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ScienceDirect
Preventive Medicine 46 (2008) 525–531
Preventive Medicine
www.elsevier.com/locate/ypmed

Action Schools! BC: A school-based physical activity intervention designed to decrease cardiovascular disease risk factors in children ☆

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Available online 10 March 2008

Abstract

Objective. Our primary objective was to determine whether a novel 'active school' model – Action Schools! BC – improved the cardiovascular disease (CVD) risk profile in elementary-school children. Our secondary objective was to determine the percentage of children with elevated CVD risk factors.

Methods. We undertook a cluster-randomized controlled school-based trial with 8 elementary schools across 1 school year, in British Columbia, Canada, beginning in 2003. Boys and girls ($n=268$, age 9–11 years) were randomly assigned (by school) to usual practice (UP, 2 schools) or intervention (INT, 6 schools) groups. We assessed change between groups in cardiovascular fitness (20-m Shuttle Run), blood pressure (BP), and body mass index (BMI, wt/ht^2). We evaluated total cholesterol (TC), total:high-density cholesterol (TC:HDL-C), low-density lipoprotein, apolipoprotein B, C-reactive protein and fibrinogen on a subset of volunteers ($n=77$).

Results. INT children had a 20% greater increase in fitness and a 5.7% smaller increase in BP compared with children attending UP schools ($P<0.05$). Forty five percent of children had at least one elevated risk factor (fitness, BP or BMI) at baseline. There were no significant differences between groups for change in BMI or in any of the blood variables.

Conclusion. Action Schools! BC was an effective school-based physical activity model for improving the CVD risk profile of elementary-school children. Our multi-component intervention exposed children to fitness enhancing physical activity. It may be important for education stakeholders to adequately resource the delivery of the active school models if cardiovascular health benefits are to be achieved on a population basis.

Keywords: Physical activity; Cardiovascular fitness; Blood pressure; Children

Introduction

Despite the known benefits of exercise and the increased prevalence of CVD risk factors in children, much of children's physical activity is not intense enough to achieve health benefits (Tremblay et al., 2002). Further, these already inadequate amounts of physical activity are in decline, particularly in clearly defined contexts such as active transport, PE class time and organised sport (Dollman et al., 2005).

The increased sedentary behaviour of children and its association with overweight has sounded the alarm for parents,

☆ Funding Sources: BC Ministry of Health, 2010 LegaciesNow. Dr. McKay is a Michael Smith Foundation for Health Research Senior Scholar and Dr. Warburton is a Michael Smith Foundation for Health Research Scholar and a CIHR New Investigator.
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doi:10.1016/j.ypmed.2008.02.020

