

PEDIATRIC ORIGINAL ARTICLE

Effects of a ‘school-based’ physical activity intervention on adiposity in adolescents from economically disadvantaged communities: secondary outcomes of the ‘Physical Activity 4 Everyone’ RCT

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BACKGROUND/OBJECTIVES: Obesity prevention during adolescence is a health priority. The ‘Physical Activity 4 Everyone’ (PA4E1) study tested a multi-component physical activity intervention in 10 secondary schools from socio-economically disadvantaged communities. This paper aimed to report the secondary outcomes of the study; to determine whether the intervention impacted on adiposity outcomes (weight, body mass index (BMI), BMI z-score), and whether any effect was moderated by sex, baseline BMI and baseline physical activity level, at 12 and 24 months.

SUBJECTS/METHODS: A cluster randomised controlled trial was conducted in New South Wales, Australia. The school-based intervention included seven physical activity strategies targeting the following: curriculum (strategies to maximise physical activity in physical education, student physical activity plans, an enhanced school sport programme); school environment (physical activity during school breaks, modification of school policy); and parents and the community (parent engagement, links with community physical activity providers). Students’ weight (kg), BMI and BMI z-score, were collected at baseline (Grade 7), 12 and 24 months. Linear Mixed Models were used to assess between-group mean difference from baseline to 12 and 24 months. Exploratory sub-analyses were undertaken according to three moderators of energy balance.

RESULTS: A total of 1150 students (mean age = 12 years) provided outcome data at baseline, 1051 (91%) at 12 months and 985 (86%) at 24 months. At 12 months, there were group-by-time effects for weight (mean difference = -0.90 kg (95% confidence interval (CI) = $-1.50, -0.30$), $P < 0.01$) and BMI (-0.28 kg m^{-2} ($-0.50, -0.06$), $P = 0.01$) in favour of the intervention group, but not for BMI z-score (-0.05 ($-0.11; 0.01$), $P = 0.13$). These findings were consistent for weight (-0.62 kg ($-1.21, 0.03$), $P = 0.01$) and BMI (-0.28 kg m^{-2} ($-0.49, -0.06$), $P = 0.01$) at 24 months, with group-by-time effects also found for BMI z-score (-0.08 ($-0.14; -0.02$), $P = 0.02$) favouring the intervention group.

CONCLUSION: The PA4E1 school-based intervention achieved moderate reductions in adiposity among adolescents from socio-economically disadvantaged communities. Multi-component interventions that increase adolescents’ engagement in moderate-to-vigorous physical activity (MVPA) may assist in preventing unhealthy weight gain.

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INTRODUCTION

Preventing obesity during adolescence is a public health priority.¹ Internationally, among adolescent populations (10–19 years), the prevalence of overweight and obesity is estimated to be between 20–30%,² and is increasing.³ During puberty, adolescents experience changes in body composition and physical fitness, and decreased insulin sensitivity.¹ Changes in eating behaviours, physical activity, sedentary behaviours and psychological wellbeing may also occur during this critical period of growth and development.¹ These behavioural and physiological changes increase the risk of overweight and obesity during adolescence.¹ Global self-reported data from 105 countries estimate that just 20% of adolescents participate in ≥ 60 min of moderate-to-vigorous physical activity

(MVPA) each day.⁴ Longitudinal studies have also shown a decline in physical activity during adolescence of $\sim 7\%$ of MVPA per year.⁵ Research across 32 countries in Europe, Israel and North America indicates a positive association between physical inactivity and socio-economic disadvantage in adolescents.⁶

The school environment is a recommended setting for the promotion of physical activity among adolescents;⁷ however, school-based physical activity interventions have resulted in only a small increase in objectively measured MVPA (~ 4 min per day) of children, and limited reductions in the adiposity of adolescents.⁸ A systematic review and meta-analysis of 18 studies (including 18 141 students) that aimed to determine the effect of school-based physical activity interventions (> 6 months duration) on

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body mass index (BMI) in children and adolescents found that neither BMI (mean difference = -0.05 kg m^{-2} , 95% CI (confidence interval): -0.19 ; 0.10) nor any other body composition measures improved.⁹ The review primarily included elementary-aged students in Grades 3–6, and 15 of the 18 studies included a nutrition co-intervention. The lack of an overall effect on BMI was explained by insufficient intervention dose, either due to the amount of physical activity or low intervention compliance by the students.⁹ In a more recent meta-analysis of 43 studies (involving 36 579 children) that aimed to evaluate the impact of nutrition and physical activity school-based interventions on BMI in children and adolescents (< 18 years old), studies that assessed physical activity-only interventions reduced BMI by -0.13 kg m^{-2} (-0.22 ; -0.04).¹⁰ Intervention duration ranged from 1 month to 6 years.¹⁰ Neither of the reviews reported the physical activity intervention findings separately for adolescents,^{9,10} precluding the drawing of conclusions regarding the effect of physical activity interventions on adiposity in adolescent populations.

