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Young investigator Research article

Determining cardiovascular disease risk in elementary school children: Developing a healthy heart score

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Abstract
At least 50% of children have one or more cardiovascular disease (CVD) risk factor. We aimed to 1) determine the prevalence of CVD risk factors in a sample of Canadian children, and 2) create a Healthy Heart Score that could be used in a school setting, to identify children with a greater number and *severity* of CVD risk factors. Children (n = 242, 122M, 120F, aged 9-11 years) were assessed for cardiovascular fitness, physical activity, systolic/diastolic blood pressure, and body mass index (BMI). Biological values were converted to age and sex specific percentiles and allocated a score. Healthy Heart Scores could range between 5 and 18, with lower scores suggesting a healthier cardiovascular profile. Seventy-seven children volunteered for blood samples in order to assess the relationship between the Healthy Heart Score and (total cholesterol (TC), high and low-density lipoprotein cholesterol (HDL, LDL) and triglycerides (TG). Fifty eight percent of children had elevated scores for at least 1 risk factor. The group mean Healthy Heart Score was 8 (2.2). The mean score was significantly higher in boys (9 (2.2)) compared with girls (8 (2.1), $p < 0.01$). A high score was significantly associated with a low serum HDL, a high TC:HDL and a high TG concentration. Our results support other studies showing a high prevalence of CVD risk factors in children. Our method of allocation of risk score, according to percentile, allows for creation of an age and sex specific CVD risk profile in children, which takes into account the severity of the elevated risk factor.

Key words: Cardiovascular, children, physical activity, cardiovascular fitness, risk factors.

Introduction

Cardiovascular disease is the leading cause of morbidity and mortality for both men and women in most developed countries. In Canada alone, treatment of the disease uses $18 billion dollars of the annual health care budget (Health-Canada, 2002).

It is widely accepted that the atherosclerotic process begins in childhood and progresses through adulthood (Strong et al., 1992). Research from the Bogalusa heart study determined that as the number of CVD risk factors increases, so does the severity of both coronary and aortic atherosclerosis in young people (Berenson et al., 1998). Risk factors for development of CVD include hypertension, smoking, low physical activity, diabetes, obesity, a high ratio of total to high-density cholesterol and a family history of heart disease. As many as 50% of children are believed to exhibit one or more CVD risk factor (Ribeiro et al., 2004) with some, though not all, studies reporting clustering (presence of more than one risk factor) to be higher in boys (Raitakari et al., 1994; Twisk et al., 1999). Investigations that reported the clustering of risk factors in children frequently classified an individual as having an elevated risk factor if the level was above the 75th percentile for that measure. Unlike adult based investigations, the severity of a risk factor is not normally assessed in paediatric 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. Researchers from the Framingham Heart Study created several algorithms, that predict risk of coronary heart disease using biological and lifestyle factors (Wilson et al., 1998). In such models, the time course and probability of an event has been calculated using risk ratios derived from adult levels of risk factors, which may have been present for some time. However, using adult-specific algorithms is inappropriate for predicting CVD risk in children.

The prediction of a cardiac event from childhood risk factor clustering is not yet possible. Despite this, the presence of risk factors in youth is known to be associated with the extent of arterial wall damage (Berenson et al., 1998) and intima-media thickness in adulthood (Raitakari et al., 2003). Furthermore, tracking (maintenance of relative rank) occurs from childhood to adulthood for many CVD risk factors, including blood pressure, obesity, serum cholesterol concentration, cardiovascular fitness and physical activity (Nicklas et al., 2002; Twisk et al., 1997). Thus, assessment and modulation of CVD risk factors during childhood is essential. There is currently a widespread prevalence of risk factors in children (Raitakari et al., 1994; Ribeiro et al., 2004; Twisk et al., 1999). This suggests that a population based prevention approach maybe required, as opposed to methods that solely target individuals deemed to be at higher risk for CVD. The Committee on 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 (Hayman et al., 2004) .

Consequently, the primary 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. We aimed to create a score

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that was independent of both age and sex that could incorporate both number and severity of CVD risk factors. Our secondary aim was to compare the difference in risk factor clustering and severity between young girls and boys using this score. As previous studies have shown a higher incidence of clustering of risk factors in boys, we hypothesised that girls would have a significantly better score than age-matched boys. We aimed to correlate the Healthy Heart Score with various serum lipid concentrations in a sub-group of children as a preliminary validation technique.