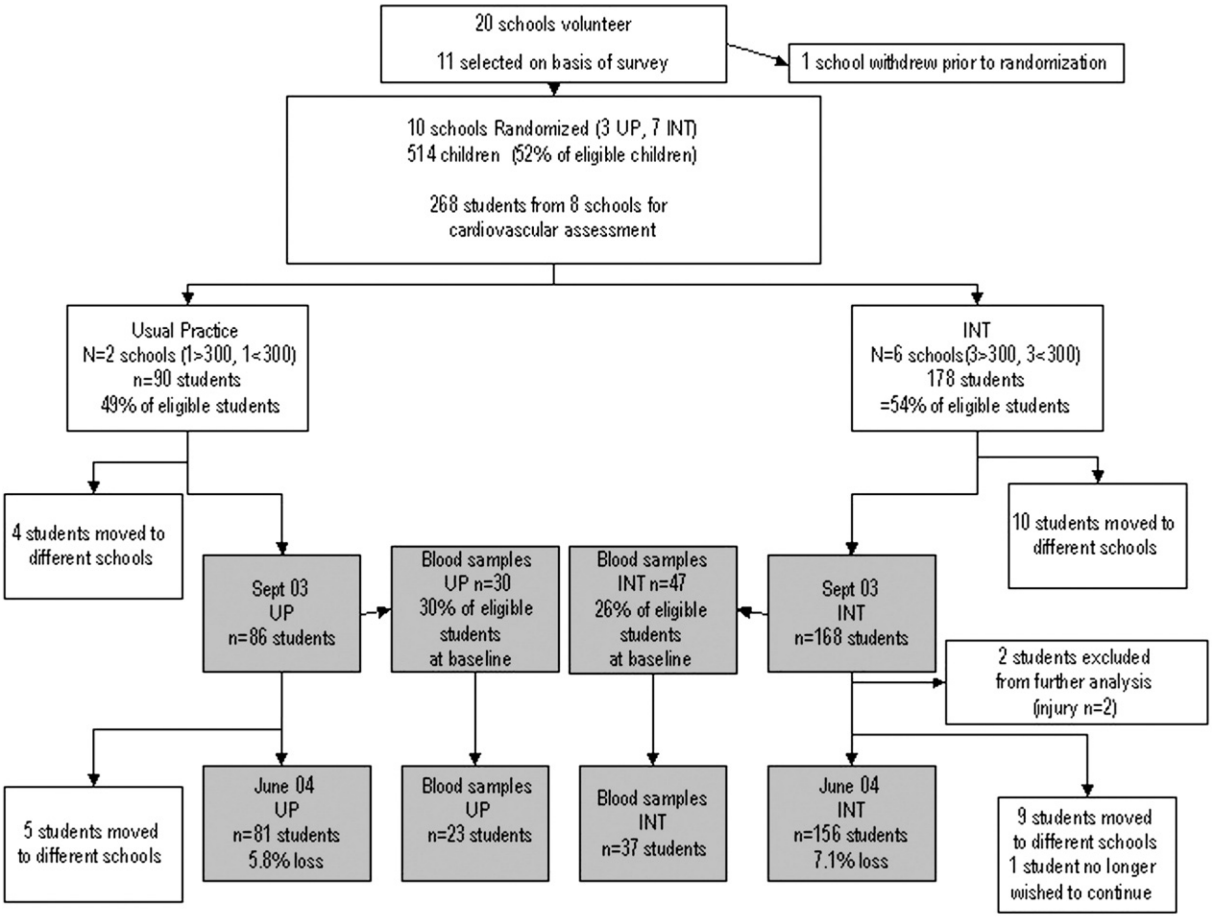

Fig. 1. Subject number throughout the Action Schools! BC study in British Columbia, Canada. 'Survey' refers to the 2002 Ministry of Education Satisfaction Survey. UP = usual practice, INT = intervention.

educators and medical practitioners (Tremblay et al., 2002). This trend has long-term consequences for both child and adult health (Riley et al., 1986; Schieken, 1987; Tracy et al., 1995; Freedman et al., 1999) as several CVD risk factors including obesity (Reilly et al., 2003), blood pressure (Lane and Gill, 2004) and several serum lipids (Nicklas et al., 2002) track from childhood into adulthood. If this trajectory is unaltered, the future economic and emotional burden of CVD will increase substantially (Tremblay and Willms, 2000; World Health Organisation, 2000; Warburton et al., 2006). Clearly, there is a need to develop effective intervention strategies to promote an active lifestyle and, thus, enhance the cardiovascular health of children.

Physical activity holds the most promise as an effective intervention as it exerts a well-established cardioprotective effect in both adults (Powers et al., 2002) and children (Ribeiro et al., 2004). Schools may be the only means to reach a large number of children from diverse socio-economic backgrounds (Taylor et al., 2000; Fox et al., 2004). We, and others, have suggested that health-promoting "active" school models can address childhood health (Naylor et al., 2006b; Verstraete et al., 2007). As curricular time dedicated to PE in schools has diminished in recent years (Pratt et al., 1999; Allison and Adlaf, 2000) it is time to explore models that encourage physical activity beyond PE class. Previous interventions have attempted to promote physical activity outside the PE class, but these models were either voluntary for students or aimed at slightly older children.

Therefore, we developed Action Schools! BC (AS! BC) for children in grades 4–7 attending elementary schools in British Columbia, Canada. AS! BC is a whole-school model that utilized a socio-ecological framework to promote physical activity (Naylor et al., 2006a,b). Briefly, socio-ecological models acknowledge that behaviour change is a product of multiple levels of influence; personal, organizational, community and policy – and interactions between them.

Our primary objective was to determine whether AS! BC was an effective model to decrease CVD risk factors in elementary-school children. Our secondary objective was to determine the percentage of participants with elevated CVD risk factors at baseline.

Methods

We detail our methods in previous reports (Naylor et al., 2006a,b) and describe them briefly below.

Schools and participants

We undertook a 16-month cluster-randomized controlled trial to determine the effectiveness of a school-based physical activity intervention (Action Schools! (AS!) BC). We recruited elementary schools from the Vancouver and Richmond

School Districts in British Columbia, Canada. We gave presentations at District Principals' meetings to 103 principals. Twenty schools volunteered to participate, which exceeded our recruitment goals. We identified 11 schools not already engaged in physical activity programs (British Columbia Ministry of Education, 2002). Of these, 10 volunteered to participate and to be randomly assigned to intervention or usual practice groups (1 principal withdrew prior to randomisation when told the school could be assigned to the usual practice group).

