Smart-Phone Obesity Prevention Trial for Adolescent Boys in Low-Income Communities: The ATLAS RCT

AUTHORS: Jordan J. Smith, BEd,[a] Philip J. Morgan, PhD,[a] Ronald C. Plotnikoff, PhD,[a] Kerry A. Dally, PhD,[a] Jo Salmon, PhD,[b] Anthony D. Okely, PhD,[c] Tara L. Finn,[a] and David R. Lubans, PhD[a]

[a]Priority Research Centre in Physical Activity and Nutrition, School of Education, University of Newcastle, Callaghan, New South Wales, Australia; [b]Centre for Physical Activity and Nutrition Research, Deakin University, Burwood, Victoria, Australia; and [c]Interdisciplinary Educational Research Institute, University of Wollongong, Wollongong, New South Wales, Australia

KEY WORDS

adolescent, intervention studies, obesity, physical activity, physical fitness, randomized controlled trial, schools, sedentary lifestyle

ABBREVIATIONS

ATLAS—Active Teen Leaders Avoiding Screen-time
RT—resistance training
SEIFA—Socio-Economic Indexes For Areas
SSB—sugar-sweetened beverage

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Address correspondence to David R. Lubans, PhD, Priority Research Centre in Physical Activity and Nutrition, School of Education, Faculty of Education and Arts, University of Newcastle, Callaghan, NSW, Australia 2308. E-mail: david.lubans@newcastle.edu.au

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WHAT'S KNOWN ON THIS SUBJECT: Adolescent males from low-income communities are a group at increased risk of obesity and related health concerns. Obesity prevention interventions targeting adolescents have so far had mixed success. Targeted interventions, tailored for specific groups, may be more appealing and efficacious.

WHAT THIS STUDY ADDS: A multicomponent school-based intervention using smartphone technology can improve muscular fitness, movement skills, and key weight-related behaviors among low-income adolescent boys.

abstract

OBJECTIVE: The goal of this study was to evaluate the impact of the Active Teen Leaders Avoiding Screen-time (ATLAS) intervention for adolescent boys, an obesity prevention intervention using smartphone technology.

METHODS: ATLAS was a cluster randomized controlled trial conducted in 14 secondary schools in low-income communities in New South Wales, Australia. Participants were 361 adolescent boys (aged 12–14 years) considered at risk of obesity. The 20-week intervention was guided by self-determination theory and social cognitive theory and involved: teacher professional development, provision of fitness equipment to schools, face-to-face physical activity sessions, lunchtime student mentoring sessions, researcher-led seminars, a smartphone application and Web site, and parental strategies for reducing screen-time. Outcome measures included BMI and waist circumference, percent body fat, physical activity (accelerometers), screen-time, sugar-sweetened beverage intake, muscular fitness, and resistance training skill competency.

RESULTS: Overall, there were no significant intervention effects for BMI, waist circumference, percent body fat, or physical activity. Significant intervention effects were found for screen-time (mean $\pm$ SE: –30 $\pm$ 10.08 min/d; $P = .03$), sugar-sweetened beverage consumption (mean: –0.6 $\pm$ 0.26 glass/d; $P = .01$), muscular fitness (mean: 0.9 $\pm$ 0.49 repetition; $P = .04$), and resistance training skills (mean: 5.7 $\pm$ 0.67 units; $P < .001$).

CONCLUSIONS: This school-based intervention targeting low-income adolescent boys did not result in significant effects on body composition, perhaps due to an insufficient activity dose. However, the intervention was successful in improving muscular fitness, movement skills, and key weight-related behaviors. *Pediatrics* 2014;134:e723–e731

Although the global prevalence of obesity seems to have plateaued in recent years,[1] the overall proportion of young people who are overweight or obese remains high, particularly among those of low socioeconomic status.[2] Considering the serious consequences of pediatric obesity,[3] and the high likelihood of weight status tracking into adulthood,[4] there is a strong rationale for targeting the health behaviors of adolescents.[5–7]

It has been recommended that obesity prevention efforts should be directed toward those most susceptible, such as adolescents living in low-income communities.[8] Adolescent boys of low socioeconomic status are particularly predisposed to unhealthy weight gain, and the global prevalence of obesity is higher among male adolescents compared with female adolescents.[1] In addition, although adolescent boys are typically more active than girls,[9] they are more likely to engage in high levels of recreational screen-time and consume large amounts of sugar-sweetened beverages (SSBs).[9,10] However, apart from our pilot study,[11] no interventions have specifically targeted adolescent boys from low-income communities.

