Action Schools! BC implementation: from efficacy to effectiveness to scale-up

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ABSTRACT

Objectives To describe Action Schools! BC (AS! BC) from efficacy to scale-up.

Participants/setting Education and health system stakeholders and children in grades 4–6 from elementary schools in British Columbia, Canada.

Intervention At the provincial level, the AS! BC model reflected socioecological theory and a partnership approach to social change. Knowledge translation and exchange were embedded as a foundational element. At the school level, AS! BC is a comprehensive school health-based model providing teachers and schools with training and resources to integrate physical activity (PA) and healthy eating (HE) into the school environment. Our research team partnered with key community and government stakeholders to deliver and evaluate AS! BC over efficacy, effectiveness and implementation trials.

Results On the basis of significant increases in PA, cardiovascular fitness, bone and HE in AS! BC schools during efficacy trials, the BC government supported a provincial scale-up. Since its inception, the AS! BC Support Team and >225 trained regional trainers have delivered 4677 teacher-focused workshops (training approximately 81 000 teachers), reaching approximately 500 000 students. After scale-up, PA delivery was replicated but the magnitude of change appeared less. One (HE) and 4 (PA) years after scale-up, trained AS! BC teachers provided more PA and HE opportunities for students even in the context of supportive provincial policies.

Conclusions Whole school models like AS! BC can enhance children's PA and health when implemented in partnership with key stakeholders. At the school level, adequately trained and resourced teachers and supportive school policies promoted successful scale-up and sustained implementation. At the provincial level, multisectoral partnerships and embedded knowledge exchange mechanisms influenced the context for action at the provincial and school level, and were core elements of successful implementation.

Trial registration number Clinical Trials Registry NCT01412203.

INTRODUCTION

It is widely accepted that many antecedents of adult chronic diseases are evident in childhood.[1–4] Specifically, multiple cardiovascular disease (CVD) risk factors were present in children as young as 8 years[5 6] and a growing body of evidence links risk factors in childhood, such as overweight and obesity, to morbidity and mortality in adulthood.[7–12] The beneficial relationship between physical activity (PA), healthy eating (HE) patterns and a broad range of risk factors in children is now well established.[13–16] Given the reports of low levels of PA[17 18] and unhealthy eating patterns,[16 19] there is a global plea for effective and sustained intervention strategies that promote active lifestyles to enhance the health of children.[20]

Comprehensive school health and health promoting schools frameworks were identified as one of the 'seven best investments for physical activity'.[21] Lodged within a 'socioecological' framework, these models incorporate many foundational tenets of health promotion. That is, they target changes to the environment, invest in developing multilevel partnerships, promote local autonomy in decision-making and accommodate variability within schools.[22 23] However, Durlak and DuPre[24] recognised that "developing effective interventions is only the first step toward improving the health and well-being of populations. Transferring effective programs into real world settings and maintaining them there is a complicated, long-term process…," a concept echoed by others.[25 26] Importantly, these researchers recognised a need for the academic community to move beyond efficacy trials to better understand whether effective interventions could be scaled up and have an impact in a real-world setting. Durlak and DuPre[24] identified a number of components deemed 'essential' for sustained implementation. These critical elements crossed the following domains: (1) community context (evidence base, political support, funding and supportive policies), (2) provider characteristics (perceptions related to the need for and potential benefits of the intervention model, self-efficacy and skill proficiency) and (3) innovation characteristics (flexibility and compatibility) of the model. While we adopted many of the tenets voiced by Durlak and DuPre,[24] we also incorporated Lewin's[27] concept of 'action research' that was advanced by Stokols[28 29] and aligns closely with current thinking around knowledge translation and exchange.[30] That is, effective collaboration among researchers from across disciplines, and a participatory approach that engages community practitioners with diverse points of view, community organisations at all levels and policymakers are essential ingredients to scalable models.[31] Consistent with our belief that widespread uptake (scale-up) of effective school-based interventions is critical to achieving a population-level impact, we also feel it is important that researchers engaged in these types of endeavours share their practice. Thus, our aim is to describe the approach to, and evolution of, Action Schools! BC (AS! BC) from efficacy through effectiveness to scale-up, to summarise previously reported findings and to present new findings—across a decade of sustained implementation.

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Background

Traditionally, most school-based interventions targeted PA within the context of physical education.[32 33] However, as curricular time dedicated to physical education in schools diminished substantially, especially in recent years,[34] there was a growing appetite for innovative models that encouraged PA opportunities beyond physical education. Thus, an 'active school' approach was recommended, whereby PA was promoted across a number of settings within schools.[35–38] Effective PA to promote child health is closely aligned with healthy eating. Therefore, there is a move toward recommending HE approaches delivered outside of the school curriculum.[39 40]

The AS! BC model

In 2005, disturbing health trends in children served as a call to action in British Columbia, Canada. A confluence of pivotal events (including hosting the Vancouver-Whistler 2010 Olympic Games) spurred on several government Ministries, a multidisciplinary research team, community groups and education stakeholders to invest in an initiative that aimed to integrate PA within schools across British Columbia. The initiative, AS! BC, was and is a comprehensive school health model that embraces a socioecological framework,[28 29] adopts many of the essential elements of scale-up and sustained implementation[41] and reflects an interdisciplinary research, cross-sectoral school, community and provincial government (stakeholders) collaboration. AS! BC was developed in phases beginning with later elementary school (grade 4–6), followed by kindergarten—grade 3 and middle school. The goals of the AS! BC PA model were to: (1) provide a school environment where students had more opportunities to be more active more often, and (2) facilitate supportive community and provincial-level environments.[42]

In response to growing concerns about obesity and unhealthy eating patterns, a trained dietician and health promotion specialist were added to the AS! BC Support Team in 2007 to design and implement an HE component that complemented the AS! BC PA component (figure 1). The AS! BC Provincial Advisory Committee was expanded to include HE stakeholders, and the HE team utilised the same framework and processes to develop, implement and evaluate the HE component in grades 4–6. Briefly, the HE component also aimed to integrate HE into the fabric of elementary schools, and maintain this integration through partnerships with the family and community. The mandate of AS! BC was then extended to incorporate the HE component and to meet the goal of "providing more opportunities for more children and youth to make healthy choices more often."

