics Board gave ethical approval for the study. Parents provided written informed consent, and children provided verbal consent.

5.2.2. Measurements

Detailed methods are provided in Chapter 2 and summarized below.

Arterial compliance: Large and small artery compliance was measured non-invasively by applanation tonometry, (HDI/Pulsewave CR-2000, HDI, Eagan, MN, U.S.). Blood pressure was also determined from this apparatus. *Fitness:* Cardiovascular fitness was assessed using Leger's 20-m incremental shuttle run [21], designed for use with children. This measurement correlates well with direct measures of oxygen uptake in children (r=0.72) [22]. *Physical activity:* The Physical Activity Questionnaire for Children (PAQ-C) was used to estimate physical activity. [23]. Total minutes of physical activity over one week were recalled then divided by 7 to provide average daily activity.

Anthropometry: Stretch stature was measured (to the nearest 1mm) by applying gently upward traction on the base of the mastoid process. Body mass in light clothing was measured using an electronic scale (SECA, Germany) to the nearest 0.1kg.

Maturity: Children self-assessed their physical maturity using line drawings and descriptions of pubic hair (boys and girls) and breast stage (girls) based on Tanner Staging [24].

5.2.3. Data analysis

Our two outcomes of interest were large and small arterial compliance. The determinants for arterial compliance were identified using two steps. First, bivariate correlations were used to identify significant relationships between compliance and independent variables (height (meters), mass (kilograms), maturity (Tanner stage 1-5), systolic blood pressure (mmHg), fitness (Leger's test), and physical activity (min/ day). Height, mass, blood pressure and maturity are potential confounders of arterial compliance and thus were included in the analysis. Second, multivariate regression models were created to evaluate the contribution of physical activity and fitness to arterial compliance. Separate models were created for large and small compliance. Correlations, beta coefficient (standardized) and cumulative R^2, are provided to show the shared variance each independent variable has with compliance and relative importance of each variable in the model.

Analysis of Covariance (ANCOVA) was used to investigate the association between gender and arterial compliance, controlling for covariates identified in the stepwise regression. ANCOVA was also used to explore the association between fitness quartiles and arterial compliance. Post-hoc (pairwise) comparisons to determine where group (quartile) differences occurred were corrected (Bonferroni). Covariates were checked for coherence to parametric assumptions. All statistical analyses were conducted using SPSS version 12.0 for Windows (SPSS inc, Chicago, IL) and results were considered statistically significant if $P<0.05$.

5.3. RESULTS

Physical characteristics of the 99 children measured are shown in Table 5.1. Subject's age ranged from 9.6 years to 11.1 years of age. There were no significant differences in age, height or body mass between boys and girls. Physical fitness, measured by Leger's 20-m shuttle run, was similar between groups. No children were in Tanner stages 4 or 5.

5.3.1. Determinants of large and small arterial compliance

Determinants of compliance varied slightly depending on artery size (small or large). Table 5.2 provides a summary of the regression model. After biological variables (height, mass, blood pressure and maturity) were entered into the model, fitness significantly contributed to the variance (R^2) of large artery compliance (C1). In the multivariate model, fitness accounted for 11% of the variance in large artery compliance. Physical activity failed to account for any variance in the multivariate model. After entering biological variables, fitness significantly contributed to the variance of small artery compliance (C2). In the multivariate model, fitness accounted for 12% of the variance in small artery compliance. Physical activity accounted for 4% of the variance of small artery compliance, although this was not significant at $p=0.05$ in the final multivariate model.

To further explore the relationship between aerobic performance and arterial compliance, children were divided into quartiles by cardiovascular fitness (number 20-m laps completed). Quartiles were; 1: lowest - 20 laps, 2: 21 - 32 laps, 3: 33 - 43 laps and 4: 44 - highest laps. Large and small artery compliance was then compared between fitness quartiles, controlling for systolic blood pressure and height (to predict large artery compliance) or body mass (to predict small artery compliance). C1 was significantly greater for children in the highest fitness quartile than children in the lowest 2 quartiles ($p<0.05$) (Table 5.3). C2 was greater for children in the highest fitness quartile compared with children in the second quartile ($p<0.05$) (Table 5. 3).

5.3.2. Effect of gender on compliance

In the unadjusted analysis, C1 did not differ between boys and girls but C2 in boys was 14.9% greater than that of girls ($p<0.05$) (Table 5.4). However, there were no gender differences in C1 or C2 after controlling for the covariates identified as significant determinants in the regression model (Table 5.2). For C1 these were laps, blood pressure, height, and for C2 these were body mass, laps, maturity, blood pressure).

5.4. DISCUSSION

This is the first investigation to examine the relationship between arterial compliance, measured by applanation tonometry, and physical fitness in children. Unique to this investigation was the finding that there is a positive relationship between fitness and large and small artery compliance in 9-11 year old children. Determinants of compliance were different for C1 and C2.

Differences in structure of the large conduit arteries, small arteries and microvasculature may explain many of our findings. The largest arteries are comprised mainly of collagen and elastin and stiffening is due to changes in collagen. Compliance in these vessels is dependent solely on structure. Importantly, the non-linear pressure/volume relationship in the large arteries results in a high sensitivity of the C1 to pressure. In the present investigation, we confirmed that systolic blood pressure to be a strong determinant of C1. Physical fitness also made significant, contributions to the multivariate model. Medium sized conduit arteries, such as the brachial and radial arteries, contain a larger amount of smooth muscle, which, via release of flow-mediated nitric oxide, plays a role in their calibre and compliance. The arterioles of the microcirculation, which determine resistance, are critically dependent on smooth muscle to determine tone and stiffness. Compliance in small arteries and arterioles is therefore dependent on a varying combination of structure and function, with the C2 being largely independent of pressure [1].This is reflected in the present study where mass, fitness and maturity were more strongly associated (Pearson's correlation coefficients) with small arterial compliance than blood pressure.

5.4.1. Effect of cardiovascular fitness on arterial compliance

In this study of 99 pre-pubertal healthy children, fitness was a strong determinant of large arterial compliance. Although arterial compliance is highly influenced by blood pressure, our findings support theories that physical fitness may influence arterial compliance across the lifespan [5, 9, 25]. Body mass, fitness, maturity and systolic blood pressure were significant determinants of small artery compliance. Fitness had a similar contribution to small artery compliance. The health relevance of fitness as a predictor of arterial compliance is heightened, when one considers that some predictors are not amendable i.e. maturity and height.

Uniquely, we have shown that children in the highest quartile for fitness had the highest large artery compliance whilst children in the lowest 2 quartiles for fitness had the lowest large artery compliance (Table 5.3). Small artery compliance showed similar patterns. These findings reflect studies in adults that associated aerobic capacity with arterial compliance [5, 10, 11]. McGavock and colleagues [11] determined that 10 weeks of exercise training increased large artery compliance by 16% in 28 post-menopausal, diabetic women. Similarly, in 12 healthy post-menopausal women, a 3-month exercise program resulted in increased aerobic capacity and a 40% increase in arterial compliance [10]. These studies support the theory proposed by Tanaka et al [9] that training status can attenuate the age-related decrease in compliance in older adults. However, the relationship between arterial compliance and physical fitness has not been previously shown in healthy children. We also noted the inverse relationship between compliance and blood pressure [12], and compliance and anthropometry [15], reported in previous studies.

In the final regression models, physical activity was not a significant determinant of arterial compliance. Unlike Abbott and colleagues [16] who correlated habitual physical activity (using radio labelled isotopes) with endothelial function in children, we assessed only deliberate activity, such as sports participation and play, via a self-report questionnaire. This discrepancy in findings could be because questionnaires, especially in children, may provide a less accurate assessment of actual habitual physical activity, compared with direct methods, such as observation or radio-isotope labelling. However, a retrospective investigation by the Northern Ireland Young Hearts Study found that the relationship between fitness and arterial stiffness in young adults was not mediated by physical activity [25]. The relative importance of both physical activity and fitness to health outcomes have been explored [26]. Interestingly, Blair's analysis of data from the Aerobics Centre Longitudinal Study determined that when activity, fitness and various other factors were included in a multivariate model, only fitness remained strongly associated with mortality. Although Blair provides a rational for this result, and states it is not possible to determine which has a greater impact on health, his meta-analysis shows fitness has a stronger and more consistent dose-response relationship with morbidity and mortality than does physical activity. However, methods used to assess fitness and physical activity should be considered.

High fitness was significantly associated with low arterial stiffness (high compliance) in adults using a number of measurement modalities including pulse wave velocity, magnetic resonance imaging and pulse contour analysis [27], but the underlying cause for this relationship has not been established. Several hypotheses exist concerning the relationship between exercise and arterial compliance. The sheer stress on the vessel lining created by exercise may increase the bioavailability of nitric oxide (NO) in the endothelium resulting in vasodilation [28]. This increase in NO may also counter balance the activity of NO inhibiting oxidants, such as superoxide [29]. Alternatively, habitual physical activity may cause chronically lowered sympathetic activity, resulting in decreased vascular tone [30]. These factors would have a large influence on C2 in particular. Kingwell [27] devised a cyclical model, linking increased arterial stiffness, increased pulse pressure, reduced coronary perfusion and myocardial performance with decreased exercise capacity and fitness. The question was posed as to whether a predisposition to stiff arteries or a low physical fitness instigated the cycle. Evidence from several intervention studies in adults would suggest the increase in fitness may initiate the cycle. However, the present study does not allow us to infer causality as to whether high physical fitness induces physiological changes that result in a higher compliance, or vice versa. However, we have shown that there is a positive association between arterial compliance and fitness in children. This relationship is now fairly established in adults, but it is novel that is also apparent in children as young as 9 years. Further, including children in such studies is of great importance as children are relatively unaffected by many of the variables that influence adults cardiovascular systems. These negative influences on cardiovascular health include smoking, illness or prolonged exposure to poor diet and inactivity.

5.4.2. Effect of gender on arterial compliance

In this study, after adjusting for the important covariates, arterial compliance values were similar for boys and girls. The influence of gender is likely to be dependent on the levels of sex steroids and these were not assessed in the current study. The difference between boys and girls would occur or diminish during times when sex steroids peak or fall i.e. during puberty and menopause [14]. Similar numbers of girls and boys reported being in each Tanner stage, however most children were pre-pubertal. Thus, gender differences may not yet have become evident in this relatively immature sample. That said maturity was a weak but significant determinant of small artery compliance.

5.5. LIMITATIONS

We acknowledge that our study has some limitations. First, physical fitness was ascertained from a field-based test as opposed to a direct measurement. However the test that we used is considered reliable and valid [22]. Second, maturational stage was established by self-report and not by direct measures of steroid level. Thus, the influence of pubertal stage cannot be determined conclusively. Tracking these children as they advanced through puberty would provide us with a clearer picture of the influence of hormones on arterial compliance. Finally, an assessment of the effects of exercise on arterial compliance would be more appropriately assessed in a well designed intervention in normal mass, healthy children. Cross sectional data, such as those reported here, have many limitations.

5.6. CONCLUSIONS

We supported the hypothesis that physical fitness is a determinant of arterial compliance, but found that physical activity, measured using 7-day recall, was not a significant determinant of arterial compliance in this population. The lack of association between arterial compliance and physical activity may, in part, be a reflection of the method used to assess activity. We found no difference in arterial compliance between boys and girls in this pre- and peri-pubertal group of elementary school children. These findings may be partially associated with the methods used to assess maturity. A between sex comparison of arterial compliance, with a greater representation across pubertal stages is warranted.

Table 5-1 Descriptive data of subjects in arterial compliance study shown as a whole group and by gender (n=99).

	All (n=99)	Boys (n=55)	Girls (n=44)
Age	10.6 (0.6)	10.6 (0.6)	10.6 (0.6)
Weight (kg)	42.8 (10.5)	43.8 (11.1)	41.48 (8.2)
Height (m)	1.46 (0.1)	1.46 (0.1)	1.46 (0.1)
PAQ-C	2.6 (0.5)	2.7 (0.5)	2.5 (0.6)
Laps completed	33.2 (15.7)	35.2 (17.1)	30.8 (12.1)
Tanner Stage (No. in stage 1, 2 or 3)	56, 32,11	31, 19, 5	25, 13, 6

Table 5-2 Multiple regression models for large and small arterial compliance (n=99).

		Correlation (Pearson)	Beta coefficient 95% (CI)	P value	R^2(cumulative)
Large artery	Height	0.28*	0.31 *(0.04, 1.81)*	0.049	0.08**
(1)	SBP	-0.33*	-0.45 *(-0.17, -0.51)*	0.001	0.26**
	Mass	0.02	0.09 *(-0.04, 0.07)*	0.521	0.26
	Maturity[a]	0.08	0.06 *(-0.66, 1.80)*	0.631	0.26
	Fitness	0.39*	0.35 *(0.02, 0.10)*	0.001	0.37**
	PA	0.02	0.03 *(-0.73, 0.97)*	0.772	0.37
Small artery	Height	0.41*	-0.02 *(-6.81, 5.81)*	0.899	0.12
(2)	SBP	0.02	-0.26 *(-0.09, -0.01)*	0.021	0.19**
	Mass	0.49*	0.63 *(0.05, 0.13)*	0.001	0.33**
	Maturity[a]	0.11*	0.28 *(0.15, 1.40)*	0.015	0.36**
	Fitness	0.14*	0.28 *(0.01, 0.68)*	0.009	0.44**
	PA	0.05	0.10 *(-0.29,0.92)*	0.307	0.49

Large artery model (1) constant=5.01, multiple r=0.61, r^2=0.37 P<0.05.

Small artery model (2) constant= 5.25, multiple r=0.66, r^2=0.44, P<0.05

[a]=Spearmans rank correlation * significant correlation ** significant contribution to R^2 in final model

Table 5-3 Large arterial compliance (mL/mmHg x 10) and small arterial compliance (mL/mmHg x 100) of the participants divided into quartiles according to aerobic fitness calculated by lap number completed on Leger's 20-m shuttle run. Data are mean (95% Confidence Interval) (n=99)

Fitness quartile	Large artery compliance (C1)	Small artery compliance (C2)
1 (lowest)	9.1 (7.9, 9.9)*	6.2 (5.6, 6.8)
2	9.5 (8.7, 10.3)*	5.9 (5.2, 6.4)**
3	10.1 (9.2, 10.9)	6.5 (5.8, 7.3)
4 (highest)	11.0 (10.3, 11.8)	7.1 (6.4, 7.7)

* Significantly different from highest quartile (C1), $P<0.01$

** Significantly different from highest quartile (C2), $P<0.05$

Table 5-4 Compliance of the large and small arteries, (non-adjusted) for all subjects and by gender (n=99).

Compliance (mL/mmHg)	All	Males	Females
Large artery x10	9.97 (2.2)	9.83 (2.3)	10.15 (2.3)
Small artery x 100	6.45 (1.7)	6.84 (1.6)*	5.95 (1.7)*

* Significantly different at $P<0.05$. Data are mean (SD).

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CHAPTER 6. DIFFERENCES IN HEART RATE VARIABILITY BETWEEN ASIAN AND CAUCASIAN CHILDREN LIVING IN THE SAME CANADIAN COMMUNITY[5]

6.1. INTRODUCTION

Heart rate variability (HRV) measured by power spectral analysis provides a quantitative marker of autonomic nervous system influence on heart rate and has been shown to reflect cardiovascular health. In adults, impaired HRV has been reported following myocardial infarction [1], in chronic heart failure, and left ventricular dysfunction [2]. In young children, reduced HRV values were associated with atrial septal defects [3] and increased likelihood of sudden infant death syndrome [4]. An unfavourable autonomic profile balance (seen as reduced beat-to-beat variability) reflects a predominately sympathetic influence on control of heart rate and was positively correlated with general obesity [5, 6, 7], high visceral fat deposition [8], lower aerobic fitness [9, 10], male gender [11], and increasing age [12,13].

Racial (Black-White) differences in HRV have been previously studied in adults, with Blacks having a lower sympathetic drive than age matched Whites [14, 15]. There are only limited HRV data in young children and none that compare Asians and Caucasians. Previous data concerning race differences in youth have been equivocal. Whilst one investigation found that Black adolescents display less favourable HRV measures (i.e. a greater sympathetic contribution to total power) than age matched Whites [16], another found a reduced sympathetic activity in Blacks [17]. HRV has been explored exclusively in Asian adults and children but findings have not been compared with other races. Results from independent studies of Asian [18, 19] or Caucasian children [16, 20], suggest there may be racial differences in time and frequency domains of HRV, with Asian children living in Asia displaying a lower HRV than Caucasian children living in Western Societies. Canada is a multi-racial society with more than 2 million Canadians reporting an Asian origin [21]. There have, however, been no comparisons of HRV between Asian and Caucasian children living in the same North American community.

The effect of male or female sex on HRV is well documented in adults, with the majority of researchers reporting that women, at least until late middle age, demonstrated a higher vagal influence on heart rate control than men [9, 15] [22]. However, the influence of sex appears to be modulated by age [12] and studies which examined sex differences in children found that girls had lower variability than boys [12, 16]. These studies, which utilized 24-hour HRV monitoring, showed lower time domain values in girls aged 14-16 years and 1-20 years respectively. To our knowledge, no studies have used 5-min recording to examine sex differences.

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Thus, our primary objective was to determine whether differences in HRV existed between Asian-Canadian (AC) and Caucasian-Canadian (CC) children living in the same community. Our second objective was to explore differences in HRV between pre-pubertal girls and boys using a 5-minute recording. We hypothesize that compared with CC children, AC children will have lower levels of the time domain variables (standard deviation of RR intervals [SDRR] and root mean square of successive RR intervals, [RMSSD]) accompanied by greater sympathetic predominance, evidenced by a higher LF:HF ratio in the frequency domain variables. Second, we hypothesize that, using 5-minute recordings, girls will demonstrate altered HRV profiles, specifically lower variability, compared with age-matched boys. These will be similar to those derived from 24-hour recordings.

6.2. METHODS

6.2.1. Participants

Sixty-six Asian and Caucasian children from grades 4 and 5 were randomly selected from a larger cohort of participants in a school-based exercise intervention (Action Schools! BC, N= 514). Parents of the children completed a health history questionnaire on the child's behalf. Children with vascular or neural disease or taking medication known to influence cardiovascular function were deemed ineligible to participate in the intervention. Based on these criteria, no children were excluded from the present study. Children were classified as Caucasian, Asian, East Indian or Mixed based on the birthplace of both parents. Children were classified as 'Asian' if both parents, or all four grandparents were born in Hong Kong, China, Japan, Taiwan, or Korea; 'Caucasian' providing both parents or all 4 grandparents were born in Europe or North America; and 'Other' if he child had parents of other origins (i.e. Africa or India) or had parents of 2 distinct races. The University of British Columbia Clinical Research Ethics Board approved the investigation and all participants and their legal guardian provided written consent.

6.2.2. Measurements

Heart rate variability: Short-term, 5-min, resting HRV was taken using Polar S810 Heart Rate Monitors (Polar Electro Oy, Finland). As measurement error attenuates the correlation observed between variables, we attempted to control potentially confounding variables by; instructing children not to consume a caffeinated beverage for at least 2 hours prior to HRV measurement, taking all measurements prior to lunch break activity and making all recordings on the school premises. Children were supine on a padded mat in a quiet, softly lit room for measurements. Recording began immediately and lasted for 6 minutes. Digitally coded R-R interval length is submitted to the Polar software using an infa-red transmitter, and a tachogram is displayed on screen. After the first minute of data was discarded, R-R intervals were automatically filtered using median and moving average based filtered methods. Acquisition and filtering of R-R data using Polar software has been previously described [23]. Data (R-R intervals) were then exported as text to HRV Analysis Software (Biomedical Signal Analysis, Kuopio, Finland) (Appendix H). The R-R series were transformed to the frequency domain via fast Fourier Transformation. Spectral power was determined, in accordance with the Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology [24] as very low frequency VLF (0.01-0.04Hz) low frequency (LF) (0.04-0.15Hz) or high frequency (HF) (0.15-0.5Hz). LF:HF ratio was chosen as the primary measure of interest, as it provides information regarding relative vagal or sympathetic predominance [25]. Values for HF and LF are given as normalized units (nu). For HF normalized units are calculated as high frequency in ms2/ (total power –very low frequency)*100. For LF, normalized units are calculated as low frequency in ms2/ (total power – very low frequency)*100. Secondary variables of interest were the global time domain measure, the standard deviation of normalized R-R intervals in milliseconds (ms) (SDRR), and the root mean squared of successive R-R intervals in ms (RMSSD). RMSSD is thought to represent vagal activity.

Detailed methods concerning these measures are provided in Chapter 2.

Anthropometry: Height in bare feet was measured to the nearest 1mm. Mass, in light indoor clothing, was measured using an electronic scale (SECA, Germany) to the nearest 0.1kg. Body mass index (BMI) was calculated as kg/m2.
Performance measures: Aerobic fitness was determined using Leger's 20-m progressive shuttle run [26].
Blood pressure: Blood pressure was measured in duplicate on the left arm after 5-10 minutes quiet rest using an automated sphygmomanometer (VSM MedTech, Canada) using an appropriately sized cuff.
Maturity: Children self-assessed their physical maturity using line drawings and descriptions of pubic hair (boys and girls) and breast stage (girls) based on Tanner Staging [27].