We presented the AS! BC model to Grade 4 and 5 students and teachers in each school. Consent forms (in English, Chinese, Punjabi and Vietnamese) were sent home for parents. Of the 1084 eligible children in Grades 4 and 5, 514 children received parental consent to participate in the AS! BC evaluation component. Importantly, *all* children in Grades 4 and 5 attending intervention schools participated in the AS! BC intervention, regardless of whether they consented to be measured. Parents completed a health-history questionnaire for their child. We excluded three girls and two boys from the analyses as they had health conditions that could affect normal physical activity or development. The University of British Columbia and the Vancouver and Richmond School Districts approved the study.

We then stratified schools by size (<300 or >300 students) and geographic location (to account for ethnic distribution). Schools were then remotely randomized to either Usual Practice (UP, $n=3$) or Intervention (INT, $n=7$) by an epidemiologist not involved in the trial. It was not possible for schools to be blinded to random assignment. To determine feasibility, the INT arm was further divided into Liaison ($n=4$) and Champion ($n=3$) schools that differed only in the level of facilitation provided to teachers (Naylor et al., 2006b). Thus, children in these two arms of the study received the same intervention so data were collapsed for analysis.

For the cardiovascular component of the evaluation, we defined a meaningful effect as a 10% difference for change in our primary outcome (cardiovascular fitness measured by 20-m shuttle run test). Approximately 200 children were required to achieve a power of 0.8 at an alpha level of 0.05. Children from 8 randomly selected schools (6 INT, 2 UP, $n=268$) underwent cardiovascular assessment. These children were measured at the beginning of Phase I (April–June 2003) and 254 of them returned for the active intervention - Phase II (September 2003–May 2004). We examined change in selected outcomes across Phase II and attrition was similar between UP and INT groups (5.8% and 7.1%, respectively) (Fig. 1).

To recruit children for blood sampling we sent a separate letter directly to parents of all children in the study. Of the 77 children who initially consented for blood sampling, 60 returned for follow up (21% and 23% attrition for UP and INT, respectively) (Fig. 1).

Action Schools! BC intervention

We described the AS! BC model in detail in two recent publications (Naylor et al., 2006a,b). Briefly, the AS! BC model was consistent with the concept of an 'active school' framework (Allensworth and Kolbe, 1987; Fox et al., 2004). It emphasized an integrated whole-school approach rather than traditional classroom-based health education (Deschesnes et al., 2003). The model targeted six Action Zones: i) School Environment, ii) Scheduled Physical Education, iii) Extra-curricular, (iv) School Spirit, v) Family and Community and vi) Classroom Action. Classroom Action was the only prescriptive component of the AS! BC model and teachers in INT schools were asked to deliver 15 min of moderate to intense physical activity daily to achieve 75 min of *extra* physical activity per week (in addition to 2×40 min PE classes). Teachers provided opportunities in the classroom for students to 'snack on physical activities' such as skipping, dancing, and resistance exercises throughout the school day.

A school *Action Team* – comprised of the school principal and/or teachers - was convened in each school. An *AS! BC facilitator* worked with Action Teams to design a program that included activities across all six Action Zones. The *AS! BC Support Team* conducted a 1-day training workshop for INT teachers. Intervention teachers were provided a Classroom Action Bin with resources to support their Action Plan. The goal for each school was to provide students 150 min of physical activity per week to students (2×40 min PE classes and 15×5 min/day of Classroom Action). Teachers in UP schools were asked to continue their regular program of physical education and school-based physical activity. Teachers in both INT and UP schools were asked to record the min of physical activity per day in Activity Logs. These were submitted to the AS! BC Support Team weekly.

Measurements

Cardiovascular fitness

We administered Leger's 20-m incremental shuttle run (Leger et al., 1988). Leger's procedure was designed for children and provides age and sex reference normative data. Children ran 20-m laps at 8.5 kmh^{-1}. Running speed then increased by 0.5 kmh^{-1} each 1-min. Children continued running until they could no longer maintain the preset and standardized pace. Total laps were recorded. Children ran in groups of six with a member of the measurement team, to ensure correct pacing.

Anthropometry

Standing height (without shoes) was measured to the nearest 1 mm (Seca stadiometer Model 242, Hanover, MD). Weight 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 as weight (kg)/height (m)^2.

Blood pressure

Duplicate measurements were taken on the left arm using an automated sphygmomanometer and an appropriately sized cuff (VSM MedTech, Canada) after 5–10 min rest in a supine position. The lowest systolic and diastolic blood pressures (mmHg) were recorded.