The challenges of modifying the health behaviors of adolescents and designing culturally appropriate interventions have prompted researchers to explore the utility of novel behavior change techniques. Such strategies include the use of e-health (ie, Internet-based) and mHealth (ie, mobile phone) technologies to encourage young people to develop physical activity behavioral skills (ie, self-monitoring, goal setting)[12,13] and improve lifestyle behaviors.[14] Mobile phone (and smartphone) ownership among young people is accelerating at a rapid rate.[15,16] Although evidence for the efficacy of mHealth interventions to improve health behaviors in young people is starting to emerge in the published literature,[17,18] it is unlikely that such interventions will provide the "silver bullet" to the global obesity pandemic. Alternatively, they may have more utility as adjuncts to face-to-face behavior change interventions. To the authors' knowledge, no previous study has used smartphone technology in a school-based obesity prevention program[14] and few existing smartphone "apps" include evidence-based behavior change techniques.[19] Therefore, the primary aim of the present study was to evaluate the effects of the multicomponent, school-based obesity prevention intervention incorporating smartphone technology, known as ATLAS (Active Teen Leaders Avoiding Screen-time). This article reports the 8-month (immediate postprogram) intervention effects.

METHODS

Study Design and Participants

Ethics approval for this study was obtained from the human research ethics committees of the University of Newcastle, Australia (July 3, 2012), and the New South Wales Department of Education and Communities (September 6, 2012). School principals, teachers, parents, and study participants all provided informed written consent. The design, conduct, and reporting of this trial adhere to the CONSORT statement.[20] The rationale and study protocols have been reported previously.[21] Briefly, ATLAS was evaluated by using a cluster randomized controlled trial conducted in state-funded coeducational secondary schools within low-income areas of New South Wales, Australia. The Socio-Economic Indexes For Areas (SEIFA) of relative socioeconomic disadvantage (scale: 1 = lowest to 10 = highest) was used to identify eligible schools. Public secondary schools located in the Newcastle, Hunter, and Central Coast regions of New South Wales with a SEIFA value of $\leq$5 (lowest 50%) were considered eligible. All male students in their first year at the study schools completed a short screening questionnaire to assess their eligibility for inclusion. Students failing to meet international physical activity or screen-time guidelines[22] were considered eligible and were invited to participate.

Sample Size and Randomization

Power calculations were conducted to determine the required sample size for detecting changes in the primary outcomes (ie, BMI, waist circumference). Baseline posttest correlations and SD estimates for BMI (r = 0.97, SD = 1.1) and waist circumference (r = 0.96, SD = 11.6) were taken from our pilot study, and calculations assumed a school clustering effect with an intraclass correlation of 0.03.[11] Based on 80% power, an α level of 0.05, and a potential dropout rate of 20%, it was calculated that 350 participants (ie, 25 from each school) would be required to detect a between-group difference in BMI of 0.4 kg.m^{-2}. In addition, the proposed sample size would be powered to detect a between-group difference of 1.5 cm in waist circumference. After baseline assessments, schools were paired on the basis of their geographic location, size, and SEIFA value and were randomized to either the control or intervention group. Randomization was performed by an independent researcher with the use of a computer-based random number–producing algorithm.

Intervention

ATLAS was informed by the PALs (Physical Activity Leaders) pilot study,[11,23,24] and a detailed description of the intervention is reported elsewhere.[21] In summary, ATLAS is a multicomponent intervention designed to prevent unhealthy weight gain by increasing physical activity, reducing screen-time, and lowering SSB consumption among adolescent boys attending schools in low-income areas. Self-determination theory[25] and social cognitive theory[26] formed the theoretical basis of the program. Briefly, the intervention aimed to increase autonomous motivation for physical activity through enhancing basic psychological needs satisfaction (ie, autonomy, competence, relatedness) during scheduled school sports. In addition, the intervention focused on improving resistance training (RT) self-efficacy and also aimed to develop self-regulatory skills (ie, self-monitoring and goal setting) to increase incidental physical activity. Similarly, the intervention was designed to increase participants' autonomous motivation to limit screen-time[27] by providing information regarding the consequences of screen-time and strategies for self-regulation. ATLAS was aligned with current guidelines recommending that youth regularly engage in vigorous aerobic activities and physical activities to strengthen muscle and bone.[22]

The intervention was delivered from December 2012 to June 2013 and involved a number of components that are described in Table 1. The smartphone app was designed to supplement the delivery of the enhanced school sport and interactive sessions by providing participants with a medium to monitor and track their behaviors, set goals, and assess their RT skill competency. In addition, the app provided tailored motivational and informational messages via "push prompts." The parental newsletters were designed to engage parents and encourage them to manage their children's recreational screen-time.