To increase the likelihood of an effect, school-based interventions that are multi-component and socio-ecologically framed are recommended.^{11,12} Systematic reviews of school-based physical activity interventions have also recommended that interventions address educational, curricular and environmental changes in the school.^{13,14} The 'Physical Activity 4 Everyone' (PA4E1) cluster randomised controlled trial (RCT) was designed based on these recommendations and aimed to reduce the decline in physical activity typically observed during adolescence.¹⁵ The multi-component intervention resulted in a significant differential change in the primary outcome (daily minutes MVPA) from baseline to 24 months of seven minutes/day ($P < 0.01$).¹⁶ The secondary aims of PA4E1 reported in this paper, were to determine whether the intervention impacted on adiposity outcomes (weight, BMI and BMI z-score), and whether any effect on such measures was moderated by (i) sex (male, female), (ii) baseline BMI (underweight/healthy weight; overweight/obese) and (iii) baseline physical activity level (active/inactive), at 12 and 24 months.

MATERIALS AND METHODS

Study design and setting

A cluster RCT was conducted in secondary schools in socio-economically disadvantaged communities in New South Wales (NSW), Australia. Communities were considered socio-economically disadvantaged if they had a socio-economic status score of five or less (lower 50% of NSW) based on the postal code. Outcome assessments were undertaken at baseline, 12 and 24 months. The study was approved by the University of Newcastle Human Research Ethics Committee (H-201-0210), the Hunter New England Ethics Committee (11/03/16/4.05) and the Department of Education and Catholic Schools Diocese. The trial adhered to the Consolidated Standards of Reporting Trials (CONSORT) guidelines¹⁷ and was registered with the Australian New Zealand Clinical Trials Registry (ACTRN 12612000382875). Detailed methods of the PA4E1 study have been reported elsewhere.¹⁵

Participants and recruitment

Secondary schools. Randomly selected secondary schools within the study region were invited to participate between October and December 2011. Schools were eligible to participate in the study if they were (i) Government or Catholic schools, (ii) had a socio-economic status score of five or less (lower 50% of NSW) based on the postal code,¹⁸ (iii) had at least 120 Grade-7 students and (iv) were not participating in any other physical activity or health intervention study. School Principals were provided with a study information package and asked to provide written informed consent. The consenting schools were randomly allocated to intervention or control groups following the collection of baseline data, using a computer generated block randomisation procedure (1:1 ratio) by an independent statistician.

Students. A cohort of first-year high-school students (Grade 7, aged 12–13 years) at the consenting secondary schools were invited to participate. Parents were provided with an information package and asked to provide written informed consent for their child. Two weeks following

the distribution of the information package, the non-responding parents were telephoned and asked to provide verbal consent. Children also provided assent for participating in the study.

'Physical Activity 4 Everyone' intervention

The design of the PA4E1 intervention was guided by social cognitive theory¹⁹ and socio-ecological theory,²⁰ and based on evidence of effective intervention features including multiple intervention components, delivery for a period of at least 12 months,^{13,14,21} and the inclusion of strategies to enhance implementation of intervention components.^{13,21–24} The intervention strategies have been outlined in detail elsewhere.^{15,16} Briefly, the intervention components targeted the school curriculum, school environment, and broader community and parental support^{7,21,25–27} in accordance with the WHO's Health Promoting Schools framework.⁷ The intervention was delivered over seven to eight school terms (19–24 months), and included the following seven physical activity intervention strategies:

School curriculum

1. 'Teaching strategies to maximise student physical activity in health and physical education (PE) lessons'. PE teachers received two professional learning workshops (conducted at 6-month intervals) that focused on (i) increasing motivation and MVPA in PE lessons to meet the target of 50% of PE lesson time in MVPA recommended by the US Centers for Disease Control and Prevention,²⁸ (ii) an implementation guide for delivering the 10-week enhanced school sport programme (that is, Program X) and (iii) recommended procedures for fitness testing and 'personal best' days. A final booster session provided a summary of all concepts and strategies included in the PA4E1 intervention.
2. 'Development and monitoring of student physical activity plans within PE lessons'. The student physical activity plans focused on (i) short- and long-term physical activity, (ii) actions and timelines, (iii) fitness assessments, (iv) recording actions and goal achievements, and (v) rewards for goal attainment (for example, balls, wrist bands and drink bottles).²⁹
3. 'Implementation of an enhanced school sports programme'. All students participated in a 10-week enhanced school sport programme during school sport. The programme was based on Program X, which was originally designed for less-active students.^{25,30–32}