Blood collection

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 by a nurse and stored on ice in a serum separator tube. Blood was separated within 30 min and then stored at −80 °C. Samples were later analysed for total cholesterol (TC mmol/L), high and low density lipoproteins (HDL-C and LDL-C mmol/L), apolipoprotein B (Apo B g/L), C-reactive protein (CRP mg/L) and fibrinogen (Fg g/L) at St. Paul's Hospital Laboratory, Vancouver. These variables were selected as they are known predictors of CVD in adults or of vascular wall damage in children (Wilson et al., 1998; Harjai, 1999; Thomas et al., 2003) .

Tanner staging

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 (Tanner 1955). Stage 1 children were considered pre-pubertal, stage 2 early puberty, stage 3 middle puberty, stage 4 represented late puberty and stage 5 is considered post pubertal. Self assessed Tanner staging correlates well with physicians' ratings (Duke et al., 1980).

Physical activity

Physical activity was determined using a modified version of the physical activity questionnaire for children (PAQ-C)

Table 1
Columns 1–3 show baseline (September 2003) descriptive data of participants in Action Schools! BC according to treatment group

	ALL (n=237)	UP (n=81)	INT (n=156)	UP adjusted final score	INT adjusted final score	Unadjusted % difference in change
Fitness (laps)	29 (13.2)	32 (4.3)	27 (12.5)	31 (27,35)	37 (36,39)*	+20.4%
SBP (mmHg)	104 (9.6)	104 (10.5)	105 (9.3)	108 (106,110)	102(100,104)*	−5.7%
DBP (mmHg)	62 (8.2)	60 (8.2)	63 (7.5)	65 (62,68.6)	63 (60,65)	−3.8%
BMI (kg/m$^{2)}$	18.9 (3.6)	19.1 (3.7)	18.8 (3.5)	19.4 (19.1,19.5)	19.2 (19.2,19.6)	−1.0%
Blood (n)	60	23	37			
TC mmol/L	4.5 (0.6)	4.5 (0.6)	4.3 (0.7)	4.3 (4.1,4.5)	4.1 (4.0,4.2)	−4.6%
TC:HDL	3.3 (0.9)	3.3 (0.8)	3.2 (0.8)	3.3 (3.1,3.5)	3.1 (3.0,3.3)	−6.0%
LDL mmol/L	2.6 (0.6)	2.5 (0.5)	2.5 (0.6)	2.5 (2.4,2.7)	2.4 (2.3,2.5)	−0.4%
ApoB g/L	0.7 (0.1)	0.7 (0.1)	0.7 (0.1)	0.7 (0.6, 0.7)	0.6 (0.6, 0.7)	−4.5%
CRP mg/L	1.4 (2.3)	2.3 (2.8)	0.9 (0.9)	0.9 (0.5,1.4)	0.8 (0.5,1.2)	−10.5%
Fg g/L	2.9 (0.5)	2.9 (0.5)	2.9 (0.5)	2.0 (1.9,2.1)	1.9 (1.9,2.0)	−2.0%

Subject numbers for blood variables are provided. Data are mean (SD). Columns 3–5 show final (June 2004) (adjusted for baseline) score by group (final and 95% CI). Percent difference refers to how much higher or lower INT percent change is compared with UP percent change (INT % change − UP % change).
AS! BC = Action Schools, British Columbia (Canada). UP = usual practice, INT = intervention, 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 = low- density lipoprotein, Apo B = apolipoprotein B, CRP = C-reactive protein, Fg = fibrinogen.

(Crocker et al., 1997). The PAQ-C is a 7-d self report questionnaire designed to assess physical activity in the moderate to vigorous range. General physical activity was calculated as a score ranging from 1 (very low) to 5 (very high). The questionnaire was administered 3 times (to account for seasonal variation) over the intervention period. We averaged the 3 measurements to represent the physical activity level for each child, and provide results for descriptive purposes only.

Statistical analysis

As we undertook a clustered trial (children within schools), it is possible that the variance between children *within* schools may have been less than the variance for children *between* schools. Although we did not account for the clustered design in our sample size calculation (described above), we did account for clustering in our statistical analysis. As we had a small number of clusters (8 schools) and a large range of participants in each school (19 to 89), it was not possible to use the more common methods designed to analyze clustered data e.g. generalized estimating equations or hierarchical linear models (Wears, 2002). Therefore, to account for the effect of "school clusters" we applied a variance inflation factor (VIF) to adjust both the variance used to calculate the test statistic and confidence intervals. 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 (Wears, 2002). The ICC summarises the relationship of between-school to within-school variance.