The control group participated in usual practice (ie, regularly scheduled school sports and physical education lessons) for the duration of the intervention but will receive an equipment pack and a condensed version of the program after the 18-month assessments.

TABLE 1 Description and Dose of Intervention Components in the ATLAS Intervention

Intervention Component	Dose	Description
Teachers		
Teacher professional development	Two 6-h workshops	Teachers attend 2 professional development workshops during the study period (preprogram and mid-program). The workshops provide a rationale for the program, outline the intervention strategies (ie, program components, behavioral messages), and explain the theory behind the intervention.
	One fitness instructor session	Each school receives 1 visit during their regularly scheduled sport session from a practicing fitness instructor (ie, personal trainer). The fitness instructor will deliver the session while the teacher observes and completes the session observation checklist.
Parents		
Parent newsletters	Four newsletters	Parents of study participants receive 4 newsletters containing information on the potential consequences of excessive screen use among youth, strategies for reducing screen-based recreation in the family home, and tips for avoiding conflict when implementing rules. They are also provided with their child's baseline fitness test results.
Students		
Researcher-led seminars	Three 20-min seminars	Participants attend 3 interactive seminars delivered by members of the research team. Seminars provide key information surrounding the program's components and behavioral messages, including current recommendations regarding youth physical activity, screen-time, and resistance training, and also outline the student leadership component of the intervention.
Enhanced school sport sessions	Twenty 90-min sessions	Sport sessions are delivered by teachers at the study schools. Activities include elastic tubing resistance training, aerobic- and strength-based activities, fitness challenges, and modified ball games. Behavioral messages are reinforced during the cool-down period.
Lunchtime physical activity–mentoring sessions	Six 20-min sessions	Students participate in 6 lunchtime physical activity mentoring sessions. These self-directed sessions involve recruiting and instructing grade 7 boys in elastic tubing resistance training.
Smartphone app and Web site	15 wk	The smartphone app and Web site are used for physical activity monitoring, recording of fitness challenge results, tailored motivational messaging, peer assessment of RT skills, and goal setting for physical activity and screen-time.
Pedometers	17 wk	Participants are provided with pedometers for self-monitoring. Students are encouraged to set goals to increase their daily step counts and monitor their progress using the pedometer. Pedometer step counts can also be entered into the smartphone app for review.

Assessments and Measures

Trained research assistants completed baseline data collection at the study schools during November through December 2012, at the same time of day whenever possible. Follow-up assessments were conducted 8 months from baseline (immediate postintervention) and will be conducted again at 18 months from baseline (long-term follow-up). Assessors were blinded to treatment allocation at baseline but not at follow-up.

Primary Outcome Measures

Height was recorded by using a portable stadiometer (model no. PE087, Mentone Educational Centre, Moorabbin, Victoria, Australia), and weight was measured with a portable digital scale (model no. UC-321PC, A&D Company Ltd, Tokyo, Japan). BMI was calculated by using the standard equation (weight in kilograms/height in meters squared). Waist circumference was measured to the nearest 0.1 cm against the skin in line with the umbilicus by using a nonextendible steel tape (KDSF10-02, KDS Corporation, Osaka, Japan). Weight status was established from BMI *z* scores calculated by using the LMS method (World Health Organization growth reference centiles).[28]

Secondary Outcome Measures

Body fat percent was determined by using the Imp SFB7 bioelectrical impedance analyzer (ImpediMed, Ltd., Eight Mile Plains, Queensland, Australia).[29] Physical activity was assessed according to standardized protocols[30] using Actigraph accelerometers (model GT3X+ ActiGraph, LLC, Fort Walton Beach, FL). Analyses for weekday physical activity were performed for participants who wore their monitor for ≥600 minutes on at least 3 weekdays (Monday–Friday); analyses for weekend physical activity included participants who wore their monitor for ≥600 minutes on at least 1 weekend day (Saturday–Sunday). Non–wear time was defined as 30 minutes of consecutive zeroes. Mean counts per minute were calculated to provide a measure of overall activity, and the cut points proposed by Evenson et al[31] were used to categorize intensity (ie, time spent in moderate to vigorous physical activity). Hand grip dynamometry (Smedley's dynamometer; TTM, Tokyo, Japan) and the 90-degree angle push-up test[29,32] provided a measure of upper body maximal strength and local muscular endurance, respectively. Recreational screen-time was self-reported by using a modified form of the Adolescent Sedentary Activity Questionnaire.[33] Two items were used to assess consumption of SSBs.[9] Finally, RT skill competency was assessed by using video analysis of the Resistance Training Skills Battery.[34,35] Participants performed 6 movement skills considered to be the foundation for more complex movements used in RT programs.