Evaluation of the AS! BC model

Implementation and scale-up of the AS! BC model was embedded within a continuous process of stakeholder input and adaptation (figure 2) supported by data from a series of research trials. Specifically, stakeholders partnered to design, implement and evaluate the AS! BC model across four trials (spanning 6 years) to assess the (1) feasibility[43] and efficacy of PA[44–47] and HE[48] components, (2) effectiveness[49–51] (PA component) and (3) implementation after scale-up across British Columbia[52] (PA and HE component). Partners adopted a long-term view of success and cycled through phases of knowledge and product development, knowledge and product transmission (efficacy

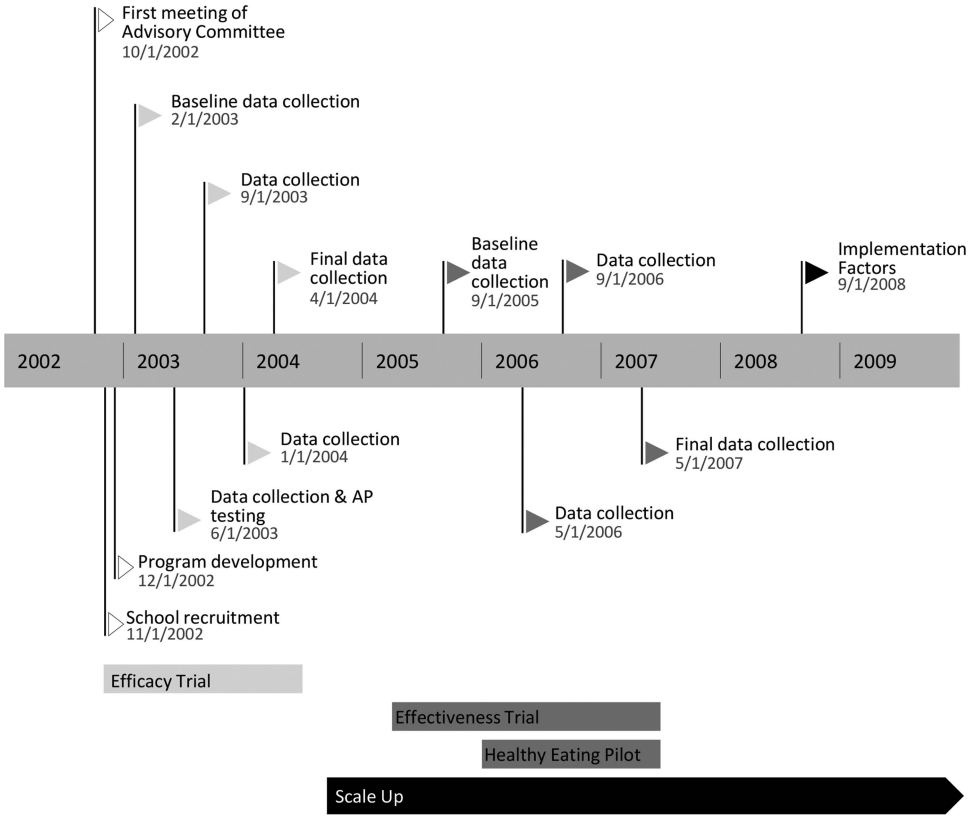

Figure 1 Action Schools! BC timeline from efficacy to scale-up. Flag colours represent various phases of the model (white—preparatory phase; light grey—physical activity efficacy trial; dark grey—effectiveness trial and healthy eating efficacy trial; black—implementation trial) and includes the start date for each activity. The model was developed in phases beginning with physical activity in older elementary schoolchildren (grade 4–6) and integrating healthy eating and younger elementary schoolchildren (kindergarten—grade 3) and middle school over time.

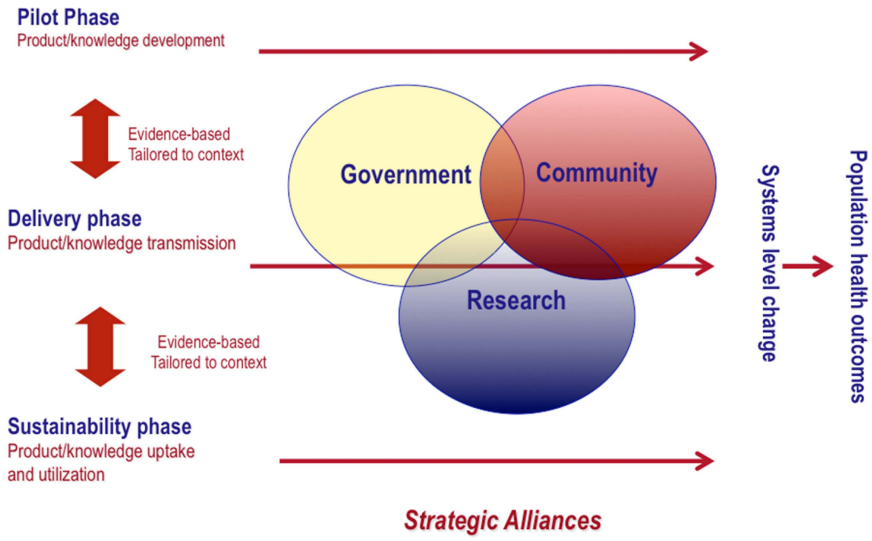

Figure 2 Implementation and scale-up of the Action Schools! BC model was embedded within a continuous process of stakeholder input and adaptation supported by data from the ongoing trials.

study) and knowledge and product dissemination (effectiveness and implementation studies).

Specific aims of the efficacy and effectiveness (2003–2007) trials were to assess whether: (1) teachers provided more PA and HE opportunities for students, (2) AS! BC increased PA levels of elementary (grades 4–6) students, (3) AS! BC ameliorated chronic disease risk factors and enhanced academic performance and (4) AS! BC increased the student's willingness to both try and consume more vegetables and fruit (V&F). We also assessed the context for and facilitators and barriers to implementation of the model. Specific aims of the implementation trial (2008–2009) were to examine implementation of the AS! BC model and characteristics of teachers and schools and attributes of the AS! BC model ('the innovation') associated with its implementation 1 or 4 years after a province wide scale-up.[52]

Overview of study design and participants

The measurement timeline for the overall initiative and efficacy, effectiveness, HE efficacy and implementation trials is illustrated in figure 1. We provide a brief overview of the study design and participants of the specific trials below.

PA efficacy trial (2003–2004)

Details of the PA efficacy trial including its design, recruitment and participants have been published previously.[43–47 53 54] Briefly, we conducted a cluster randomised controlled trial with schools as the unit of randomisation. We recruited schools from two BC school districts (Vancouver, Richmond). Of the 20 schools that volunteered to participate, 11 met our entry criteria and 10 participated. The efficacy trial spanned 16 months (February 2003–June 2004); the AS! BC intervention was delivered over an 11-month period; children did not participate during their summer holiday (July–August).