Methods

Rationale for choice of factors included in the profile

One criterion for including factors into the profile was a school nurse or trained classroom teacher could easily measure them. Thus, factors such as TC or HDL concentration, despite their relationship with CVD, were not included.

We included systolic blood pressure and diastolic blood pressure, as they are established risk factors in adults (Wilson et al., 1998). Furthermore, childhood blood pressure is a strong predictor of adult blood pressure explaining up to 25% of the adult variance in blood pressure (Bao et al., 1995). BMI is associated with several important CVD risk factors in both adults and children, such as left ventricular hypertrophy, insulin resistance and endothelial dysfunction (Reilly et al., 2003). Cardiovascular fitness is associated with several important CVD risk factors variables, including high-density lipoprotein concentration, and has recently been identified as an independent risk factor for CVD (Wei et al., 1999). Poor cardiovascular fitness during youth and young adulthood is associated with development of diabetes, hypertension and metabolic syndrome in later life (Carnethon et al., 2003). Regular physical activity in childhood is associated with several CVD risk factors including a healthy serum lipid profile (Raitakari et al., 1997), endothelial function (Abbott et al., 2002). Despite the potential association between cardiovascular fitness and physical activity, we included both in the score. Although fitness(Kuczmarski and Flegal, 2000) during youth has been shown to be the stronger predictor of cardiovascular health in adulthood (Twisk et al., 2002, Boreham et al., 2002), physical activity in childhood, and change in physical activity during youth, are also related to CVD risk profiles in adulthood (Hasselstrom et al., 2002). In fact, investigations with adults have shown that it is difficult to detect whether cardiovascular fitness_or physical activity is a better predictor of health status (Blair et al., 2001).

Subjects

Subjects were 242 children (122 boys, 120 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. Children were included in the present study if they participated in normal school physical education class and were free of overt disease as assessed by questionnaire, 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.

Measurements

Cardiovascular fitness: Cardiovascular fitness was assessed using Leger's 20-m incremental shuttle run test, designed for use with children (Leger et al., 1984) . The test begins with children running 20-m laps at 8.5kmph. Running speed increases by 0.5kmph after each 1-min stage. Children continue running until they can no longer maintain the pace. The test has been shown to be a valid and reliable measure of cardiovascular fitness in children (Liu et al., 1992).

Anthropometry: Standing height (stretch stature without shoes) was measured to the nearest 1mm using a wall mounted digital stadiometer (Seca Model 242, Hanover, MD). Stretch stature was measured by the standard method, by applying gently upward traction on the base of the mastoid process. Mass in light clothing was measured using an electronic scale (Seca Model 840, Hanover, MD) to the nearest 0.1kg. Two measures of height and mass were taken, unless measurements differed by more than 4mm or 0.2kg respectively, in which case a third measure was taken. The average of the two values or the median of 3 values was taken for analysis. BMI was determined using the equation mass (kg) / height $(m)^2$.

Blood pressure: Duplicate measurements were taken on the left arm in the seated position 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. If values were within 5mmHg, the lowest value was recorded. If the difference exceeded 5mmHg, a third measurement was taken.

Physical activity: The Physical Activity Questionnaire for Children (PAQ-C) refers to the previous 7-days and requires children to recall, from a list of common moderate to vigorous activities, those activities that they participated in over the previous week (Crocker et al., 1997). 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 to give a daily amount).

Blood collection: For a small subset of children (40 boys, 37 girls) 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 analysed for serum TC, HDL and LDL and TG concentration at St. Paul's Hospital Laboratory, Vancouver.

Determination of risk level

Creating age and sex appropriate percentile scores for each risk factor: Unlike adult levels of many risk CVD risk factors, recommended ranges of physiological