School environment

4. 'Development and modification of school policies'. School policies were established or modified with the aim of enhancing students' physical activity.^{33,34} For example; incorporating pedometer-based lessons with PE, offering the enhanced school sport programme as a standard school sport option, routinely providing physical activity information to parents.
5. 'Physical activity programmes during school breaks'. Schools were provided with physical activity equipment (for example, balls, skipping equipment) and encouraged to offer supervised physical activity on at least 2 days per week during recess and lunch breaks.³⁵

Partnership and services

6. 'Promotion of community physical activity providers (community links)'.^{33,36} Schools were supported to host a physical activity expo that promoted local physical activity providers to students in Grade 8. Community physical activity providers were also promoted in school newsletters.
7. 'Parent engagement'. Information was regularly sent to the parents via existing school newsletters, the school website and PA4E1 newsletters on physical activity recommendations, school-based physical activity strategies, promotion of community physical activity providers and strategies to support their child's physical activity.^{31,37}

Four of the seven intervention strategies were implemented during the first 12 months (strategies 1, 2, 5 and 7 above). The remaining strategies were implemented over the next 12 months, with delivery of the initial strategies being maintained. The intervention strategies, particularly those under the curriculum domain, included a range of behaviour-change techniques with students^{15,38} such as the provision of information

about the behaviour and the consequences, general encouragement, prompting specific goal setting and a review of behavioural goals, prompting self-monitoring, prompting practice, modelling and demonstrating the behaviour, and the provision of feedback on performance.³⁸ The intervention further used six strategies to support the implementation of the seven physical activity intervention strategies listed above. The intervention implementation strategies included (i) an in-school physical activity consultant 1 day per week (change agent position),³⁶ (ii) establishing leadership and support, (iii) teacher training,^{39,40} (iv) resources, (v) teacher prompts⁴¹ and (vi) intervention implementation performance feedback to schools.⁴²

Control schools

Schools allocated to the control group participated in the measurement components of the study. Control schools were requested to follow their usual PE and sport programmes during the study period and were offered all intervention materials, equipment packs and the findings at the conclusion of the study.

Measures

Study outcome assessments were conducted at baseline and on the same cohort of students after 12 and 24 months post baseline. Data were collected at the schools by trained research assistants using standardised protocols.

Student characteristics. Students completed an online survey to collect data regarding their socio-demographic characteristics including age, sex, Aboriginal and Torres Strait Islander status, language spoken at home and residential postal code. Baseline accelerometer data were collected to derive minutes of MVPA per day. Students wore an accelerometer (Actigraph GT3X+ and GT3X models, Pensacola, FL, USA⁴³) for 7 days during waking hours. Physical activity data were included in the physical activity analyses if the accelerometer was worn for ≥ 600 min on ≥ 3 days per week.^{44–46} The Evenson cutpoints were used to categorise the intensity of physical activity.⁴⁷

Outcome measures: indicators of adiposity. At each measurement point, trained research assistants used the International Society for Advanced Kinanthropometry (ISAK) procedures to assess height and weight.⁴⁸ Participants were required to complete the assessments in light clothing and wearing no shoes. Weight was measured to the nearest 0.1 kg on a portable digital scale (Model no. UC-321PC, A&D Company Ltd, Tokyo, Japan). Height was measured to the nearest 0.1 cm using a portable stadiometer (Model no. PE087, Mentone Educational Centre, Springvale, VIC, Australia). Two recordings of height (cm) and weight (kg) measures were taken to calculate baseline BMI (weight (kg)/height (m)²). BMI z-scores were calculated using the WHO 2007 growth reference ranges for 5–19 years of age.⁴⁹

Statistical analysis

Data were analysed using SAS Version 9.2 (SAS Institute Inc., Cary, NC, USA). Summary statistics were used to describe student characteristics and accelerometer wear time. Participants were categorised as 'active' at baseline if they participated in ≥ 60 min of MVPA per day for a least 3 days and 'inactive' if they participated in < 60 min of MVPA per day. Weight status (underweight/healthy weight; overweight/obese) was categorised according to International Obesity Task Force cutpoints.⁵⁰ Participants with a baseline BMI ≥ 60 kg m⁻² and weight ≥ 150 kg were excluded from the analysis. The characteristics of those that provided follow-up data were compared with those that did not, using *t*-tests for continuous variables and χ^2 -tests for categorical variables.

