A trial of a six-month sugar-sweetened beverage intervention in secondary schools from a socio-economically disadvantaged region in Australia

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Abstract

Objective: This study assessed the effectiveness of a school-based intervention in reducing adolescents' sugar-sweetened beverage (SSB) consumption and percentage of energy from SSBs. Secondary outcomes were SSB consumption within school, average daily energy intake, and body mass index z-scores.

Methods: Six secondary schools located in New South Wales, Australia were recruited to participate in a six-month pilot randomised controlled trial (1:1). The intervention included components targeting the school nutrition environment, curricula and community. Outcomes were collected via online surveys, observations, anthropometric measurements and project records. Between-group differences were assessed via linear mixed models.

Results: At the six-month intervention endpoint (n=862) there were no statistically significant differences between students in intervention or control schools for mean daily intake of SSBs (8.55mL; CI -26.77, 43.87; p=0.63), percentage daily energy from SSBs (0.12% kJ; CI -0.55, 0.80; p=0.72), or for secondary outcomes. Acceptability of the school-based strategies were high, however intervention fidelity varied across schools.

Conclusion: While acceptable, improving fidelity of implementation and increasing the duration or intensity of the intervention may be required to reduce SSB intake.

Implications for public health: Engaging parents and education stakeholders in the development phase to co-design interventions may prove beneficial in improving intervention fidelity and enhance behavioural outcomes.

Key words: adolescent health, nutrition, childhood obesity, schools, behaviour change

Globally, between 1975 to 2016, the number of children and adolescents aged five to 19 years who were overweight or obese increased from 11 million (4%) to 124 million (18%).[1] In Australia in 2017, 20.8% of 12 to 15 year olds and 28.1% of 16 to 17 year olds exceeded healthy weight recommendations for their age.[2] As excess body weight tracks into adulthood, increasing the risk of a variety of chronic diseases,[3] health organisations and governments have prioritised strategies to reduce the prevalence overweight and obesity in adolescents.[4]

Excess intake of free sugars (all sugars added to foods, plus the sugars that are naturally present in honey, syrups and fruit juices) is a key contributor to unhealthy weight gain, among other dietary patterns.[5,6] Despite the World Health Organization (WHO) recommendation that free sugar intake be limited to less than 10% of total daily energy intake,[7] population surveys of high-income countries internationally suggest that most adolescents exceed this.[8,9] Globally, adolescents are the largest consumers of SSBs across all age groups.[7] In Australia, for example, over half of the free sugar intake in adolescent diets come from sugar-sweetened beverages (SSBs), especially from soft drinks, electrolyte drinks and energy drinks (19%).[8] Many studies have drawn associations between socio-economic status and health, such as rates of overweight and obesity being particularly high in adolescents from disadvantaged socio-economic groups.[10,11] Additionally, SSB consumption is generally higher among the socio-economically disadvantaged.[12-14] The 2011 Health Survey by the Australian Bureau of Statistics reported that Australians in the most disadvantaged socio-economic quintile were more likely to consume SSBs compared to the least disadvantaged Australians (38% versus 31%).[15]

Schools are an attractive setting for public health nutrition interventions targeting adolescents,[14,16,17] given their health education mandate, links to families and the community, access to large numbers of children for prolonged periods, and as one of the main food and beverage retailers for adolescents in many countries.[18] Reviews investigating the effectiveness of behavioural interventions on reduction of SSB consumption in this setting report a number of intervention characteristics that appear to be associated with effectiveness.

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These include price increases on SSBs, greater availability of healthier alternatives, the use of promotional strategies to facilitate healthier food or beverage selection, involving the community stakeholders, interventions with a targeted parental component, and interventions that are of 12 or more months in duration.[17,19] Additionally, interventions based on theoretical frameworks and incorporating behavioural change theories (for example the Behaviour Change Wheel[20]) have been suggested to improve effectiveness.[17] Such evidence supports the use of the Health Promoting Schools (HPS) framework in the design of school-based nutrition interventions. Specifically, the framework recommends interventions include strategies across three main domains: i) ethos and environment (encompassing the physical environment and setting of the school); ii) the curriculum (what is taught at school); and iii) the community (including the engagement of the wider community and families).[21,22]

Despite the developing evidence base, trials of school-based interventions targeting SSB consumption of students often have a number of methodological shortcomings. A recent systematic review of secondary school-based SSB trials identified 13 randomised controlled trials (RCTs); nine reported the tested intervention was effective in reducing SSB intake.[23] Of those, however, only five employed a validated measure of dietary intake, four used a comprehensive theoretical framework and three assessed daily energy consumption. A further limitation of school-based SSB intervention trials and school-based nutrition interventions broadly, is the limited reporting of strategies employed to support the implementation of the intervention within schools.[24] Previous research suggests enablers of healthy changes in the food environment of schools include providing sufficient funding, effective communication and involving stakeholders.[25] The reporting of these or other implementation strategies employed as part of intervention trials is needed so that end-users interested in supporting public health nutrition intervention in schools are able to adequately assess the feasibility of doing so.