Forty-two grade 4 and 5 teachers consented to participate from February–June 2003 (phase I) and 49 teachers participated from September 2003–June 2004 (phase II). Twenty-three teachers taught grade 4 or 5 across both years. Of 1084 eligible children, 515 (48%) received parental consent to participate. Importantly, all grade 4 and 5 children enrolled in intervention schools participated in AS! BC activities, regardless of whether parents provided consent for children to be evaluated. We determined the effect of the model over either phase I and II (18 months)[42 43 45–47 55] or phase II (10 months–1 school year)[44 54]—depending on the research question we addressed.

After we obtained consent, we stratified schools by size (<300 or >300 students—to account for operational differences) and geographic location (to account for ethnic distribution). Schools were then remotely randomised to either Usual Practice (UP, n=3) or Intervention (INT, n=7). Within the INT group, there were two study arms that differed only in the amount of support offered to schools and teachers. Both groups received training in model delivery and all resources required for implementation. The 'Champion' arm (n=3) had a facilitator designated from within the school while the 'Liaison' arm (n=4) had an external facilitator who contacted teachers weekly. We evaluated the effect of the intervention by separate groups[43 45] or after collapsing the two intervention groups.[44 46 47 54]

PA effectiveness trial (2005–2007)

As a next step, we adopted a similar process and conducted a cluster randomised controlled trial (Clinical Trials Registry NCT01412203) to evaluate the effectiveness of AS! BC after dissemination across four BC provincial health authorities over two school years. The effectiveness trial spanned 20 months (September 2005–June 2007) across two school years; children did not participate during their summer holiday (July–August). We assessed children attending 30 schools (1529 children aged 8–11 years; 64% consent rate), randomised to the INT group (n=16 schools; 747 children) or UP group (n=14 schools; 782 children).

HE efficacy trial (2005–2007)

In conjunction with the PA effectiveness trial, we conducted an efficacy trial of the HE component in 10 schools (n=300 children at 5 INT schools; n=227 children at 5 UP schools). The HE efficacy trial spanned 16 months (January 2006–June 2007) across two school years. As with the PA efficacy trial, we evaluated the model in two phases: March–May 2006 (phase I[48]) and September 2006–June 2007 (phase II).

Implementation after scale-up (2008–2009)

As a final step, we examined factors associated with successful implementation of AS! BC PA 4 years after scale-up[52] and HE 1 year after scale-up (under review). For the PA implementation

study, we identified 702 eligible schools and randomly invited 348 to participate. School principals (n=122; 92% response rate) and grade 4–7 teachers (n=599; 71% response rate) from 133 schools completed an online survey during the 2008–2009 school year. Thirty-six school principals (92% response rate) across 39 school districts (n=36) and 168 grade 4–7 teachers (70% response rate) agreed to participate in the HE implementation survey.

Intervention—AS! BC

The AS! BC intervention is described in detail elsewhere.[42] Briefly, we adopted a multilevel, multisectoral partnership based approach that targeted two levels within the socioecological framework: (1) the meso level which represents settings or organisations that a child will interact with, and (2) the macro level which represents systems or provincial policies that influence meso-level environments.[29] At the provincial level, we adopted a model that incorporated horizontal (across sectors) and vertical (from teacher to provincial policymaker) integration of stakeholders and ongoing interaction with them that supported us continuously reflecting on both their input and our data from across studies (figure 2). Later (2011), AS! BC was embedded within the Directorate of Agencies for School Health (DASH) BC and managed by a cross-government committee.

To achieve student-level health outcomes, we targeted the school environment using a comprehensive whole school model.[43] The main components of the AS! BC model are provided in table 1. There are six Action Zones within the AS! BC model and the features of the delivery model were: a local *school action team*, tools to foster creation of individualised school *action plans* (planning and resource guides), an AS! BC central *support team*, a local AS! BC *school facilitator* and *classroom action bins* containing equipment and resources for providing in-class PA and promoting healthy living.[43] Schools enrolled in the HE intervention arm received additional resources and training specific to the HE component.[48] Schools were given an introductory workshop, assembled a team, identified their strengths and gaps across the six action zones using inventories provided by the AS! BC Support Team and set goals for action in each zone. The action bin (PA) or pack (HE) supported individualised action plans, which were reviewed and updated annually. The PA model included two prescriptive, experiential components within the Classroom Action Zone: a minimum of 15 additional minutes of PA (over and above physical education) per day (15×5) and jumping exercises 3×/day (Bounce at the Bell[47 56]). The HE model included both curricular and experiential components within the Classroom Action Zone. HE schools were asked to provide a standard dose of two HE activities/week and one tasting activity/month within the Classroom Action Zone during phase I.[48] As a result of the HE phase I formative evaluation during phase II, the HE initiative emphasised three of the six Action Zones (School Environment, Classroom Action, and Family and Community) and teachers were asked to implement two Vegetable and Fruit (V & F) Units (multiple lessons) across the fall and spring school terms (ie, two units/year, each lasting approximately 1 month), as well as monthly tasting activities and a minimum of three other activities in the school environment or family and community zone.

The growth and scale-up of the AS! BC model is planned and implemented by a provincially funded Support Team working with partners and school personnel to: (A) identify ongoing needs, (B) create and update resources based on these needs (print-based and web-based), (C) manage a phalanx of regional trainers who deliver training workshops to teachers, (D) develop and manage the AS! BC communications and marketing (including the stakeholder relations, website, newsletters, supplementary resources, reports) and (E) manage the distribution of classroom PA bins and HE packs to registered schools (1 per grade at registration). Ongoing district-level monitoring and reports are also provided to administrators and school 'Success Stories' are updated and shared through newsletters and the website (http://actionschoolsbc.ca/).

METHODS

We provide a brief description of the methods adopted to evaluate outcomes across key research objectives (these were similar between efficacy and effectiveness trials). We provide more detailed methods in our individual publications; these are summarised in online supplementary table S1.

Provincial-level outcomes

PA and HE efficacy trials

We used a descriptive case study methodology to assess the context and impact of the AS! BC model at the provincial/systems level. We conducted three focus groups to identify the provincial-level context and impact of the project.[42] The AS! BC Support Team tracked all meetings with external

Table 1 Key components of the Action Schools! BC (AS! BC) model

Component	Description
Action Zones	Six areas in which opportunities for physical activity could be provided to students. The six zones were: (1) School Environment, (2) School Spirit, (3) Physical Education, (4) Extra-curricular, (5) Family and Community and (6) Classroom Action
AS! BC Support Team	A central technical support unit that developed and provided AS! BC resources (training workshops, written materials, Action Bins, school newsletter inserts for families) and ongoing consultation (on-site and telephone) to administrators, teachers and the School Action Team
AS! BC School Facilitators	Two elementary schoolteachers seconded by the AS! BC Support Team to provide training, support and advice to the schools and liaise between the Support Team and the School Action Team
School Action Team	A committee of school stakeholders (eg, interested intermediate grade teachers, administrators, parents, health, sport/recreation practitioners) that created and supported implementation of the Action Plan
Planning Guide for Schools and Teachers	A set of inventories and worksheets that guided teachers and the School Action Team to identify school priorities and create their Action Plan
Action Pages!	A resource directory using curriculum organisers to link teachers, coaches or community instructors with recommended and available resources
Classroom Action Bin	A storage bin for the classroom filled with playground balls, videos, skipping ropes, exercise bands, strength grippers and teaching resources that supported the Action Plan

stakeholders; government announcements were tracked and randomly constructed. We also used programme management information systems to describe reach.