The study was powered on the primary trial outcome (daily minutes of MVPA), based on ten schools providing 120 students per school (assuming 50% of the Grade consented and provided valid accelerometer data).^{51,52} If 65% of the cohort provided usable data at 24 months,⁵³ and after adjustment for a design effect of 1.38, the effective sample size was estimated to be 141 students per group. Previous studies were used to estimate the standard deviation of mean daily minutes of MVPA per group (17.1)⁵⁴ and intra-class correlation coefficient (0.01).⁵⁵ With 80% power and an α -level of 0.05, the study was able to detect a difference in daily mean minutes of MVPA between intervention and control students of ± 5.73 min at 24 months. On the basis of this, the detectable difference for weight with a standard deviation of 12.1 kg was 4 kg.

Analyses followed intention-to-treat principles. Significance levels were set at $P < 0.05$. Linear mixed models (LMM) were used to examine

the outcome measures of weight, BMI and BMI z-score. A three-level hierarchical model was used to capture correlations in the data with random intercepts for repeat measures (level 1), on individuals (level 2) and clustering within schools (level 3). The LMM analyses aimed to determine if there was a significant difference in mean change from baseline to 12 months and baseline to 24 months between intervention and control groups for each outcome measure, both assessed using an interaction term between treatment group (intervention vs. control) and time (baseline vs. 12 months and baseline vs. 24 months). Two sensitivity analyses were conducted, first using only those that provided complete adiposity outcomes at all three time points (complete cases), and second using multiple imputation to fill in the missing data. The multiple imputation model used the method of chained regression equations, including variables that were prognostic of missing data and additional demographic and outcome data to create five imputed data sets. The results from fitting the LMM were pooled over the five data sets using Rubin's method.⁵⁶

Sub-analyses. Exploratory sub-analyses (defined *a priori*) were undertaken to determine whether the intervention impacted on the outcome measures for students according to three moderators of energy balance (i) sex (male; female), (ii) baseline BMI (underweight/healthy weight; overweight/obese) and (iii) baseline physical activity level (active; inactive). The moderator interaction terms were included in individual LMM analyses for each outcome, and the *P*-value for the three-way interaction term (group \times time \times moderator) was used to assess the level of evidence against the null hypothesis of no effect modification. Treatment effects are presented within each subgroup regardless of this *P*-value.

RESULTS

Sample

Of the 22 eligible schools, 13 were approached to participate in the study. Ten schools consented to participate (77%) and parental consent was obtained for 1233 of the 1468 Grade-7 students in the 10 schools (84%). A total of 1150 students provided adiposity outcome data at baseline, 1051 (91%) at mid-point (12 months) and 985 (86%) at 24 months. Demographic characteristics of the sample at baseline, 12 and 24 months are outlined in Table 1. At baseline, the mean age of participants was 12 years, 51% were female, 17% were overweight and 5% were obese, and 64% did not meet the physical activity recommendation of ≥ 60 min of MVPA per day. Participants who were lost to follow-up were more likely to be older in age ($P = 0.03$) and did not speak English as a primary language ($P = 0.02$) compared with those who provided outcome data at all time points.

At 24 months, all 5 intervention schools had implemented 6 of the 7 physical activity strategies. The exception was strategy 5 (school policy); 4 of the 5 schools had developed a school policy. All intervention implementation strategies were delivered as planned. The majority of intervention group PE teachers ($n = 35$) reported using pedometers to increase activity levels in PE (88.9%), and 58.8% reported including student physical activity plans each term. All schools were represented by at least one PE teacher (range 1–5) at each professional learning workshop. More information on intervention delivery can be found in the 24-month physical activity outcome paper.¹⁶

Indicators of adiposity

The results for the 12- and 24-month adiposity outcomes are presented in Table 2. At 12 months, there were group-by-time effects for weight (mean difference (95% CI) = -0.90 kg (-1.50 ; -0.30), $P < 0.01$) and BMI (-0.28 kg m⁻² (-0.50 ; -0.06), $P = 0.01$) in favour of the intervention group, but not for BMI z-score (-0.05 (-0.11 ; 0.01), $P = 0.13$). These findings were consistent for weight (-0.62 kg (-1.21 ; -0.03), $P = 0.01$) and BMI (-0.28 kg m⁻² (-0.49 ; -0.06), $P = 0.01$) at 24 months, with group-by-time effects also found for BMI z-score (-0.08 (-0.14 ; -0.02), $P = 0.02$) favouring the intervention group.