Given the higher rates of SSB consumption among socio-economically disadvantaged students, interventions that are effective in these populations may be particularly important to address existing health inequities. However, the RCTs of school-based interventions targeting SSBs identified in systematic reviews did not identify whether the studies were undertaken in samples of socio-economically disadvantaged students.[19,23] In this context, this study sought to address some of the shortcomings of previous trials, and draw on past research regarding effective intervention componentry to test the effectiveness of a secondary school-based intervention on student SSB intake in a New South Wales (NSW), Australia context.

Therefore, the aim of this study was to assess the potential efficacy of a school-based nutrition intervention in reducing daily SSB consumption and daily percentage energy from SSBs of Australian secondary school students from a socio-economically disadvantaged region in NSW. As secondary outcomes, the trial also sought to assess the efficacy of the intervention on i) mean daily SSB consumption within school, ii) average daily energy intake. Additionally, as interventions targeting SSB intake have previously, but not consistently yielded changes in measures of adiposity,[23] we also sought to assess as a secondary outcome the impact of the intervention on student BMI z-scores.

Methods

Trial registration and ethics

This trial was prospectively registered with the Australian New Zealand Clinical Trials Registry ACTRN12617001213336 and this manuscript is reported in adherence with the CONSORT extension for Cluster Trials 2012 guidelines.[26] Ethics approval was obtained from the Hunter New England Human Research Ethics Committee (reference number: 17/06/21/4.07), and the Catholic Schools Office for the Dioceses of Maitland-Newcastle. Funding was provided by the Ministry of Health's Translational Grant Research Scheme (TRGS).

Study Design

The study was implemented as a parallel group, pilot cluster RCT in six secondary schools in NSW, Australia. The schools were recruited in the Hunter region of NSW which has a lower socio-economic status than the New South Wales average. Secondary schools in Australia cater for students aged between 12 and 18 years. A full description of the trial methods is reported in the published protocol.[27]

Eligibility criteria

Schools from the Catholic Schools Office (CSO) and the Association of Independent Schools (AIS) were eligible for inclusion if they were i) co-educational, ii) enrolled year 7 to 9 students (generally ages 12-15 years), iii) had an average of ≥100 students per year level, iv) had an onsite food outlet (i.e. school canteen) selling SSBs to students, v) had an electronic communication channel for the school to communicate directly with parents of students and vi) not participating in another current school-based physical activity or nutrition program. All students in Years 7 to 9 of participating schools were invited to take part in the data collection component of the study.

Recruitment and randomisation

An invitation to participate in the study was posted to a convenience sample of schools after which a research officer contacted the school principal to invite participation. Following recruitment and baseline data collection, participating schools were randomised. Further recruitment and randomisation details can be found in the protocol for this study.[27]

Due to the nature of the intervention, students and staff were not blinded to their school's group allocation, however, the intervention components were not detailed specifically to them.

Intervention

Theoretical framework

The intervention was developed using the WHO's HPS framework and included strategies aligned to each of the three domains of the framework: ethos and environment, curriculum and teaching, and partnerships and services.[21] The intervention targeted modifiable factors suggested to mediate SSB intake identified in recent reviews.[14,28-31] These factors included school SSB availability[14,28,29] and convenience,[14,29] pricing of SSBs,[14,29] health-related self-efficacy,[28,29] peer influence,[28,29] home SSB availability[14,28,29] and parental intake of SSBs.[28,32] The Behaviour Change Wheel (BCW) is a consolidated behavioural framework intended for use in the development of behavioural interventions, whereby there are three main tiers. The sources of the

behaviour are at the core, policies such as guidelines and legislation on the outermost layer and the intervention functions such as education, enablement and modelling in the middle layer, linking the policy categories to the changes in behaviour.[20] The BCW was used to map the targeted factors with behavioural change techniques, to improve student capability and provide opportunity or motivation to limit SSB consumption.[20] The intervention components mapped to the BCW framework are described in Figure 1.