Outcome measures were final value for; fitness, blood pressure (systolic and diastolic), BMI, TC, TC:HDL-C, LDL-C, Apo B, CRP and Fg. We used analysis of covariance (ANCOVA) to compare outcome measures between UP and INT groups, controlling for baseline value. We used SPSS version 13.0 (Chicago, Il) for all statistical analysis.

To achieve our secondary objective, we determined the percentage of children, at baseline, with elevated risk factors. An elevated risk factor was considered to be elevated if; 20-m shuttle performance was less than the recommended age- and sex-specific value (California Department of Education, 2002), if BMI was greater than the age- and sex-specific 85th percentile (Centre for Disease Control, 2000) or blood pressure was greater than age-, sex- and height- specific 85th percentile (National High Blood Pressure Education Program, 2004). Levels of serum factors that constitute 'risk' in children are less well established. High-normal values for serum factors assessed in this study are; total cholesterol > 4.4 mmol/L, TC:HDL-C > 4, LDL-C > 2.8 mmol/L, ApoB > 0.92 g/L, CRP > 9 mg/L, and Fg > 4.7 g/L.

Results

There were no differences at baseline for any variable between those children who were measured at baseline only (drop outs) and those children measured twice. Children who provided a blood sample were not different from children who did not (data not provided). At baseline, the percentage of children in Tanner stages 1, 2 and 3 was similar (INT boys: 61/34/5 and girls: 39/51/10, UP boys: 70/27/3 and girls: 43/52/5). There where no Tanner 4 or 5 children at baseline. At final, the percentage of children at each Tanner stage was also similar (INT boys; 33/38/26/3 versus UP boys; 42/37/19/1 and INT girls; 11/43/40/6 versus UP girls; 13/35/48/4). Baseline data are provided (Table 1).

For teachers, compliance with Activity Logs was 97% across UP schools and 94% across INT schools. From the Activity logs we ascertained that during Phase II, teachers in INT schools delivered approximately 60 min more physical activity per week than teachers in UP schools (+58.9 min/week CI: 25.4, 92.4) (Naylor et al., 2006b).

Physical activity level for INT children was slightly higher at all 3 timepoints (NS) compared to UP children. Overall INT children had a higher average physical activity score than UP children (2.61 ± 0.42 versus 2.55 ± 0.37).

Final (adjusted for baseline) value by treatment group (INT vs UP) and final (unadjusted) percent difference in change between groups are provided (Table 1). The INT group demonstrated a significantly greater increase in fitness (20-m shuttle run) compared with the UP group ($P < 0.05$). Systolic blood pressure in the INT group decreased significantly compared with an increase in the UP group ($P < 0.05$). There was no difference for change in diastolic blood pressure. Although all serum variables in the INT group decreased more than these same variables for the UP group — changes failed to reach significance (Table 1). There were no adverse events related to the intervention.

Discussion

AS! BC was an effective intervention that led to a substantial (20%) improvement in cardiovascular fitness and reduced systolic blood pressure. Previous studies assessing CVD risk, have measured fitness, BMI, blood pressure and occasionally cholesterol (Vandongen et al., 1995; Harrell et al., 1996; Luepker et al., 1996; Sallis et al., 1997; Verstraete et al., 2007). We extend this literature by assessing several relatively novel serum factors (apolioprotein B, fibrinogen and C-reactive protein). The combination of these novel factors, together with the traditional serum factors, allows us to build a more comprehensive cardiovascular profile in this (albeit small) group of children.

The success of previous studies varied depending on the scope to the intervention model. Generally, *comprehensive* school models were successful in that they positively modified at least one element of children's health related behaviour. These models extended beyond the PE class to include elements of nutritional and health behaviour advice and provided opportunities for children to be active outside of class (Vandongen et al., 1995; Harrell et al., 1996; Luepker et al., 1996; Sallis et al., 1997; Verstraete et al., 2007).

The Child and Adolescent Trial for Cardiovascular Health (CATCH) program (Luepker et al., 1996) and the Cardiovascular Health in Children (CHIC) studies (Harrell et al., 1996) were conducted in the US. Both trials improved physical activity participation. The 2.5 year CATCH trial increased physical activity by 12 min/day, whilst the CHIC trial increased physical activity by 7% across 8 weeks. However given the short time frame, the CHIC trial, was unlikely to elicit substantial changes in physiological variables. The Sports Play and Recreation in Kids (SPARK) model (Sallis et al., 1997) provided children with 3 × 30 min/week of physical activity during PE class time and aimed to increase physical activity outside school. After the 2-year intervention, children attending the intervention schools improved fitness (1 mile run time) 6–11% more than children attending control schools, but there was no difference between groups for physical activity outside of school time.