6.2.3. Data analysis

HRV measures that were skewed (Kolmogorov-Smirnov Z, $p < 0.05$) were transformed (natural logarithm (Ln)) to normalize the distribution. In these cases, statistical comparisons were based on the Ln scales. Analysis of covariance (ANCOVA) was used to evaluate race and sex differences in HRV. Due to their established relationship with HRV, we controlled for aerobic fitness (Leger's 20-m shuttle) and mean resting heart rate by including them as covariates in the analysis. Statistical significance was set at alpha $p<0.05$. All statistical analyses were performed using SPSS version 12.0 for Windows (Chicago, IL).

6.3. RESULTS

Sixty-two children (32 AC children: 15 boys and 17 girls, and 30 CC children: 15 boys and 15 girls) aged 9-11 years were included in the analysis. Data from 4 children were excluded due to excessive movement during the HRV recording. Descriptive characteristics (means, SD) of the participants by sex and race are provided (Table 6.1). All children were in Tanner stage 1 or 2.

There were no sex differences for age, BMI, aerobic fitness, heart rate or blood pressure. There were no racial differences for age, body mass index, heart rate or blood pressure. CC children ran a significantly greater number of 20-m laps compared with AC children (26.5 (11.3) and 19.9 (5.7), respectively, p=0.006).

Heart rate variability

Group means (non-adjusted) for raw and log-transformed data by race and sex are provided (Table 6.2). There were no race or sex differences for total power, SDRR intervals or RMSSD. There was a difference in the LF:HF ratio between AC and CC children (F= 5.8, p=0.01), with AC children having a higher LF:HF ratio than CC children (Table 6.2). Analysis by sex showed a higher LF:HF ratio (F=4.3, p=0.04), for girls compared with boys (Table 6. 3). Within sex differences showed that AC children had a higher (NS) LF:HF ratio than CC children. Values for boys were 93.9 (16.6) and 59.2 (16.5), F=2.1, p=0.17 for AC and CC respectively. Values for girls were 144.5 (20.7) and 86.2 (22.1), F=3.5, p=0.71 for AC and CC, respectively

6.4. DISCUSSION

6.4.1. Comparison between Asian and Caucasian children

This was the first investigation to examine differences in HRV between Caucasian and Asian children living in the same Canadian community. AC children had a higher LF:HF ratio, compared with CC children of the same age. A lower LF:HF ratio may indicate, although not definitive, a higher sympathetic and/or a lower vagal influence on heart rate. This finding of a differential influence on heart rate by race is further supported by the higher (NS) values for RMSSD observed in the CC children. This time domain measure is strongly influenced by vagal modulation of the SA node. Additionally, when measured in the supine position, as in the present study, global measure of HRV such as SDNN are modulated primarily by the activity of the vagus nerve. Although differences in SDNN and RMSSD between AC and CC children failed to reach statistical significance, both measures are clearly higher in the latter group.

Our findings support previous work that highlights a racial difference in HRV for adults and adolescents [15-17]. Investigations that compared African-Americans with Caucasian Americans adolescents have been equivocal. One study reported that 15-year old African-American males generally had less favourable HRV outcome measures (greater sympathetic modulation of heart rate) [16] than Caucasian Americans. A similar study [17], reported that 13-17 year old African-American male youth had less sympathetic tone and greater short-term variability than same age Caucasians. Racial differences in HRV were evident at rest and during cardiovascular stress tests such as Valsalva manoeuvre [17]. Similar comparisons have not previously been made in younger age groups or, until now, between Asian and Caucasian children.

Comparison between girls and boys

In this cohort, boys had a greater contribution of high frequency power to total power than girls did. Boys and girls scored similarly on aerobic fitness tests, but girls had an elevated LF:HF power ratio compared with boys. These results support previously reported sex differences [16, 28] wherein girls, aged 15 years and 1-20 years respectively, demonstrated a lower HRV than boys. Both these investigations found that time domain variables (namely SDRR and the standard deviation of normal RR intervals for 5 minute segments - SDANN) were higher in boys. In the same investigation, however, Silvetti and colleagues [28] reported no sex differences for RMSSD. Conversely, the present study found that differences in HRV measures were significant when measured in the frequency domain (LF:HF).

Differences were also evident in the time domain variables measures (SDRR and RMSSD) but these failed to reach statistical significance. It has not been previously shown that sex differences in HRV were observed with short-term (5-min) recordings. The discrepancies between the findings of this study, and those of other studies, i.e. no difference in time domain, only in frequency domain variables, is likely due to the duration of the recording. Frequency domain methods should be preferred to the time domain methods when short-term recordings are investigated [24].

The relationships between physical activity and indices of spectral power parallel those reported in adults (i.e. more active individuals typically demonstrate greater vagal predominance) [9]. Aerobic training is believed to improve the electrical stability of the myocardium, with regular exercise improving the cardiac autonomic profile [29]. Nagai and colleagues [5] conducted a cross-sectional investigation and separated 96 girls and boys into 4 groups; lean physically active, lean sedentary, obese physically active and obese sedentary. Lean active children had significantly better HRV parameters compared with the other groups. However, physical activity also appeared to contribute to enhanced autonomic nervous system activity in both lean and obese children. In the present investigation, differences in HRV between girls and boys and between AC and CC children persisted after adjusting for physical fitness.

Although a substantial proportion of the variance in HRV can be accounted for by factors such as age, sex, BMI, physical activity and fitness, the Framingham Heart Study and the Kibbutzim Family study found that up to 34% of the variance was accounted for by genetic factors [30, 31]. Sex differences in adult HRV measures are well documented, but race differences and sex differences in children have not been well investigated.

6.5. LIMITATIONS

We acknowledge that our study has some limitations. First, although we controlled for aerobic fitness we were unable to match children on physical activity. Second, we performed a cross sectional comparison by sex and race. Analysis of HRV in children is a complex issue, and the evolving nature the autonomic nervous system as maturation occurs adds further complexity. Longitudinal investigations of HRV are necessary to determine whether time and frequency domain measures show similar age, race and sex related patterns over time. Third, we classified children as Asian or Caucasian according to parents or grandparents birthplace. We acknowledge that the term 'Asian' encompasses originating from a wide variety of countries (i.e. China, Japan, Taiwan etc). Similarly, 'Caucasian' children may have parents or grandparents originating from Germany, Russia or Australia. The influence of specific ethnic or cultural practices was not assessed. We attempted to limit the confounding effects of cultural differences by assessing children of different racial backgrounds from the same geographical area and the same schools. We acknowledge therefore that these influences may have confounded our findings.

6.6. CONCLUSION

There is a paucity of literature describing HRV in young children and none that compared Asian and Caucasian children. We demonstrated that AC children aged 9-11years had a significantly elevated LF:HF ratio compared with CC children living in the same geographic proximity. These findings support previous investigations suggesting that there are Black/White differences in HRV in children. We extend these results by introducing new findings regarding altered variability profiles between Asian and Caucasian children. Although this difference is unlikely to result in adverse health implications during childhood, racial norms for HRV measures should be determined and considered during clinical examinations and experimental investigation. Further studies to establish racial norms across the developmental time course may be warranted.

Table 6-1 Descriptive characteristics of heart rate variability study participants by sex and race. Values are means (SD) (n=62).

	Asians	Caucasians	Boys	Girls
n=	32	30	30	32
Age (years)	10.3 (0.6)	10.5 (0.6)	10.2 (0.6)	10.5 (0.6)
BMI (kg/m^2)	18.6 (3.5)	18.6 (2.6)	18.8 (2.9)	18.4 (3.2)
20-m Laps run	19.9 (5.7)*	26.5 (11.3)*	21.8 (8.5)	24.4 (10.2)
SBP (mmHg)	102.2 (9.1)	105.7 (10.5)	103.9 (8.1)	103.6 (11.2)
DBP (mmHg)	65.1 (7.5)	65.5 (8.2)	66.6 (6.8)	64.1 (8.5)
Heart rate (bpm)	81.1 (12.1)	76.9 (10.1)	77.9 (12.1)	80.0 (10.1)

*shows race difference p<0.05

Table 6-2 Raw and log transformed heart rate variability data (non-adjusted) shown by race and sex. Data are mean (SD) (n=62)

	Asian	Caucasian	Boys	Girls
LFnu	48.78 (16.62)	37.57 (14.81)	38.71 (14.81)	47.62 (17.41)
Ln	3.82 (0.38)†	3.54 (0.40)†	3.57 (0.41)*	3.79 (0.39)*
HFnu	51.22 (16.62)	62.53 (14.83)	61.25 (14.81)	52.33 (17.39)
Ln	3.87 (0.35)†	4.10 (0.28)†	4.07 (0.28)*	3.89 (0.36)*
LF:HF	120.57 (85.31)	72.92 (59.42)	76.57 (62.4)	117.19 (85.12)
Ln	4.54 (0.73)†	4.05 (0.67)†	4.11 (0.68)*	4.51 (0.74)*
RMSSD	55.11 (34.45)	75.50 (54.77)	65.18 (38.21)	64.12 (53.17)
Ln	3.83 (0.59)	4.06 (0.72)	4.03 (0.56)	3.87 (0.76)
SDRR	56.41 (27.37)	64.92 (38.02)	60.17 (30.01)	60.81 (35.91)
Ln	3.89 (0.59)	4.01 (0.62)	3.94 (0.63)	3.94 (0.59)
TP	559 (660)	626 (824)	624 (855)	558 (735)
Ln	5.66 (1.27)	5.58 (1.41)	5.64 (1.41)	5.61 (1.27)

† shows race difference p<0.05 * shows sex difference p<0.05

Statistical significance refers to log transformed and raw units data in each case.

(HF= high frequency power, LF= low frequency power, RMSSD= root mean squared of successive RR intervals, SDRR = standard deviation of R-R intervals, TP= total power, Ln = log transformed)

Table 6-3 Adjusted (aerobic fitness and heart rate) means of log transformed low: high frequency power data by sex and race. Data are mean (SE) (n=62)

Group	Adjusted Log LF:HF
Asians	4.52 (0.12) †
Caucasians	4.07 (0.13) †
Males	4.11 (0.13) *
Females	4.48 (0.12) *

† indicates race difference $p<0.05$ * indicates sex difference $p<0.05$

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CHAPTER 7. DO CHILDREN AT RISK FROM CARDIOVASCULAR DISEASE ACHIEVE A GREATER BENEFIT FROM A SCHOOL-BASED PHYSICAL ACTIVITY INTERVENTION THAN CHILDREN NOT AT RISK?[6]

7.1. INTRODUCTION

Cardiovascular disease (CVD) continues to be the leading cause of morbidity and mortality in most developed countries. In Canada, the financial cost of treating CVD is greater than for any other single disease and uses approximately 12% of annual health care costs [1].

It is widely accepted that the atherosclerotic process begins in childhood and progresses through adulthood [2]. The rise in sedentary behaviours in children, increased propensity for childhood obesity [3] and the presence of multiple CVD risk factors in children as young as 8 years [4] is cause for grave concern. This troubling trend has both short-term and long-term consequences for both child and adult health [5-8] as the relative rank for several factors including obesity [9], blood pressure [10] and several serum lipids [11] tracks from childhood into adulthood. Thus, the need to effectively intervene at a young age to offset this negative trend and aggressively promote a healthy lifestyle in childhood is very clear.

Physical activity exerts a cardioprotective effect. This occurs due to direct effects on the myocardium (such as increasing electrical stability) and by influencing CVD risk factors (such as altering serum lipid levels) [12]. This has been observed in children as young as 8 years old [4]. Despite the many known benefits of regular physical activity, rates have declined dramatically in youth in recent years [3]. To counter this downward trend, several school-based physical activity and healthy eating interventions have been designed and implemented and these have met with varying degrees of success [13-15].

Most previous interventions focused on changing physical activity levels during physical education (PE) class time. However, curricular time dedicated to PE in schools has diminished substantially in recent years [16]. It therefore becomes important to develop novel programs that provide opportunities for children to be physically active outside of PE class time. To address this need we developed Action Schools! BC (AS! BC) which is describes as a "best-practice physical activity model designed to assist elementary schools in creating individualized action plans to promote healthy living". It utilizes a socio-ecological health framework and aims to integrate physical activity and healthy eating into the school environment to increase opportunities for children to engage in positive health

[6] A version of this chapter has been submitted to Pediatrics, June 2006 as Reed KE, Warburton DE, Naylor PJ and McKay HA. Do children at risk for cardiovascular disease achieve a greater benefit from a school-based physical activity intervention than children not at risk? The Action Schools! BC model.

behaviours. The AS! BC model is novel as its focus is to increase physical activity across six action zones with a focus on scheduled PE and the school classroom.

Finally, whilst it is important to optimize the health of all children, it is vital to identify and intervene with especially those children at greatest potential risk for future CVD disease. This 'high risk' target group of children have elevated levels of one or more CVD risk factor and could achieve more benefit from a physical activity intervention. Importantly, the focus shifts subtly away from already physically active children increasing activity further and shifts towards less active children becoming more physically active.

Thus, our primary aim was to determine whether AS! BC was an effective model for decreasing CVD risk factors in children. Our secondary aim was to assess the cardiovascular response to the intervention in children deemed "at risk" for CVD. First, we hypothesized the CVD risk profile would improve significantly more in intervention compared with usual practice children. Second, we hypothesized that children deemed "at risk" at baseline would demonstrate the greatest positive response to the intervention, compared with both the usual practice and intervention children deemed not at risk for CVD.

7.2. METHODS

7.2.1. Subjects

Action Schools! BC was a 16-month (cluster randomized) controlled trial of a school-based physical activity intervention. We describe changes over a 9-month (1 school year) period. We recruited elementary schools from the Vancouver and Richmond School Districts in British Columbia, Canada. Presentations were given at District Principals' meetings, reaching approximately 130 principals. Twenty schools volunteered to participate. From these 20 schools, we invited 10 schools to participate based on results from the physical activity section of the BC Ministry of Education Satisfaction Survey [17]. The survey asked students and parents if they were satisfied with the physical activity delivered at school and responses were given on a 1-5 scale, with 1 being not satisfied and 5 being very satisfied. As a means to identify schools not already engaged in physical activity programs schools with a score of 3 or lower were invited to participate (n=10). These schools were stratified by size (<300 or >300 students) and geographic location (Vancouver or Richmond) and randomly assigned to either Usual Practice (UP) or Intervention (AS! BC).

All children in grades 4 and 5 who were actively involved in regular PE, had no pre-existing medical conditions and were not taking medications related to cardiovascular health were eligible to participate. Presentations were given to grade 4 and 5 students in each of the 10 schools and consent forms were distributed in 4 languages (English, Chinese, Punjabi and Vietnamese). A total of 514 children (257 boys, 257 girls) aged 9-11 years and their parents provided informed consent. Each child's parents completed a health-history questionnaire before the study began. The Clinical Research Ethics Board at the University of British Columbia and the Vancouver and Richmond School Districts approved this study.

For the cardiovascular component of the AS! BC evaluation we estimated that a 10% difference for change in our primary outcome measure (fitness) between groups constituted a meaningful effect. Approximately 200 children were required to achieve a power of 0.8 at an alpha level of 0.05. Thus, we randomly selected 4 schools (3 AS! BC, 1 UP) to undertake the cardiovascular component of the evaluation. In addition, children whose parents provided consent for a blood draw where also included in the cardiovascular measurement component. Thus, a total of 268 children from 8 schools (6 AS! BC, 2 UP) were measured at the beginning of Phase 1 (which ran April-June 2003) and 254 children were measured at the beginning of Phase II (September 2003-May 2004). This study examines change over Phase II, meaning the 2-month summer vacation was not included in any analysis. Separate consent was obtained from a subset of children who volunteered to provide blood samples (n=77). Study recruitment, participation and attrition are illustrated in Figure 7.1

7.2.2. Action Schools! BC Intervention

The AS! BC model promotes and facilitates teachers to create a portfolio of inclusive and diverse physical activity opportunities for students throughout the school day. To support this, the AS! BC Support Team developed intervention ideas that could be delivered across six identified Action Zones: i) School Environment (creating a safe and inclusive environment that fosters healthy living), ii) Scheduled Physical Education (supports the curriculum goal of 150 minutes per week) iii) Extra-curricular (provides opportunity for staff and students to be physically active before and after school plus during lunch and recess), iv) School Spirit (cultivating a good school spirit through inclusive physical activity), v) Family and Community (fostering partnerships outside the immediate school environment) and vi) Classroom Action. The AS! BC Support Team facilitated the development of an Action Plan that incorporated activities across all 6 Action Zones. The only mandatory component of the model was Classroom Action. The Classroom Action Zone provided creative, alternative classroom physical activity ideas to complement the existing physical education curriculum. Teachers in AS! BC schools were trained by AS! BC facilitators to implement the Classroom Action 15 x 5 program (15 additional minutes of physical activity, 5 days a week). During classroom action students participated with their teacher in a number of different classroom activities (skipping, dancing and resistance exercises with hand grippers and exercise bands). Teachers were provided with a Classroom Action Bin, which contained equipment and resources to facilitate these activities. Teachers at UP schools were asked to continue with their regular program of physical education and school-based physical activity. Participating teachers were asked to track their classroom action minutes and activities each day in log books that were submitted to the AS! BC Support Team on a weekly basis.

7.2.3. Measurements

Detailed methods are provided in Chapter 2 and summarized below:

Fitness: Cardiovascular fitness was assessed using the Leger's 20-m incremental shuttle run test, designed for use with children [18]. Children ran in groups of six, with a member of the measurement team, to ensure accurate pacing.

Anthropometry: Standing height (stretch stature without shoes) was measured to the nearest 1mm using a wall mounted digital stadiometer (Seca Model 242, Hanover, MD). Mass in light clothing was measured using an electronic scale (Seca Model 840, Hanover, MD) to the nearest 0.1 kg. Body mass index (BMI) was determined using the equation mass (kg) / height $(m)^2$.

Blood pressure: Duplicate measurements were taken on the left arm after 5-10 minutes quiet rest using an automated sphygmomanometer and an appropriately sized cuff (VSM MedTech, Canada). Systolic and diastolic blood pressures were recorded.

Push ups and curl ups: Following standard FITNESSGRAM [19] instructions, children were asked to perform push-ups and curl-ups at a cadence of 20 per minute. Children were asked to stop if the quality of the exercise failed to meet required standards. The number of correctly performed repetitions was recorded.

Blood collection: For a small subset of student volunteers (n=77) intravenous samples were taken from the antecubital vein between 8.00 AM and 9.30 AM after an overnight fast. A 10 ml sample was taken and stored on ice in a serum separator tube. Blood was separated within 30 minutes and then stored at -80°C. Samples were later analyzed for total cholesterol (TC), high and low density lipoproteins (HDL-C and LDL-C), apolipoprotein B (Apo B), C-reactive protein, and fibrinogen at St. Paul's Hospital Laboratory, Vancouver.

7.2.4. Data analysis

To account for the clustered design, we used the variance inflation factor (VIF) to correct the variance used in calculation of the test statistic and to correct the confidence intervals [20]. The VIF was calculated as 1+ (m-1)*ICC, where m is the adjusted mean cluster size and ICC is the intracluster correlation co-efficient. ICC for each variable is provided (Appendix G).

The outcomes that addressed both our primary and secondary research objectives were final value for fitness, blood pressure (systolic and diastolic), BMI, push-ups, curl ups, TC, TC/HDL-C, LDL-C, Apo B, C-reactive protein and fibrinogen. To address our primary objective, final scores for each variable were compared between UP and AS! BC groups using analysis of covariance (ANCOVA), controlling for the baseline value for each variable.

To address our secondary research objective, we first established baseline risk, which was defined as the presence of known CVD risk factors. Specifically, children in the intervention (AS! BC) group were divided into quartiles, according to baseline levels of each CVD variable. As lower values are preferable for blood pressure, BMI and serum factors, children's scores were considered normal (NORM) if values fell within the lower 3 quartiles, and higher risk (RISK) if values fell within the top quartile. Similarly for fitness, push-ups and curl ups, children in the top 3 quartiles (better performance) were assigned to the NORM group and children in the lowest quartile were assigned to the RISK group. Blood pressure was adjusted for height.

To analyze change according to baseline value, change (final – baseline) for each variable was compared between the 3 groups (UP vs. NORM vs. RISK) using one-way analysis of variance (ANOVA). *Post hoc* examination (Bonferroni) was used to locate differences between groups. Data were examined using SPSS version 13.0 (Chicago, Il).

7.3. RESULTS

Attrition was similar between UP and AS! BC groups (5.8% and 7.1% over the school year) (Figure 7.1). Of the 77 children who volunteered blood samples at baseline, 60 (22% loss) returned for follow up. There were no differences at baseline for any variable between those children who completed 1 and those children who completed 2 sets of measurements. There were no differences in baseline variables (BMI, fitness, age, blood pressure) between those children who consented to a blood draw and those who did not. Compliance with Activity Logs was 97% across UP school and 94% across AS! BC schools (Appendix I). From these logs, we ascertained teachers at AS! BC schools delivered approximately 60 minutes more physical activity per week than teachers at UP schools (+58.9min/week CI: 25.4, 92.4) (Appendix I). These data have been reported in detail previously [21].