Table 1. **Descriptive data of the participants. Data are means (SD).**

Variable	All children n = 242	Boys n = 122	Girls n = 120
Age (years)	10.7 (0.6)	10.7 (0.6)	10.7 (0.6)
BMI ($kg·m^{-2}$)	19.1 (3.5)	20.3 (3.9)	17.9 (2.7)
SBP (mmHg)	105 (9.5)	106 (9.7)	104 (9.2)
DBP (mmHg)	62 (7.9)	62 (8.0)	62 (7.9)
20m shuttles completed	29 (13.2)	29 (12.7)	28 (13.8)
Physical activity ($min·day^{-1}$)	74 (40.2)	74 (40.8)	74 (39.6)
Total cholesterol ($mmol·L^{-1}$)	4.4 (0.6)	4.3 (0.6)	4.6 (0.6)
Ratio TC:HDL	3.3 (0.9)	3.2 (0.8)	3.4 (0.9)
HDL cholesterol ($mmol·L^{-1}$)	1.4 (0.4)	1.4 (0.4)	1.4 (0.3)
LDL cholesterol ($mmol·L^{-1}$)	2.5 (0.6)	2.5 (0.5)	2.7 (0.6)
Triglycerides ($mmol·L^{-1}$)	0.9 (0.5)	0.8 (0.5)	1.0 (0.4)

Abbreviations: BMI = body mass index, SBP = systolic blood pressure, DBP = diastolic blood pressure, TC = total cholesterol , HDL = high density lipoprotein, LDL = low density lipoprotein.

variables change as children mature and grow in stature. For this reason, values of all biological risk factors (systolic and diastolic blood pressure and BMI) were converted to age and sex appropriate percentiles.

BMI was calculated then converted to a percentile using sex specific Centre for Disease Control (CDC) growth charts (Centre for Disease Control, 2000). Systolic and diastolic blood pressures were converted to age, sex and height appropriate percentiles using normal values from the National High Blood Pressure Education Program (National High Blood Pressure Education Program, 2004).

Cardiovascular fitness score was allocated according to age and sex appropriate criterion values set by FITNESSGRAM (California Department of Education, 2002). Physical activity "risk level" was determined according to whether children met the suggested guidelines (60 minutes per day) provided by the American Alliance for Health (Council for Physical Education for Children, 2003).

Allocation of healthy heart score: In adults, hypertension is frequently defined as a yes/no variable, but research by the Framingham group has shown that additional blood pressure categories are important in predicting coronary heart disease risk (Wilson et al., 1998). Thus, the Framingham Coronary Heart Disease risk factor prediction algorithm uses both continual and categorical values (5 categories) of blood pressure value. We adopted a similar approach to reflect varying levels of hypertension of children in the current study. Systolic and diastolic blood pressure value were assigned scores of 1 to 4; score 1 ≤ 75th percentile, score 2 = 76th-85th percentile, score 3=86th-95th percentile and score 4 ≥95th percentile. BMI was allocated a score of 1 to 4 and standard definitions of obese as BMI >95th percentile (score 4) and overweight as BMI between 85th-95th percentile (score 3) (Kuczmarski and Flegal, 2000). We added additional categories of BMI between 75-85th percentile (score 2) and BMI <75th percentile (score 1). In adults, cardiovascular fitness quartile is related to relative risk of death and although this had not been established in children, cardiovascular fitness has been shown to track from childhood to adulthood (Janz et al., 2000). We allocated cardiovascular fitness score according to whether children were above (score 1), within (score 2) or below (score 3) criterion based aged and sex appropriate values (California Department of Education, 2002). For physical activity, children were assigned a score of 1 to 3, to reflect a daily level of physical activity; >60min (score 1), 30-60 min (score 2), < 30 min (score 3).

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

Data analysis

Descriptive data are mean (SD). Healthy Heart Scores are given as mean (SD) and median value. Due to negative skew mean Healthy Heart Scores for girls and boys were compared using non-parametric 2 sample tests (Mann Whitney). Statistical significance was set at $p < 0.05$.

Healthy Heart Scores were correlated with serum factors using Pearson's Correlation.

Results

Table 1 provides descriptive data for the 242 children, 120 girls and 122 boys.

Healthy Heart Score was calculated for the group and for girls and boys separately. The group mean Healthy Heart Score was 8 (2.2) with a range of 5-16. Girls' mean was 8 (2.1) with a median of 7. Boys' score was significantly higher than girls' score with a mean of 9 (2.2) and a median of 8 (Z=3.9, $p < 0.01$). The distribution of Healthy Heart Score by sex is shown (Figure 1).

The number of children assigned to each scoring category is shown in Table 2. Data for the entire group and then data by sex are provided.

Forty two percent of children had no elevated risk factors (blood pressure above 75th percentile, obesity or overweight, cardiovascular 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 serum TC: HDL cholesterol ($r = 0.30$, $p = 0.01$), HDL cholesterol ($r = -0.32$, $p = 0.01$) and triglyceride concentration ($r = 0.23$, $p = 0.05$).