Intervention components

A multi-component intervention designed to reduce students' consumption of SSBs was implemented in the three intervention schools between May and September 2018. Intervention implementation occurred in two phases with strategies targeting the school ethos and environment implemented in the first intervention term (first three months). Following midpoint data collection, strategies targeting school curriculum and family and community strategies were implemented in the second intervention term (final three months) (Figure 2). Detailed intervention components were described in the intervention protocol and Supplementary File 1.[27]

Ethos and environment:

- School guiding principles to supplement the school's existing plans
- Food outlet (school canteens) modifications based on principles of choice architecture
- Installation of water stations on school grounds

Curriculum and teaching:

- Curriculum lessons targeting SSBs
- Peer-led school challenge designed and led by a student committee
- Six short fortnightly health messages to students

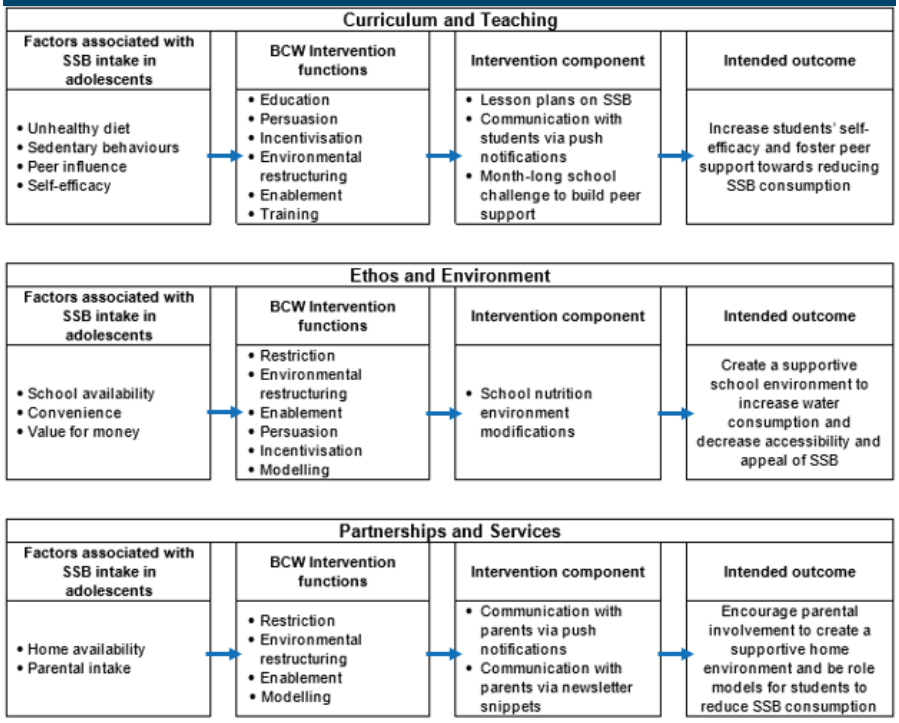
Partnerships and services:

- Six short fortnightly health messages to parents
- Newsletter snippets to provide updates on the intervention

Implementation support strategies

To facilitate the delivery of *switchURsip* in schools, a number of implementation support

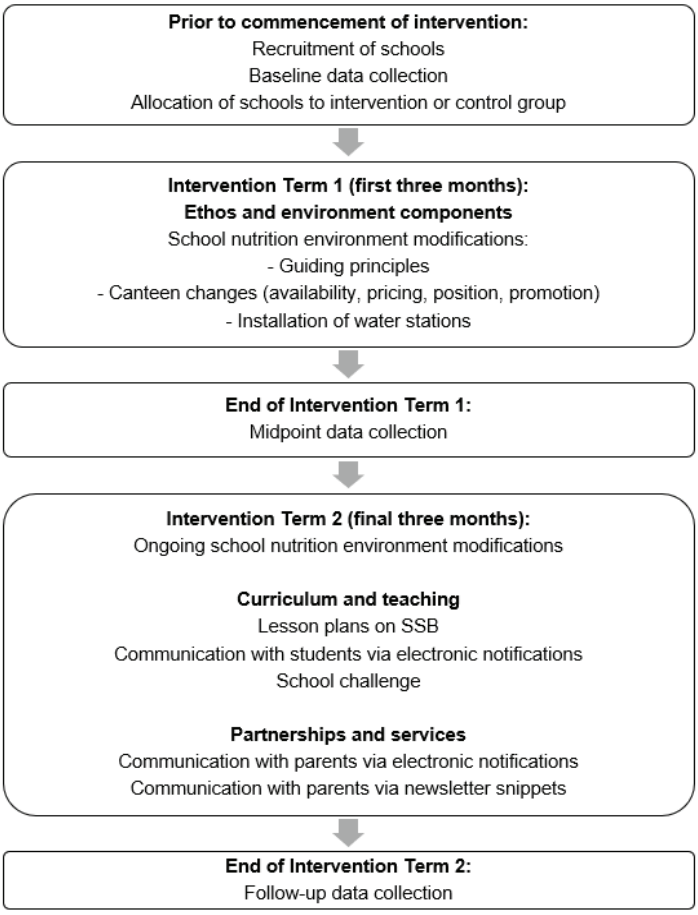
Figure 1: Mapping of modifiable factors associated with SSB intake in adolescents to the BCW intervention functions.