Implementation trials

We used programme management monitoring systems to describe implementation in terms of reach, training delivered, adaptations and programme extensions.

School-level outcomes

PA and HE efficacy and effectiveness trials

Physical activity and healthy eating activities delivered: Teachers at INT schools completed weekly Activity Logs during efficacy[43] and effectiveness trials. Each day teachers recorded the type, frequency and duration (minutes) of PA implemented in the classroom, in physical education or in the other Action Zones. Teachers at UP schools completed a modified version of the Activity Log. Similarly, teachers at HE schools reported HE activities.[48]

Intervention fidelity and feasibility: We assessed teacher compliance with AS! BC by reviewing Action Plans and Activity Logs.[43 48] As part of both efficacy trials (PA and HE), we used feedback surveys and focus groups with administrators, teachers, parents and children to evaluate intervention feasibility and determine barriers and facilitators to model delivery.[43 48]

PA and HE implementation trials: We adopted constructs from the Theories of Organizational Change, Social Cognitive Theory and Rogers's Diffusion of Innovation Model[57–60] and administered cross-sectional multistage surveys to principals and grade 4–7 teachers in 2008–2009.[52] We used multilevel mixed-effect logistic regression analyses to examine characteristics of teachers and schools and attributes of the innovation associated with implementation. Specifically, we explored how 10 factors (organisational climate; organisational capacity; level of institutionalisation; environmental influences; teacher self-efficacy; outcome expectations; being physically active; teaching physical education; support for training; intervention attributes) were related to implementation of AS! BC by classroom teachers.[52] As mandated provincial Daily Physical Activity (DPA) guidelines were implemented in 2008 and Guidelines for Food and Beverage Sales were enhanced, we asked about any changes in school or teacher practice related to PA and HE over the past 3 years, what influenced the change and whether they planned to use AS! BC to meet the guidelines.

Student-level outcomes

PA and HE efficacy and effectiveness trials

Descriptive characteristics of student participants: We adopted standard methods to measure each participant's standing height (cm) and body weight (kg) at baseline and follow-up, and we calculated body mass index (BMI) as kg/m^2. We used BMI values to classify children as being of normal weight, overweight or obese according to the International Obesity Task Force (IOTF) sex-specific and age-specific cut-offs.[61] Ethnicity was self-reported and based on parents' and grandparents' place of birth.[56 62] For the efficacy trial only, maturity status was assessed at baseline and follow-up using Tanner staging[63] and girls' menarcheal status was determined using a self-report questionnaire.

Primary and secondary outcomes: We assessed our primary outcome, *PA*, objectively using pedometers (efficacy trial)[45] or accelerometers (effectiveness trial)[50] and via a self-report questionnaire (both trials).[44–47]

For the PA *efficacy* trial, we assessed *cardiovascular health* on a subset of children (n=268) randomly selected from 8 of the 10 participating schools.[44] We also evaluated blood biochemistry on a small subset of children (n=77) to obtain measures of total cholesterol, high-density and low-density lipoproteins. We used peripheral quantitative CT to estimate tibial *bone strength*[47] and dual energy X-ray absorptiometry (DXA) and hip structure analysis to estimate femoral neck bone strength.[46] We determined *per cent body fat* (*% fat*) from whole body DXA scans. We assessed *perceived competence* with Harter's scale for children[64] and used specific subscale measures of athletic competence, social competence, academic competence and general self-esteem.[53 55] Finally, we used the Canadian Achievement Test (CAT-3) to assess the impact of AS! BC on *academic performance* in a subset of children (n=288).[54]

For the PA *effectiveness* trial, we measured physical fitness in a subset of 25 schools (INT: n=640 children; UP: n=679 children). For the efficacy and effectiveness trials, we evaluated cardiovascular fitness (laps completed) using Leger's 20 m incremental shuttle run test,[65] health-related fitness using Fitnessgram[66] and blood pressure using standard methods. We also measured psychosocial variables (Physical Self-Perception Scale, Perceived Competence[64 67]) and dietary intake (24 h recall and Food Frequency Questionnaire[68]).

For the *HE efficacy* trial, we measured patterns of V&F consumption via 24 h recalls and a Food Frequency Questionnaire in 516 children. We also assessed willingness to try and V&F exposure using a purpose built questionnaire. We specifically focused on the: (1) number of servings of fruit/day, (2) number of servings of V&F/day, (3) number of different V&F eaten (ie, variety), (4) number of V&F tried/eaten from a fixed list and (5) willingness to try new V&F.[48]

RESULTS

Results from our trials and overall programme implementation are summarised below. Results of the efficacy trial are summarised in online supplementary table S1. Baseline data for cardiovascular health,[69–73] bone health[74] and PA[50] outcomes for AS! BC cohorts are available elsewhere.

Provincial-level outcomes

Focus group and tracking data demonstrated that AS! BC contributed to macro-level changes.[30] Half of the provincial stakeholders noted that AS! BC positively affected their strategic approach and collaboration on PA initiatives. After the efficacy study was completed, the provincial government provided political support and 10 years of sustained investment (approximately $20M) to support scale-up of the AS! BC model (integrated PA and HE).