Process Evaluation

A number of process measures were used to determine the reach, implementation, and participant and teacher satisfaction of the ATLAS intervention. The process evaluation included: (1) intervention implementation (ie, the percentage of intended school sports sessions and lunchtime mentoring sessions conducted by teachers); (2) school sport session fidelity determined by using the ATLAS session observation checklist (ie, compliance with the proposed session structure and activities, recorded by a member of the research team); (3) attendance at sessions; (4) engagement with intervention components (eg, smartphone app, pedometers); and (5) program satisfaction (ie, responses to a postprogram evaluation questionnaire).

Statistical Analysis

All analyses were conducted in December 2013 by using SPSS for Windows version 20.0 (IBM SPSS Statistics, IBM Corporation, Armonk, NY; 2010) with α levels set at $P < .05$; data were assessed for normality. Intervention effects for the primary and secondary outcomes were examined by using linear mixed models adjusted for school clustering and participant socioeconomic status, and all analyses followed the intention-to-treat principle.[36] Prespecified subgroup analyses[21] for all body composition outcomes were conducted for those classified as overweight/obese (combined as a single group) at baseline. In addition, the proportional difference between treatment groups among those improving their weight status (ie, moving from "obese" to "overweight" or from "overweight" to "healthy weight") or regressing to a poorer weight status (ie, moving from "healthy weight" to "overweight" or from "overweight" to "obese") was explored by using Pearson's χ^2 test.

RESULTS

The flow of participants through the study is reported in Fig 1. Fourteen schools were recruited, and 361 boys (mean age: 12.7 ± 0.5 years) were assessed at baseline (Table 2). Follow-up assessments at 8 months were completed for 154 (85.6%) control group participants and 139 (76.8%) intervention group participants, representing an overall retention rate of 81.2% from baseline. Participants who did not complete follow-up assessments were more active on weekdays ($P = .03$) and weekends ($P = .01$). There were no significant differences for body composition outcomes.

Changes in Body Composition

Changes for all outcomes are reported in Table 3. No intervention effects were found for the primary outcomes of BMI and waist circumference or for percent body fat. Changes in BMI (mean ± SE: –0.4 kg.m^{-2} ± 0.26; $P = .15$), waist circumference (mean: –0.5 ± 0.95 cm; $P = .57$), and percent body fat (mean: –0.9% ± 0.77%; $P = .22$) for those classified as overweight/obese at baseline were all in favor of the intervention group. However, these effects were not statistically significant. Of the 19 participants who improved their weight status, 13 (68%) were in the intervention group; of the 9 participants who regressed to a more unhealthy weight status, only 1 (11%) was in the intervention group. Pearson's χ^2 test indicated a significant difference in favor of intervention boys: χ^2 (2) = 8.08, $P = .02$.

Changes in Behavioral Outcomes

No significant differences were observed for overall activity (mean counts per minute) or moderate to vigorous physical activity. However, intervention boys reported less screen-time (mean: −30 ± 10.08 min/d; $P = .03$) and SSB consumption (mean: −0.6 ± 0.26 glass/d; $P = .01$) than control boys at follow-up.

Changes in Fitness and Skill Outcomes

There was a significant intervention effect for upper body muscular endurance (mean: 0.9 ± 0.49 repetition; $P = .04$). In addition, a significant between-group difference was observed for RT skill competency in favor of intervention boys (mean: 5.7 ± 0.67 units; $P < .001$).