Notes:

BCW = Behaviour Change Wheel; SSBs = sugar-sweetened beverages; HPS = Health Promoting Schools

Figure 2: Intervention timeline.



strategies were utilised in the trial. These included supporting schools to demonstrate executive leadership, establishing oversight committees, providing audit and feedback, provision of resources, staff professional learning, and communication and marketing materials. Further details describing the implementation strategies in detail, and the rationale for their selection were described and elaborated in detail in the published protocol.[27]

Control group

Students attending schools allocated to the control group participated in baseline, midpoint (after first intervention school term) and follow-up data collection (after second intervention school term), but otherwise continued with their standard school programs and operations. Schools in New South Wales are required to teach to a standard curriculum that includes nutrition curriculum aligned to the Australian Dietary Guidelines (though it does not target SSBs explicitly).[33] These schools were given access to the program resources and support once follow-up data collection was completed.

Data collection procedures and measures

Data was collected via online student, teacher and parent surveys, anthropometric measurements and school environment observations at three time points: baseline (prior to commencement of intervention), midpoint (end of the first term following implementation of ethos and environment components), and follow-up (endpoint of intervention following implementation of the curriculum and partnership components) (Figure 2). A team of researchers visited schools to administer the online survey to all students using tablets provided by the research team and supervised by school teachers and research assistants. All surveys except the Australian Children and Adolescent Eating Survey (ACAES) were hosted on the Research Electronic Data Capture (REDCap) software. Anthropometric measurements and school environment observation were conducted by trained research assistants.

This paper focuses on the follow-up outcomes (endpoint) of the intervention, evaluating the impact of the multi-component intervention targeting all three domains of the HPS framework. Midpoint data is reported elsewhere.

Primary outcomes

The primary outcomes of this trial were i) overall daily SSB consumption (millilitres (mL)), and ii) daily percentage energy (% kilojoule (kJ)) from SSBs. Data for these outcomes were collected using the ACAES, a 120-item online food frequency questionnaire validated in a sample of 224 children aged between nine and 16 years in the study region.[34]

Secondary outcomes

The secondary trial outcomes included i) mean daily SSB consumption in school, ii) mean daily energy intake (kJ), and iii) student body mass index (BMI) z-scores. Mean daily SSB consumption in school were collected using questions adapted from the ACAES, modified to specify usual intake while at school. Average daily energy intake was calculated from the ACAES and student BMI was calculated objectively by measuring height and weight.[35] BMI status was determined using the using International Obesity Taskforce cut points.[36] Following the advice of dietitians specialising in eating disorders and our institutional research ethics committee, BMI was measured in a nested sample of students, only year 7 students who consented had their height and weight measured.

Additional measures

Intervention acceptability: At follow-up, we assessed the acceptability of intervention components to students, parents and staff via the online surveys (eight items). Acceptability items were not validated but were modelled on previous items of school-based intervention developed by the research team.[4,5] The survey items assessed acceptability of school environment and curriculum strategies in addition to the materials targeting the home environment. A full list of survey items can be found in Supplementary Table 1.

Compensatory dietary behaviours: Comparison of percentage energy from core and non-core foods obtained from the ACAES were examined to assess any compensatory eating behaviours caused by any changes in student SSB intake as a result of the intervention (e.g. increased intake of other unhealthy snack foods).[37]

Process evaluation

A detailed process evaluation has been described in the protocol[27] in addition to the paper on the midpoint intervention results.[38]

In brief, the intervention fidelity and uptake of availability, pricing, placement and promotion strategies of SSBs prescribed by the intervention to school canteens was assessed by research staff during a one-day school visit for a school environment audit at each time point. Installation and condition of the water stations were also recorded during an audit of school facilities during the visit. To assess the curriculum and partnerships intervention components, school liaison officers and canteen managers of intervention schools were asked to complete an online survey evaluating the fidelity and acceptability of each intervention component.

Sample size calculation

Assuming an intraclass correlation (ICC) of 0.02,[39] across six participating schools, a sample size of 630 participating students per group or 1,260 overall would be sufficient to detect a difference in mean overall daily SSB consumption of 81.05mL (80% power, 0.05 significance level).

Statistical analyses

Descriptive statistics were used to describe the study sample. Analyses of the food frequency questionnaire were conducted by the Australian Eating Survey team. Further comparison analyses were undertaken by an independent statistician using SAS V.9.3 software.[40]

Between-group differences at follow-up for primary and secondary outcomes were assessed under an intention to treat framework using linear mixed models, through a group-by-time interaction term, to account for school level clustering, controlling for baseline values, gender and school Socio-Economic Indexes for Areas.[41] Dietary records with highly implausible values were excluded from the analyses by applying cut off points for energy using a minimum of 2,090 kJ and a maximum of 20,900 kJ,[34] and then removing values wider than three standard deviations (SD) (-2,750.11 to 19,584.81 kJ) from the mean energy intake. A dietitian reviewed the data and removed any implausible variations in energy intake between time points.