Table 1. Sample characteristics at baseline, 12 and 24 months for students who provided adiposity outcome measures

Variable	Subgroup	Baseline		Mid-point (12 months)		Follow-up (24 months)	
		Control (n = 505)	Intervention (n = 645)	Control (n = 459)	Intervention (n = 592)	Control (n = 425)	Intervention (n = 560)
Sex ^a	Male	244 (49%)	299 (48%)	219 (48%)	268 (46%)	219 (52%)	266 (48%)
	Female	254 (51%)	329 (52%)	233 (52%)	311 (54%)	204 (48%)	287 (52%)
ATSI ^b	No	456 (91%)	581 (92%)	415 (91%)	540 (92%)	390 (92%)	520 (93%)
	Yes	44 (8.8%)	53 (8.4%)	39 (8.6%)	45 (7.7%)	35 (8.2%)	40 (7.1%)
Language ^c	English	474 (97%)	593 (99%)	425 (97%)	539 (98%)	392 (97%)	506 (98%)
	Other	15 (3.1%)	8 (1.3%)	11 (2.5%)	9 (1.6%)	11 (2.7%)	8 (1.6%)
SEIFA ^d	Low	295 (61%)	349 (59%)	260 (60%)	308 (57%)	236 (59%)	285 (56%)
	High	190 (39%)	246 (41%)	172 (40%)	235 (43%)	163 (41%)	222 (44%)
Rurality	Metropolitan	236 (47%)	340 (53%)	220 (48%)	324 (55%)	207 (49%)	304 (54%)
	Rural	269 (53%)	305 (47%)	239 (52%)	268 (45%)	218 (51%)	256 (46%)
BMI category ^e	Underweight	30 (6.3%)	41 (7.3%)	19 (5.8%)	29 (6.9%)	7 (2.0%)	12 (2.5%)
	Normal weight	321 (67%)	397 (71%)	214 (65%)	291 (69%)	214 (62%)	320 (66%)
	Overweight	100 (21%)	97 (17%)	72 (22%)	75 (18%)	95 (28%)	111 (23%)
	Obese	29 (6.0%)	27 (4.8%)	25 (7.6%)	24 (5.7%)	27 (7.9%)	45 (9.2%)
MVPA ^f	Inactive (< 60 min per day)	324 (67%)	414 (67%)	277 (72%)	340 (68%)	226 (72%)	261 (66%)
	Active (≥60 min per day)	162 (33%)	207 (33%)	108 (28%)	158 (32%)	90 (28%)	137 (34%)
Age ^g	median (min., max.)	12 (11,13)	12 (11,13)	13 (12,14)	13 (12,14)	14 (12,15)	14 (12,15)
Height ^h	Mean (s.d.)	156.81 (7.92)	157.13 (7.47)	162.56 (8.20)	162.39 (8.73)	167.28 (9.40)	167.02 (7.88)
Weight ⁱ	Mean (s.d.)	50.01 (12.05)	49.43 (11.05)	55.96 (12.60)	55.22 (12.51)	61.50 (13.23)	60.52 (12.72)
BMI ^j	Mean (s.d.)	20.19 (3.81)	19.90 (3.59)	21.04 (3.76)	20.77 (3.96)	21.90 (4.33)	21.64 (4.06)
BMI z-score ^k	Mean (s.d.)	0.58 (1.16)	0.54 (1.11)	0.61 (1.13)	0.55 (1.11)	0.72 (1.09)	0.65 (1.12)

Abbreviations: ATSI, Aboriginal and Torres Strait Islander; BMI, body mass index; MVPA, moderate-to-vigorous physical activity; SEIFA, Socio-Economic Indexes for Australia. ^aBaseline (control = 7, intervention = 17), mid-point (control = 7, control = 13), follow-up (control = 2, intervention = 7). ^bBaseline (control = 5, intervention = 11), mid-point (control = 5, control = 7), follow-up (control = 0, intervention = 0). ^cBaseline (control = 16, intervention = 44), mid-point (control = 23, control = 44), follow-up (control = 22, intervention = 46). ^dBaseline (control = 20, intervention = 50), mid-point (control = 27, control = 49), follow-up (control = 26, intervention = 53). ^eBaseline (control = 25, intervention = 83), mid-point (control = 129, control = 173), follow-up (control = 82, intervention = 72). ^fBaseline (control = 19, intervention = 24), mid-point (control = 74, control = 94), follow-up (control = 109, intervention = 162). Participants (n). ^gBaseline (control = 491, intervention = 593), mid-point (control = 409, control = 516), follow-up (control = 407, intervention = 534). ^hBaseline (control = 491, intervention = 590), mid-point (control = 442, control = 573), follow-up (control = 415, intervention = 549). ⁱBaseline (control = 491, intervention = 587), mid-point (control = 440, control = 562), follow-up (control = 410, intervention = 547). ^jBaseline (control = 491, intervention = 584), mid-point (control = 440, control = 562), follow-up (control = 409, intervention = 547). ^kBaseline (control = 484, intervention = 571), mid-point (control = 406, control = 502), follow-up (control = 343, intervention = 488).