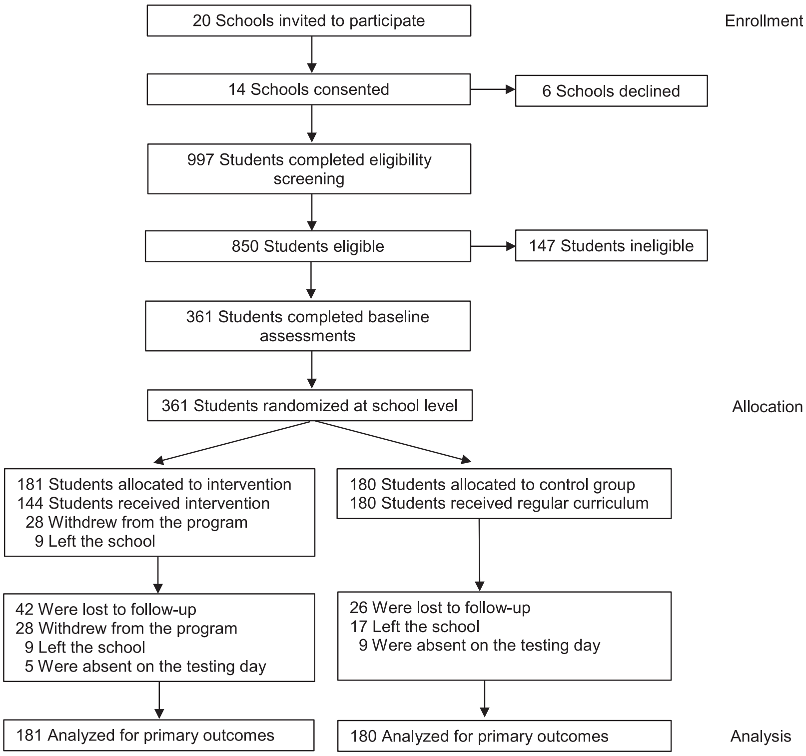

FIGURE 1
Flow of participants through the study process.

Process Evaluation

No adverse events or injuries were reported during the school sports sessions, lunchtime leadership sessions, or assessments. On average, schools conducted 79% ± 15% of intended school sports sessions and 64% ± 40% of intended lunchtime sessions. Four sport session observations (2 per school term) were conducted at each school. Adherence to the proposed session structure at observations 1, 2, 3, and 4 was 61%, 58%, 90%, and 96%, respectively. Students were expected to attend at least 70% of sport sessions and at least two-thirds of lunchtime sessions. Sixty-five percent of boys attended ≥70% of the sport sessions but only 44% of boys attended at least two-thirds of lunchtime sessions. Participant satisfaction with the ATLAS intervention was high (mean: 4.5 ± 0.7 [scale of 1 = strongly disagree to 5 = strongly agree]). Students enjoyed the sports sessions (mean: 4.5 ± 0.7); however, satisfaction with the lunchtime sessions was somewhat lower (mean: 3.7 ± 1.0).

A detailed evaluation of the smartphone app can be found elsewhere.[37] Briefly, smartphone (or similar device) ownership was reported by 70% of boys, and 63% reported using either the iPhone or Android version of the ATLAS app. Those students who did not have access to a smartphone could access the same features via the ATLAS Web site. Almost one-half of the group agreed or strongly agreed that the "push prompt" messages reminded them to be more active, reduce their screen-time, and drink fewer sugary drinks, and 44% of participants agreed or strongly agreed that the ATLAS app was enjoyable to use. Self-reported pedometer use was moderate, with 44% of boys wearing their pedometer sometimes and 30% wearing their pedometer often. In addition, all 4 newsletters were sent to 86% of parents. Teacher satisfaction with the intervention was high (mean: 4.4 ± 0.5), and they reported enjoying both the preprogram (mean: 5.0 ± 0.0) and mid-program (mean: 4.9 ± 0.4) professional development workshops.

DISCUSSION

The goal of the present study was to determine the effectiveness of the school-based ATLAS intervention for adolescent boys. No significant intervention effects were observed overall for body composition. However, for those who were overweight/obese at baseline, there was a trend in favor of intervention participants for all body composition outcomes. Significant intervention effects were found for secondary outcomes, including upper body muscular endurance, RT skill competency, self-reported screen-time, and SSB consumption.