Outcomes were analysed using all available data. As part of sensitivity analyses, missing data at follow-up time points were imputed using multiple imputation methods. Exploratory sub-group analyses were conducted for primary and secondary

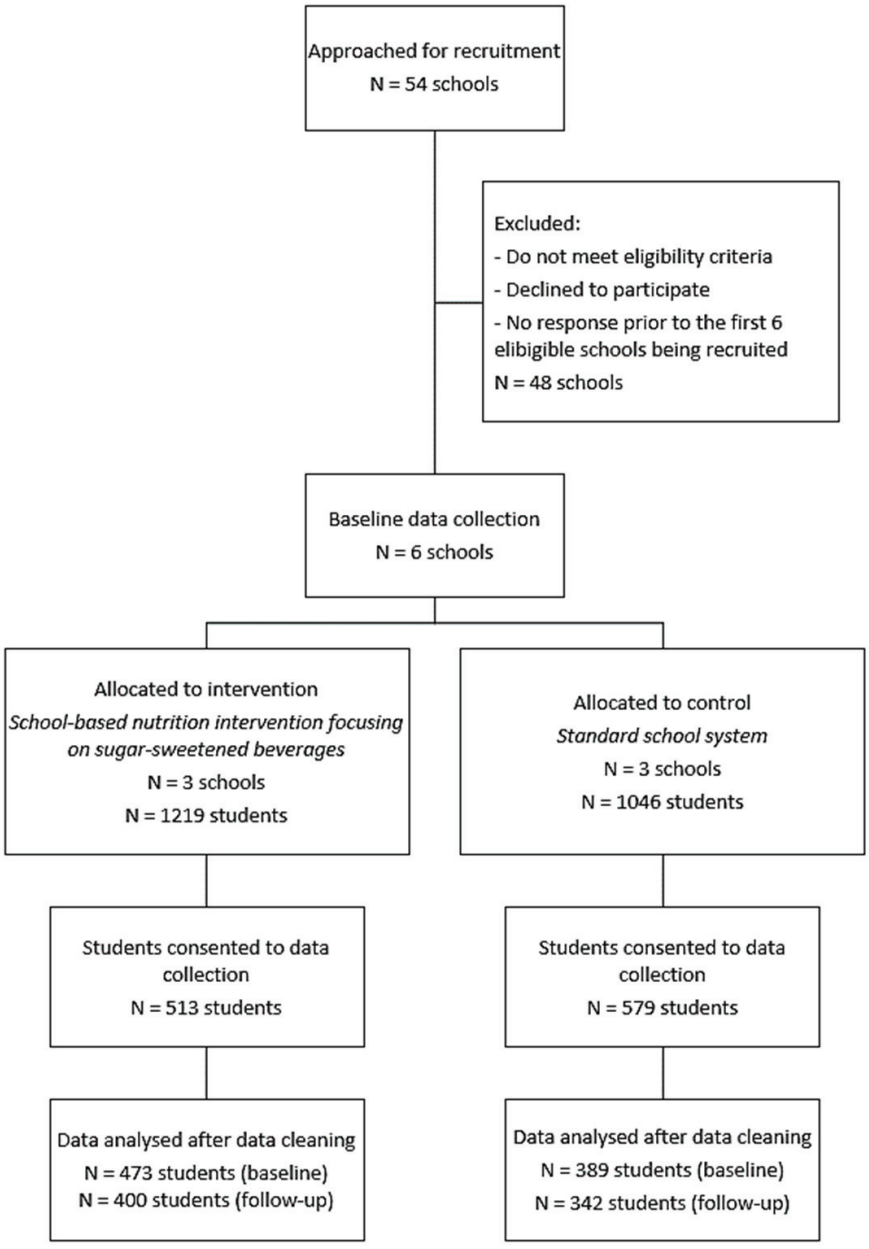
outcomes by gender, school year level (Years 7; 8; 9), BMI z-score categories (healthy weight or under; overweight or obese), and frequency of canteen usage (never; once or twice a week; three or more times a week).