Intervention effects were significant for all adiposity outcomes at 12 and 24 months in both the complete cases and multiple imputation analyses (Supplementary Appendix 1 and 2).

Subgroup analyses

The results of the subgroup analyses are presented in Supplementary Appendix 3.

Sex. There was weak evidence of a differential treatment on effect on weight in males compared with females (three-way interaction $P=0.22$). Among males there was a statistically significant treatment effect at 24 months in favour of the intervention group (-1.26 kg (-2.11 ; -0.41), $P=0.01$). There were no significant effects on weight, BMI and BMI z-score at either 12 or 24 months for females.

Weight status at baseline. We found very little evidence of differential treatment effects depending on baseline weight for weight ($P=0.50$), BMI ($P=0.57$) or BMI z-score ($P=0.64$). Nevertheless, we did observe the following results.

Among underweight and normal weight participants combined, there were significant effects for weight (-0.71 kg (-1.28 ; -0.14), $P=0.04$), BMI (-0.33 kg m^{-2} (-0.55 ; -0.10), $P=0.01$) and BMI z-score (-0.08 (-0.15 ; -0.01), $P=0.01$) in favour of the intervention group at 12-month follow-up. Similar findings for weight (-0.71 kg (-1.28 ; -0.14), $P=0.04$), BMI (-0.33 kg m^{-2} (-0.55 ; -0.10), $P=0.01$) and BMI z-score (-0.08 (-0.15 ; -0.01), $P=0.01$) in

underweight/normal weight participants were found at 24 months in favour of the intervention group.

Among overweight and obese students, no significant effects were found at 12 or 24 months for weight (12 months = -1.29 kg (-3.12 ; 0.53), $P=0.16$; 24 months = -1.16 kg (-2.98 ; 0.67), $P=0.30$), BMI (12 months = -0.39 kg m^{-2} (-1.01 ; 0.22), $P=0.21$; 24 months = -0.18 kg m^{-2} (-0.80 ; 0.44), $P=0.45$) and BMI z-score (12 months = -0.07 (-0.21 ; 0.07), $P=0.31$; 24 months = -0.00 (-0.14 ; 0.14), $P=0.54$).

Physical activity level at baseline. We found no evidence of differential treatment effects depending on activity status at baseline for weight ($P=0.94$), BMI ($P=0.95$) or BMI z-score ($P=0.31$). There was no significant effect on weight, BMI or BMI z-score for either active or inactive students at 12 or 24 months.

DISCUSSION

This study reports the 12- and 24-month effects of PA4E1 on the secondary outcomes of weight, BMI and BMI z-score. The intervention had a favourable impact on adiposity outcomes, having a moderate effect on weight and BMI at 12 months, and weight, BMI and BMI z-score at 24 months. A difference in BMI of -0.28 kg m^{-2} over 24 months between intervention and control groups is twice the effect found in a meta-analysis of 11 school-based physical activity intervention studies (-0.13 kg m^{-2}).¹⁰ However, of the 11 physical activity interventions, only 2 were conducted in secondary schools and only 1 of these during school

Table 2. Changes in adiposity outcomes from baseline to 12- and 24-month follow-up

Outcome	Intervention			Control			Intervention-Control						
	Baseline (n = 645) mean (95% CI)	12 m (n = 592) mean (95% CI)	24 m (n = 560) mean (95% CI)	P-value (baseline to follow-up)	Baseline (n = 505) mean (95% CI)	12 m (n = 459) mean (95% CI)	24 m (n = 425) mean (95% CI)	P-value (baseline to follow-up)	Baseline to 12 m	P-value	Baseline to 24 m	P-value	Group × time P-value
Weight (kg)	50.08 (48.83, 51.34)	55.91 (54.65, 57.17)	61.08 (59.83, 62.34)	< 0.0001	50.04 (48.69, 51.38)	56.48 (55.13, 57.83)	61.94 (60.59, 63.30)	< 0.001	-0.90 (-1.50, -0.30)	0.0034	-0.62 (-1.21, -0.03)	0.0396	0.0106
BMI (kg m ⁻²)	20.27 (19.76, 20.78)	21.07 (20.56, 21.59)	21.86 (21.34, 22.37)	< 0.0001	20.19 (19.65, 20.72)	21.27 (20.73, 21.81)	22.06 (21.52, 22.60)	< 0.001	-0.28 (-0.50, -0.06)	0.0126	-0.28 (-0.49, -0.06)	0.0116	0.0145
BMI z-score	0.62 (0.47, 0.77)	0.61 (0.46, 0.75)	0.69 (0.54, 0.84)	0.0002	0.59 (0.43, 0.74)	0.66 (0.50, 0.81)	0.71 (0.55, 0.86)	< 0.0001	-0.05 (-0.11, 0.01)	0.1307	-0.08 (-0.14, -0.02)	0.0062	0.0226