In 2006, the model was expanded from the original focus on grades 4–6 to encompass kindergarten—grade 7. Following the efficacy trial, the Support Team developed more than 12 different specialty PA, HE and Refresher Workshops (http://actionschoolsbc.ca/) to complement original PA and HE workshops. Over 10 years of scale-up (2004–2014), more than 225 AS! BC Trainers have been trained; 75 actively deliver training workshops to teachers each year. The Support Team and Trainers deliver 400–500 workshops per year. To date, 4677 workshops have been delivered to more than 80 000 teachers. In 2006, a student leadership component was added and over 1300 student leadership workshops (outdoor games, indoor PA and HE) were provided to 19 000 students. AS! BC is now active in 100% of BC school districts (n=60+) with 94% of

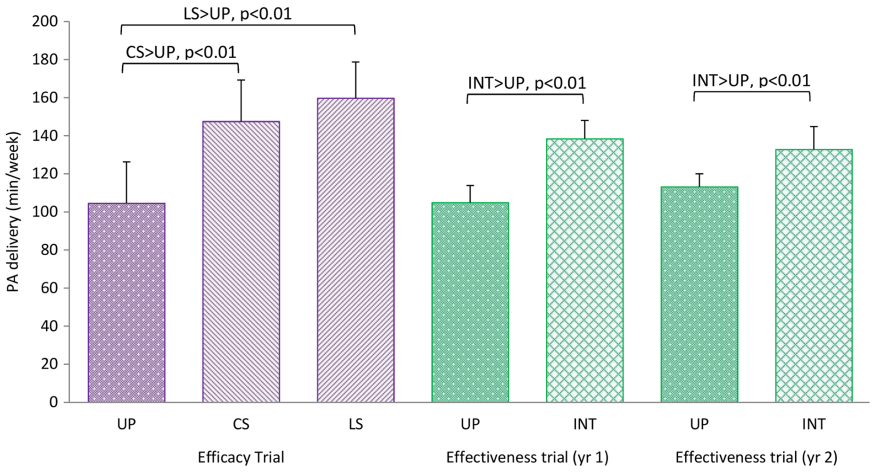

Figure 3 Physical activity (PA; minutes/week) delivered by teachers at Usual Practice (UP), Champion (CS) and Liaison (LS) schools (efficacy trial) as well as at Intervention (INT) and UP schools (effectiveness trial). Bars represent 95% CIs.

schools registered (1474/1571 schools); of those, 89% received teacher training through a workshop.

School-level outcomes

For the PA efficacy trial, PA delivered by teachers was significantly greater in both intervention arms (Liaison: +67.4 min/week; 95% CI 18.7 to 116.1 and Champion: +55.2 min/week; 95% CI 26.4 to 83.9) compared with UP schools across phases I and II (figure 3).[42 43] Teacher implementation was moderate (75% of the goal of 15 additional min/day) and Action Plans and reports showed fidelity to the AS! BC model. Teachers deemed AS! BC feasible to deliver and were highly satisfied with AS! BC training workshops, resources and facilitation by the AS! BC Support Team.[43]

For the HE efficacy trial, teachers reported high levels of satisfaction with the training, resources and support provided. During phase I, teachers at INT schools provided, on average, 1.3±1.1 HE activities per week within the classroom, and completed 80% of planned activities across five Action Zones.[48] During phase II, teachers at INT schools provided, on average, 2.02 HE activities within the classroom each week and 4.1 tasting events over the school year. Generally, 76% of planned activities were completed across three targeted Action Zones.

Teacher focus groups and surveys identified time, lack of coordination between staff and lack of support from school administrators as barriers to AS! BC HE implementation in phases I[48] and II. Facilitators to implementation were similar in phases I[48] and II. Key facilitators were support from the Support Team, AS! BC resources, grant money (for tasting activities) and student enthusiasm.

During the effectiveness trial, teachers' compliance to completing Activity Logs was 57% (year 1) and 66% (year 2; range 0–100%). On average, teachers at INT schools delivered significantly more PA/week than teachers at UP schools in year 1 (+33.5 min/week, 95% CI 20.6 to 46.4) and year 2 (+19.5 min/week, 95% CI 5.9 to 33.1 min/week). PA delivery in year 1 compared with year 2 was not significantly different (−5.6 min/week, 95% CI −9.5 to 20.8 min/week).

During the implementation trial, and in the context of a Provincial DPA guideline being implemented (requiring 30 min/day of PA), an AS! BC teacher was 2.5 times ($p<0.002$) more likely to be providing greater than 15 min/day of classroom PA breaks for their class. A large majority of principals (96%) and teachers (75%) indicated that they were using or planning to use AS! BC to meet DPA requirements. School principals reported that the priority given to PA and HE had increased in the past 3 years; 76% indicated an increase in priority for PA and 86% an increase related to HE. Eighty-six per cent of these principals attributed this increase to a combination of AS! BC (voluntary model) and the implementation of DPA requirements (a non-voluntary guideline). Similarly, of the principals who reported an increased priority given to HE over the past 3 years, 51% attributed this to both AS! BC and the Guidelines for Food and Beverage Sales in BC Schools.

Univariate analysis identified seven factors that were significantly associated with implementation: teacher self-efficacy (eg, confidence in their skills), outcome expectation (eg, belief in the benefits), training (eg, participation in AS! BC workshops), organisational climate/support (eg, HE was a priority), level of institutionalisation (eg, supportive guidelines or policy, adapted concepts to fit their school, allocated budget), environmental influence (eg, compliance with Provincial guidelines) and attributes of the innovation (eg, relative advantage). Only training, level of institutionalisation and teacher self-efficacy remained significant in the multilevel analysis.[52]

Student-level outcomes

Descriptive characteristics

Our efficacy cohort reflected the demographics of Vancouver's Lower Mainland, which has the highest proportion of visible minorities in Canada.[75] Most children (54%) were of Asian descent. At baseline, 41% of children accumulated less than 60 min/day of PA, while 12% accumulated less than 30 min/day. Most children (58%) had at least one CVD risk factor and 9% of the sample had four or more risk factors.[73] At baseline, 23% of boys and 19% of girls were overweight and 9% of boys and 4% of girls were obese (IOTF criteria[61]). Only 37% of children consumed six or more servings/day of V&F at baseline.

In contrast, children who participated in the effectiveness trial more closely reflected the demographics of the whole province of BC (2006 census[76]). Most children (56%) were of North American/European descent, while the rest were of East, South East or South Asian (24%), North American Aboriginal (10%), or mixed/other (10%) descent. At baseline, 33% of children accumulated less than 60 min/day of PA, while 13% accumulated less than 30 min/day. Using IOTF criteria,[61] 21% of boys and 19% of girls were overweight and 10% of boys and 6% of girls were obese at baseline.

Physical activity

PA levels in the efficacy trial, as measured by pedometer steps/day averaged across four time points, were significantly higher

(p=0.03) among boys attending AS! BC Liaison Schools compared with boys attending UP schools (+1175 steps/day, 95% CI 97 to 2253).[45] Boys attending AS! BC Champion Schools tended to have higher PA than boys attending UP schools, but this difference was not statistically significant (+804 steps/day, 95% CI −341 to 1949; p=0.17). Among girls, there were no between-group differences in PA as measured by a pedometer. As measured by a questionnaire (averaged across three time points), girls attending AS! BC schools had a higher average PA score compared with children attending UP schools (2.61±0.42 vs 2.55±0.37).[44] Girls attending AS! BC Champion Schools reported significantly more minutes of daily moderate-to-vigorous physical activity (MVPA) than both AS! BC Liaison School (+19 min/day, p=0.005) and UP girls (+14 min/day, p=0.04).