At baseline the percentage of children in each Tanner stage (1/2/3) was similar (AS!BC boys: 61/34/5 and girls: 39/51/10, UP boys: 70/27/3 and girls: 43/52/5). At the end of Phase II the percentages of children in each Tanner group (1/2/3/4) was again similar (AS! BC boys; 33/38/26/3 and girls; 11/43/40/6, UP boys: 42/37/19/1 and girls: 13/35/48/4)

Baseline data are provided (Tables 7.1 and 7.2). We also provide the cut-off scores used to determine allocation of AS! BC children to NORM or RISK quartile (Descriptive statistics by sex at September (baseline) and June (follow-up) timepoints are provided in Appendix J)

7.3.1. *Comparison of change between AS! BC and Usual Practice children*

Performance and anthropometry variables: We provide change by treatment group (UP vs. AS! BC) (Table 7.3). There was a significantly greater increase in fitness (laps run) in the AS! BC group compared with the UP group ($P<0.05$). There was a reduction in systolic blood pressure in the AS! BC group compared with a rise in the UP group ($P<0.01$). There were greater, though non-significant, increases in curl ups and push-ups in the AS! BC group.

Serum variables: There were greater, though non-significant decreases in all serum variables in the AS! BC group compared with UP (Table 7.3).

7.3.2. *Comparison of change between Usual Practice and AS! BC RISK and NORM groups*

Performance and anthropometry variables: Of the 6 risk variables measured, 5 changed significantly more in the RISK group compared with UP (Table 7.4). Only 1 risk variable (fitness) was improved significantly more in the NORM group compared with UP. Within the intervention group, the RISK group showed a significantly greater positive change than the NORM group for 3 of the 6 variables.

Serum variables: Of the 6 serum factors assessed, 4 changed significantly more in the RISK group compared with the UP group (Table 7. 4). There were no significant changes between the UP group and the NORM group. Within the intervention groups, the RISK group showed a significantly more positive change compared with the NORM group for 4 of the 6 serum variables.

7.4. DISCUSSION

We demonstrated that AS! BC was an effective model to positively affect several CVD risk factors in elementary school children. We extend previous literature by introducing the AS! BC model and by reporting change in relation to several cardiovascular health indicators. We also demonstrated that children deemed at greater risk improved significantly more than normal healthy children for a number of key CVD risk factors.

7.4.1. *Comparison of change between AS! BC and Usual Practice children*

We assessed a group of children who were, on average, relatively healthy. That said 58% of children presented with at least one CVD risk factor at baseline and 17% had 3 or more risk factors. These values are consistent with studies in similar aged children [4]. The magnitude of the effect that we observed in response to the intervention was enhanced when those children deemed at greatest risk based on CVD indicators were compared with our UP and normal healthy groups. This suggests that the AS! BC model was also effective for those children who could benefit most from adopting a physically active lifestyle.

Previous studies that assessed CVD risk commonly measured fitness, BMI, blood pressure and occasionally cholesterol. We contribute to the current literature by also assessing several serum factors, such as apo B, fibrinogen and C-reactive protein in a subset of children. Our results are more promising than findings from some previous school-based intervention studies [13] and comparable to others [22] when similar outcomes were evaluated.

The extensive and ongoing Child and Adolescent Trial for Cardiovascular Health (CATCH) program [14] and the Cardiovascular Health in Children (CHIC) studies [13] in the U.S. both improved physical activity participation in elementary school children who undertook the program. However, despite increasing physical activity by 12 minutes per day by the end of the 2.5 year CATCH [23] study and by 7% in the CHIC trial after 8 weeks [13], neither intervention reported significant change in any physiological variables. However, whether 8 weeks is sufficient to elicit substantial changes in physiological variables is debatable.

The Sports Play and Recreation in Kids (SPARK) [15] program delivered 3 x 30-min of physical activity during PE class time. PE was conducted by either a specialist teacher or by the classroom teacher. At the end of the 2-year intervention, children in the intervention schools improved fitness (1 mile run time) by between 6-11% more than children in control schools (depending on girls/boys and specialist/classroom teacher interaction). They also demonstrated a greater increase in abdominal strength in the intervention schools. A 9-month physical activity based trial in Australia also resulted in significant cardiovascular improvements including enhanced fitness (15% in girls, 3% in boys), and decreased blood pressure (3% girls only). Skinfold thickness was also significantly reduced (5% girls only) [22].

Almost all school-based interventions to date that targeted CV health focused on increasing physical activity levels during PE class. The exceptions are notable. Similar to the AS! BC model, Vandongen et al [22] implemented an additional 15 minutes of physical activity during the school day. For Action Schools! BC we took this a step further and developed a model whereby resources were provided and action plans were developed across 6 Action Zones, including a 15 x 5 mandatory Classroom Action component. Thus, the AS! BC model adopted the concept of comprehensive school health and a 'whole school' approach rather than focusing solely on the PE curriculum.

7.4.2. Comparison of change between NORM, RISK and Usual Practice groups

We reported an enhanced effect of the intervention for those children at potentially greater risk for CVD. Comparisons of mean change between 2 groups of healthy children may mask the patterns of change within the sample, as there are marked differences in the individual responses to exercise training [24-26]. Specifically, there is considerable variability for change in aerobic fitness in response to standardized training programs and initial fitness is an important determinant of change, even in children [26].

We observed a substantial increase in fitness (46%) in the RISK group compared with a 10% increase in the UP group. This is substantially greater than the 15% reported by Vandongen et al [22] who undertook a similar trial in healthy elementary school children. The 4% decrease in systolic blood pressure in the RISK group was similar to the 3% decrease for girls reported by Vandongen et al [22].

We also report similarly greater improvements in the RISK groups compared with the NORM group. There are a number of possible explanations for these findings which have been previously observed [27]. Only 25% of elementary schools in British Columbia devote the recommended 10% of curriculum time to PE [28]. The literature supports the notion that in order to enhance and sustain a physical activity benefit for children a more comprehensive 'ecological' approach is required. Sallis et al [29] state that making realistic improvements to the school environment and increasing adult supervision can increase physical activity throughout the day. Although difficult to quantify, we strove to incorporate this approach in the AS! BC model and provided physical activity opportunities across the 6 Action Zones. We have previously reported an increased dose of physical activity delivered [30] by teachers in the AS! BC schools compared with the UP schools.

Only two school-based interventions have assessed changes in CVD risk factor change in relation to levels of baseline risk. Burke et al [27] examined the differences in response to a 9-month, school-based fitness and nutrition program in relation to baseline level of cardiovascular risk. The children were allocated to a high-risk group if they showed clustering of risk factors (elevated systolic blood pressure, total cholesterol, high body fat *and* low fitness). Boys in high-risk groups had a greater decline in systolic blood pressure and a greater increase in aerobic fitness than boys in normal risk groups. In high-risk girls there was a greater reduction in triceps skin fold compared with girls in the normal risk group. In contrast, Harrell and colleagues [31] conducted a short, 8-week, physical activity intervention in elementary schools and showed positive results for both a 'classroom group' and an intervention group of children with 1 or more CVD risk factor. The researchers concluded that the 'classroom-based' approach was easier to implement and evidenced stronger results than the 'risk-based' approach. The classroom-based group had more favourable changes in aerobic power and BMI compared with both the control group and the risk group.

Results of the present study were somewhat contrary to Harrell's [31] data, and broadly similar to Burke's [27] data in that we also observed an enhanced effect for the intervention in the RISK group. Taken together, these few trials support that those children who present with increased CVD risk factors may benefit most from adopting healthy lifestyle behaviours. This is important for a number of reasons. First, several studies have linked elevated risk factors in childhood to short-term and long-term damage to the cardiovascular system. Obesity during childhood, for example, is frequently associated with dislipidemia, abnormalities in left ventricular mass, hyperinsulinemia and alterations in endothelial function [5, 32]. Childhood obesity is also known to influence adult morbidity and premature mortality [9]. Second, elevations in blood pressure during childhood are associated with left ventricular abnormalities, altered endothelial thickness and aortic stiffness [6-8] and although the long-term impact of childhood hypertension on adult health is not fully understood, tracking of blood pressure into adulthood is established [33]. Third, physical fitness during youth is also related to cardiovascular health in adulthood. The Amsterdam Growth and Health Longitudinal Study [34] demonstrated that a high aerobic fitness during adolescence was inversely related to skinfold thickness, waist circumference and total serum cholesterol at 32 years of age. Recently, Chen et al [35] demonstrated that low levels of metabolic syndrome risk during childhood (BMI, insulin sensitivity, blood pressure and cholesterol ratios) are strongly associated with low levels of the same variables during adulthood.

7.5. LIMITATIONS

We acknowledge a number of limitations in the present study. First, we do not know the clinical significance of the findings we report in children as they related to CVD in adulthood. There are as yet no data regarding the impact of childhood CVD risk factors on future mortality risk and no data regarding the impact of randomized intervention trials on mortality. However, we do know that the positive findings we observed in this young group would be clinically significant in adults. The American College of Sports Medicine showed that a decrease in blood pressure of 2mmHg results in a 9% reduction in risk of coronary heart disease [36]. The Framingham study showed that an increase in total cholesterol from <200 to >240mg/dL (<5.1 to >6.1 mmol/L) increased the age adjusted 10 year coronary heart disease event rate from 8.2 to 18.8 in adults [37]. Longitudinal studies, such as the Framingham and the Bogalusa Heart Study, will, in future provide valuable information regarding the impact of childhood risk factor values on future cardiovascular morbidity and mortality.

Second, it was not possible to specifically quantify the physical activity undertaken within the AS! BC model across all 6 Action Zones. However, based on the nature of the AS! BC model, the mandatory components (Classroom Action and PE) would have provided the greatest opportunities for children to be more active within schools. Results from the teachers logs showed that the teachers in the AS! BC schools delivered on average, 60 minutes more physical activity per week than teachers in the UP schools (Appendix I).

Third, the AS! BC pilot was a 16-month trial, with the teachers adjusting to the model (Feb-May) and actively delivering the intervention from September to June. Our results represent 1-school year (9 months) so that summer vacation (2 months) did not impact on results. Ideally, children will be followed prospectively to observe the long-term effects of the model on cardiovascular health.

Finally, we selected schools based on physical activity opportunities provided to students to exclude schools that were involved in ongoing interventions or programs (detailed in Chapter 2). This may limit the generalizability of our findings to school that are only providing minimal opportunities for physical activity throughout the school day. We have shown that the effect of a school-based physical activity intervention is partially dependent on baseline levels of cardiovascular risk. Students attending schools that provide more physical activity opportunities may have more favourable cardiovascular risk profiles at baseline and will potentially respond to a lesser extent than children in this study.

7.6. CONCLUSION

Action Schools! BC positively influenced the cardiovascular health of elementary school children who undertook the intervention. Positive benefits were enhanced in those children who showed less favourable CVD risk factor levels at baseline. We conclude that Action Schools! BC is a feasible and effective model of physical activity that can be easily adopted within elementary schools and could potentially improve the cardiovascular health of children attending schools where physical activity opportunities are minimal.

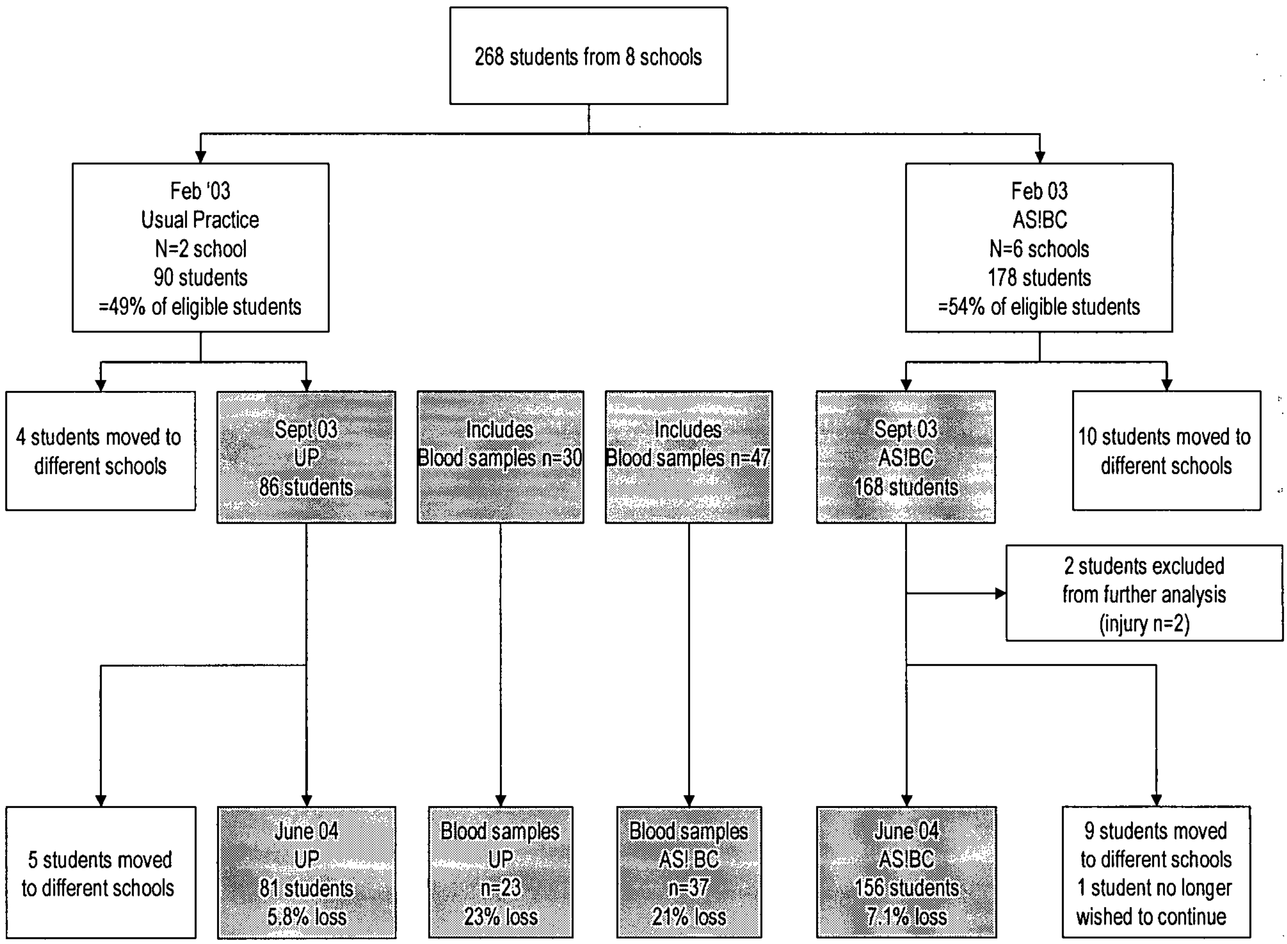

Figure 7.1 Flow diagram showing recruitment and attrition across the intervention time span. Numbers are shown for AS! BC and Usual Practice Schools. This study is concerned with Phase II – September 2003 to June 2004, shaded boxes.

Table 7-1 Baseline descriptive data of participants and variable specific cut-off score, used to allocate children into NORM or RISK quartiles. 'Quartile Cutoff' shows the level above or below which children in the AS! BC group were placed in the NORM or RISK group. Data are mean (SD) (n=237)

	Whole group N=237	UP n=81	AS! BC all n=156	*AS! BC NORM**	*AS! BC RISK**	Quartile Cut-off
Fitness (laps)	28.7 (13.2)	31.6 (4.3)	27.3 (12.5)	*31.4 (12.0)*	*16.4 (4.2)*	<19
SBP (mmHg)	104.8 (9.6)	104.6 (10.5)	105.2 (9.3)	*101.3 (6.3)*	*117.7 (5.6)*	>111
DBP (mmHg)	62.2 (8.2)	60.0 (8.2)	63.3 (7.5)	*59.8 (4.9)*	*72.4 (5.3)*	>68
BMI (kg/m^2)	18.9 (3.6)	19.1 (3.7)	18.8 (3.5)	*17.1 (1.9)*	*23.7 (2.5)*	>20.7
Curl-ups (no.)	18.5 (13.8)	16.7 (14.4)	18.9 (13.1)	*23.6 (12.1)*	*5.7 (2.2)*	<9
Push-ups (no.)	5.1 (5.2)	6.1(5.6)	4.6 (4.9)	*6.6 (4.8)*	*0.3 (0.4)*	<2

SBP=systolic blood pressure, DBP=diastolic blood pressure, BMI = body mass index

*Exact numbers of children allocated to RISK and NORM groups within INT vary depending on each variable. Numbers of children in the RISK group varies from 40 to 43 and children within the NORM group vary from 116 to 113.

Table 7-2 Baseline serum values of participants and variable specific cut-off score, used to allocate children into NORM or RISK quartiles. 'Quartile Cutoff' shows the level above or below which children in the AS! BC group were placed in the NORM or RISK group. Data are mean (SD) (n=60)

	Whole group (n=60)	UP (n=23)	AS!BC all (n=37)	AS! BC NORM*	AS! BC RISK*	Quartile cut-off
TC mmol/L	4.5 (0.6)	4.5 (0.6)	4.3 (0.7)	4.1 (0.4)	5.2 (0.3)	*>4.9*
TC:HDL	3.3 (0.9)	3.3 (0.8)	3.2 (0.8)	2.8 (0.4)	4.4 (0.5)	*>3.6*
LDL-C mmol/L	2.6 (0.6)	2.5 (0.5)	2.5 (0.6)	2.3 (0.5)	3.3 (0.3)	*>3.1*
ApoB mmol/L	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)	0.6 (0.1)	0.9 (0.1)	*>0.8*
CRP mmol/L	1.4 (2.3)	2.3 (2.8)	0.9 (0.9)	0.4 (0.3)	2.3 (0.5)	*>1.8*
Fg mmol/L	2.9 (0.5)	2.9 (0.5)	2.9 (0.5)	2.7 (0.3)	3.7 (0.5)	*>3.3*

TC=total cholesterol, TC/HDL= ratio of TC to high-density lipoprotein, LDL-C= low- density lipoprotein, Apo B= apolipoprotein B, CRP= C-reactive protein, Fg= fibrinogen

*Exact numbers of children allocated to RISK and NORM groups within INT vary depending on each variable. Numbers of children in the RISK group varies from 9 to 11 and children within the NORM group vary from 26 to 28.