Two studies are particularly notable in that they promoted physical activity outside of PE (Verstraete et al., 2007; Vandongen et al., 1995). In the first instance, in addition to adapting PE, children were provided sports equipment to encourage exercise during recess and lunchtimes (Verstraete et al., 2007). No increases were found in any of the physiological variables measured. However, physical activity (accelerometry) declined less in intervention schools than control schools over the 2-year period. In the second case, children were provided with 15-min/day of additional physical activity for 9 months (Vandongen et al., 1995). Fitness levels of children attending intervention schools was enhanced (15% in girls, 3% in boys), blood pressure decreased (3%) and adiposity (skinfold thickness) was reduced (5%, girls only) compared with children attending control schools. Recently, the effectiveness of various interventions to promote physical activity has been examined (van Sluijs et al., 2007). Generally, multi-component interventions demonstrated positive results, compared with interventions targeting single components such as school, family or community.

AS! BC adopted the concept of comprehensive school health and a multi-component 'active' school model and achieved significant positive results by working across 6 action zones. Action Zones encompassed a 5 × 15 mandatory Classroom Action component, an adapted school environment to promote physical activity, and PE class enhancement. We previously reported that teachers in INT schools provided more opportunities for physical activity compared with UP schools (55–67 min week) (Naylor et al., 2006b). Importantly, reducing curricular time to provide more physical activity did not compromise the academic performance of children in INT schools (Ahamed et al., 2007).

To address our second objective we determined the percentage of children with elevated risk factors. Almost half (45%) the children presented with at least one risk factor. Specifically, 25% had lower than age- and sex-recommended fitness levels, 15% had elevated SBP, 9% had elevated DBP, and 29% were above the 85th percentile for BMI. These results are alarming for children aged 9–11 years, but are consistent with studies of similar aged children (Andersen et al., 2003; Ribeiro et al., 2004). Notwithstanding the small sample size, we observed elevated serum factors in a substantial proportion of children; TC 33%, TC:HDL 20%, LDL 23%, Apo B 26%, CRP 30% and Fg 26%. Given this preliminary evidence, it is important to investigate these novel factors in an adequately powered study.

CVD risk factors in childhood have been linked with short-term and long-term damage to the cardiovascular system. Childhood obesity , is associated with dislipidemia, abnormalities in left ventricular mass, hyperinsulinemia and altered endothelial function (Freedman et al., 1999; Woo et al., 2004) and influences adult morbidity and premature mortality (Reilly et al., 2003). Elevated blood pressure during childhood is associated with left ventricular abnormalities, altered endothelial thickness and aortic stiffness (Riley et al., 1986; Schieken 1987; Tracy et al., 1995). Tracking of risk factors from childhood into adulthood has also been shown for blood pressure (Bao et al., 1995), cardiovascular fitness, skinfold thickness, waist circumference, serum cholesterol (Twisk et al., 2002) and insulin sensitivity (Chen et al., 2005).

Limitations and future directions

We acknowledge several limitations. First, we do not know the clinical significance of our findings, or how they potentially relate to CVD in adulthood. Data regarding the impact of childhood CVD risk factors on future risk have, for the most part, been limited to obesity. There are no data regarding the impact of randomized school-based interventions on adult mortality. Given the complex and long-term nature of such trials, they may never be conducted. However, if the positive findings we observed here were achieved in adults, they would be clinically significant. Longitudinal studies, such as Framingham and the Bogalusa Heart Study will eventually provide valuable data regarding the impact of childhood risk factors on future cardiovascular events.

Second, it was not possible to specifically quantify 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. This is supported by findings from teacher's logs (Naylor et al., 2006b).

Third, the AS! BC pilot was a 16-month trial. Teachers adjusted to the model in Phase I (April–May) and actively delivered the intervention in Phase II (Sept-June). Our results encompass 1 school year (9 months) so that summer vacation (2 months) did not impact results. Ideally, children could be followed prospectively to determine the long-term benefits, if any, of the model on cardiovascular health.

Fourth, only a relatively small number of children volunteered to provide blood samples. This may be due, in part, to demands on parents to transport their children to the hospital. The low uptake for this component of the study could potentially influence external validity. We accept results from this aspect of our trial as preliminary; however, our data may aid the design of future studies.

Conclusion

In summary, AS! BC positively influenced the cardiovascular health of elementary-school children who undertook the intervention. The AS! BC intervention provided children with more opportunities for daily physical activity without disrupting the academic curriculum. Action Schools! BC is a feasible and effective model which could potentially benefit the cardiovascular health of a large number of children.