Cardiovascular health

Children in the PA efficacy trial INT group had a 20% greater improvement in the number of laps completed compared with the UP group (+10 laps for INT compared with −1 lap for UP from baseline to follow-up after adjustment, p<0.05).[44] At follow-up, and after adjusting for baseline values, the INT group completed 6.6 (95% CI 3.8 to 9.5) more laps than the UP group (corresponding to a difference in the estimated VO_2 max of 1.6 mL/kg/min). AS! BC children also demonstrated a significant decrease (−6%) in systolic blood pressure compared with an increase in the UP group (−3 mm Hg for INT compared with +4 mm Hg for UP from baseline to follow-up after adjustment, p<0.05).[44] AS! BC children deemed 'at risk' at baseline, based on several CVD indicators, had greater changes in fitness and blood pressure compared with their 'at-risk' peers in the UP group (p<0.05).[77] In the effectiveness trial, girls and boys attending AS! BC schools had a greater improvement (+40%) in fitness compared with the UP group after the first year of intervention (under review).

Bone health

In the efficacy trial, prepubertal boys in AS! BC schools tended to have a greater increase in bone strength than UP boys at the distal (~3%) and mid tibia (~2%).[47] At the hip, the change in bone strength tended to be greater (~2%) for AS! BC girls than UP girls (intent-to-treat analysis).[46] This change was significantly greater in girls (n=43, p=0.03) whose teachers reported at least 80% compliance with the intervention. AS! BC boys also had greater gains (2–3%) in the lumbar spine and total body bone mineral content as measured by DXA.

Healthy weight

In the efficacy trial, changes in % body fat[78] and BMI[44] were not significantly different across groups.

Perceived competence

In the efficacy trial, perceived competencies (athletic, social and academic) decreased significantly over time in boys and girls.[55]

Academic performance

Children attending UP schools scored significantly higher on the CAT-3 compared with children attending AS! BC schools at baseline (June 2003).[54] Despite this, test scores between children attending AS! BC and UP schools were not significantly different at follow-up (June 2004; −15.3; 95% CI −41.8 to 11.2).

Vegetable and fruit consumption

From baseline (Fall 2005) to follow-up (June 2007), children attending AS! BC schools demonstrated significantly greater increases in the number of servings of fruit (INT: +0.2 servings/day vs UP: −0.5 servings/day) and V&F (INT: +0.4 servings/day vs UP: −0.7 servings/day) compared with children attending UP schools. They also demonstrated significantly greater increases in the variety of V&F consumed (INT: +0.3 servings/day vs UP: −0.2 servings/day) compared with children attending UP schools. The frequency of fruit consumption decreased at both AS! BC and UP schools, while vegetable consumption increased at both.

Willingness to try new vegetables and fruit

Children attending AS! BC and UP schools were similar in their willingness to try new V&F at baseline. By follow-up, AS! BC children increased their willingness to try new V&F more than children attending UP schools (INT: 3.0 vs UP: 1.1; a 5% greater increase in children attending AS! BC schools). Concomitantly, children attending AS! BC schools demonstrated a 10% increase in the per cent of V&F tried compared with a 4% increase in children attending UP schools (p<0.05).

DISCUSSION

Scale-up and sustained investment in evidence-based school PA and HE interventions is most likely one key solution to curb downward trends in PA and HE and improve child health. We offer up AS! BC as one clear illustration of how, through committed and sustained cross-sectoral partnerships, comprehensive evaluation, feedback and adaptation, an innovative whole school model was implemented, scaled up and sustained for 10 years in British Columbia. The reach of AS! BC is substantial—94% of schools and over 80 000 teachers, administrators and other key stakeholders. We know of only a handful of other school-based models worldwide that have achieved widespread and sustained implementation, for example, CATCH[79] SPARK,[80] TAKE-10!/PAAC[81] and JUMP-in.[82] We discuss key aspects of implementation of the AS! BC model as they relate to the literature on scale-up and implementation of other school-based PA and HE promotion.

First, we adopted a multilevel approach based on socioecological theory and established partnerships with key education, health and not-for-profit stakeholders to develop, implement and evaluate a school-level model. Second, we began efficacy trials with a potential scale-up in mind. The provincial model recognised and utilised joint decision-making with stakeholders, government partnerships and the connection between school and community at each stage and over time. We also employed an iterative approach, embedding evaluation in each stage and utilising interdisciplinary research teams and participatory processes to facilitate knowledge to action cycles. At the school level, we developed and implemented a comprehensive whole school intervention that was flexible and allowed schools to choose activities that worked best for their context while providing a required dose of PA or HE. Importantly, the AS! BC model, while including physical education and the HE curriculum, moved beyond physical education to provide more opportunities for children to make healthy choices throughout the school day. A centralised technical support unit acted, and continues to act, as a knowledge broker linking with school stakeholders to: provide training, tools and resources for them to implement PA and HE activities, develop and continue to refine tools and support resources and link the Provincial Advisory Group to school-level stakeholders and feedback.

Scaling up efficacious models into real-world settings is increasingly recognised as important in the public health research community.[41 83 84] In support of this, there is now substantial evidence across multiple disciplines regarding factors

that support successful implementation. Damschroder *et al*[85] reviewed 19 models that emerged from the implementation science literature across the healthcare, business and education sectors. Many of the factors identified in these models were common across disciplines. We adopted an implementation approach at the provincial level that incorporates factors identified as key at the macro level.[24 86] Our approach also aligns with a successful scale-up model proposed by Yaney.[84] Strong leadership, a local delivery system, engaged government[87] and community stakeholders all played a key role in the implementation and sustainability of the AS! BC model. Importantly, we focused on identifying the needs of teachers using a cascade (train the trainer) and phased approach, tailored to context, supported by decentralised delivery and integrated into the existing education system. The school context was embedded within a supportive system—with engaged and activated school communities, substantial political will and supportive policies.

At the school level, we incorporated two conceptually distinct but inter-related components that Domitrovich *et al*[86] considered key to quality school-level implementation. These were: (1) a novel intervention (AS! BC) and (2) an effective support system. This is not dissimilar to Simmons and Shiffman's[83] concept of scale-up strategies.