Table 7-3 Unadjusted and adjusted (baseline and VIF)) score by group at follow-up. Unadjusted data are mean (SD) and adjusted data are mean (*95% Confidence Interval)*. Percent difference refers to how much higher or lower AS!BC final score is compared with UP final score (n=237, n=60 for serum factors)

	Usual Practice unadjusted	Usual Practice adjusted	AS! BC unadjusted	AS! BC adjusted	% difference (adjusted)
Fitness (laps)	34 (13)	31 *(27,35)*	36 (16)	37 *(36,39)**	+20.4%
SBP (mmHg)	107 (9)	108 *(106,110)*	103 (11)	102*(100,104)**	-5.7%
DBP (mmHg)	64 (7)	65 *(62,68)*	63 (6)	63 *(60,65)*	-3.8%
BMI kg/m²	19.5 (3.7)	19.4 *(19.1,19.5)*	19.2 (3.4)	19.2 *(19.2,19.6)*	-1.0%
Curl-ups no.	26 (12)	26 *(23,30)*	31 (12)	30 *(27,32)*	+12.6%
Push-ups no.	7 (5)	6*(5,7)*	7 (6)	7 *(6,8)*	+20.3%
TC mmol/L	4.4 (0.5)	4.3 *(4.1,4.5)*	4.1 (0.5)	4.1 *(4.0,4.2)*	-4.6%
TC:HDL	3.4 (0.8)	3.3 *(3.1,3.5)*	3.1 (0.7)	3.1 *(3.0,3.3)*	-6.0%
LDL-C mmol/L	2.5 (0.5)	2.5 *(2.4,2.7)*	2.3 (0.5)	2.4 *(2.3,2.5)*	-0.4%
ApoB mmol/L	0.7 (0.1)	0.7 *(0.6, 0.7)*	0.6 (0.1)	0.6 *(0.6, 0.7)*	-4.5%
CRP mmol/L	1.9 (1.6)	0.9 *(0.5,1.4)*	0.8 (0.7)	0.8 *(0.5,1.2)*	-10.5%
Fg mmol/L	2.0 (0.2)	2.0 *(1.9,2.1)*	2.0 (0.2)	1.9 *(1.9,2.0)*	-2.0%

SBP=systolic blood pressure, DBP=diastolic blood pressure, BMI = body mass index, TC=total cholesterol, TC/HDL= ratio of TC to high-density lipoprotein, LDL-C= low- density lipoprotein, Apo B= apolipoprotein B, CRP= C-reactive protein, Fg= fibrinogen

* Significant difference at $p<0.05$ between groups after adjusting for VIF

Table 7-4 Change (unadjusted) from baseline by group, and for the NORM and RISK subgroups. Data are mean change and *95% Confidence Intervals*

	Usual Practice	AS! BC (all)	*AS!BC NORM*	*AS!BC RISK*
Fitness (laps)	**3.3** *(1.0, 5.5)*	**8.9** *(7.3, 10.4)**	***9.3*** *(7.5, 11.2)**	***7.6*** *(4.4, 10.8)**
SBP (mmHg)	**2.3** *(–0.1, 4.6)*	**-1.1** *(-2.7, 0.5)**	***0.1*** *(–1.7, 1.9)*	***-5.1*** *(–8.1, 2.1)** †
DBP (mmHg)	**4.0** *(2.0, 6.1)*	**0.6** *(-0.8, 2.0)**	***3.0*** *(1.4, 4.6)*	***-5.8*** *(–7.8, 3.8)** †
BMI (kg/m2)	**0.4** *(0.2, 0.6)*	**0.4** *(0.2, 0.5)*	***0.4*** *(0.2, 0.5)*	***0.3*** *(0, 0.6)*
Curl ups	**9.2** *(5.5, 12.9)*	**11.8** *(8.5, 14.2)*	***7.8*** *(4.7, 10.8)*	***21.3*** *(15.7, 26.9)** †
Push ups	**0.8** *(–0.2, 1.8)*	**2.1** *(1.3, 2.9)*	***1.6*** *(0.5, 2.7)*	***3.1*** *(2 .1, 4.1)**
TC (mmol/L)	**-0.09** *(-0.27, 0.09)*	**-0.24** *(-0.40, -0.08)*	***-0.10*** *(–0.25, 0.05)*	***-0.63*** *(–0.97, -0.28)** †
TC/HDL	**0.03** *(–0.18, 0.09)*	**-0.10** *(-0.27, -0.06)*	***0.00*** *(–0.09, 0.09)*	***-0.40*** *(–1.07, 0.23)** †
LDL-C (mmol/L)	**0.00** *(–0.22, -0.01)*	**-0.14** *(-0.25, -0.03)*	***-0.11*** *(–0.19, 0.19)*	***-0.25*** *(–0.65, 0.14)*
Apo B (mmol/L)	**-0.02** *(-0.06, 0.01)*	**-0.05** *(-0.07, -0.02)*	***-0.04*** *(-0.07, -0.01)*	***-0.06*** *(-0.15, 0.03)*
CRP (mmol/L)	**-0.43** *(-0.98, 0.12)*	**-0.13** *(-0.46, 0.20)*	***0.28*** *(-0.01, 0.56)*	***-1.37*** *(-1.77, -0.96)** †
FG (mmol/L)	**-0.93** (-1.17, -0.67)	**-0.98** (-1.19, -0.77)	***-0.74*** *(-0.85, -0.64)*	***-1.80*** *(-2.41, -1.19)** †

* Significantly different from usual practice group † significantly different from NORM group, p<0.05

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CHAPTER 8. EFFECT OF A SCHOOL-BASED PHYSICAL ACTIVITY INTERVENTION ON ARTERIAL COMPLIANCE IN YOUNG BOYS[7]

8.1. INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in developed society and are a massive burden on healthcare systems, costing more than any other single illness to treat annually [1, 2]. Persons who regularly undertake moderate to vigorous physical activity achieve a cardioprotective benefit [3]. Unfortunately, over the last decade the prevalence of CVD risk factors has increased while the number of persons who exercise regularly has decreased.

Arterial stiffness is an asymptomatic early sign of CVD, associated with increased risk of experiencing a cardiovascular event in adulthood [4]. It is noteworthy that impaired vascular function may be evident in children as young as 6 years [5]. Regular exercise can enhance arterial compliance in previously sedentary adults [6], post-menopausal women [6, 7] and obese children [5, 8]. However, as study participants often fail to maintain the prescribed exercise regimen after cessation of the study, it is unknown whether benefits in vascular function persist [5] . The time-course over which these benefits reverse are likely consistent with physiological de-conditioning.

A model whereby schools provide additional opportunities for students to engage in physical activity may be one means to address the primary prevention of cardiovascular disease through enhanced arterial compliance. Whether regular exercise prevents the development of arterial stiffness in normal weight school children has not previously been examined. Previous school-based interventions have successfully ameliorated risk factors including improved cardiovascular fitness [9], decreased total cholesterol [10] and decreased body fat [9].

We have previously described the Action Schools! BC model, which was designed to promote physical activity in order to achieve positive health benefits in elementary school children [11]. In cross-sectional analysis of the Action Schools! BC cohort, arterial compliance was positively associated with physical fitness at baseline [12].

The aim of the present study was to extend our cross-sectional findings [12] and investigate the effects of the Action Schools! BC physical activity model on changes in arterial compliance across one school year in boys. We hypothesized that at the end of the trial, boys attending schools randomly assigned to the Action Schools! BC model would show a greater positive change in arterial compliance compared with boys attending schools assigned to usual practice.

[7] A version of this chapter has been submitted to Vascular Medicine June 2006 as Reed KE, Warburton DE, Lewanczuk R Z, Haykowsky MJ, McKay HA. Effects of a 9-month school-based physical activity intervention on arterial compliance in elementary school boys.

8.2. METHODS

8.2.1. Study design

This was a repeated measures design, with measurements taken before (September 2003) and after (June 2004) a 9-month school-based physical activity intervention (Action Schools! BC).

8.2.2. Recruitment

School and student recruitment into the Action Schools! BC study is described in detail in Chapter 2 and briefly summarized below.

We recruited elementary schools from the Vancouver and Richmond School Districts in British Columbia, Canada. Following presentations to approximately 130 principals, 20 schools volunteered to participate in the Action Schools! BC study and we selected 10 schools based on results from the physical activity section of the BC Ministry of Education Satisfaction Survey [13] as described previously . Schools were stratified by size (<300 or >300 students) and geographic location (Vancouver or Richmond) and randomly assigned to either Usual Practice (UP) or Intervention (AS! BC) groups. All parents completed a health-history screening questionnaire for their children. Children who participated in normal school physical education class and were free of overt disease were eligible to participate in the study. Children were excluded if they had any disease or taking medication that would prevent normal physical development or participation in physical activity. The University of British Columbia's Clinical Research Ethics Board gave ethical approval for the study. Parents provided written informed consent and children provided verbal consent.

For this small study, we selected a subset of boys (n= 30, 15 Usual Practice and 15 AS! BC) for the arterial compliance measurement from those children participating in the Healthy Hearts component of AS! BC during September 2003 (n= 127 boys). Selection was stratified random. Children completed Healthy Hearts testing in groups of 6, and the first boy listed from each group was chosen for arterial compliance measurement.

8.2.3. Measurements

Detailed methods are provided in Chapter 2 and summarized below.

Arterial compliance: Large artery and small artery compliance was measured non-invasively by applanation tonometry, using the HDI/Pulsewave CV Profiling system (CR-2000 System, Hypertension Diagnostics Inc., Eagan, Minnesota, U.S.). Children were not permitted to exercise or consume a caffeinated beverage two hours prior to measurement. Children rested in a supine position in a quiet space for 5 to 10-min after which radial arterial pressure waveform (ml/mmHg x10 and x 100) of the right arm was acquired using the applanation tonometer. This tool is clinically valid and reliable to assess arterial health [14, 15]. Automated blood pressure was taken concomitantly on the left arm using standard procedures and systolic and diastolic blood pressures (mmHg) were recorded.
Anthropometry: We assessed stretch stature in cm to the nearest 1mm using a wall mounted digital stadiometer and standard protocol (Seca Model 242, Hanover, MD). We determined children's body mass in kg using an electronic scale (Seca Model 840, Hanover, MD) to the nearest 0.1kg.
Cardiovascular fitness: Cardiovascular fitness was assessed using Leger's 20-m incremental shuttle-run, designed for use with children [16]. Children ran in groups of six, with a trained measurer, to ensure accurate pacing.

Intervention: We have described the Action Schools BC model in detail elsewhere [17] and in Chapter 2 (Methods) . Briefly, Action Schools! BC (AS! BC) uses a socioecological approach to promote physical activity in elementary schools. The AS! BC model provides a framework for schools and teachers to create individualized Action Plans that provide increased physical activity opportunities across 6 Action Zones; 1) school environment, 2) physical education, 3) classroom action, 4) family and community, 5) extracurricular and 6) school spirit. The AS! BC model provides teachers with training and resources to operationalize their Action Plan with the ultimate goal of providing students with 150 minutes of moderate intensity physical activity per week. This is achieved through 2x 40-minute PE class and 75 minutes per week of Classroom Action.

The most novel component of AS! BC was Classroom Action - designed to complement the existing physical education curriculum. The Classroom Action component provided creative ideas for teachers so that teachers could provide children with short physical activity bouts that could be undertaken in the classroom or the schoolyard. Teachers in intervention schools were asked to deliver Classroom Action for 15 minutes, 5 days per week. Activities undertaken in the classroom were skipping, dancing or resistance exercises with hand grippers and exercise bands (Appendix E). Teachers were provided with a Classroom Action Bin that contained equipment and resources to facilitate selected activities. Teachers maintained daily activity logs where type, frequency and duration of physical activities delivered to students were recorded. Logs were collected by an AS! BC research assistant on a monthly basis. We report total minutes of physical activity per week (min/wk) delivered by AS! BC teachers. Children attending Usual Practice schools participated in their regular program of two 40-minute classes of physical education per week. Usual Practice teachers also completed weekly activity logs that were collected by research assistants on a regular basis.

8.2.4. Data analysis

The primary variables of interest were i) large and ii) small, artery compliance. We used ANCOVA (adjusted for baseline) to compare our primary outcomes between AS! BC and UP groups at final measurement. Study 3 (Chapter 5) identified several determinants of arterial compliance, and these data were incorporated into the present study. Large artery compliance was adjusted for height and systolic blood pressure. Small artery compliance was adjusted for mass and systolic blood pressure.

8.3. RESULTS

Twenty-five boys (11.3 (0.5) years, 146.5 (8.6) cm, 46.6 (13.7) kg) from the original 30 were available for re-testing (12 Usual Practice and 13 AS! BC). Three boys had moved to different schools and 2 boys were unavailable for testing. At baseline, there were no significant differences in systolic blood pressure (SBP), height, mass or arterial compliance between AS! BC and UP groups.

Compliance with Activity Logs averaged 97% across UP school and 94% across AS! BC schools (Appendix I). From these logs, we ascertained teachers at AS! BC schools delivered approximately 60 minutes more physical activity per week than teachers at UP schools (+58.9min/week CI: 25.4, 92.4) (Appendix I).

Unadjusted large and small arterial compliance by group is provided (Table 8.1). Boys attending AS! BC schools had a significantly greater adjusted large artery compliance at follow up (June 2004) boys compared with boys attending UP schools (13.7ml/mmHg x 100, *95% CI: 12.6, 14.8 vs.* 10.4ml/mmHg x100, *95% CI: 8.8, 12.0,* p=0.02*)* (Figure 8.1). There was no difference between AS! BC and UP groups for small artery compliance (8.5ml/mmHg x 10, *95% CI: 7.9, 10.*1 vs. 7.4ml/mmHg x 10, *95% CI: 6.3, 8.5,* p=0.06).

8.4. DISCUSSION

At the end of our 9-month trial, boys in the Action Schools! BC group had 32% greater compliance in their large arteries compared with boys attending Usual Practice schools. First, our finding has public health implications; a program of physical activity delivered by generalist teachers within schools can be effective in children for offsetting risk factors for CVD. Second, our finding is physiologically novel, as the response of arterial compliance to exercise has, to our knowledge, not previously been studied in healthy children. The present study extends our understanding of how this measure of cardiovascular function changes with exercise training in young children. Although we cannot know the lifetime risk of cardiovascular disease in these children, if these benefits were maintained into adulthood it would likely translate into a decrease in risk of coronary artery disease. Previous studies, either exercise or diet based, in adults have also resulted in changes in large, but not small artery compliance [7, 18]. The mechanisms, which result in this inconsistent change, have not been explored.

Increased arterial stiffness is an established marker for CVD risk in adults and arterial compliance improves in response to exercise interventions in adults [7, 19]. Increased stiffness exerts greater afterload on the heart [20] and is associated with stroke and renal disease [4]. Sugawara et al [19] showed that exercise could mediate central arterial compliance independently of exercise intensity. Post-menopausal women exercising at either low (40% HRmax) or moderate (70% HRmax) intensity showed similar gains in large arterial compliance. This was attributed to equal total energy expenditures of the groups over the 12-week program.

Little is known about the response of arterial compliance to variations in frequency, intensity and total volume of exercise in adults; even less is known of the response in children. Boys in the Action Schools! BC schools had significantly greater large artery compliance at the end of the study. However, at the final time point the difference in small artery compliance between AS! BC and UP (15%) was not statistically significant. Other studies that measured the effects of exercise on pediatric vascular health (assessed by physiologically analogous measures of endothelial function) introduced exercise sessions of at least one hour duration, 2-3 times per week, at an intensity of up to 70% HRmax [8] or 180bpm [5]. Although physiologically effective, such interventions are likely not practicable in the school environment. We did not assess the intensity of the AS! BC activities on an individual level. However, the frequency (5 days per week) and duration (9 months) were sufficient to elicit a similar effect on the large but not the small arteries. This frequency and duration of activity would have significantly increased total energy expenditure, and this increase may have been sufficient to increase arterial compliance even if the intensity of the activity was not as high as in previous studies.

Health Canada [21] recommends that children accumulate 90 minutes of physical activity daily, but reports that only 38% of girls and 48% of boys are active enough to meet this requirement. Action Schools! BC aimed to provide 150 minutes per week of physical activity. This comprised two thirty-five minute classes of physical education plus an additional 15 minutes of physical activity each day (75 minutes per week) within the classroom action component of the AS! BC model. Teachers in AS! BC schools delivered 60 minutes more physical activity per week, on average, than teachers in UP schools.

The mechanisms by which exercise alters vascular function have been described previously. Briefly, increased blood flow and shear stress on the intima, at both local and systemic levels [22], results in the release of the powerful vasodilator, nitric oxide (NO) [23]. Additionally, regular exercise causes a chronic lowering of blood pressure, due to reduced sympathetic discharge [24] and systolic blood pressure is highly correlated with arterial compliance. It is likely that our intervention, which called for repeated bouts of exercise, would have resulted in frequent periods of increased shear stress and post-exercise hypotension. Further, training-mediated changes in oxidant stress [25] or changes in fibrinolytic processes [26] may have contributed to the alterations in vascular stiffness noted in the present study. Previous investigations which measured the effects of exercise training on vascular health have studied obese children [5, 8] However, the children in the current study were of average weight, so it is less likely that changes in insulin sensitivity, known to affect vascular function [4] would have had a substantial impact on change.

8.5. LIMITATIONS

We acknowledge that the current study has a number of limitations. The relatively small sample size, as a result of attrition over the year, may have resulted in us reporting a non-significant change for small artery compliance. As no previous studies have examined the effects of a physical activity intervention or an exercise trial on arterial compliance in children, determining an adequate sample size was difficult and relied on data from adult studies. It is likely that a greater number of children are required in future studies to overcome the effects of confounding variables, such as maturation.

Further, we did not assess the intensity or duration of the intervention on an individual level, rather on a classroom level. There was, however, a larger increase in *fitness* (20-m shuttle run test) in the intervention group which, according to our findings in Study 3 (Chapter 5), would have significantly influenced arterial compliance.

Further, our non-random selection of school (as mentioned previously) may limit generalizability of findings to school that provide only minimal physical activity opportunities throughout the school day. Intervention involving children with higher activity levels at baseline may produce different results.

8.6. CONCLUSION

This was the first study to examine the effect of a physical activity intervention on arterial compliance in children. We supported our hypothesis by finding a positive effect of the intervention on large arteries. We did not however, find a significant effect of the intervention on small artery compliance. We designed a physical activity model that could be delivered by non-specialist teachers in the classroom or playground and outside of physical education. Thus, the AS! BC model has the capacity to reach a large number of children from diverse geographical regions and a wide range of socio-economic and ethnic backgrounds. The model was found to be effective for increasing large, but not small artery compliance in a group of young boys.

Table 8-1 Participant characteristics including arterial compliance at baseline and final time-points. Unadjusted data are means (SD) (n=25).

	Baseline UP	Final UP (n=12)	Baseline AS! BC	Final AS! BC (n=13)
Large artery (mmHg/ml x 100)	9.2 (1.9)	10.5 (3.1)	9.6 (1.9)	13.4 (2.7)
Small artery (mmHg/ml x 10)	6.3 (1.4)	7.3 (1.7)	7.4 (1.6)	8.6 (2.4)
Systolic blood pressure (mmHg)	109.6 (10.6)	107.7 (6.6)	110.5 (10.2)	103.8 (6.1)
Cardiovascular fitness (20-m laps)	28.1 (16.7)	28.0 (12.8)	29.6 (16.8)	44.3 (18.9)

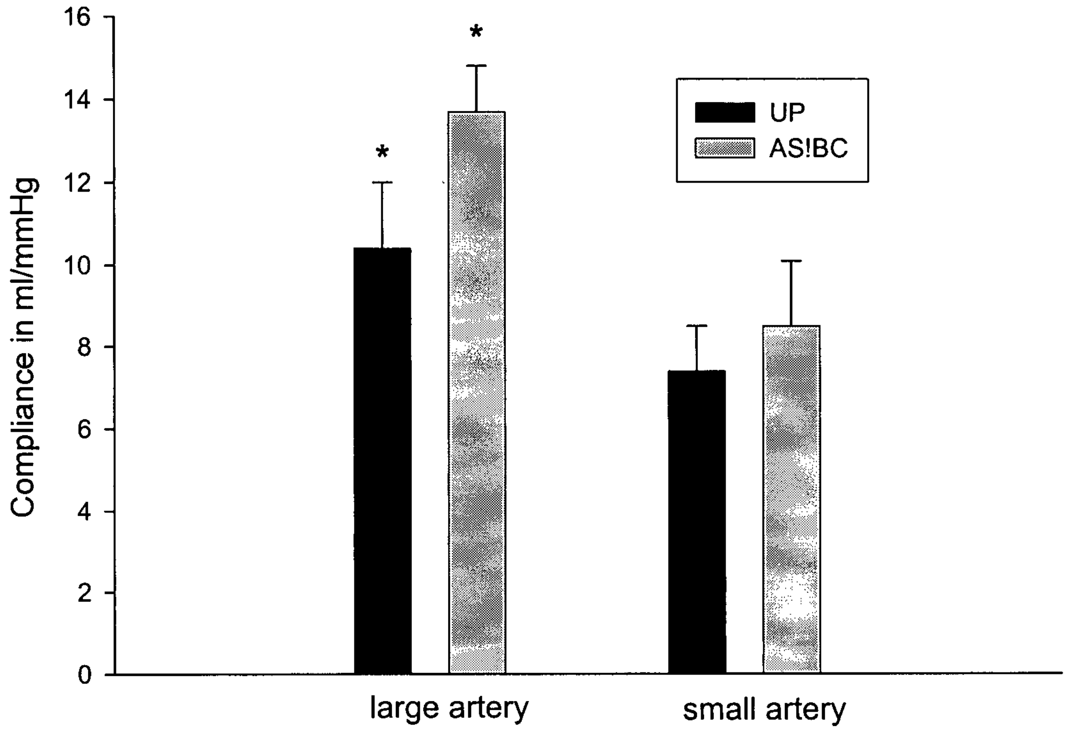

Figure 8.1 Arterial compliance [ml/mmHg x100 (large artery) or x 10 (small artery)] at final measurement controlling for baseline compliance and systolic blood pressure (n=25)

Data are mean and 95% CI. * Significant difference between groups P =0.02.

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CHAPTER 9. INTEGRATED DISCUSSION

In this chapter I discuss the key components and primary findings of my thesis in its entirety. I focus on how the findings I report in the thesis as a whole contribute to the field of child cardiovascular health.

9.1. SUMMARY OF FINDINGS AND CONTRIBUTIONS TO PEDIATRIC RESEARCH LITERATURE.

We adopted a socioecological approach and developed an intervention that was aimed at reversing trends that highlighted increased obesity and decreased physical activity in children of elementary school age. Utilizing a socioecologic approach was one novel component of my research. It combines creating supportive environments through advocacy and public policy, with community outreach where stakeholders are partners in the design, implementation and evaluation of health promotion interventions. The school provides a critical environment for interventions to promote child health. Further, it is an ideal setting to explore the impact of a socioecological approach to positively effect the physical activity behaviours and, ultimately, to improve physical (cardiovascular) fitness levels of children. I utilized data collected between February 2003 and June 2004 to address 6 key questions that together provide a solid framework that supports the effectiveness of a socioecologic approach for improving childhood fitness.

In sub-study one 'Determining cardiovascular disease risk in elementary school children: developing a Healthy Heart Score' I found that 58% of children in the cohort had at least one elevated biological CVD risk factor. This number, although co-incident with studies from same age children [1, 2], is alarming. As nearly all CVD risk factors show some evidence of tracking, these findings represent a time bomb, for if such trends continue, they guarantee a future increase in the incidence of adult heart disease and stroke. I extended previous studies as they did not explore risk factor clustering in children as I have done, i.e. they did not include the *degree* of the elevation of CVD risk factors. In creating the Healthy Heart Score, I included both the number of elevated risk factors and the degree to which they were elevated to reflect algorithms common in the adult literature [3]. Recently, researchers in Norway devised a similar score using age adjusted Z scores [4]. This score relies heavily on serum factors and blood samples are not easy to obtain from participants in a school environment. However, this publication highlights the need to evaluate children in a more comprehensive way to determine their cardiovascular health. It may no longer be adequate to simply label children based on to whether they are above or below one set criterion value. My findings add weight to this argument and are among the first to address developing a CVD risk score for children.