Abbreviations: BMI, body mass index; CI, confidence interval. Bold values are statistically significant.

time.¹⁰ In the latter study, the effectiveness of a 12-week school exercise training programme was tested in 24 obese, adolescent males, and found a significant intervention effect of -0.59 kg m^{-2} (95% CI = $-1.4; 0.23$).⁵⁷ The small sample in a high-risk, single-sex obese subgroup and the short intervention duration makes it difficult to equate to PA4E1. In an earlier meta-analysis of 18 studies, the intervention effect on BMI was much lower at -0.05 kg m^{-2} ($-0.19; 0.10$).⁹ However, only two of the 18 studies exclusively investigated the effect of a physical activity intervention in middle- or secondary-school students.⁹

The exploratory subgroup analyses found a significant effect at 24 months, favouring the intervention group on (i) weight among male adolescents, and (ii) weight, BMI and BMI z-score among underweight/healthy weight adolescents. There were no treatment effects on any of the adiposity measures for the other subgroups examined including females, overweight/obese students or active/inactive students. Although the moderator analyses indicate that the PA4E1 intervention was effective in limiting weight and BMI increases in the underweight/healthy weight subgroup, there was no evidence that the intervention had an adverse effect on underweight students as the proportion of underweight students decreased during the study, from 7.3% at baseline to 2.5% at 24 months. Weight, BMI and BMI z-score increased in both intervention and control underweight/healthy weight students, but increased to a lesser extent among students in the intervention group.

In PA4E1, 76% of students were not overweight or obese at baseline meaning a lower propensity to reduce adiposity measures. For this reason the authors of the HEALTHY study⁵⁸ have suggested that although population-based primary prevention interventions should continue to target all children, the study aim and primary outcomes should be evaluated in the highest-risk subgroup (overweight/obese adolescents) instead of the entire cohort. Although there were no significant intervention effects in the PA4E1 overweight/obese subgroup, the adiposity results for the intervention group are trending in the hypothesised direction and the effect was larger than that found in the main analysis and among healthy weight/underweight students. A lack of significant findings in overweight and obese students is likely to be a sample size issue, as the disproportionate number of adolescents in each weight status group may have contributed to the sub-analyses being underpowered.

At 24 months, the mean difference in BMI change between groups was -0.28 kg m^{-2} , with the intervention group's students increasing BMI by 1.59 kg m^{-2} and control by 1.87 kg m^{-2} over 2 years. This BMI trajectory is higher (intervention = $\sim 0.80 \text{ kg m}^{-2}$ per year; control = $\sim 0.94 \text{ kg m}^{-2}$ per year) than that found in a longitudinal study in Britain that aimed to examine the developmental trajectory of obesity throughout adolescence in relation to sex, ethnicity and socio-economic status in a cohort of 5836 adolescents.⁵⁹ Over 5 years from Grade 7 to Grade 11, BMI increased by 0.73 kg m^{-2} per year.⁵⁹ The rate of BMI increase did not differ by sex; however, socio-economically disadvantaged and black female adolescents had higher rates of overweight and obesity.⁵⁹ The higher BMI trajectory in participants of the PA4E1 study may also explain why PA4E1 was effective in limiting the adiposity increases in underweight/healthy weight adolescents, but had a limited, non-significant effect on overweight and obese adolescents.