The intervention effects for body composition outcomes were negligible, which is similar to the findings of a trial involving Dutch teenagers.[38] Our inclusion criteria aimed to identify boys at increased risk of obesity based on their physical activity and screen behaviors. This approach was selected to reduce the potential for weight stigmatization, which may occur if inclusion is contingent on participants' BMI. However, it is possible that by using these broad inclusion criteria, our ability to see significant improvements in anthropomorphic measures was minimized, as a number of "healthy weight" boys with little scope for change were included in the study. Indeed, the majority of recruited boys were classified as having a healthy weight at baseline and remained so for the duration of the intervention. Interestingly, it has been suggested that while school-based interventions should continue to target all students, analysis of the primary outcome(s) should perhaps focus on overweight/obese youth.[39]

The findings of the present study were in contrast to those of our pilot study in which significant intervention effects for multiple measures of body composition

TABLE 2 Baseline Characteristics of Study Sample

Characteristics	Control (n = 180)	Intervention (n = 181)	Total (N = 361)
Age, y	12.7 ± 0.5	12.7 ± 0.5	12.7 ± 0.5
Born in Australia	168 (93.3)	174 (96.1)	341 (94.7)
English language spoken at home[a]	169 (94.4)	175 (96.7)	344 (95.6)
Cultural background[b]			
Australian	132 (73.7)	145 (80.6)	277 (77.2)
European	31 (17.3)	22 (12.2)	53 (14.8)
African	6 (3.4)	1 (0.6)	7 (1.9)
Asian	3 (1.7)	4 (2.2)	7 (1.9)
Middle Eastern	2 (1.1)	0	2 (0.6)
Other	5 (2.8)	8 (4.4)	13 (3.6)
Socioeconomic position[c]			
1–2	55 (30.9)	49 (27.1)	104 (29.0)
3–4	81 (45.5)	120 (66.3)	201 (56.0)
5–6	27 (15.2)	4 (2.2)	31 (8.6)
7–8	8 (4.5)	8 (4.4)	16 (4.5)
9–10	7 (3.9)	0	7 (1.9)
Weight, kg	53.1 ± 13.4	54.0 ± 15.0	53.5 ± 14.2
Height, cm	160.2 ± 8.4	160.9 ± 9.0	160.5 ± 8.7
BMI	20.5 ± 4.1	20.5 ± 4.1	20.5 ± 4.1
Weight status			
Underweight	5 (2.8)	2 (1.1)	7 (1.9)
Healthy weight	115 (63.9)	110 (60.8)	225 (62.3)
Overweight	38 (21.1)	39 (21.5)	77 (21.3)
Obese	22 (12.2)	30 (16.6)	52 (14.4)
Waist circumference, cm	76.5 ± 12.3	76.2 ± 12.2	76.3 ± 12.2

Data are presented as mean ± SD or n (%).

[a] One participant did not report language spoken at home.

[b] Two participants did not report cultural background.

[c] Socioeconomic position determined according to population decile by using SEIFA of relative socioeconomic disadvantage based on residential postal code (1 = lowest, 10 = highest). Two participants did not report residential postal code.

were observed.[11] This inconsistency could be due to differences in the quantity and intensity of physical activity during the enhanced school sport sessions. Process data indicated that toward the end of the program, boys in the PALs study became disengaged due to the lack of variety in activities. To maintain engagement, the ATLAS sport sessions provided a greater variety of activities and also incorporated a stronger focus on movement skill development. Although program satisfaction was higher in ATLAS compared with PALs, these modifications may have resulted in lower overall activity and/or lower activity intensity during the sessions, and hence smaller effects on body composition. Alternatively, because PALs participants had a higher baseline BMI, they may have had a greater propensity for change.

Although our study was not powered to detect subgroup differences, changes in body composition outcomes favored intervention boys who were overweight or obese at baseline. The magnitude of these changes, although not statistically significant, may nonetheless be clinically meaningful. For example, the adjusted mean difference in body fat for overweight/obese participants in the ATLAS intervention was 0.9%. According to Dai et al,[40] an increase of 1% body fat is significantly associated with unfavorable changes in total, high-density lipoprotein, and low-density lipoprotein cholesterol, as well as triglycerides. Furthermore, in a study of children and adolescents, Weiss et al[41] reported that each 0.5-unit increase in BMI was associated with significantly increased risk of the metabolic syndrome. The adjusted mean difference in BMI for overweight/obese subjects in our study was –0.4 units, which may have clinical significance. Finally, the proportional shift in weight status between study groups provides additional support for the efficacy of the intervention for overweight/obese participants.