In the United Kingdom screening programs to assess normal cardiovascular function in children are currently being piloted [5]. These programs, are expensive to administer, however, and are running in only a few private schools at present. A screening tool, such as the Healthy Heart Score, is easy and inexpensive to administer in a school situation. Thus, it may increase our ability to monitor the cardiovascular health of large populations of children. I previously acknowledged (See Limitations) that the Healthy Heart Score has several limitations. However, it provides a positive stepping stone from which scientists can devise new, more comprehensive models for assessing children's cardiovascular health and formulate important research questions.

Sub-study two ' Secular changes in shuttle run performance; a 23 year retrospective comparison of 9-11 year old children', highlighted that children living in British Columbia, especially boys, were substantially less fit than Canadian children assessed two decades ago. There is currently a paucity of population data in Canada that accurately describes children's fitness. Further, the few studies that assessed physical fitness in various regions of Canada on a larger scale utilized different methods [6] do not detail results for children under the age of 15 years. Thus, it is not possible to accurately assess changes in children's fitness over time. The published paper that resulted from this chapter is the first to directly compare the physical fitness of two groups of children residing in Canada across more than 20 years -- assessed using the same standardized measurement protocol. The impact of these results is illustrated by a request we have received to contribute to establishing international standards for Leger's 20-m shuttle run. Our data will make a significant contribution to this database.

In sub-study three 'Arterial compliance in young children – the role of cardiovascular fitness', I explored the determinants of arterial compliance. I reported the novel finding that cardiovascular fitness is a major determinant of arterial compliance. This relationship has not been previously investigated in children.

In sub-study four 'Differences in heart rate variability between Asian and Caucasian children living in the same Canadian community', I explored racial differences in this non-invasive measure of autonomic function. Although racial differences in HRV between Afro-American and Caucasian children have been shown previously, the present study contributed novel findings by describing differences between Asian and Caucasian children. Although these findings were not clinically significant, they emphasise the fact that normative data relating to HRV measures may need to be race specific. These findings have already had an impact amongst researchers in the field. At the 2006 Physiology Society Conference in England, Qureshi and colleagues [7] cited our findings as a stimulus for their investigation into racial differences in HRV (European vs South Asian individuals in the UK).

In my final 2 studies I examined the changes in CVD risk factors in response to a school-based physical activity intervention. Sub-study five was entitled 'Do children at risk for cardiovascular disease achieve a greater health benefit from a school-based intervention than children not at risk?' In this study I examined change in CVD risk factor profile i) by group and ii) based on baseline risk. I found a significantly greater increase in fitness and a decrease in blood pressure in the AS! BC group compared with the UP group.

The increase that we observed in physical fitness (20%) was greater than changes reported by Vandongen *et al* [8] (approximately a 10% increase compared with control children), Arbeit *et al* [9] (5% increase), Harrell *et al* [10] (4%

increase) and Luepker *et al* [11] (no change) and similar to the increase reported by Sallis for the SPARK trial [12] (20% increase) following a 2-year intervention. For SPARK, the greatest increases in physical fitness were observed in children who received the intervention from PE specialists (20% increase), while children who received the intervention from classroom teachers failed to show any significant gains in fitness [12]. I acknowledge that the Action Schools! BC children had low initial fitness and this may have influenced the magnitude of change.

In the current study, I demonstrated that gains in fitness could be achieved using a whole school model with a classroom component delivered by generalist teachers. This unprecedented finding is likely due to the training and resources provided to the teachers and the active facilitation of the model provided by the AS!BC Support Team -- comprised of PE specialists. Not surprisingly, when change data were evaluated based on a child's baseline CVD risk the results observed for the entire cohort (of healthy plus at risk children) were enhanced. Thus, this novel model was effective for alleviating risk factors in the subset of children who could benefit the most from programs such as AS! BC.

The final study that comprised this thesis was 'Effects of a school-based physical activity intervention on arterial compliance in young boys'. This was the first study to examine changes in arterial compliance in children as a result of a school-based physical activity intervention. Previous studies have examined change in endothelial function in obese children, but not normal weight children [13, 14]. My novel findings suggest that vascular health in children can be improved without concomitant weight change. It also suggests that a novel model of school-based physical activity may serve as an effective primary prevention against developing these risk factors at a young age.

In summary, I feel that this thesis has advanced the field of pediatric cardiovascular literature; by quantifying the decrease in fitness in Canadian children (sub-study 2), by describing new relationships between CVD risk factors (sub-study 3), by identifying important racial differences in one cardiovascular health indicator (sub-study 4), and by showing that a relatively simple model of school-based physical activity can substantially improve children's cardiovascular health (sub-studies 5 and 6).

9.2. STUDY LIMITATIONS AND CHALLENGES ASSOCIATED WITH SCHOOL-BASED INTERVENTION

I acknowledge that my study had a number of limitations. First, due to the nature of a standard elementary school year, the intervention period included a 2-month summer break. This would impact several cardiovascular variables, such as physical fitness, that respond relatively rapidly to increased or decreased training. To counter this I evaluated children over 1 school year so that the impact of the intervention in this timeframe could be assessed.
Second, dietary intake was not fully examined in all children. Macronutrient and micronutrient intake likely influences a number of CVD risk factors, such as blood pressure and BMI. Although a 24-hour dietary recall was administered

to approximately 150 children 3 times during the study, dietary variables were not identified *a priori* as a key outcome of this investigation. I suggest future assessments include a more *comprehensive* evaluation that includes key dietary variables on a larger number of students; i.e. the same children undergo assessment of arterial compliance *and* serum factors *and* dietary analysis. This would allow a closer examination of the interaction between several variables.

Third, the study was powered to assess change in the primary outcome variable – physical fitness. Thus, the study was underpowered to detect change in some secondary variables such as serum factors and arterial compliance. This was, in part, a function of the attrition rate (specifically, 22% for the blood draw).It is therefore not appropriate to draw firm conclusions when there was no statistical effect of the intervention on these outcomes. However, the data (i.e. 95% confidence interval width) suggest that the results would have been significant if the study was adequately powered.

Fourth, despite randomization, control and intervention girls were, on average, at a different maturational stage at baseline. As growth is not a linear event, a small difference in baseline maturity between groups (despite controlling for this difference) has the potential to confound results over the course of a longer intervention. In the AS! BC group 25% of girls reached menarche during the study compared with 58% of girls in the UP group. Thus I was unable to assess change in girl's arterial compliance in response to the intervention. In future, girls should be matched on maturational stage prior to randomization.

Fifth, all researchers agree that assessing physical activity in children is a challenge. Although no subjective measure of children's physical activity is ideal, I utilized the PAQ-C to assess children's level of physical activity in and outside of school. The PAQ-C is a valid instrument that performs better than most other published children's physical activity questionnaires relative to direct measures of physical activity [15]. That said, the relationship between self-report and direct measures of physical activity are, at best, only moderately strong. The current study would have been enhanced had accelerometers been used to assess individuals' physical activity.

Sixth, I utilized teacher logs to assess the delivery of physical activity in the school. I assumed that activities recorded by teachers were of the quality demonstrated during teacher training workshops. This assumption may not have been valid. Although I requested the opportunity to randomly observe teacher's delivery of the Action Schools! BC model within the school, Principals considered this appropriate. However, Action Schools! BC facilitators provided some feedback regarding teachers' delivery of the intervention.

Seventh, the school was the unit of randomization in the present study while children were the unit of analysis. Therefore, students no longer represented independent observations. In school-based studies, children are nested within classes and classes are nested within schools. This clustering effect can be accounted for by including school as a random variable in the statistical design (when there are sufficient clusters) or by adjusting for the ICC (as in the current study). Correcting for school clusters, although appropriate, effectively reduces statistical power. Ideally, one would randomly allocate individuals, from randomly selected classes to intervention or control arms. Given the nature of schools this is not possible as child- or classroom-based randomization would likely lead to contamination of the control group. We were also obligated to invite all children in the target schools to take part in the study. To overcome this clustering effect in future, a greater number of clusters (>10) from a wider catchment area, in this case, all over BC might be recruited. Although this would allow for a more robust statistical analysis and enhance statistical power by having a larger effective sample size - it would be an expensive and time consuming study to conduct which might limit its feasibility.

A final limitation is the generalizability of study outcomes. Although schools were randomly allocated to treatment group, all schools volunteered to participate in the study. This introduced volunteer bias. It is important to note that many schools demonstrated a strong interest in adopting the Action Schools! BC model but could not commit to the rigours of the study evaluation. Further, we excluded schools that were *already* participating in ongoing physical activity interventions or programs. As in all studies of volunteers, this limits the generalizability of both the cross sectional findings of high risk factor prevalence and the improvements in CVD risk profile that occurred as a result of the intervention. Finally, we evaluated a relatively large, mixed-ethnic sample of children residing in two urban BC school districts. Results can therefore not be applied to rural or urban populations of children who reside in other regions. Future studies should randomly select a wide variety of schools from different regions to enhance the generalizability of the findings

9.3. HEALTH IMPLICATIONS OF ACTION SCHOOLS! BC AND CONSEQUENT RECOMMENDATIONS

Ultimately, the goal of Action Schools! BC was to reduce children's risk for CVD and other chronic diseases in later life. Although the long term impact of the model on the incidence of CVD may not be recognised for many years, it is known that physical activity during childhood is associated with adult health. The relationship between childhood physical fitness and adult health has also been demonstrated [16]. I provide a model that summarises 3 pathways through which adult health can be influenced (Figure 9.1). I represent physical fitness as a mediator of health, as this was the primary outcome in my thesis.

In the first pathway, fitness tracks from childhood into adulthood [18], and adult fitness is known to strongly influence adult health [19]. In the second pathway, childhood fitness influences childhood health. As discussed in previous chapters, numerous studies support this relationship [20-23], including data collected for this thesis, that demonstrated an association between childhood fitness and vascular health (sub-study 3).The second relationship in this pathway (between childhood health and adult health) has been previously examined and several studies demonstrated that CVD risk factors tracked into adulthood. Those factors most likely to track are; body fat [24], blood pressure [25,26] and lipoproteins [27,28]. The third pathway demonstrates that childhood fitness directly influences adult health. Evidence of this direct relationship is scarce as it requires investigators to conduct long term, large scale follow up studies that are fraught with challenges. That said, evidence supporting a relationship between childhood behaviour and health in young adulthood was reported in the Danish Youth and Sports study that followed 160 children over 8 years. Significant, but weak, relationships were found between childhood fitness and adult levels of blood pressure, body fat and lipids [29]. This study, however, only followed subjects for a relatively short time period, and investigations with a longer duration are required to determine if a relationship truly exists.

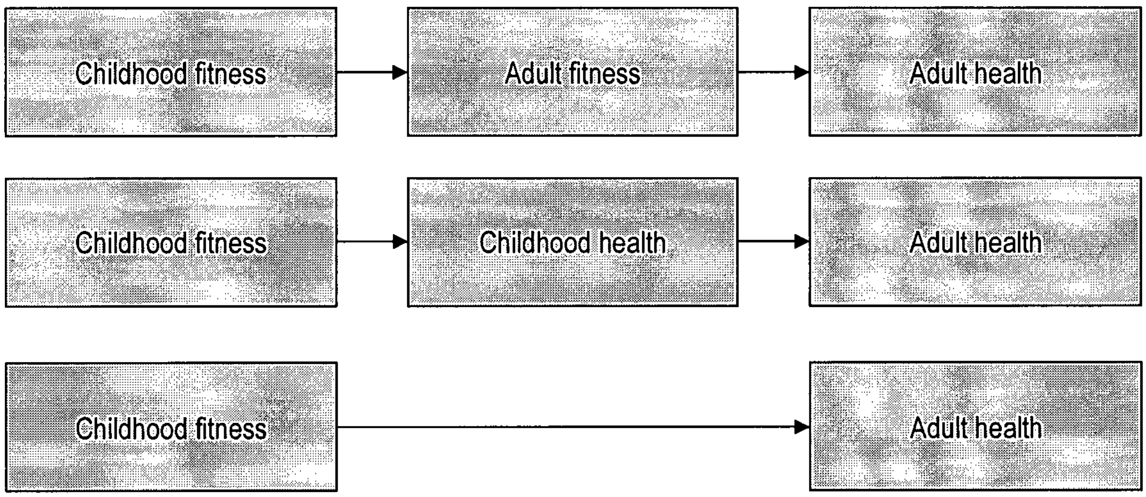

Figure 9.1 Schematic model showing childhood fitness and the direct and indirect effects it may have on adult health. Adapted from Twisk 2002 [16]

Action Schools! BC increased fitness by, on average, 20% in intervention children (sub-study 5). As the dose-response relationship between change in physical fitness and cardiovascular risk is likely not linear [19], it is difficult to quantify the change in health status related to a 20% increase in fitness. Research has shown that adults in the lowest 20% for fitness have significantly greater morbidity and mortality than adults above this threshold [19] and children in the lowest 20% for fitness have the highest CVD risk factor prevalence [30]. By successfully improving the fitness of *all* children, we have likely improved health over the short-term, however children would have to be followed to later adulthood to assess whether benefits observed in the current study persist. A brief review of 6 longitudinal observational studies [16] led to the conclusion that physical fitness during youth is associated with a 'healthy' CVD profile in later life, but the researchers went on to state that this relationship is likely mediated by several factors, including body weight. As a randomized controlled trial into the effects of childhood activity on adult CVD is unlikely to ever occur, large scale, long duration cohort studies are necessary.

Similarly, as cardiovascular disease does not present until later adulthood (on average) it is not possible to quantify the clinical significance of the changes I observed in response to the intervention without long term follow up. For example, although I reported a 6mmHg reduction in systolic blood pressure (sub-study 5) the significance of this finding to child or later adult health is not known. However, in adults, a 2mmHg reduction in systolic blood pressure was associated with a 9% reduction in the risk of coronary artery disease [31]. This suggests that if the reduction in blood pressure I observed is sustained, it would confer direct health benefits. There were also greater reductions in the intervention group for diastolic blood pressure (2mmHg, 4% less at follow up than UP), total cholesterol (0.2mmol/L, 4.6% less than UP group), and the ratio of TC:HDL-C (0.2, 6% less than UP). Following this cohort over several years to monitor the long-term effects of the intervention would be highly beneficial.

This thesis supports a number of recommendations for schools and individuals responsible for children's health.

1. Focus on physical activity models that improve physical fitness in boys and girls.
My thesis identified a high incidence of CVD risk factors in children. Specifically, I highlighted the high prevalence of overweight and low fitness in boys. In the light of these findings, and findings from previous studies showing the combination of high BMI and low fitness to be particularly detrimental to childhood health [20].

2. Invest in socioecological or comprehensive models of school health.
Action Schools! BC is unique compared with previous school-based physical activity interventions in that the focus of change was the whole school environment. This 'active school' approach, whereby physical activity becomes embedded in the fabric of school-life may provide a sustainable alternative to modifying the PE curriculum.

3. Provide school-based physical activity opportunities suitable for all children.
Approximately 500 children took part in the Action Schools! BC evaluation, but over 1400 students in our target grades participated in the program. Children were from various socio-economic backgrounds and had varying skill levels. This supports schools as an ideal environment for physical activity interventions in order to reach diverse groups of children. Finally, given the evidence of tracking of physical activity habits from childhood to adulthood [32], and the current low levels of physical activity in Canadian children [33], adopting a model such as Action Schools! BC should be a priority for all schools.

9.4. REFERENCES

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CHAPTER 10.APPENDICES

10.1. APPENDIX A. ETHICS AND CONSENT

1. Ethical consent from University of British Columbia
2. Information and consent forms sent to families

Action Schools! BC

Information for Families

In partnership with community and government organizations, a group of investigators from the University of British Columbia would like to launch a program of physical activity within elementary schools in the Richmond and Vancouver School Districts.

Our motive is based on the sad reality that many Canadian children are not active enough to achieve health benefits. We are also aware that being physically inactive is a major player in the development of a host of chronic diseases including osteoporosis, obesity, heart disease and Type II diabetes. In addition, many of the antecedents of these diseases that present in adulthood, are often rooted in childhood. Therefore, we feel there is a need to develop innovative and effective physical activity and healthy living strategies that can be implemented during childhood. As schools serve children of all ages, ethnicities and backgrounds we feel that a partnership with principals, teachers, parents and the children themselves provides the best means to introduce Action Schools! BC.

The Aims of the Action Schools! BC program

Our overall goal is to increase physical activity levels of schools and children and to improve each individual's chronic disease risk factor profile. We have provided our vision statement below:

Action Schools! BC is a sport and physical activity initiative integrated into the fabric of our elementary schools and maintained through family and community partnerships. The ultimate aim of Action Schools! BC is to promote healthy hearts, healthy bones, healthy weight and positive self-esteem. Program development will involve children, teachers, parents and community partners. Most importantly, this initiative will allow each school to develop their own program for action. Action Schools! will lead to long term health benefits that are measurable and sustainable.

Our ultimate goal is to introduce Action Schools! BC to interested schools throughout the province of BC by years' end, 2004. In order to achieve that goal we wish to first pilot the program in several elementary schools in Vancouver and Richmond, beginning January, 2003.

The Action Schools! BC Program

The physical activity program will be comprised of a menu of physical activities designed, as our vision statement suggests, to promote healthy hearts, healthy bones, healthy eating, healthy weight and positive self esteem. The menu of activity choices will offer a selection of activities that span the entire school year. Clearly, for a program like this to succeed the support of parents, teachers and principals is key. Thus, we envision a partnership between the school and its larger community, our team at UBC and the Premier Sports Award program to develop a means to incorporate a school-specific Action Schools! BC program into the 'whole school' environment. Examples of menu choices will include some old favorites like "Walking School Bus" and "Heart Smart Kids" and some new offerings such as "Bounce at the Bell". Menu options and the materials and resources required to implement Action Schools! BC activities will be provided to participating schools.

The Action Schools! BC Evaluation

In order for a program like Action Schools! BC to be sustained it must be affordable and effective. Although a number of physical activity programs have previously been introduced into elementary schools in Canada very few have been evaluated as to their effectiveness. Therefore, we wish to assess whether the program is sustainable, whether there are measurable changes in children's physical activity levels and whether cardiovascular and bone health risk factors and self-esteem improve over an 18-month period.

To determine if such changes occur as a result of the intervention, it is important for us to compare the Action Schools! BC program with regular routines of physical activity. For this reason, schools who chose to participate in the Action Schools! BC program will be randomly assigned to one of two groups; intervention or usual practice. Students from all schools will be evaluated according to the following procedures, however only the intervention schools will receive the Action Schools! BC program. At the end of the evaluation period the Action Schools! BC program will be offered to all schools.

Part 1 of the evaluation is administered in the schools to grade four and five students who volunteer to participate. We will administer questionnaires to students in the classroom 4 times during the 18 month study to assess dietary intake and psychosocial well being. Three of the school visits will require 60 minutes of class time each and the remaining visit will require 30 minutes of class time to administer the questionnaires. In addition in June 2003 and June 2004, students will complete the Canadian Achievement Test, 3rd Edition (CAT/3) which evaluates academic performance.

Part 2 is administered at the Vancouver General Hospital (VGH) Bone Health Research Laboratory. At the beginning and end of the study (twice over 18 months) children in grades 4 and 5 who volunteer for measurement, and with consent from parents, will travel to the Bone Health Research Laboratory at VGH. There we will assess bone health, cardiovascular health and administer the questionnaires once again. These measurement sessions will each require that participating students be out of school for approximately three hours. Detailed information for all measurement protocols is provided on the attached consent form. Prior to the laboratory visits, parents will be asked to complete a health history questionnaire for their child.

Action Schools! BC

Consent Form for Families

Investigators:

Heather McKay PhD, Karim Khan MD PhD, Darren Warburton PhD, Ryan Rhodes PhD, Kate Reed MSc, Heather Macdonald BSc.

Your child's school is currently involved in the *Action Schools! BC* program. Children from all grades are participating in a variety of activities targeted towards healthy bones, healthy hearts, healthy weight and positive self-esteem. In order to measure the success of *Action Schools! BC* we wish to evaluate children from grades 4 and 5 according to the following procedures. Please read the following with your child, and if you or your child have any questions, please do not hesitate to contact us. If you and your child wish to participate in the evaluation, you will find a consent form attached to this document that both you and your child can sign and return to your child's teacher.

Procedures:

Your child's participation in the *Action Schools! BC* Program evaluation will involve two testing sessions (approximately 3 hours each, including transportation time), one in January of this year and one in June 2004, at the Vancouver General Hospital, Bone Health Research Lab located at the VGH Research Pavilion - 5th Floor, 828 West 10th Avenue, Vancouver. The children will be transported from the school via mini–van in groups of 5 – 6 and supervised en route by the *Action Schools! BC* chaperone, in addition to the driver. Parents will be sent a notification 24 hours prior to the dates for these visits.