References

Ahamed, Y., Macdonald, H., Reed, K., Naylor, P.J., Liu-Ambrose, T., McKay, H., 2007. School-based physical activity does not compromise children's academic performance. Med. Sci. Sports Exerc. 39 (2), 371–376.

Allensworth, D., Kolbe, L., 1987. The Comprehensive School Health Programme: exploring the expanded concept. J. Sch. Health 57 (10), 409–412.

Allison, K.R., Adlaf, E.M., 2000. Structured opportunities for student physical activity in Ontario elementary and secondary schools. Can. J. Public Health 91 (5), 371–375.

Andersen, L.B., Wedderkopp, N., Hansen, H.S., Cooper, A.R., Froberg, K., 2003. Biological cardiovascular risk factors cluster in Danish children and adolescents: the European Youth Heart Study. Prev. Med. 37 (4), 363–367.

Bao, W., Threefoot, S.A., Srinivasan, S., Berenson, G., 1995. Essential hypertension predicted by tracking of elevated blood pressure from childhood to adulthood: the Bogalusa Heart Study. Am. J. Hypertens. 8 (7), 657–665.

British Columbia Ministry of Education, 2002. Schools Satisfaction Survey. Victoria, Ministry of Education.

California Department of Education, SaAD, 2002. California Physical Fitness Testing, FITNESSGRAM criterion values. 2004.

Centre for Disease Control, 2000. Growth Charts, National Centre for Health Statistics.

Chen, W., Srinivasan, S.R., Li, S., Xu, J., Berenson, G.S., 2005. Metabolic syndrome variables at low levels in childhood are beneficially associated with adulthood cardiovascular risk: the Bogalusa Heart Study. Diabetes Care 28 (1), 126–131.

Crocker, P.R., Bailey, D.A., Faulkner, R.A., Kowalski, K.C., McGrath, R., 1997. Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. Med. Sci. Sports Exerc. 29 (10), 1344–1349.

Deschesnes, M., Martin, C., Hill, A., 2003. Comprehensive approaches to school health promotion: how to achieve broader implementations. Health Promot. Int. 18 (4), 387–396.

Dollman, J., Norton, K., Norton, L., 2005. Evidence for secular trends in children's physical activity behaviour. Br. J. Sports Med. 39 (12), 892–897.

Duke, P.M., Litt, I.F., Gross, R.T., 1980. Adolescents' self-assessment of sexual maturation. Pediatrics 66 (6), 918–920.

Fox, K., Cooper, A., McKenna, J., 2004. The school and promotion of children's health enhancing physical activity. J. Sch. Health 23, 338–358.

Freedman, D.S., Dietz, W.H., Srinivasan, S.R., Berenson, G.S., 1999. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. Pediatrics 103 (6 Pt 1), 1175–1182.

Harjai, K.J., 1999. Potential new cardiovascular risk factors: left ventricular hypertrophy, homocysteine, lipoprotein(a), triglycerides, oxidative stress, and fibrinogen. Ann. Intern. Med. 131 (5), 376–386.

Harrell, J.S., McMurray, R.G., Bangdiwala, S.I., Frauman, A.C., Gansky, S.A., Bradley, C.B., 1996. Effects of a school-based intervention to reduce cardiovascular disease risk factors in elementary-school children: the Cardiovascular Health in Children (CHIC) study. J. Pediatr. 128 (6), 797–805.

Lane, D., Gill, P., 2004. Ethnicity and tracking blood pressure in children. J. Hum. Hypertens. 18, 223–228.

Leger, L.A., Mercier, D., Gadoury, C., Lambert, J., 1988. The multistage 20 metre shuttle run test for aerobic fitness. J. Sports Sci. 6 (2), 93–101.

Luepker, R.V., Perry, C.L., McKinlay, S.M., et al., 1996. Outcomes of a field trial to improve children's dietary patterns and physical activity. The Child and Adolescent Trial for Cardiovascular Health. CATCH collaborative group. JAMA 275 (10), 768–776.

National High Blood Pressure Education Program, 2004. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics 114 (2 Suppl 4th Report), 555–576.

Naylor, P., Macdonald, H., Reed, K., McKay, H., 2006a. Action Schools BC: a socio-ecological approach to modifying disease risk factors in elementary school children. Prev. Chronic Dis, 3 (2), A6017–A6019.

Naylor, P., Macdonald, H.M., Zebedee, J.A., Reed, K.E., McKay, H.A., 2006b. Lessons learned from Action Schools BC: an active schools model to promote physical activity in elementary schools. J. Sci. Med. Sport 9 (5), 413–419.