The AS! BC model enhanced PA opportunities for students who participated. However, the measurable effects were modest.[45] The most substantial health benefit from the intervention was improved cardiovascular fitness—enhanced more so in children who were considered of higher risk at baseline.[77] Not surprisingly, and in keeping with effective implementation related to dose,[24] beneficial effects on bone health were exaggerated in schools where the magnitude of implementation was greatest.[46] Taken together, AS! BC may be an effective means to ameliorate some chronic disease risk factors in children.

Our results are similar to other school-based interventions.[32 33 36 88–90] That is, the response to our intervention varied depending on the outcome examined, the specific measure we used and the sex of participants. We found no difference for change in BMI or % body fat across conditions. We engaged the whole school population where a large proportion (about 70%) of children were of healthy weight. Although the converse of this, that almost 30% of children were overweight or obese, is alarming, our sample size was most likely too small and our intervention too short to positively and significantly shift this outcome. We are unable to speculate as to whether results would have been different had PA and HE components been implemented simultaneously rather than phased in over time.[91] Our findings support several recent systematic reviews and meta analyses of childhood obesity prevention interventions that demonstrated improved PA levels and/or eating behaviour but no, or minimal, impact on BMI.[92–94] Despite our model having no effect on body weight, it is noteworthy that cardiovascular fitness improved. This is key, given the relation of childhood fitness to obesity in adolescence[95] and adulthood.[96–98] Furthermore, fitness and adiposity have independent relationships with CVD risk in this age group.[97–99] Studies that focused on metabolic syndrome showed that changes in diet and exercise improved insulin resistance independent of weight loss.[100 101]

Similar to previous longitudinal research conducted with this age group,[102–105] our intervention had no impact on perceived self-competence. Although activities were chosen whereby children of all physical skill levels could participate, the model did not focus on teaching children cognitive-behavioural strategies. The intervention may have also been insufficient to overcome the age-related decline in self-concept.[53 102 106]

Our results at the school level should be viewed in the context of the 'real world'. Schools are complex systems that adapt continuously.[107] For instance, frequent changes in those who deliver the innovation (eg, teachers and administrators) are common.[107] Schools most likely also respond to factors in the wider school system and community that we did not assess, for example, geographic, curricular or economic changes. Our findings, previous evidence from the implementation science literature[24 25] and the variable and dynamic nature of school contexts, frame the need for ongoing training and support for schools and teachers.

The AS! BC school model is a customised, participatory, comprehensive school health-based model that we implemented in the current context of BC elementary school education. With training and resources, schools provided at least 10 additional min/day of PA during the efficacy trial.[43] This is comparable to physical education-based strategies (CATCH)[33 108] and 'activity' break strategies from other jurisdictions.[36 90 109–111] However, the classroom was a key location for reaching all students and measuring change. That said, a modest increase in minutes of MVPA in physical education[32 108] may have also contributed to the improved cardiovascular fitness of children in INT schools. We were unable to discern the time of day of PA using pedometers[112] and used accelerometers[113] in our effectiveness trial to address this. Activities planned across zones other than physical education and Classroom Action were intermittent and we were unable to assess their specific contribution to overall PA. These types of whole school activities may signal cultural change and support by administrators for school-based healthy living initiatives. The process evaluation noted that teachers perceived enhanced support for PA promotion within INT schools.[43]

Ours is one of the very few studies in the literature that examined factors thought to influence scale-up and dissemination of a school-based PA and HE model. Notably, SPARK assessed sustainability 4 years after dissemination.[80] Most other studies examined factors that influenced implementation in efficacy trials.[106 114–120] A takeaway message regarding scale-up is the importance of policies and guidelines (eg, provincially mandated PA or dietary guidelines; school policy to include PA in all school assemblies) that support adoption and sustained implementation[52 121] and the need to create a supportive environment for implementation, for example, by providing adequate training and resources for teachers.[52]

We acknowledge that our trials had several limitations and many of these have been noted in our published work. Our ability to draw conclusions about subtle changes in PA and health outcomes was limited by measurement challenges with children (especially for PA) that we[43] and others[122 123] documented previously. Our efficacy trial was developed within some real-world 'constraints' that typically influence public health interventions and evaluations. Most importantly, we implemented the model amidst a rapidly changing social context for action on PA and HE. Our effectiveness trial was even more pragmatic in nature and measured the impact of a delivery approach that was financially feasible during scale-up where teachers received training but slightly less school level support than in the efficacy study. This may explain the lower volume of PA delivered by teachers in the effectiveness trials compared with the efficacy trial. AS! BC was also implemented in the context and aftermath of a Provincial teacher strike that may have dampened the enthusiasm of some teachers for voluntary add-ons. We acknowledge that the magnitude of some effects on children's health was small. For example, during the efficacy trial, children in the intervention group demonstrated 2–3% greater

gains in bone mass and strength compared with controls. We were unable to evaluate sustainability of these outcomes, or the impact these small improvements would have on adult bone health and fracture risk. However, other school-based studies demonstrated sustained benefits of a PA intervention on bone health 8 years after cessation of the intervention,[124] and recent evidence suggests that participation in PA during childhood provides sustained,[125] and even lifelong,[126] benefits to bone strength. Furthermore, the onset of osteoporosis might be delayed by 13 years[127] and risk of fracture in postmenopausal women halved[128] if the peak bone mass were increased by 10% or 1 SD, respectively. Small changes in health-related behaviour during childhood may also impact adolescent and adult health due to the tracking of behaviours across these time frames.[129] Finally, it seems important that public health action on child health extend beyond the school door if we are to stem the obesity epidemic, as there is little evidence that PA within school transfers to out-of-school activity.[32 36 108 130 131] School-based approaches might best be considered as one component of a broader social change strategy.

In closing, the success of AS! BC in British Columbia to date speaks of the readiness of the community to adopt a model that addresses the health concerns confronting a generation of children and adolescents, their parents, teachers, health practitioners and the larger community. In future, sustained multisite trials that engage larger numbers of schools and children are required to account for the clustering inherent in school-based research and to determine the impact of school-based interventions on overweight and obesity. However, in jurisdictions where leveraging funding for such large longitudinal trials is a challenge, we believe that mixed methods and multiple studies over time may contribute substantially to the knowledge base. In addition, we encourage studies that compare and combine voluntary and policy-regulated models to determine if implementation levels and issues vary substantially based on approach.

What are the new findings?

- Ongoing, multidisciplinary and cross-sectoral research partnerships may enhance the potential of school-based initiatives to have public health impact.
- The development, adaptation and evaluation of school-based physical activity and healthy eating interventions from efficacy to effectiveness to provincial/state level scale-up is essential to understand whether these models can be implemented and sustained in real-world settings. This demands substantial investment by government and engaged collaborators across research disciplines, schools, communities and multiple levels and sectors of government.
- At the school level, whole school models, such as Action Schools! BC, can positively influence children's physical activity, health and healthy eating attitudes and behaviours.
- In real-world settings such as schools, effects may diminish over time. Thus, it is essential that ongoing training and supportive policies and guidelines are in place. Where training and supportive policies are in place, implementation of physical activity and healthy eating models is greater.