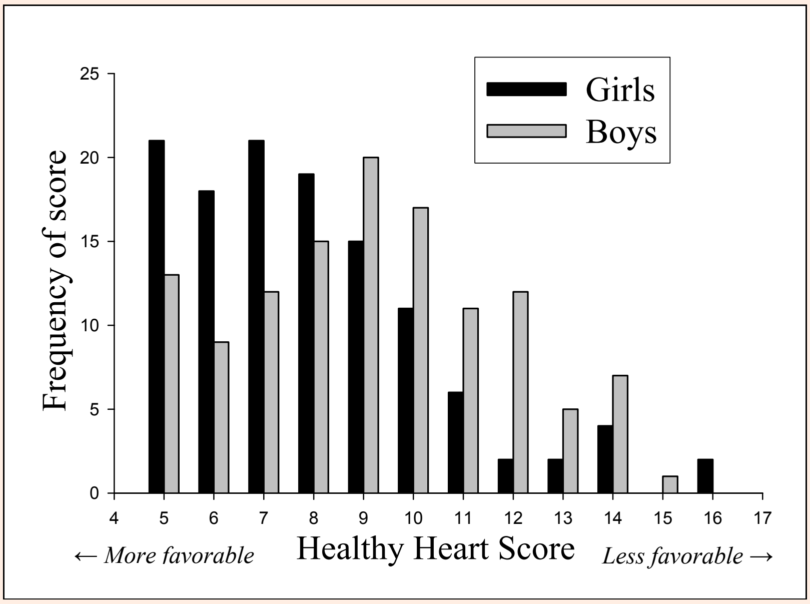

Figure 1. **Distribution of Healthy Heart Scores by sex.**

Discussion

We created a composite cardiovascular health profile that encompasses both biological and lifestyle risk factors. Unique to this study, we allocated a score based on the level of severity of 5 known risk factors for CVD and found that in the majority of children at least one risk factor was elevated. We showed that, in a subgroup of children, significant correlations existed between the Healthy Heart Score and several serum lipid and lipoprotein concentrations (TC:HDL, HDL and TG). Although these relationships do not validate the score, they show that the non-invasive measures we used in the study are associated with these lipid and lipoprotein concentrations.

It was disconcerting that by a mean age of 10.7 years, an alarming number of children were displaying risk factors. In this study, 58% of children had elevated levels of at least one CVD risk factor. The presence of risk factors in young people is associated with damage to the aorta and the coronary vessels (Berenson et al., 1998). The Bogalusa heart study (Berenson et al., 1998) 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 old. Subjects with 0, 1, 2, and 3 or 4 risk factors were found to have, respectively, 19%, 30%, 38%, and 35% of the aorta covered in fatty streaks. The comparable figures for the coronary arteries were 1.3 %, 2.5%, 7.9 % and 11%.

Levels of risk factor in the present study correspond with studies that reported trends of declining physical activity and declining shuttle run performance and increasing prevalence of overweight in children (Harten, 1999; Tomkinson et al., 2003; Tudor-Locke et al., 2001). Cardiovascular fitness of 20% of the children failed to

Table 2. **Number (% in parentheses) of children assigned to each percentile range / category for each risk factor measured. Risk level is shown as low to highest in parentheses next to score (n = 242, boys n = 122, girls n = 120).**

	Score			
	1 (low)	**2 (mod)**	**3 (high)**	**4 (highest)**
BMI (all)	142 (59)	25 (10)	40 (17)	35 (14)
Boys	61 (50)	13 (11)	18 (15)	30 (24)
Girls	81 (68)	12 (10)	22 (18)	5 (4)
SBP (all)	187 (77)	18 (8)	24 (10)	13 (5)
Boys	87 (71)	13 (11)	15 (12)	7 (6)
Girls	100 (83)	5 (4)	9 (8)	6 (5)
DBP (all)	201 (83)	19 (8)	17 (7)	5 (2)
Boys	98 (80)	13 (11)	10 (8)	1 (1)
Girls	103 (86)	6 (5)	7 (6)	4 (3)
Fitness (all)	21 (9)	181 (71)	51 (20)	
Boys	3 (3)	77 (63)	42 (34)	
Girls	17 (14)	94 (78)	9 (8)	
PA(all)	167 (69)	49 (20)	26 (11)	
Boys	89 (73)	22 (18)	11 (9)	
Girls	78 (65)	27 (23)	15 (12)	