The majority of school-based physical activity interventions targeting adolescents from socio-economically disadvantaged communities have not reported the effect on adiposity outcomes, and few have found an intervention effect.^{60,61} However, the results of PA4E1 are similar to findings from the 'Intervention Centred on Adolescent Physical Activity and Sedentary Behaviour' (ICAPS) study, which found intervention effects on BMI z-score.⁶² Similar to PA4E1, ICAPS was a socio-ecologically framed, multi-component intervention, implemented over a longer 4-year

period.⁶² The intervention involved changing attitudes towards physical activity (that is, educational component), promoting social support from teachers and parents (that is, regular meetings), and providing environmental and institutional conditions to promote physical activity (for example, break-time and after-school physical activity, sporting events and cycle to school days).⁶² The impact of ICAPS on adiposity (BMI z-score = -0.11; $P=0.02$) was comparable to PA4E1 (BMI z-score = -0.08; $P < 0.01$), and were maintained for 2 years 6 months after the intervention had finished, indicating that the results could be sustained. Similar proportions of overweight and obese adolescents were reported in ICAPS (23%) and PA4E1 (22%), and neither of the studies found significant adiposity effects on adolescents who were initially overweight or obese. The findings provide evidence for long-term multi-component interventions that target determinants at all socio-ecological levels (that is, intra-personal, inter-personal, organisation, community and policy).

PA4E1 is one of few school-based physical activity interventions to reduce the risk of overweight and obesity in adolescents living in socio-economically disadvantaged areas.^{9,63,64} A recent systematic review of childhood-obesity-prevention programmes incorporating diet and physical activity strategies, found that the strength of evidence was high for physical activity-only interventions in schools with home involvement, and for combined diet-physical activity interventions delivered with both home and community components. The PA4E1 findings indicate that school-based physical activity-only interventions (with home and community components) show promise, particularly adolescent populations. The impact of the intervention on adiposity outcomes could also be enhanced by incorporating a dietary school-based component with home and community involvement.

Although the adiposity results are unlikely to be clinically significant at an individual level, the reduced adiposity trajectory may produce health benefits at a population level and over an individual's lifetime. A 1% reduction in the prevalence of overweight and obesity in 16–17-year-old adolescents today has been projected to reduce the number of obese adults by 52 821 in the future, decrease total lifetime medical costs by \$586.3 million dollars and increase the quality-adjusted life years by 47 138 years.⁶⁵ The positive effect of PA4E1 on adiposity may have occurred due to the increase in objectively measured MVPA of 7 more minutes of MVPA per day than the control students at 24 months.¹⁶ The PA4E1 intervention was a multi-component and socio-ecologically framed school-based intervention, key elements of which have been recommended to increase physical activity and reduce the prevalence of obesity during adolescence.^{11,12} The intervention addressed educational, curricular and environmental changes in the school, supported by evidence from recent systematic reviews of school-based interventions.^{13,14} A 'change agent', who was a trained PE teacher, visited each of the intervention schools 1 day per week for the duration of the intervention to support the school and PE teachers in implementing the strategies (the change agent did not deliver any classes). The use of strategies within a sustainable framework of PA4E1 makes it a potentially scalable intervention. The intervention could be disseminated more broadly in secondary schools by education departments, and therefore, warrants dissemination evaluation.

This PA4E1 study had several strengths including the RCT design, the long intervention duration and a large sample size. The study included a suite of intervention implementation strategies based on the theoretical frameworks and evidence from past school-based physical activity reviews. Analyses were repeated using complete cases only and multiple imputation which reported similar results to the main analysis with regard to weight, BMI and BMI z-score, suggesting that the findings are robust. A number of limitations of the study need to be acknowledged. Although BMI is an acceptable measure of change in adiposity, direct measures, such as dual-energy radiography

absorptiometry, give a more accurate measure of adiposity.⁶⁶ Although the study was implemented over a 24-month period, the study did not assess whether the adiposity differences were sustained in the longer term once the 'change agent' ceased visiting the intervention schools. The students were recruited from moderate-to-large sized, socio-economically disadvantaged schools from one area in Australia, which may reduce the generalisability of the findings. The study did not collect maturation data from students. The study is likely to be underpowered for the subgroup analyses so these findings should be interpreted with caution, as the lack of a treatment effect may have been due to type II error (failing to detect an effect that is present). Assessment of the cost and cost effectiveness of the PA4E1 intervention will be reported in a separate paper.

There is a need for innovative physical activity interventions to target adolescents most at risk of overweight and obesity. The results from the PA4E1 intervention provide evidence for a multi-component physical activity intervention implemented in secondary schools to have a moderate effect on adiposity outcomes at the population level among adolescents from socio-economically disadvantaged communities. Multi-component interventions that increase adolescents' engagement in MVPA may assist in preventing overweight and obesity.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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AUTHOR CONTRIBUTIONS

JW, PJM, DRL, LC, LW and KG obtained funding for the research. All authors contributed to developing the intervention and data collection protocols and materials. JLH drafted the manuscript, and all authors reviewed, edited and approved the final version of the paper. All authors accept full responsibility for, and have read and approved, the final manuscript.

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