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Supplementary Table 1. Details of the published manuscripts and abstracts related to the Action Schools! BC efficacy trial.

Author	Sample	Objective	Instrument	Outcomes	Statistical Analysis	Results
Naylor et al [40]	N = 10 schools (4 LS, 3 CS, 3 UP) N = 7 administrators N = 49 teachers N = 26 students	1. To describe the implementation (feasibility/fidelity) of AS! BC 2. To evaluate the impact of AS! BC on the provision of PA	1. Teacher Activity Logs 2. Action Plans 3. Teacher surveys 4. Focus groups (Administrators, teachers, parents, students)	1. Minutes per week of classroom PA. 2. Teacher compliance 3. Teacher satisfaction 4. Qualitative outcomes (from focus groups)	Physical activity: Linear mixed model - DV = minutes/week of PA - Fixed effect = group - Random effect = school - Group x Phase (I or II) interaction included Qualitative outcomes: - NVivo and an editing analysis approach with open coding	1. Physical activity delivered was significantly greater in LS and CS schools compared with UP schools (~10-12 min/day, $p < 0.05$). 2. Teacher compliance with AS! BC was moderate (75%). 3. Teachers were highly satisfied with training and support. Benefits of AS! BC included positive changes in students and school climate.
Macdonald et al. [44]	N = 410 (281 INT, 129 CON; 209 boys, 201 girls)	To determine if AS! BC was effective for increasing bone strength at the distal tibia and tibial midshaft.	Peripheral quantitative computed tomography (pQCT)	**Distal tibia:** Bone strength index (BSI) **Midshaft tibia:** Polar strength-strain index (SSI_p)	Linear mixed model - DV = change in BSI and SSI - Fixed effect = group (INT, CON) - Random effect = school - Covariates = baseline bone value, baseline weight, change in leg length, change	1. INT boys tended to have a greater gain in BSI and SSI_p than CON boys, but the difference was only significant for BSI among prepubertal boys (BSI, $p = 0.03$). 2. Change in BSI and SSI_p was similar between INT and

					in muscle area, final Tanner stage (girls) - Group x maturity (pre- or early pubertal) interaction	CON girls.
Ahamed et al. [51]	N = 287 (214 INT, 73 UP; 143 boys, 144 girls)	To assess the influence of school-based physical activity on children's academic performance.	Canadian Achievement Test (CAT-3)	**Total score** – summation of scores from the math, reading and language/writing components	Linear mixed model - DV = Total score at followup - Fixed effects = group (INT, CON), sex - Random effect = school - Covariate = baseline Total score	1. No difference in Total Score between INT and UP at followup. 2. Group x sex interaction not significant.
Rhodes et al. (abstract) [52]	N = 344 children	To determine the effect of AS! BC on perceived competencies.	Harter's perceived competence scale for children	1. Athletic competence 2. Social competence 3. Academic competence 4. General self-esteem	Repeated measures ANOVA - time x group interaction terms	1. Time x group interaction was not significant for any outcome. 2. Significant main effect of time for all outcomes – perceived competencies decreased during the study.

Naylor et al. [42]	N = 444 children (165 LS, 146 CS, 133 UP; 225 boys, 219 girls)	To determine the effect of AS! BC model on children's physical activity levels.	1. Pedometers 2. Physical Activity Questionnaire for Children (PAQ-C)	1. Steps/day (average of 4 time points) 2. Minutes of MVPA/day	Linear mixed effects model - Fixed effect = group (LS, CS, UP) - Random effect = school - Analyses conducted for boys and girls together and separately	1. Children in LS schools took ~1200 more steps per day than children in UP schools ($p = 0.04$). Analysis by gender showed this group difference to be significant for boys only. 2. Girls in the CS group reported more minutes per day of PA than girls in the LS and UP groups ($p < 0.05$).
Reed et al. [41]	N = 237 (156 INT, 81 UP) N = 77 for blood samples	1. To determine if AS! BC is an effective model for decreasing CVD risk factors. 2. To assess the CVD risk profile to the intervention in children deemed "at risk".	1. Leger's 20-m incremental shuttle run test 2. Automated sphygmomanometer 3. Intravenous blood samples	1. Fitness 2. Systolic & diastolic blood pressure 3. Total cholesterol, high and low density lipoproteins, apolipoprotein B, C-reactive protein and fibrinogen.	ANCOVA - DV = fitness, BP, BMI, blood markers - Fixed effect = group (INT, UP) - Covariates = baseline value for each DV ANOVA (for 'at-risk' comparison of 4 groups with Bonferroni correction) - UP NORM - UP RISK - INT NORM - INT RISK	1. INT children had greater increases in fitness and lower increases in BP than UP children ($p < 0.05$). 2. INT children had larger (NS) decreases in all serum variables than UP children. 3. INT children in the 'at-risk' group had significantly greater changes in BP and serum markers than INT children in the NORM group.

Macdonald et al. [43]	N = 412 (294 INT, 117 CON; 213 boys, 199 girls)	1. To evaluate the effectiveness of AS! BC for enhancing femoral neck bone strength in boys and girls. 2. To determine the effects of AS! BC on total body, lumbar spine and proximal femur bone mass.	1. Dual energy X-ray absorptiometry (DXA) 2. Hip structure analysis (HSA)	**Femoral neck:** - section modulus (FN- Z) (indicator of bone bending strength), cross-sectional area and subperiosteal width - Bone mineral content (BMC) - Bone area **Total body, lumbar spine & proximal femur** - Bone mineral content - Bone area	Linear regression - DV = change in bone outcomes - variance inflation factor applied to standard error to account for clustered design - group = INT, CON - covariates = baseline height (girls) or weight (boys), change in height, change in lean mass, final Tanner stage	1. Change in FN-Z tended to be greater (+3.5%, p=0.1) in INT girls. This difference increased to 5.4% (p=0.05) in a per-protocol analysis that included girls who teachers reported at least 80% compliance. 2. INT boys had greater gains in BMC at the lumbar spine (+2.7%, p=0.05) and total body (+1.7%, p=0.03) than CON boys.

LS = Liaison schools; CS = Champion schools; UP = Usual practice; AS! BC = Action Schools! BC; PA = physical activity; DV = dependent variable; IV = independent variable; INT = intervention; CON = control; CVD = cardiovascular disease; ANCOVA = analysis of covariance; ANOVA = analysis of variance