Recent literature has identified muscular fitness as an important indicator of health status for young people.[42,43] Notably, we found significant intervention effects for upper body muscular endurance and RT skill competency. The intervention activities were predominantly resistance-based and as such focused on developing muscular fitness. Furthermore, the workouts and fitness challenges performed throughout the intervention were designed to be high repetition, targeting local muscular endurance rather than maximal strength specifically. Therefore, the significant improvement in muscular endurance and nonsignificant findings for muscular strength are not surprising. In addition, the improvement in skill competency was expected because a core component of the sport sessions was time dedicated to RT skill development during which teachers modeled correct exercise technique and provided corrective feedback on boys' movement skill performance. Furthermore, approximately two-thirds of boys reported using the app to assess and monitor their RT technique.

Intervention boys in our study reported spending 30 minutes less per day engaged in screen-based recreation at follow-up compared with control subjects. Similar findings were described in the Planet Health intervention,[44] with the authors reporting an adjusted difference of 24 minutes in favor of intervention boys. The reduction in screen-time observed in ATLAS is likely to be conservative compared with other studies, as our measure of screen-time was modified to account for screen multitasking. Reducing screen-time was an explicit intervention target, and ATLAS used a number of strategies to encourage boys to reduce their screen-time. The relative contribution of the individual intervention components

TABLE 3 Changes in Primary and Secondary Outcomes

Outcome[a]	Baseline	8 Months	Change	*P* Value	Adjusted Difference in Change	*P* Value
BMI						
Intervention	20.7 ± 0.64	21.3 ± 0.64	0.60 ± 0.09	<.001	0.0 ± 0.12[b]	.84
Control	20.6 ± 0.57	21.2 ± 0.57	0.61 ± 0.08	<.001		
Waist circumference, cm						
Intervention	77.1 ± 1.89	77.1 ± 1.89	0.0 ± 0.33	.98	0.5 ± 0.45[b]	.16
Control	77.0 ± 1.69	76.5 ± 1.69	−0.5 ± 0.31	.10		
Body fat, %						
Intervention	20.3 ± 1.27	21.6 ± 1.28	1.3 ± 0.35	<.001	0.0 ± 0.48	.99
Control	22.5 ± 1.14	23.8 ± 1.14	1.3 ± 0.33	<.001		
Grip strength, kg						
Intervention	22.5 ± 0.97	28.5 ± 0.98	6.0 ± 0.32	<.001	0.5 ± 0.45	.30
Control	20.4 ± 0.87	25.9 ± 0.88	5.5 ± 0.31	<.001		
Push-ups (repetitions)						
Intervention	9.1 ± 0.99	9.8 ± 1.0	0.7 ± 0.35	.04	0.9 ± 0.49[b]	.04
Control	6.6 ± 0.89	6.5 ± 0.89	−0.1 ± 0.34	.73		
Weekday PA, counts/min[c]						
Intervention	538 ± 30.81	515 ± 33.51	−23 ± 18.08	.21	−19 ± 23.30	.41
Control	477 ± 27.18	473 ± 28.58	−3 ± 14.69	.81		
Weekend PA, counts/min[d]						
Intervention	435 ± 47.19	410 ± 54.85	−25 ± 40.25	.53	−8 ± 53.94[b]	.57
Control	404 ± 42.42	387 ± 47.13	−17 ± 35.97	.64		
Weekday MVPA, %[c]						
Intervention	8.6 ± 0.58	8.3 ± 0.63	−0.4 ± 0.34	.28	−0.7 ± 0.44	.14
Control	7.5 ± 0.51	7.8 ± 0.54	0.3 ± 0.28	.30		
Weekend MVPA, %[d]						
Intervention	6.2 ± 0.78	6.0 ± 0.90	−0.2 ± 0.67	.73	−0.1± 0.90[b]	.80
Control	5.8 ± 0.70	5.7 ± 0.78	−0.1 ± 0.60	.82		
Screen-time, min/d						
Intervention	109 ± 14.18	112 ± 14.52	3 ± 7.25	.67	−30 ± 10.08[b]	.03
Control	132 ± 12.78	165 ± 12.94	33 ± 7.0	<.001		
SSB intake, glasses/d						
Intervention	3.9 ± 0.40	3.1 ± 0.41	−0.8 ± 0.19	<.001	−0.6 ± 0.26[b]	.01
Control	3.9 ± 0.36	3.7 ± 0.36	−0.1 ± 0.18	.44		
RT skill competency[e]						
Intervention	31.7 ± 0.56	40.1 ± 0.60	8.4 ± 0.48	<.001	5.7 ± 0.67	<.001
Control	30.7 ± 0.53	33.4 ± 0.55	2.7 ± 0.46	<.001		