Each session will include the following procedures:

1. Measures of height, sitting height, weight, calf, waist and hip girth will be taken. In addition your child will be asked to complete questionnaires that will assess their physical activity, calcium intake, self-esteem and perceptions of physical activity. In addition, your child may be asked to complete a 24-hour dietary recall to assess total nutrient intake. A trained study staff person will discuss the importance of these assessments with the children. A brief health history questionnaire will be sent home to be completed by a parent or guardian and returned to the University in a self-addressed stamped envelope. This questionnaire will be sent home again before the 2nd laboratory visit.

2. Following individual instruction, the children will be asked to complete the physical maturity assessment forms. There is a space in our laboratory where they may do this in private, seal the results and return the envelope to us. Results remain confidential and data entry is by subject number only so that children can not be identified. Parents wishing to complete this form for their children may indicate so by attaching a note to the returned consent form.

3. Your child's whole body, hip and spine bone status will be evaluated using a bone densitometer. This procedure is painless and routinely used in modern medical practice. It requires only that the child lie still on the padded measurement table for about 15 minutes. We will also assess changes in bone structure at the tibia using a peripheral computerized tomography system. This procedure is performed while the child is sitting with one leg extended and takes approximately 10 minutes. Although the bone measurements are X-ray based, the total patient effective dose per session will be approximately 10 millirem. This is less than you receive on an airplane flight across the country. A trained operator will perform all the bone measurements.

4. Cardiovascular fitness will be assessed by means of a shuttle run test. Children run at a set pace, that steadily increases in speed, until they can no longer keep up. This will take up to 15 minutes. Blood pressure will also be measured using a cuff and a sphygmomanometer. All of these procedures have been performed extensively with children and are harmless.

Action Schools! BC

Consent Form for Participation
Parent's Consent Statement:

I, ____ (please print the name of one or both parents) understand the purpose and procedures of this evaluation as described and I voluntarily agree to allow my child, ____________________, to participate in the *Action Schools! BC* Program evaluation (height, weight, physical activity / nutrition / maturity questionnaires, bone measurements, cardiovascular fitness, blood pressure)

I understand that at any time during the *Action Schools! BC Program* evaluation we will be free to withdraw without jeopardizing any medical management, employment or educational opportunities. I understand the contents of all three pages of this form, the proposed procedures and possible risks. I have had the opportunity to ask questions and have received satisfactory answers to all inquiries regarding this program.

____________________ ____________________ ____________________

Signature of Parent/Guardian   Print Name   Date

____________________ ____________________

Signature of Witness   Print Name   Date

____________________ ____________________

Signature of Investigator   Print Name   Date

Child's Statement:

I understand the purpose and procedures of this program as described and I voluntarily agree to participate. I understand that at any time during the program, I will be free to withdraw without jeopardizing any medical management, employment or educational opportunities. I understand the contents of the consent form, the proposed procedures and possible risks. I have had the opportunity to ask questions and have received satisfactory answers to all inquiries regarding these procedures.

____________________ ____________________

Signature of Child   Date

10.2. APPENDIX B: QUESTIONNAIRES USED IN THE STUDY

These are the questionnaires used in the study. Only the English versions are provided.

1. Personal data form
2. Health History Questionnaires
3. Physical Activity Questionnaire for Children (PAQ-C)
4. Maturity
5. Cardiovascular fitness record sheet

ID: ____________

Action Schools! BC
Personal Data Form – Winter 2003

NAME: ______________________________

TODAY'S DATE: ____________________

AGE: ________ BIRTHDATE: ____________________

GENDER: (circle one) MALE FEMALE

SCHOOL: ____________________ GRADE: ________

TEACHER: ____________________

ADDRESS: ____________________ CITY: ____________________

POSTAL CODE: ____________________ PHONE NUMBER: ____________________

MOTHER'S NAME: ____________________ FATHER'S NAME: ____________________

DO YOU HAVE A COMPUTER AT HOME? (circle one) YES NO

DO YOU USE EMAIL? (circle one) YES NO

EMAIL ADDRESS ______________________________

DURING THIS SCHOOL YEAR:

DID YOU BREAK ANY BONES? (circle one) (YES / NO) WHICH BONE(S)? ____________

HOW LONG WAS IT IN A CAST? ____________

WERE YOU SICK FOR GREATER THAN A MONTH? (circle one) YES / NO

WHAT DID YOU HAVE? ____________________

WERE YOU IN THE HOSPITAL? (circle one) YES / NO) FOR HOW LONG? ________

ANTHROPOMETRY, JUMPS, pQCT and DXA:

MEASURERS: Anthro: ________ Jumps: ________

HEIGHT:	________	________	________
WEIGHT:	________	________	________
SITTING HEIGHT:	________	________	________
CALF GIRTH:	________	________	________
LONG JUMP:	________	________	________

Child's birthweight____________________(grams or lbs/ozs)

Nutrition History:

Who prepares your child's meals (i.e., mother, father, grandmother, nanny)________________________

Does your child drink milk every day?

______YES: if **yes:**

How many cups per day? ________

Has your child always drank milk every day (after being weaned from breast or bottle)?

yes ________ no ________

if **no**, at what age did she/he start drinking milk every day? ________ years old.

______NO: if **no:**

Has your child ever drank one or more cups of milk per day (after being weaned from breast or bottle)?

______ yes: at what age did she/he stop drinking milk every day? ________ years old.

How many cups did he/she drink until that age? ________ cups per day.

______ no : (never drank milk on a daily basis after being weaned)

Is your child on a special diet? ________ Yes ________ No

If **yes:** ________ vegetarian

________ low sodium

________ low cholesterol

________other

Please specify: ____

Medical History and Status:

Has your child ever been treated for any of the following conditions?

	Yes	No
food allergies	O	O
hypothyroidism	O	O
other allergies	O	O
hyperthyroidism	O	O
asthma	O	O

other conditions (please list)____

____

____

Is your child currently taking any medications? ________ Yes ________ No

If **yes**, what medication(s) is your child taking? ________________________

____

____

What are these medication(s) for? ________________________________

____

____

Has your family doctor ever said that your child has a heart condition and that he/she should only do physical activity recommended by a doctor? _______Yes _______No

Does your child complain of chest pain when they are doing physical activity?

_______Yes _______No

In the past month, has your child complained of chest pain when they were not doing any physical activity?

_______Yes _______No

Does your child have a bone or joint problem that could be made worse by a change in their physical activity?

_______Yes _______No

Does your child lose their balance because of dizziness or do they ever lose consciousness?

_______Yes _______No

Do you know of any other reason why your child should not participate in physical activity?

_______Yes _______No

Bone History:

Has your child ever been hospitalized, confined to bed or had a limb immobilized (i.e., arm in a cast)?

________ Yes ________ No

If **yes:** list condition, approximate date and time involved

(Example: wrist fracture summer, 1990 10 weeks)

Reason	Date	Time Involved

Is there a history of wrist, hip, or spine fractures in your family? ________ Yes _______ No

If **yes:** indicate who was affected

______ mother ______ father
______ maternal grandmother ______ paternal grandmother
______ maternal grandfather ______ paternal grandfather

Is there a history of osteoporosis in your family? _______ Yes _______ No

If **yes:** indicate who was affected

______ mother ______ father
______ maternal grandmother ______ paternal grandmother
______ maternal grandfather ______ paternal grandfather

Is there a history of any other bone disease in your family?

________ Yes ________ No

If **yes:** please indicate the family member(s) affected

1. ____
2. ____

What is the name of the condition(s) affecting this family member?

1. ____
2. ____

Physical Activity:

How would you rate the physical activity level of your child?

Physical activity is defined as vigorous activity that makes them sweat and/or breathe hard.

________ Inactive
________ Sometimes active
________ Moderately active

________ Often active
________ Very active

THANK YOU FOR YOUR PARTICIPATION

Action Schools! BC
Physical Activity Questionnaire

ID: ____

We would like to know about the physical activity you have done in the last 7 days. This includes sports or dance that make you sweat or make your legs feel tired, or games that make you huff and puff, like tag, skipping, running, and climbing.

Remember:

A. There are no right or wrong answers – this is not a test.

B. Please answer all questions as honestly and accurately as you can – this is very important.

---

1. PHYSICAL ACTIVITY IN YOUR **SPARE TIME (this <u>does not</u> include P.E classes).**

Have you done any of the following activities in the **past 7 days**? If yes, how many times and for how long? (Remember, **recess is 15 minutes long, and lunch is usually ½ an hour** (30 minutes)).

Tick only one circle per row	No	1-2	3-4	5-6	7 or more times		time per session
Skipping		O	O	O	O	O	____
Four Square		O	O	O	O	O	____
Creative Playground		O	O	O	O	O	____
Tag		O	O	O	O	O	____
Walking for exercise		O	O	O	O	O	____
Bicycling		O	O	O	O	O	____
Jogging or running	O	O	O	O	O		____
Swimming		O	O	O	O	O	____
Baseball, softball		O	O	O	O	O	____
Dance		O	O	O	O	O	____
Football		O	O	O	O	O	____
Badminton		O	O	O	O	O	____
Skateboarding/Scooter		O	O	O	O	O	____
Soccer		O	O	O	O	O	____
Street Hockey		O	O	O	O	O	____
Volleyball	O	O	O	O	O		____
Floor Hockey		O	O	O	O	O	____
Basketball		O	O	O	O	O	____
Ice skating		O	O	O	O	O	____
Cross-country skiing		O	O	O	O	O	____
Ice hockey/ringette	O	O	O	O	O		____
Martial Arts		O	O	O	O	O	____
Gymnastics		O	O	O	O	O	____
Rollerblading		O	O	O	O	O	____
Skiing/Snowboarding		O	O	O	O	O	____
Other: ____________		O	O	O	O	O	____

2. In the last 7 days, during your **PHYSICAL EDUCATION (PE) CLASSES**, how often were you very active (playing hard, running, jumping and throwing)? Check only one.

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

3. In the last 7 days, what did you do most of the time at **RECESS?** Check only one.

O Sat down (talking, reading, doing school work).
O Stood around or walked around.
O Ran or played a little bit.
O Ran around and played quite a bit.
O Ran and played hard most of the time.

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

O Sat down (talking, reading, doing school work)
O Stood around or walked around.
O Ran or played a little bit.
O Ran around and played quite a bit.
O Ran and played hard most of the time.

5. In the last 7 days, on how many days **RIGHT AFTER SCHOOL**, did you do sports, dance, or play games in which you were very active? Check only one.

O None.
O 1 time last week.
O 2 or 3 times.
O 4 times last week.
O 5 times last week.

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

O None.
O 1 time last week.
O 2 - 3 times.
O 4 - 5 times last week.
O 6 - 7 times last week.

7. How many times did you do sports, dance, or play games in which you were very active **LAST WEEKEND?** Check only one.

O None.
O 1 time.
O 2 - 3 times.
O 4 - 5 times.
O 6 or more times.

8. Which **ONE** of the following five statements describes you best for the last 7 days? Read all 5 before deciding on the one answer that describes you.

O All or most of my free time was spent doing things that involved **little physical effort** (e.g. watching TV, homework, playing computer games, Nintendo).

O **I sometimes (1-2 times last week) did physical things** in my free time (e.g. played sports went running, swimming, bike riding, did aerobics).

O **I often (3-4 times last week) did physical things** in my free time.

O **I quite often (5-6 times last week) did physical things** in my free time.

O **I very often (7 or more times last week) did physical things** in my free time.

9. How many hours per day did you watch television or play video games (Playstation, X-Box) or computer games last week? (each show is usually a half hour or 30 minutes). Check only one.

O I watched/played less than 1 hour or have no TV (or no video/computer games).
O I watched/played more than 1 hour but less than 2.
O I watched/played more than 2 hours but less than 3.
O I watched/played more than 3 hours but less than 4.
O I watched/played more than 4 hours.

10. Were you sick last week, or did anything prevent you from doing your normal physical activities?

O Yes
O No

If yes, what prevented you?____

11. Mark how often you did physical activity (like playing sports, games, doing dance or any other physical activity) for each day last week (this includes P.E, lunch, recess, after school, evenings, spare time, etc). **Circle the days that you had P.E. during the last week.**

	None	Little Bit	Medium	Often	Very Often
Monday	O	O	O	O	O
Tuesday	O	O	O	O	O
Wednesday	O	O	O	O	O
Thursday	O	O	O	O	O
Friday	O	O	O	O	O
Saturday	O	O	O	O	O
Sunday	O	O	O	O	O

12. Do you participate in **organized sport** (soccer, dance, karate etc.) outside of school?

O Yes
O No

13. Do you participate in other **organized activities** (music lessons, Chinese school tutoring, girl guides, boy scouts) outside of school?

O Yes
O No

14. If you do participate in organized sport or other activities, how many nights during the week do you do these sports and/or activities? (If you have swimming lessons on 2 nights of the week, check the circle beside "2" and write swimming lessons on the line. You can have more than one activity on a line).

SPORTS		OTHER ACTIVITIES	
O 1	________________	O 1	________________
O 2	________________	O 2	________________
O 3	________________	O 3	________________
O 4	________________	O 4	________________
O 5	________________	O 5	________________

O 6 ______________________ O 6 ______________________
O 7 ______________________ O 7 ______________________

15. During the last 7 days, on how many days did you **travel to school by car or by bus?**

O None.
O 1 time last week.
O 2 or 3 times.
O 4 times last week.
O 5 times last week.

16. During the last 7 days, on how many days did you **travel home from school by car or by bus?**

O None.
O 1 time last week.
O 2 or 3 times.
O 4 times last week.
O 5 times last week.

17. During the last 7 days, on how many days did you **walk or bike to school?**

O None.
O 1 time last week.
O 2 or 3 times.
O 4 times last week.
O 5 times last week.

18. During the last 7 days, on how many days did you **walk or bike home from school?**

O None.
O 1 time last week.
O 2 or 3 times.
O 4 times last week.
O 5 times last week.

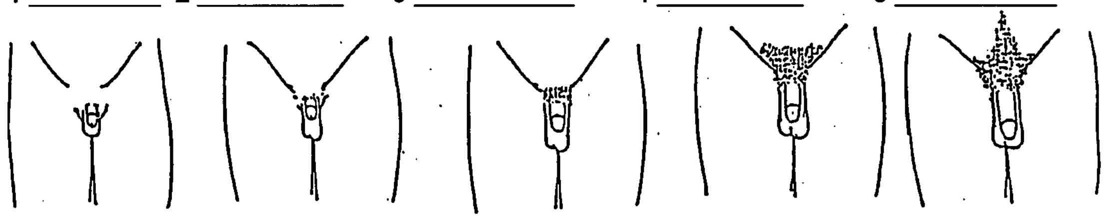
19. If you walk to and from school, how long does it take you? __________minutes

20. If you bike to and from school, how long does it take you? __________minutes

Action Schools! BC - Winter 2003 **Name:**

BOYS: After reading the descriptions under each drawing, please place a check mark above the drawing that looks most like your stage of pubic hair development. Seal your response in the envelope provided. Thank you!

1 ________ **2** ________ **3** ________ **4** ________ **5** ________



1	2	3	4	5
There is no pubic hair at all.	There is a small amount of long, lightly coloured hair. This hair may be straight or a little curly.	There is hair that is darker, curlier and thinly spread out to cover a somewhat larger area than in stage 2.	The hair is thicker and more spread out, covering a larger area than in stage 3.	The hair now is widely spread and covering a large area, like that of an adult male.

Self Assessment of Maturity Status: Boys

As you keep growing over the next few years, you will see changes in your body. These changes happen at different ages for different children, and you may already be seeing some changes, others may have already gone through some changes. Sometimes it is important to know how a person is growing without having a doctor examine them. It can be hard for a person to describe themselves in words, so doctors have drawings of stages that all children go through.

There are 5 drawings of pubic hair growth, which are attached for you to look at. All you need to do is pick the drawing that looks like you do now. Put a check mark above the drawing that is closest to you stage of development for pubic hair. Put the sheet in the envelope and seal it so your answer will be kept private.

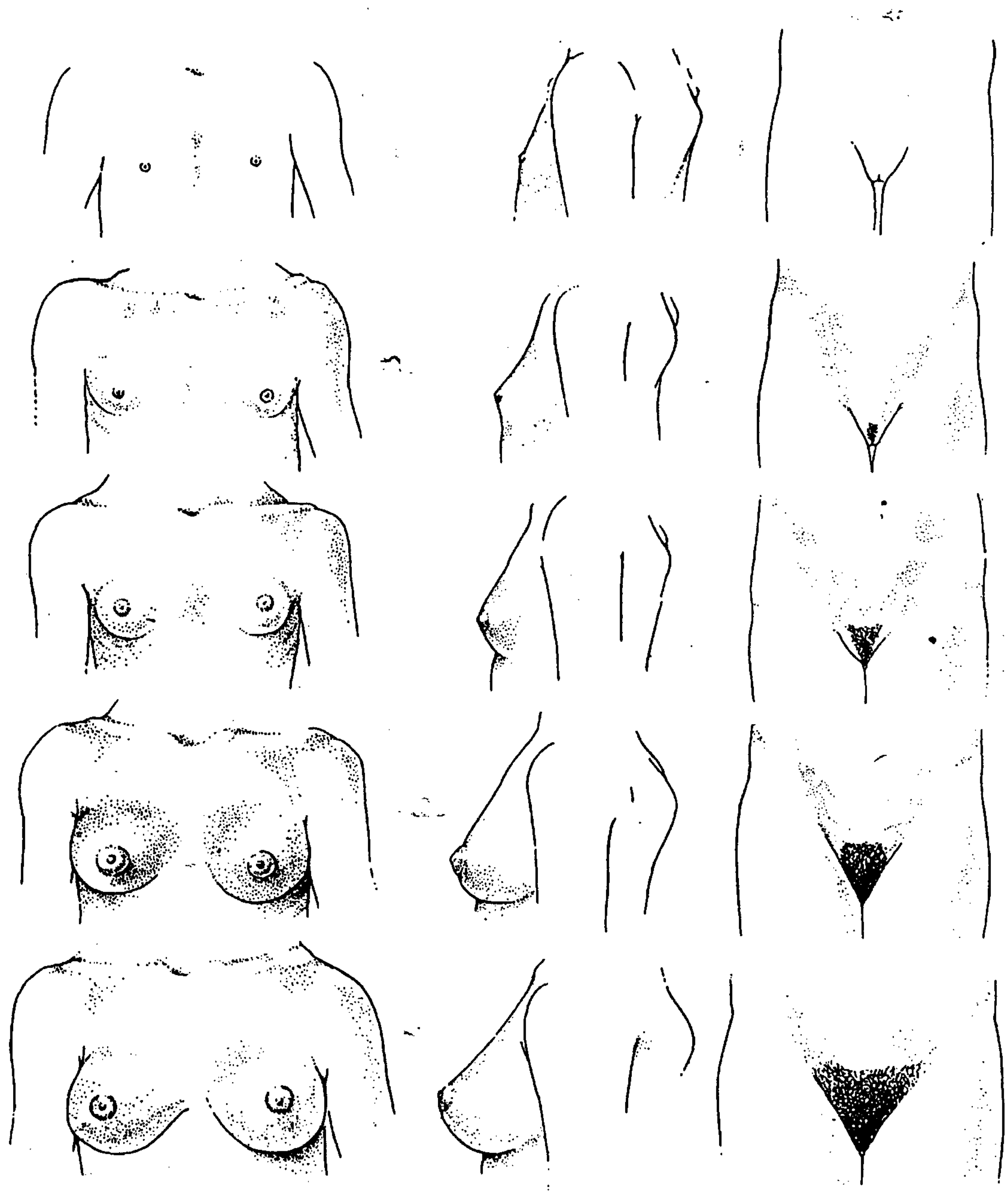
Action Schools! BC - Winter 2003 Name:

Please put a check mark on the drawing that looks most like (1) your stage of breast development, and (2) your stage of pubic hair development. Seal your response in the envelope provided. Thank you!