Results

Sample

Fifty-four eligible schools were informed of the study and invited to participate in the study. Recruitment continued until a total of 25 schools were contacted before six schools consented to participate (2 CSO, 4 AIS). Of the 2,265 eligible students in Years 7 to 9 at participating schools, 1,092 students consented to have their data collected and 940 students (86.0% of consenting students) participated in baseline data collection (Figure 3). After removal of implausible dietary records and within-person variation over time, 862 students were retained in the sample and included in the final analysis (52.6% female) (Table 1). Of the 765 total year 7 students, 401 (54.7%) provided consent to have their anthropometric measures taken and data from 333 students were collected. The prevalence of children with overweight or obesity was higher among students in the control compared to the intervention group at baseline. Otherwise, the baseline characteristics of participants between groups were similar (Table 1). There were no significant differences between participants who completed data collection and those who did not in terms of gender, school year, weight status, and energy and SSB intake ($p>0.05$).

Figure 3: Participant consort diagram.



Primary outcomes

There were no significant differences between groups for the primary trial outcomes when data was analysed using all available data or following multiple imputation as part of sensitivity analyses (Table 2). For the mean overall daily SSB consumption, there was a within group reduction in mL of SSBs consumed per day in the intervention schools by 51.29mL, and in the control schools by 35.31mL. The relative adjusted differences between groups from baseline to follow-up was a decrease of 8.55mL (CI -26.77, 43.87; $p=0.63$) less in the intervention schools than the control schools. For daily percentage energy from SSBs, there was a within group reduction in intervention school students of 0.89% and 0.66% in control schools. At follow-up the relative adjusted difference between groups in daily percentage energy contributed by SSBs was a decrease of 0.12% (CI -0.55, 0.80; $p=0.72$) less in the intervention schools compared to the control schools.

Similarly, there were no significant differences between groups on any primary trial outcomes in any of the examined subgroups (Supplementary Table 2).

Secondary outcomes

There were no significant differences on secondary trial outcomes between groups when data was analysed using all available data or following multiple imputation as part of sensitivity analyses (Table 2).

In school consumption of SSBs: At follow-up, the odds of consuming one or more serves did not differ significantly between groups (OR=1.06; CI: 0.51, 1.70, $p=0.83$).

Daily energy intake: The relative adjusted difference between groups at follow-up was a decrease of 336kJ (CI -751, 78; $p=0.11$) more in control schools compared to intervention schools.

BMI z-score category: Students with BMI z-scores in the overweight and obese category increased by 1.0% in intervention schools, and by 1.2% in control schools between baseline and follow-up, a relative change between groups that was not significant (OR=0.94; CI 0.35, 3.15; imputed $p=0.90$).

Additional measures

Intervention acceptability: Across all participant groups the installation of water stations and school guiding principles were reported most frequently as acceptable (Table 3). SSB-related health messages to parents and students were reported by few parents and staff as acceptable (38.4% for parents; 48.1% for staff).

Compensatory dietary behaviours: Intervention school students obtained 35.1% of their average daily energy from non-core foods at baseline, and 35.2% at follow-up, while control school students obtained 39.0% of their average daily energy from non-core food at baseline, and 39.2% at follow-up (relative difference 0.50; CI -1.18, 2.17; p=0.56).

Intervention fidelity: Process evaluation data found that implementation fidelity varied across the three intervention schools (Table 3). Full implementation of the multi-component intervention ranged from 64% to 81% of all intervention components implemented. Components for school guiding principles, pricing and promotion of beverages, water station installation, and newsletter snippets were fully implemented across all intervention schools. Overall, schools seemed to have most difficulties implementing the peer-led school challenge, in addition to disseminating the fortnightly health messages to students and parents.

Table 1: Baseline characteristics of schools and students included in analyses (n, %).

School characteristic	Intervention (n=3)	Control (n=3)
SEIFA classified as disadvantaged[a]	2 (66.7%)	3 (100.0%)
Student characteristic[b]	**Intervention (n=473)**	**Control (n=389)**
Year		
Year 7	163 (34.5%)	137 (35.2%)
Year 8	128 (27.1%)	133 (34.2%)
Year 9	182 (38.4%)	119 (30.6%)
Female	249 (52.6%)	204 (52.4%)
BMI (mean, SD)	19.09 (3.07)	19.66 (4.17)
BMI z-scores[c]		
Overweight or obese	36 (22.2%)	40 (29.9%)

Notes:

a: Based on the Australian 2016 Socio-Economic Indexes for Areas (SEIFA)

** All students who had valid dietary data at baseline*

 # Year 7 students who provided valid height and weight measurements only

SD = standard deviation

Discussion

This study sought to evaluate an intervention targeting adolescent SSB intake in Australia by undertaking a cluster RCT in secondary schools. At six months follow-up, despite the majority of intervention components being considered acceptable by students, parents and staff, there was little difference between groups on any of the assessed primary or secondary behavioural outcomes. The findings provide important information for policy makers and educators responsible for promoting public health nutrition within the Australian context.