Abbreviations: BMI = body mass index (kg·m^{-2}), SBP = systolic blood pressure (mmHg), DBP = diastolic blood pressure (mmHg), Fitness = no. 20m laps completed, PA = physical activity (min·day^{-1}).

meet standards set for health (California Department of Education, 2002). Interestingly, poor performance was particularly common in boys, with 33% failing to meet criterion standards. A recent meta-analysis of 55 studies from 11 countries, showed that cardiovascular fitness has been declining in children by, on average, 0.5% per year over the last 2 decades (Tomkinson et al., 2003). In Canada the decline has been 0.75% per year. Similarly, researchers in Europe found that the average cardiovascular fitness level of children in 2002 was 1.2 SD below the recommended population mean (Andersen et al., 2003).

Physical activity levels both inside and outside of school are low, as shown in this and other studies. Approximately 24% of the children in this study engaged in less than 30 minutes of moderate to vigorous physical activity per day and this value was similar between boys and girls. The Canadian Fitness and Lifestyle Research Institute (CFLRI) 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 (Canadian Fitness and Lifestyle Research Institute, 2003). The U.S. National Institute of Child Health and Human Development observed typical physical activity levels of elementary school children during physical education class (Nader, 2003). Children accrued only 4.8 minutes of very active and 11.9 minutes of moderate to vigorous physical activity per physical education lesson. Outside of school hours, leisure time physical activity is also decreasing. 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 (Tudor-Locke et al., 2001).

Conversely, BMI has been increasing by an average of 0.6% per year in children since 1990 (Harten, 1999). 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% (Gielen and Hambrecht, 2004). In the present study, 15.2% of children were in the highest risk category (>95th percentile) for BMI. 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 (Tremblay and Willms, 2000).

The prevalence of single or multiple risk factors in children is high. According to researchers in Europe, at least 50% of children aged 8-15 years have at least one biological risk factor for CVD (Ribeiro et al., 2004). Children with low levels of moderate to vigorous physical activity have an increased likelihood of having an additional elevated risk factor for CVD. 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 (2003) 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 had 4 CVD risk factors. We too found a high prevalence and clustering of risk factors. However, unlike most studies, 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 number of children with elevated BMI and elevated blood pressure reflect levels reported in several other studies (Hayman et al., 2004, Gielen and Hambrecht, 2004, Dwyer et al., 2000) .

Limitations

We acknowledge limitations of the current study. The methods we used to assess cardiovascular fitness and physical activity may have greater variability compared with a direct measure such as oxygen uptake or a more objective assessment of physical activity, such as direct observation. However, one criterion for assessment was that teachers or health care professionals could undertake procedures in school. The tools we used are valid and reliable for evaluating cardiovascular fitness and physical activity in children (Crocker et al., 1997; Liu et al., 1992). Further, with these fields based assessments we measured several children at one time, and they were not required to leave the school premises. Similarly, the self-report physical activity questionnaire again allowed us to assess several children at one time and included an estimation of after school and weekend activity. Thus, these are feasible tools that can be administered in the school setting.

We also acknowledge that we assessed a relatively small sample of Canadian children, and cannot extrapolate our finding too widely. Finally, we cannot categorically state that a score of 3 for BMI is as potentially detrimental to adult cardiovascular health as a score of 3 for blood pressure. However, the Healthy Heart Score is designed to give an indication of CVD risk, as opposed to accurately predict the occurrence of a future cardiac event.

Conclusion

The prevalence of CVD risk factors in many 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 allocated risk by determining a percentile score for 5 known CVD risk factors and created a cardiovascular profile for children that accounted for the severity of the risk factor. In addition, the variables used to calculate the Healthy Heart Score can be assessed in a school setting. We found the Healthy Heart Score correlated with a number of serum lipid and lipoprotein concentrations in a subgroup of children.

Given that many CVD risk factors track through adolescence and into adulthood, it is vital that CVD risk be assessed as children progress through puberty and into early adulthood. Further, there is a need for effective interventions that target reduction of CVD risk factor levels beginning at an early age.

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Key points

- There was a high incidence of elevated risk factors for cardiovascular disease in Canadian elementary school children.
- Physical fitness and physical activity levels were particularly low.
- In this cohort, boys had increased levels of cardiovascular disease risk factors compared with age-matched girls.

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