Nicklas, T.A., von Duvillard, S.P., Berenson, G.S., 2002. Tracking of serum lipids and lipoproteins from childhood to dyslipidemia in adults: the Bogalusa Heart Study. Int. J. Sports Med. 23 (Suppl 1), S39–S43.

Powers, S.K., Lennon, S.L., Quindry, J., Mehta, J.L., 2002. Exercise and cardioprotection. Curr. Opin. Cardiol. 17 (5), 495–502.

Pratt, M., Macera, C., Blanton, C., 1999. Levels of physical activity and inactivity in adults and children in the United States; current evidence and research issues. Med. Sci. Sports Exerc. 31, 526–533.

Reilly, J.J., Methven, E., McDowell, Z.C., et al., 2003. Health consequences of obesity. Arch. Dis. Child. 88 (9), 748–752.

Ribeiro, J.C., Guerra, S., Oliveria, J., et al., 2004. Physical activity and biological risk factor clustering in pediatric population. Prev. Med. 39 (3), 596–601.

Riley, W.A., Freedman, D.S., Higgs, N.A., Barnes, R.W., Zinkgraf, S.A., Berenson, G.S., 1986. Decreased arterial elasticity associated with cardiovascular disease risk factors in the young. Bogalusa Heart Study. Arteriosclerosis 6 (4), 378–386.

Sallis, J.F., McKenzie, T.L., Alcaraz, J.E., Kolody, B., Faucette, N., Hovell, M.F., 1997. The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students. Sports, play and active recreation for kids. Am. J. Public Health 87 (8), 1328–1334.

Schieken, R.M., 1987. Measurement of left ventricular wall mass in pediatric populations. Hypertension 9 (2 Pt 2), II47–II52.

Tanner, J., 1955. Growth at adolescence. Blackwell Scientific Publications, Oxford.
Taylor, G., Foerster, S., DiSogra, L., 2000. Effective behaviour change in community environments: Children in Schools. 5-a-day International Symposium. CAB International.
Thomas, N.E., Baker, J., Davies, B., 2003. Established and recently identified coronary heart disease risk factors in young people: the influence of physical activity and physical fitness. Sports Med. 33 (9), 633–650.
Tracy, R.E., Newman III, W.P., Wattigney, W.A., Srinivasan, S.R., Strong, J.P., Berenson, G.S., 1995. Histologic features of atherosclerosis and hypertension from autopsies of young individuals in a defined geographic population: the Bogalusa Heart Study. Atherosclerosis 116 (2), 163–179.
Tremblay, M.S., Willms, J.D., 2000. Secular trends in the body mass index of Canadian children. CMAJ 163 (11), 1429–1433.
Tremblay, M.S., Katzmarzyk, P.T., Willms, J.D., 2002. Temporal trends in overweight and obesity in Canada, 1981–1996. Int. J. Obes. Relat. Metab. Disord. 26 (4), 538–543.
Twisk, J.W., Kemper, H.C., van Mechelen, W., 2002. Prediction of cardiovascular disease risk factors later in life by physical activity and physical fitness in youth: general comments and conclusions. Int. J. Sports Med. 23 (Suppl 1), S44–S49.
van Sluijs, E.M., McMinn, A.M., Griffin, S.J., 2007. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. BMJ 335 (7622), 703.
Vandongen, R., Jenner, D.A., Thompson, C., et al., 1995. A controlled evaluation of a fitness and nutrition intervention program on cardiovascular health in 10- to 12-year-old children. Prev. Med. 24 (1), 9–22.
Verstraete, S., Cardon, G., De Clercq, D., De Bourdeaudhuij, I., 2007. A comprehensive physical activity promotion programme at elementary school: the effects of physical activity, physical fitness and psychosocial correlates of physical activity. Public Health and Nutrition 10 (5), 477–484.
Warburton, D.W., Nicol, C.W., Bredin, S.S., 2006. Health benefits of physical activity; the evidence. Can. Med. Assoc. J. 174 (6), 801–809.
Wears, R., 2002. Advanced statistics: statistical methods for analyzing cluster and cluster-randomized data. Academy of Emergency Medicine 9, 330–341.
Wilson, P.W., D'Agostino, R.B., Levy, D., Belanger, A.M., Silbershatz, H., Kannel, W.B., 1998. Prediction of coronary heart disease using risk factor categories. Circulation 97 (18), 1837–1847.
Woo, K.S., Chook, P., Yu, C.W., et al., 2004. Effects of diet and exercise on obesity-related vascular dysfunction in children. Circulation 109 (16), 1981–1986.
World Health Organisation, 2000. Obesity: Preventing and Managing the Global Epidemic. Report Series no 894. World Health Organisation, Geneva.