These findings are in contrast with a previous systematic review of school-based SSB interventions in adolescents which found that nine of the 13 RCTs included had an improvement on student diet.[23] While a number of factors may have contributed to this apparent discrepancy, key characteristics of the trial may have contributed most. First, findings from a review on SSB interventions suggest that the interventions of at least 12 months duration are required to achieve changed in student intake or BMI,[42] however, ethics restrictions required that the program be reduced to just six months in length. The review reported shorter interventions generally had either mixed effect or no significant impact on such outcomes.[42] As the duration of this intervention was just six months due to time constraints, improvements that may have manifest over a longer period were not able to be detected. Whilet not significant, outcomes mostly trended in the right direction, with reductions in total daily energy consumption in the intervention group approaching significance compared to changes in the control group (p=0.12). It is possible that should the intervention duration increase, the effectiveness may also improve.

Second, despite every effort to support implementation of the intervention, our process evaluation data indicated that implementation at the school level varied across intervention components, ranging from 64 to 81% of the multicomponent intervention delivered as intended. The lack of intervention fidelity for certain components may mean that a reliable causal relationship between the intervention and outcomes cannot be determined, as poor fidelity may result in strategies that are not sufficiently reaching the participants.[43,44] While poor intervention fidelity appears to plague many behavioural interventions targeting secondary schools,[45,46] greater insight identifying the reasons for poor fidelity is required in order to identify the more suitable, evidence-based and ultimately effective strategies to support intervention implementation in future.[47]

Third, the mean intake of SSBs among students at baseline participating in *switchURsip* was considerably lower than expected. At baseline, SSB intake ranged between 160-205mL per day, equating to

Table 2: Between group differences for primary and secondary outcomes (mean, SD).

Outcome	Intervention		Control		Effect size			
	Baseline (n=473)	Follow-up (n=400)	Baseline (n=389)	Follow-up (n=342)	All available data	P-value	Sensitivity analyses[a]	P-value[a]
Primary outcomes								
Overall SSB consumption (mL)	159.67 (245.05)	124.36 (178.36)	204.23 (278.01)	152.94 (216.49)	8.55 (CI -26.77, 43.87)	0.63	15.99 (CI -18.14, 50.11)	0.36
Energy from SSBs (%)	3.24 (4.60)	2.58 (3.72)	4.25 (5.69)	3.36 (5.35)	0.12 (CI -0.55, 0.80)	0.72	0.29 (CI -0.37, 0.96)	0.38
Secondary outcomes								
SSB consumption in school (≥250mL /day)	15.1%	10.8%	21.4%	17.9%	OR: 1.06 (CI 0.51, 1.70)	0.83	OR: 0.85 (CI 0.46, 3.06)	0.72
Total daily energy (kilojoules)	8,136 (3366)	8,159 (3471)	8,153 (3402)	7,942 (3178)	-336 (CI -751, 78)	0.11	-314 (CI -705, 78)	0.12
BMI z-score category (overweight or obese)[b]	23.6%	24.6%	29.7%	30.9%	OR: 0.94 (CI 0.35, 3.15)	0.90	OR: 0.93 (CI 0.43, 2.62)	0.89

Notes:

a: Missing values at follow-up imputed

b: Year 7 students only

SSBs = sugar-sweetened beverages; mL = millilitres; CI = confidence interval; SD = standard deviation

Table 3: Process evaluation: Fidelity of the intervention and acceptability of intervention component to students, parents and staff.

Intervention Fidelity			
Intervention component[a]	**Intervention school 1**	**Intervention school 2**	**Intervention school 3**
Ethos and environment			
School guiding principles to supplement the school's existing plans	Fully implemented	Fully implemented	Fully implemented
Food outlet (school canteens) modifications based on principles of choice architecture			
Removal of SSBs from canteen	Partially implemented	Fully implemented	Fully implemented
Placement of healthy drinks over SSBs	Partially implemented	Fully implemented	Fully implemented
Promotion of healthy drinks over SSBs	Fully implemented	Fully implemented	Fully implemented
Favourably pricing healthy drinks over SSBs	Fully implemented	Fully implemented	Fully implemented
Installation of water stations on school grounds	Fully implemented	Fully implemented	Fully implemented
Curriculum and teaching			
Curriculum lessons targeting SSBs	Fully implemented	Partially implemented	Fully implemented
Peer-led school challenge designed and led by a student committee	Fully implemented	Partially implemented	Not implemented
Six short fortnightly health messages to students	Fully implemented	Partially implemented	Partially implemented
Partnerships and services			
Six short fortnightly health messages to parents	Fully implemented	Partially implemented	Partially implemented
Newsletter snippets to provide updates on the intervention	Fully implemented	Fully implemented	Fully implemented
Intervention components fully implemented	81%	64%	73%
Intervention acceptability			
Responded with Strongly Agree or Agree	Students (n=407)	Parents (n=171)	Staff (n=79)
School guiding principles	78.4%	97.4%	100.0%
School canteen changes	66.0%	97.4%	98.7%
Water stations on school grounds	82.3%	100.0%	100.0%
Classroom SSBs lessons	54.2%	88.1%	96.2%
School student challenge	67.5%	94.0%	96.2%
SSBs-related messages to students	61.1%	41.7%	39.2%
SSBs-related messages to parents	58.4%	38.4%	48.1%
Program-related newsletter to parents	58.9%	72.2%	96.2%