Have you had your 1st period? Yes _____ No _______

If yes, do you remember when? Month _______ Year

Choose one: ↓



____

Action Schools! BC
Cardiovascular Measurements

Name ______________________ **ID no** ______________________

School ______________________ **Grade** _________ **Date** ____________

Blood pressure Reading 1 ______________________

Reading 2 ______________________

Reading 3 ______________________

Flexibility

Sit and reach To nearest 0.5cm	1.	2.	max.	☐
Trunk lift To nearest 0.5cm	1.	2.	max.	☐

Strength

Curl up	☐		**Push ups**	☐
Grip	Right 1.	Right 2.	max	
	Left 1.	Left 2.	max	
			Total	☐

Laps run : ☐

10.3. APPENDIX C. STUDENT NUMBERS FROM FEBRUARY 2003 TO JUNE 2004

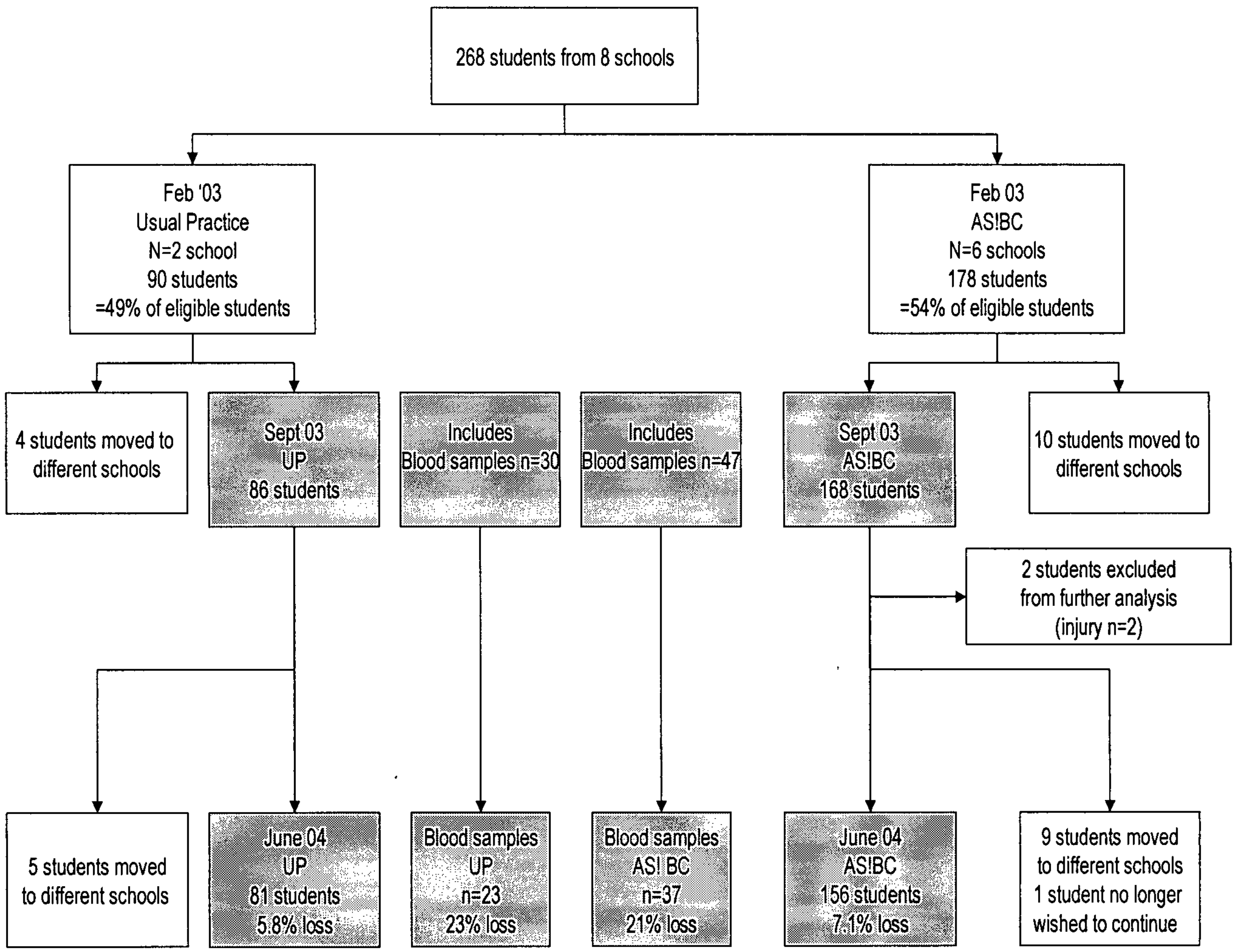


Figure 10.1 Flow diagram of subject numbers throught the timecourse of the study. Numbers of students in February and September 2003 and in June 2004 are shown.

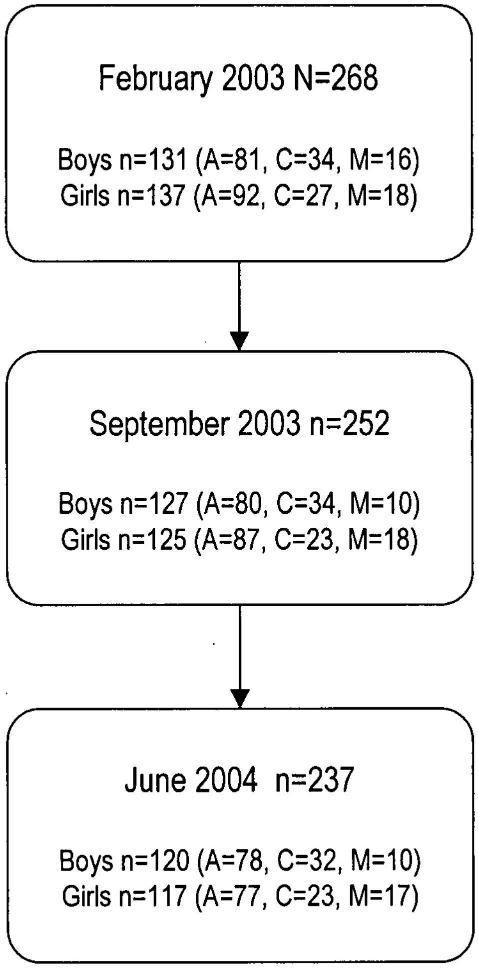


Figure 10.2 Flow diagram showing participant numbers by sex and race in February 2003, September 2003 and in June 2004. A=Asian, C=Caucasian, M=Mixed

10.4. APPENDIX D: AS! BC ADVISORY COMMITTEE MEMBERS

Table 10-1 AS! BC Advisory Committee Members

Name	Title
Marion Lay	President & CEO, 2010 Legacies Now
Patti Hunter	Director, Physical Activity and Healthy Living, 2010 Legacies Now
Bruce Dewar	Executive Vice President, 2010 Legacies Now
Marion Taylor	Consultant, 2010 Legacies Now - Action Kids! BC
Jane MacCarthy	Senior Communications and Media Relations Manager, 2010 Legacies Now – Sport & Recreation Now
Andrew Hazlewood	Assistant Deputy Minister, BC Ministry of Health
Laurie Woodland	Acting Executive Director, Healthy Living/Chronic Disease Prevention
Lori Zehr	Manager, Physical Activity/Chronic Disease Prevention/Healthy Living, BC Ministry of Health
Bobbi Plecas	Lead Director, Initiatives Department, BC Ministry of Education
Heather Hoult	Director, Health Promoting Schools, BC Ministry of Education
Sharon White	Policy Analyst/Sport Consultant, Ministry of Tourism, Sport and the Arts
Lee Southern	Executive Director, BC School Trustees Association
Tom Hierck	President, Principals & Vice Principals Association of BC
Shirley Wilson	External Committee Volunteer, BC Confederation of Parent Advisory Councils
Don Hutchinson	Middle School Teacher, Montgomery Middle School
Jane Hunter	Principal, RJ Tait Elementary School
Lorraine Greaves	Executive Director, BC Centre of Excellence for Women's Health
Michelle Kilborn	Teacher & President, Physical Education BC
Dr. Ron Wilson	Physician, BCMA – Athletics & Recreation Committee
Heather McKay	Principal Investigator, University of BC, Faculty of Medicine
PJ Naylor	Associate Director of Research, University of Victoria
Bryna Kopelow	Program Consultant, Manager, AS! BC, JW Sporta
Jennifer Fenton	Program Consultant, AS! BC, JW Sporta
Janice Macdonald	Regional Executive Director, Dieticians of Canada, BC Region
Douglas McCall	Executive Director, Joint Consortium for School Health
Kathy Cassels	DASH/Breakfast for Learning Coordinator, The Directorate of Agencies for School Health
Karen Strange	Healthy Eating Team, Action Schools! BC
Meghan Day	Graduate Student, Dietician, Healthy Eating Team, Action Schools! BC

10.5. APPENDIX E: EXAMPLES OF AN ACTION PLAN AND HEALTHY HEART ACTIVITIES.

Action Schools! BC

School Action Plan Sample
September to June

Action Schools! BC is a best practices model designed to assist schools in creating individualized Action Plans to promote healthy living.

Goal Statements *(see Guide)*	Actions *(see Guide)*	Date(s) or Timing for Action
Action Zone: School Environment – policies, professional development, facilities/equipment		
To increase the variety of equipment available To improve healthy choices in vending machines To provide sport skill development training for teachers	PAC fundraising Research vendors Survey teachers/conduct 2 in-services	November–March September–November October and February
Action Zone: Scheduled Physical Education – Gr 4-7 (150 min/wk) – Active Living, Movement, Personal & Social Responsibility		PE schedule (e.g. 2x40min/wk): 2x40min/wk
Achieve curriculum outcomes	Fitness Outdoor Action Dance Indoor Action Park Games	**Sept:** SportFit, Fitness Circuits **April:** Track **Oct:** Disc Sports **May:** Orienteering **Nov:** Multicultural **March:** Hip Hop **Dec-Feb:** Judo, Basketball, Gymnastics **June:** Kanga Ball, Badminton
Action Zone: Classroom Action – 15x5, health, nutrition		
Provide 15 min/day of physical activity (outside of scheduled PE)	Action Schools! BC Classroom Action 15x5*	All year, September–June
Action Zone: Family & Community – active field trips, guest demonstrations, family nights		
Maintain community physical activity experiences Encourage family involvement in school physical activity Increase community connections	Link with community programs off-site Sneaker Club* Provide 2 community presentations on-site	**Jan:** Skating **May–June:** Swimming **April-May** **Nov:** Esteem Team **Feb:** Wheelchair Basketball
Action Zone: Extra-Curricular – clubs, intramurals, team sports		
Increase physical activity opportunities for girls Increase sport skill opportunities for all	Girls only gym time Non-competitive intramural program	Tuesday mornings and Thursdays at lunch **Fall:** Badminton **Winter:** Floor Hockey **Winter:** Yoga **Spring:** Kanga Ball
Action Zone: School Spirit – school wide events		
Increase opportunity for more to be more active Maintain school wide participation in events	Join intermediate grades together for 2 events Terry Fox Run Sports Day	**Dec:** Mini-Olympics **June:** Splish Splash Bash **September** **May**

Abbreviations
r = recess
l = lunch
wk = week
* Refer to Classroom Action Resource

Community Activity Choices:
swimming, bowling, bicycling, martial arts, golfing, curling, canoeing, hiking, skateboarding, skiing, skating

Community Presentations:
Esteem Team
Wheelchair Basketball Demo
Multicultural
Other Sport Demo

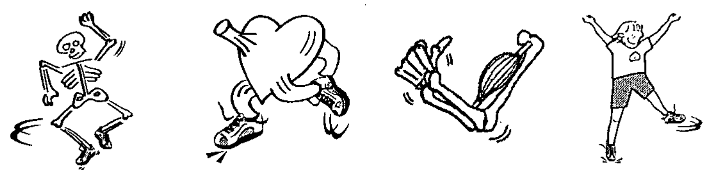
PE Themes:
Fitness, Playground Games, Outdoor Action, Dance, Indoor Action, Park Games (see Action Zone: Scheduled Physical Education section in the Planning Guide for activities in each theme).

School Spirit Events:
water day, beach day
fun sports day
Summer/Winter Active
mini-olympics

Fitness circuits (in/outdoors)

Description: Fitness circuits are fun and easy ways to teach students about cardiovascular and muscle fitness and muscle identification while improving their overall health.

Health Targets:



Learning Outcomes (see p. 57):
✓ **Active Living**
✓ **Movement**
✓ **Personal & Social Responsibility**

Equipment:
Mats
Benches, chairs, hurdles
Exercise bands (in Action Bin)
Skipping ropes (single) (in Action Bin)
Skipping ropes (double, Chinese)
Hoops, cones, buckets
Balls, beanbags, beach balls

Implementation Ideas:
- Fill buckets with different "instant" activities and distribute around the gym or multipurpose room for a quick circuit break (e.g. racquets and birdies, skipping ropes, exercise bands, cards with specific activities).

Recommended Resources:
1. *Action Schools! BC Classroom Action Resource (FREE download or order) (in Action bin) (refer to Action Pages!)*
2. *Ever Active…Everywhere (in Action Bin) Fitness Frantics, pp.54-64*
3. *Ready-to-Use P.E. Activities for Grades 5-6 (refer to Action Pages!)*
4. *Station Games (refer to Action Pages!)*
5. *Dance and Fitness Workshops by Judy Howard (refer to Action Pages!)*
6. *Sittercise CD (refer to Action Pages!)*

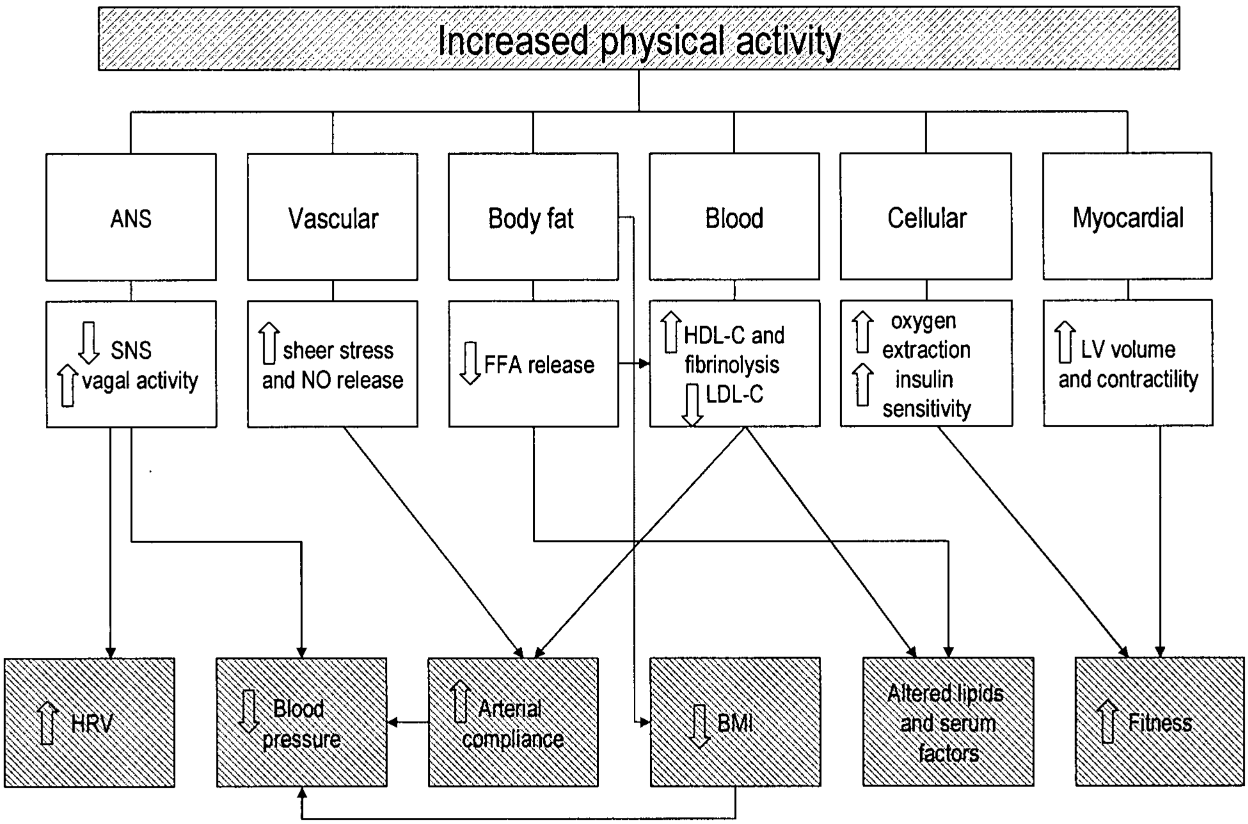

Action Schools! BC
Classroom Action Resource
Action Pages!
A PHYSICAL ACTIVITY AND SPORT EDUCATION RESOURCE GUIDE

Action Bin

10.6. APPENDIX F: AETIOLOGICAL PATHWAY OF CHANGE IN RISK FACTORS

Figure 10.3 Possible aetiological pathways of changes in outcome variables to be assessed in Action Schools! BC resulting from increased physical activity

ANS=autonomic nervous system, SNS=sympathetic nervous system, HRV=heart rate variability, NO=nitric oxide, FFA=free fatty acid, HDL-C=high density lipoprotein cholesterol, LDL-C=low density lipoprotein cholesterol, BMI=body mass index, LV=left ventricular



10.7. APPENDIX G: STATISTICAL CONSIDERATIONS

Table 10-2 Intracluster coefficients (ICC) and variance inflation factors for baseline data, used in the cluster analysis model

	ICC	VIF
Fitness (laps)	0.03	1.72
Systolic blood pressure	0	1
Diastolic blood pressure	0.06	2.41
Body mass index	0	1
Push ups	0.009	1.19
Curl ups	0.002	1.05
Total cholesterol	0.02	1.17
High density lipoprotein	0.028	1.24
Low density lipoprotein	0.042	1.36
TC:HDL	0.003	1.02
Triglycerides	0.010	1.08
Apolipoprotein B	0	1
Lipoprotein (a)	0.038	1.33
C-reactive protein	0.002	1.02
Fibrinogen	0.011	1.09
Homocysteine	0.014	1.12

Table 10-3 Normal ranges for FITNESSGRAM and blood pressure by age and sex

	Age (years)	Girls	Boys
Leger test * (no. 20-m laps)	10	15-41	23-61
	11	15-41	23-72
	12	23-41	32-72
Curl ups * (number)	10	12-26	12-24
	11	15-29	15-28
	12	18-32	18-36
Push ups* (number)	10	7-15	7-20
	11	7-15	8-20
	12	7-15	10-20
Blood pressure (mmHg)	10	86- 116	87 - 117
Systolic**	11	88 -119	88 - 120
	12	89 - 120	90 - 122
Diastolic**	10	47- 70	48 - 72
mmHg	11	48 - 70	49 - 73
	12	48 - 71	49 - 74

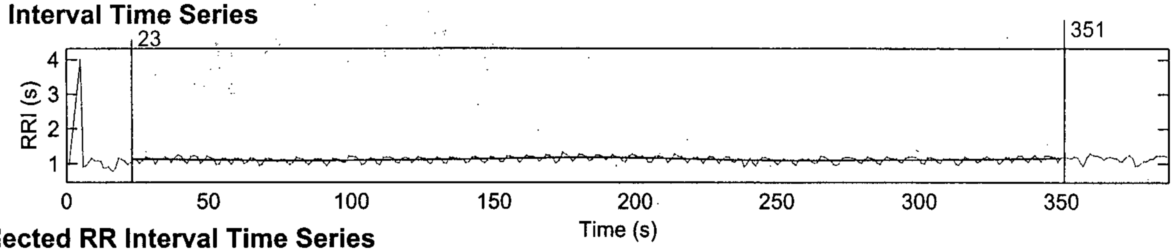
* indicates normal values taken from the California Department of Education achievement criteria tables.