Means ± standard errors are reported for all outcomes. MVPA, moderate to vigorous physical activity; PA, physical activity.
a All models were adjusted for school clustering and participant socioeconomic status.
b Variable transformed for analysis.
c A total of 240 and 120 participants wore accelerometers on weekdays at baseline and posttest, respectively.
d A total of 120 and 83 participants wore accelerometers on weekend days at baseline and posttest, respectively.
e Possible values range from 0 to 56.

to change in screen-time is difficult to ascertain. However, the consequences of excessive screen-time and current screen-time guidelines were made explicit to boys during the researcher-led seminars and were reinforced by teachers during the face-to-face sport sessions. In addition, the majority of parents received and read the screen-time newsletters, as reported by the boys. Finally, 70% of boys reported using the goal-setting function of the app, which allowed users to set goals for reducing screen-time.

In addition to these effects on screen-time, intervention boys also reported significantly reducing their consumption of SSBs. The adjusted mean difference was 0.6 glass per day (∼150 mL). A reduction in the consumption of SSBs has been recommended to prevent unhealthy weight gain and the onset of metabolic disorders.[48] Although improvements in body composition have accompanied reductions in SSB consumption in previous studies,[45,46] these studies were of longer duration than ATLAS and also focused solely on this outcome. If the reduction in SSB consumption observed in our study is sustained, the corresponding decrease in daily energy intake may have a considerable impact on body composition over the longer term.

Although it is difficult to determine the relative contribution of individual components in multicomponent interventions, by conducting a comprehensive process evaluation we were able to gather important information on the efficacy of individual strategies. Attendance at the sport sessions was reasonable, with approximately two-thirds of boys attending a satisfactory number of sessions, whereas attendance at the lunchtime sessions was poor. Boys reported lower satisfaction with the lunchtime sessions, which may be due to a preference to use this period for socializing. Compliance with the intended session structure was moderate at the first observation but improved substantially over the course of the intervention. Usage of the ATLAS app for self-monitoring and goal setting was moderate. Therefore, additional strategies and features may be needed to enhance engagement in adolescent boys. It is important to note that the proportion of dropouts who were overweight/obese was lower than it was for completers, indicating that ATLAS was successful in retaining overweight/obese boys. Finally, all teachers agreed or strongly agreed that their students benefited from involvement in ATLAS, thus providing a strong endorsement for the program.

Strengths of the present study include the randomized controlled design, the identification and targeting of adolescents at risk of obesity, objective assessment of physical activity, the extensive process evaluation, and the high retention at follow-up. However, there were also some limitations. Although BMI is considered a suitable and stable measure of change in adiposity,[47] direct measures such as dual-energy radiograph absorptiometry provide a more accurate assessment of body fat. Second, we cannot rule out social desirability bias in our assessment of screen-time and SSB consumption. Third, we were unable to collect ATLAS app usage data, which prevented a more thorough examination of the efficacy of this novel component. Fourth, similar to previous studies with adolescents,[12] poor compliance to accelerometer protocols reduced the available sample size, preventing more comprehensive assessment of change in physical activity. Finally, due to the targeted nature of the intervention, the results may not be generalizable to other groups (eg, female subjects, those from other socioeconomic strata).

CONCLUSIONS

There is a clear need for innovative obesity prevention programs that target adolescents at risk of obesity. School-based interventions that use smartphone technology have the potential for health behavior change, but strategies for identifying and recruiting participants and increasing the intervention dose are needed. Although the ATLAS program failed to achieve short-term changes in body composition in the overall study sample, there was a trend in favor of overweight/obese boys. In addition, there were favorable outcomes for behaviors known to be associated with adiposity and cardiometabolic disorders. This study demonstrates that a school-based intervention targeting economically disadvantaged adolescent boys can have a favorable impact on muscular fitness, movement skills, and key weight-related behaviors. We encourage practitioners and policy makers to advocate for targeted programs in schools for young people who are disengaged in current physical education programs. Future interventions using smartphone technology should capture objective data on app/Web site usage throughout the intervention period, and analyses should be conducted examining its association with changes in intervention outcomes. Furthermore, future smartphone apps should integrate stimulating features such as social media linkage and "gamification" to support ongoing engagement with this intervention component.

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Jordan J. Smith, Philip J. Morgan, Ronald C. Plotnikoff, Kerry A. Dally, Jo Salmon, Anthony D. Okely, Tara L. Finn and David R. Lubans

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