Note:
a: Fidelity to intervention components assessed via school environment audits and project records

less than a serve (250mL) compared with the national average for Australian adolescents of 360mL per day.[8] Such low levels of SSB intake may be attributed to the sample of schools comprising of those from the catholic and independent school sector, which may draw on students from higher socio-economic households where SSB intake is typically lower.[15] Schools from the government sector were not invited to participate due to ethics restrictions, which may have limited the generalisability of the sample. However, SSB interventions are generally more effective when baseline consumption levels are high as they avoid a floor effect.[42] Future research which is conducted in schools where SSB intake is more representative of the general population may find effects that differ from those reported in this trial.

Finally, the intervention was undertaken within schools that were more socio-economically disadvantaged than the state average. Improving dietary behaviour among socio-economically disadvantaged groups is a considerable challenge, given the unique barriers to healthy eating that they experience.[48,49] As such, nutrition interventions have been found to have differential effects by a socio-economic gradient.[50] The findings of this study suggest that the intervention may not have sufficiently addressed the key drivers to SSB intake among the socio-economically disadvantaged population recruited in this study.

Given that such a study has not been conducted in NSW prior, we sought to closely examine intervention acceptability to provide a better understanding of the potential impact of the trial. The overall acceptability of the intervention components was high with the exception of health messages to students and parents. The text messages to parents promoting healthier drinks options at home, in particular, were rated least acceptable by parents (38.4%). Previous research suggests that advice to parents regarding child nutrition may be perceived as challenging their "good mothering", which may explain the lower reports of acceptability for this component.[51]

Parent involvement may be particularly important in improving the impact of these interventions.[52] For example, systematic reviews have found multi-component school-based nutrition interventions targeting children and adolescents tend to be more effective in reducing SSB consumption when they include a parent-targeted component. However, numerous studies have reported challenges with adequately engaging parents in school-based interventions.[53,54] Given that parents play a key role in influencing adolescent diet and their SSB consumption,[29] future iterations of this intervention need to consider incorporating strategies to appropriately engage parents.[55] In particular, the framing, content, frequency or mode of the messages to parents may need to be revised to be deemed more acceptable and effective by parents. Achieving this may require greater input of parents in the development of program materials, for example, through the application of participatory and user-centred design principles in intervention development.[56]

Strengths and limitations

The strengths of this study included the randomised controlled design of the trial and pre-registered study outcomes, the use

of a validated and high-quality measure to assess student diet, high retention rates for data collection and the application of theory to support the development of a comprehensive intervention. However, there are a number of limitations that should be noted. Blinding of school staff, students and parents to group allocation was not possible in this intervention. Ethics approval was not granted to include Government sector schools in the study due to research fatigue, which may limit the generalisability of the study findings. Additionally, we were not able to collect information about the characteristics of non-participants, and systematic differences in their capacity or motivation for dietary improvement may have impacted on the potential for the intervention to have an impact. The final sample size of the study was less than anticipated, due to lower-than-expected study participation rates and the inclusion of schools with smaller student populations than was planned. As a result, the effect size reported in this study was not of sufficient magnitude to be detected as significant. Nonetheless, the trial provides useful study parameters that could be useful for those planning more definitive randomised trials of similar interventions. Notwithstanding these limitations, this represents one of few school-based studies undertaken in Australia to improve adolescent's diet and provides important learnings for consideration in the design of future SSB interventions.

Conclusion

This study found that a multi-component school-based intervention did not significantly reduce effects on adolescents' overall daily SSB consumption and percentage daily energy from SSBs. The study provides useful evidence for Australian policy makers and practitioners interested in improving public health nutrition in this setting. Specifically, the findings suggest that more potent implementation support strategies are required to improve the fidelity of implementation. Extending the duration of the intervention, inclusion of other environmental modifications and enhancing parent targeted strategies should also be considered.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supplementary File 1: Modifiable Factors for Adolescent SSB Intake

Supplementary Table 1: Question on acceptability of intervention components for students, parents and school staff.

Supplementary Table 2: Between group differences for primary outcomes by subgroups (mean, SD).