** indicates values calculated according to National High Blood Pressure Education Program Standards, 2004. This is for an average height child. Taller children will have higher blood pressure. These values are the 10th and 90th percentiles (approximately)

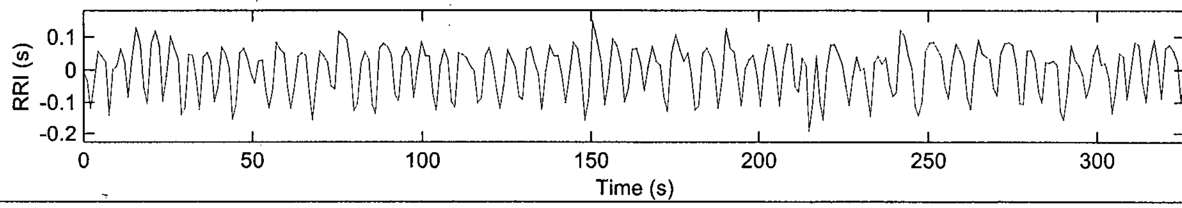
10.8. APPENDIX H: HEART RATE VARIABILITY ANALYSIS EXAMPLE

Heart Rate Variability Analysis

RR Interval Time Series



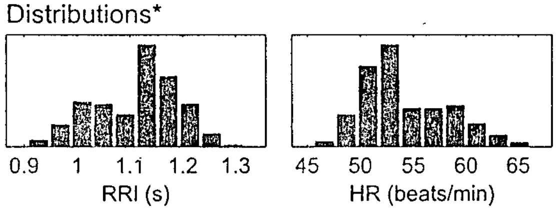
Selected RR Interval Time Series



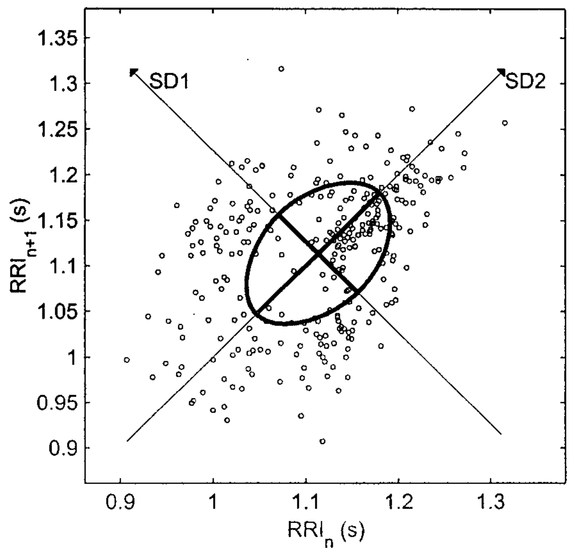
Time Domain Results

Variable	Units	Value
Statistical Measures		
Mean RR*	(s)	1.113
STD	(s)	0.073
Mean HR*	(1/min)	54.18
STD	(1/min)	3.84
RMSSD	(ms)	85.1
NN50	(count)	161
pNN50	(%)	54.9
Geometric Measures		
RR triangular index		0.099
TINN	(ms)	280.0

Distributions*

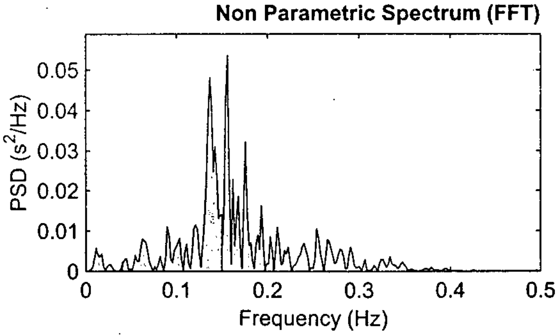


Poincare Plot* SD1 = 60.5 ms ↔ (Short-term HRV)
SD2 = 94.3 ms ↔ (Long-term HRV)



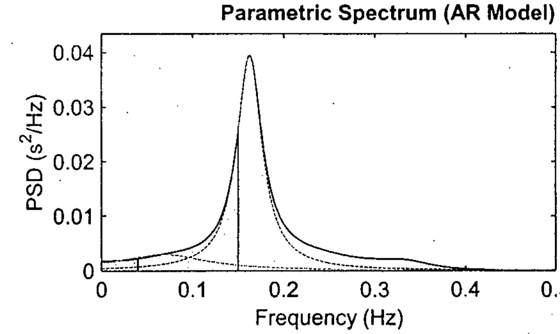
Frequency Domain Results

Non Parametric Spectrum (FFT)



Frequency Band	Peak (Hz)	Power (ms^2)	Power (%)	Power (n.u.)
VLF	0.0117	59	2.9	
LF	0.1367	884	42.7	43.9
HF	0.1563	1128	54.5	56.1
LF/HF			0.783	

Parametric Spectrum (AR Model)



Frequency Band	Peak (Hz)	Power (ms^2)	Power (%)	Power (n.u.)
VLF	0.0000	0	0.0	
LF	0.0664	217	9.9	8.5
HF	0.1621	1974	90.1	77.4
LF/HF			0.110	

10.9. APPENDIX I: MODEL DELIVERY INFORMATION BY SCHOOL

Table 10-4 Minutes of physical activity delivery per week (April to June 2003 and September to June 2004) and Teacher's Log Compliance for Usual Practice and AS! BC Schools September 2003 – June 2004. The maximum number of weeks for which Activity Logs could be submitted was 32.

Randomization	April-June			Sept-June			
	No. classes	No. students per class evaluated Range	PA delivery min/week Mean (SD)	No. classes	No. students per class evaluated Range	PA delivery min/week Mean (SD)	Compliance % Mean (range)
UP 1	3	5-12	123 (37)	4	4-6	90 (40)	99 (97-100)
UP 2*	5	4-18	220 (71)	5	6-14	75 (42)	82 (53-100)
UP 3*	6	4-24	140 (22)	7	2-13	90 (35)	94 (75-100)
AS! BC 1 (L)*	3	9-20	170 (60)	2	12-18	160 (50)	100 (100-100)
AS! BC 2 (L)*	4	8-17	205 (45)	5	6-13	110 (40)	93 (78-100)
AS! BC 3 (L)*	4	6-12	187 (62)	6	3-9	160 (60)	97 (88-100)
AS! BC 4 (L)*	4	14-19	158 (72)	5	7-20	130 (30)	96 (88-100)
AS! BC 5 (C)*	5	7-13	116 (84)	6	3-10	120 (30)	76 (0-94)
AS! BC 6 (C)*	5	5-23	198 (30)	5	4-20	135 (35)	93 (78-100)
AS! BC 7 (C)	2	14-16	214 (26)	5	4-7	190 (40)	95 (88-100)

UP=Usual Practice School, AS! BC (L) = Intervention School Liaison Arm, AS! BC (C) = Intervention School Champion Arm. * indicates those schools that were involved in Healthy Hearts Measurement (n=8). Teacher log compliance was not recorded April-June due to differences in start dates.

10.10. APPENDIX J: ADDITIONAL DATA FOR STUDIES 1-6

Table 10-5 Baseline data, shown by race and sex (February 2003 data). Data are mean (SD) (n=268)

	Age (years)	Height (cm)	Weight (kg)	BMI	SBP mmHg	DBPmmHg	Laps	PAQ-C	PA min/day
All (n=268)	10.2 (0.5)	141.4 (7.3)	36.7 (8.5)	18.3 (3.3)	104 (11.4)	65 (8.4)	22 (9.4)	2.55 (0.5)	81 (55)
Boys (n=131)	10.2(0.5)	141.5 (7.0)	37.4 (9.3)	18.5 (3.7)	104 (11.8)	66 (9.1)*	23(10.8)*	2.59 (0.5)	90 (61)*
Girls (n=137)	10.2 (0.5)	141.3 (7.7)	36.1 (7.7)	18.1 (2.9)	103 (11.1)	64 (7.5)*	21 (7.8)*	2.51 (0.4)	72 (47)*
Asian (n=173)	10.2 (0.5)	140.1 (6.9)	35.7 (8.1)	18.0 (3.2)	103(11.8)	65 (8.4)	21 (8.8)	2.47 (0.5)†	70 (51)†
Boys (n=81)	10.2 (0.5)	139.3 (6.1)*	36.0 (9.2)	18.3 (3.8)	103 (13.0)	66 (10.2)	23 (10.9)	2.46 (0.5)**	72 (55)**
Girls (n=92)	10.2 (0.5)	140.9 (7.4)	35.4 (6.9)	17.7 (2.5)	104 (10.9)	65 (6.7)	20 (6.7)**	2.49 (0.4)	68 (48)
Cauc (n=61)	10.2 (0.5)	143.9 (7.6)	38.7 (9.4)	18.8 (3.7)	105 (10.9)	66 (8.1)	25 (10.8)	2.67 (0.5)†	104 (59)†
Boys (n=34)	10.3 (0.5)	144.8 (7.6)*	39.8 (9.7)	19.1 (3.8)	106 (11.7)	67 (8.2)	24 (11.0)	2.77 (0.5)**	121 (59)**
Girls (n=27)	10.2 (0.5)	142.5 (7.5)	37.1 (8.9)	18.4 (3.6)	103 (9.4)	64 (7.8)	26 (10.6)**	2.52 (0.5)	81 (52)
Mixed (n=34)	10.2 (0.5)	142.3 (7.5)	38.0 (8.8)	18.6 (3.2)	103 (10.9)	64 (8.7)	22 (9.4)	2.64 (0.5)†	83 (50)†
Boys (n=16)	10.1 (0.5)	142.9 (6.5)*	38.1 (8.6)	18.5 (3.1)	104 (7.8)	66 (7.2)	24 (10.8)	2.75 (0.5)**	93 (60)
Girls (n=18)	10.4 (0.5)	141.6 (8.6)	37.9 (9.2)	18.7 (3.3)	103 (13.4)	62 (9.5)	19 (7.4)**	2.54 (0.5)	74 (36)

SBP= systolic blood pressure (mmHg), DBP= diastolic blood pressure (mmHg), BMI= body mass index (kg/m^2), Laps = number of laps run in Legers 20-m shuttle test, PAQ-C= physical activity questionnaire for children, PA min = minutes of physical activity per day (derived from questionnaire)

† significant differences between races, * significant difference between sexes , ** significant difference between races in one sex only

Table 10-6 Pearson Product Moment Correlation Coefficients of CVD risk factors, February 2003 (n=268)

	SBP	BMI	Weight	Laps	PAQ-C	Total fat	Trunk fat
DBP	0.66*	0.13*	0.27*	-0.15*	-0.01	0.16*	0.15*
SBP		0.26*	0.33*	- 0.13*	-0.08	0.28*	0.26*
BMI			0.91*	- 0.35*	-0.29*	0.87*	0.83*
Weight				- 0.26*	-0.31*	0.75*	0.73*
Laps					0.38*	- 0.49*	- 0.49*
PAQ-C						- 0.38*	- 0.35*
Total fat							0.98*

SBP= systolic blood pressure (mmHg), DBP= diastolic blood pressure (mmHg), BMI= body mass index (kg/m^2), Laps = number laps in Legers 20-m shuttle, PAQ-C= physical activity questionnaire for children,
Total fat and trunk fat estimated from DXA

Table 10-7 Pearson Product Moment Correlation Coefficients of serum factors, BMI and fitness (Baseline 2003) (n=77)

	HDL	TRG	LDL	Ratio	Lpa	Hcy	CRP	Fg	BMI	Laps
TC	0.26*	0.21	0.88*	0.34*	0.26*	0.23*	0.05	0.19	0.18	-0.09
HDL		- 0.57*	-0.15	- 0.79*	0.02	0.14	-0.21	-0.01	- 0.40*	0.18
TRG			0.29*	0.73*	0.09	0.17	0.28*	0.09	0.44*	-0.01
LDL				0.59*	0.26*	0.14	0.09	0.19	0.30*	-0.22
Ratio						0.05	0.29*	0.17	0.54*	-0.19
Lpa						0.11	-0.15	0.18	-0.06	0.10
Hcy							0.26*	0.09	0.03	0.16
CRP								0.59*	0.47*	- 0.28*
Fg									0.27*	- 0.26*
BMI										- 0.35*

TC=total cholesterol, HDL=high density lipoprotein cholesterol, LDL= low density lipoprotein cholesterol, TG=triglycerides, ratio=TC/HDL, Lpa=lipoprotein a, Hcy=homocysteine, CRP= C-reactive protein, Fg=fibrinogen, BMI=body mass index, Laps= Laps = number laps in Legers 20-m shuttle

Table 10-8 Serum factors at baseline shown by race and sex. Data are mean (SD) (n=77)

	TC	HDL	TRG	LDL	Ratio	Lpa	Hcy	CRP	Fg
Group	4.47	1.42	0.91	2.61	3.32	377.1	5.01	1.42	2.93
mean	(0.66)	(0.37)	(0.50)	(0.58)	(0.90)	(420.8)	(0.78)	(2.66)	(0.54)
Boys	4.34	1.41	0.84	2.53	3.23	322.3	4.94	1.67	2.86
n=40	(0.64)	(0.39)	(0.53)	(0.52)	(0.83)	(411.4)	(0.88)	(2.94)	(0.52)
Girls	4.61	1.43	1.01	2.69	3.43	436.4	5.08	1.17	3.01
n=37	(0.66)	(0.39)	(0.45)	(0.64)	(0.97)	(428.4)	(0.66)	(2.32)	(0.55)
Asians	4.68**	1.54**	0.96	2.70	3.29	459.3	5.20	1.14	2.93
n=26	(0.58)	(0.45)	(0.59)	(0.57)	(1.05)	(90.1)	(0.98)	(2.89)	(0.51)
Boys	4.85*	1.58	0.91	2.85*	3.37	520.5	5.38	1.75	2.99
n=13	(0.54)	(0.53)	(0.69)	(0.44)	(1.12)	(590.6)	(1.11)	(4.02)	(0.62)
Girls	4.52	1.50	1.01	2.55	3.22	345.7	5.04	0.53	2.86
n=13	(0.58)	(0.37)	(0.47)	(0.65)	(1.01)	(272.3)	(0.84)	(0.56)	(0.41)
Caucasians	4.29**	1.33**	0.88	2.50	3.38	386.3	4.96	1.76	2.94
n=34	(0.64)	(0.31)	(0.43)	(0.61)	(0.89)	(448.6)	(0.62)	(2.91)	(0.59)
Boys	4.10*	1.34	0.72	2.42*	3.13	217.6	4.78	1.66	2.82
n=20	(0.57)	(0.27)	(0.29)	(0.51)	(0.54)	(233.1)	(0.67)	(2.43)	(0.46)
Girls	4.57	1.31	1.12	2.74	3.74	627.3	5.20	1.91	3.12
n=14	(0.66)	(0.36)	(0.49)	(0.69)	(1.16)	(570.1)	(0.47)	(3.58)	(0.73)
Mixed	4.48	1.42	0.92	2.57	3.24	273.1	4.82	1.18	2.90
n=17	(0.74)	(0.33)	(0.52)	(0.58)	(0.69)	(282.4)	(0.69)	(1.61)	(0.49)
Boys	4.04*	1.32	1.02	2.24*	3.22	253.4	4.61	1.53	2.73
n=7	(0.38)	(0.30)	(0.69)	(0.44)	(0.95)	(321.3)	(0.69)	(2.29)	(0.55)
Girls	4.81	1.51	0.84	2.80	3.25	286.8	4.97	0.94	3.02
n=10	(0.78)	(0.34)	(0.40)	(0.57)	(0.49)	(269.3)	(0.67)	(0.98)	(0.44)

TC=total cholesterol, HDL=high density lipoprotein cholesterol, LDL= low density lipoprotein cholesterol, TG=triglycerides, ratio=TC/HDL, Lpa=lipoprotein a, Hcy=homocysteine, CRP= C-reactive protein, Fg=fibrinogen

Ratio is total cholesterol / high density lipoprotein.

** Asians had significantly higher total cholesterol and a higher HDL than Caucasians

* Asian Boys had a significantly higher total cholesterol and LDL cholesterol compared with boys from Mixed group

Table 10-9 Baseline arterial compliance data (September 2003) shown by race and sex. Data are mean (SD) (n=99).

		Asian (n=53)	Caucasian (n=35)	Mixed (n=11)
All (n=99)	Large artery	9.6 (2.1)	10.0 (1.6)	9.8 (2.7)
	Small artery	6.6 (1.8)	6.1 (1.6)	6.4 (1.5)
Boys (n=55)	Large artery	9.7 (2.4)	9.9 (2.3)	10.5 (1.8)
	Small artery	7.1 (1.7)	6.6 (1.7)	6.7 (1.2)
Girls (n=44)	Large artery	10.3 (1.3)	9.7 (3.1)	9.6 (1.4)
	Small artery	6.1 (1.8)	5.6 (1.4)	6.2 (1.8)

Large artery compliance is m/mmHg x 100, small artery compliance is ml/mmHg x 10

There were no significant differences between races ($p>0.05$).

Table 10-10 Cardiovascular variables (September 2003) shown by race and sex. Data are mean (SD) (n=252)

	SBP	DBP	BMI	Laps	PAQ-C	PA min/day
All (n=252)	105 (9.5)	62 (7.9)	19.1 (3.5)	29 (13.2)	2.59 (0.53)	74 (40)
Boys (n=127)	106 (9.7)	62 (8.0)	20.3 (3.9)	29 (12.7)	2.66 (0.56)*	75 (42)
Girls (n=125)	104 (9.2)	62 (7.9)	17.9 (2.7)	28 (13.8)	2.52 (0.51)*	74 (39)
Asian (n=167)	104 (9.3)	62 (8.1)	18.5 (3.4)	27 (12.3)	2.55 (0.53)	65 (51) †
Boys (n=80)	105 (9.3)	62 (8.0)	19.3 (4.0)	28 (12.2)	2.63 (0.53)	67 (55) **
Girls (n=87)	103 (9.1)	62 (8.1)	17.8 (2.3)	27 (11.8)	2.48 (0.51)	63 (48)
Caucasian (n=57)	105 (10.3)	61 (7.9)	19.5 (3.7)	31 (15.1)	2.71 (0.53)	100 (59) †
Boys (n=34)	106 (10.9)	63 (8.4)	19.9 (4.1)	31 (15.7)	2.77 (0.58)	117 (59) **
Girls (n=23)	105 (9.6)	60 (6.7)	18.9 (3.7)	32 (14.3)	2.58 (0.43)	78 (52)
Mixed (n=28)	106 (10.8)	63 (7.7)	19.1 (3.5)	26 (125)	2.66 (0.54)	80 (50)
Boys (n=10)	109 (11.6)	63 (7.3)	19.2 (3.3)	28 (14.4)	2.67 (0.55)	90 (60)
Girls (n=18)	105 (10.3)	64 (8.2)	18.9 (3.7)	25 (11.6)	2.64 (0.55)	71 (36)

SBP= systolic blood pressure (mmHg), DBP= diastolic blood pressure (mmHg), BMI= body mass index (kg/m^2), Laps = number of laps run in Legers 20-m shuttle test, PAQ-C= physical activity questionnaire for children, PA min = minutes of physical activity per day (derived from questionnaire)

† significant differences between races

** significant difference between races - boys

* significant difference between sexes

Table 10-11 Cardiovascular variables at final measurement (June 2004) shown by race and sex. Data are mean (SD) (n=237)

	SBP	DBP	BMI	Laps	PAQ-C	PA min/day
All (n=237)	104.0 (10.9)	63.3 (6.9)	19.2 (3.5)	35.6 (15.6)	2.69 (0.53)	90 (61)
Boys (n=120)	104.7 (11.5)	63.4 (6.3)	19.8 (4.0)*	37.7 (17.4)*	2.67 (0.56)*	102 (67)
Girls (n=117)	102.8 (10.2)	63.2 (7.5)	18.7 (2.9)*	33.2 (13.1)*	2.59 (0.51)*	78 (52)*
Asian (n=155)	103.9 (11.2)	63.1 (6.7)	19.0 (3.4)	35.5 (15.3)	2.55 (0.53) †	77 (52) †
Boys (n=78)	105.3 (12.1)	62.7 (7.8)	19.6 (4.0)	38.2 (17.4)	2.66 (0.53)	87 (59)**
Girls (n=77)	102.6 (10.1)	63.4 (6.4)	18.4 (2.5)	32.5 (12.1)	2.51 (0.51)	67 (43)***
Caucasian (n=55)	103.2 (10.3)	63.7 (7.8)	19.7 (3.8)	37.3 (16.0)	2.77 (0.53) †	117 (74) †
Boys (n=32)	103.0 (11.1)	63.9 (8.6)	20.3 (4.2)	36.9 (16.9)	2.81 (0.58)	134 76**
Girls (n=23)	103.6 (9.7)	63.4 (6.8)	19.0 (3.1)	37.8 (15.1)	2.68 (0.43)	96 (66)
Mixed (n=27)	104.0 (10.7)	63.8 (6.5)	19.5 (3.7)	32.8 (16.1)	2.69 (0.54)	108 (61)***
Boys (n=10)	105.8 (9.0)	64.4 (7.2)	19.5 (3.3)	36.3 (19.1)	2.70 (0.55)	120 68
Girls (n=17)	102.8 (11.9)	63.4 (8.2)	19.5 (4.1)	30.6 (13.7)	2.68 (0.55)	100 (56)***

† significant differences between races
*** significant difference between races: girls, ** significant difference between races: boys
* significant difference between sexes

Table 10-12 Pearson Product Moment Correlation Coefficients of change in CVD risk factors and anthropometric variables (September 2003-June 2004) (n=237)

	Weight	BMI	SBP	DBP	Laps	PA
Height	0.24*	-0.15*	-0.01	-0.09	0.17*	-0.05
Weight		0.87*	0.21*	-0.19*	-0.08	0.01
BMI			0.09	0.01	-0.16*	0.01
SBP				0.30*	-0.16*	0.19*
DBP					0.03	-0.14*
Laps						-0.13

SBP= systolic blood pressure (mmHg), DBP= diastolic blood pressure (mmHg), BMI= body mass index (kg/m^2), Laps = number of laps run in Legers 20-m shuttle test, PA min = minutes of physical activity per day (derived from questionnaire. * significant correlation $p<0.05$

Table 10-13 Pearson Product Moment Correlations of change in serum and CVD risk factors between Baseline 2003 and Final 2004 (n=60)

	HDL	TRG	LDL	Ratio	Hcy	CRP	Fg	ApoB	Laps	BMI	Total fat
TC	0.42*	0.26*	0.83*	0.30*	0.21	-0.33*	-0.08	0.81*	-0.04	0.28*	0.42*
HDL		-0.43*	0.21	-0.67*	0.22	-0.38*	0.06	0.17	0.05	-0.14	-0.13
TG			-0.01	0.66*	0.06	-0.07	-0.14	0.26*	-0.06	0.28*	0.37*
LDL				0.36*	0.16	-0.13	0.01	0.72*	-0.01	0.26*	0.34*
Ratio					-0.01	0.29*	0.02	0.39*	-0.02	0.39*	0.49*
Hcy						-0.12	0.15	0.21	-0.03	-0.18	-0.12
CRP							0.59*	-0.10	0.07	0.07	-0.02
Fg								0.02	0.19	-0.07	-0.10
ApoB									-0.10	0.30*	0.46*
Laps										-0.25	-0.22
BMI											0.85*

TC=total cholesterol, HDL=high density lipoprotein cholesterol, LDL= low density lipoprotein cholesterol, TG=triglycerides, ratio=TC/HDL, Lpa=lipoprotein a, Hcy=homocysteine, CRP= C-reactive protein, Fg=fibrinogen, ApoB=Apolipoprotein B, BMI= body mass index (kg/m^2), Laps = number of laps run in Legers 20-m shuttle test, total fat is estimated from DXA. * significant correlation $p<0.05$