International Journal of Obesity (2016) 40, 1486–1493
www.nature.com/ijo

OPEN

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

JL Hollis[1,2], R Sutherland[1,2,3], L Campbell[1,2,3], PJ Morgan[4], DR Lubans[4], N Nathan[1,2,3], L Wolfenden[1,2,3], AD Okely[5,6], L Davies[1,3], A Williams[1,2], KE Cohen[4], C Oldmeadow[2,3], K Gillham[1,3] and J Wiggers[1,2,3]

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.

International Journal of Obesity (2016) **40,** 1486–1493; doi:10.1038/ijo.2016.107

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 ~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

[1]Hunter New England Population Health, The University of Newcastle, Wallsend, New South Wales, Australia; [2]School of Medicine and Public Health, University of Newcastle, Callaghan, New South Wales, Australia; [3]Hunter Medical Research Institute, Lambton, New South Wales, Australia; [4]Priority Research Centre in Physical Activity and Nutrition, School of Education, University of Newcastle, Callaghan, New South Wales, Australia; [5]Early Start Research Institute, Faculty of Social Sciences, University of Wollongong, Wollongong, New South Wales, Australia and [6]Illawarra Health and Medical Research Institute, University of Wollongong, Wollongong, New South Wales, Australia. Correspondence: Mrs R Sutherland, Hunter New England Population Health, The University of Newcastle, Locked Bag 10, Wallsend 2287 New South Wales, Australia.
E-mail: Rachel.Sutherland@hnehealth.nsw.gov.au
Received 20 January 2016; revised 18 April 2016; accepted 2 May 2016; accepted article preview online 10 June 2016; advance online publication, 19 July 2016

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) guidelines[17] 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 theory[19] 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 prompts[41] 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. Controls 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, USA[43]) for 7 days during waking hours. Physical activity data were included in the physical activity analyses if the accelerometer was worn for $\geqslant$600 min on $\geqslant$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 Kinathropometry (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 $\geqslant$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 $\geqslant$60 kg m^{-2} and weight $\geqslant$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 × time × 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 $\geqslant$60 min of MVPA per day. Participants who were lost to follow-up were more likely to be older in age ($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. [a]Baseline (control = 7, intervention = 17), mid-point (control = 7, control = 13), follow-up (control = 2, intervention = 7). [b]Baseline (control = 5, intervention = 11), mid-point (control = 5, control = 7), follow-up (control = 0, intervention = 0). [c]Baseline (control = 16, intervention = 44), mid-point (control = 23, control = 44), follow-up (control = 22, intervention = 46). [d]Baseline (control = 20, intervention = 50), mid-point (control = 27, control = 49), follow-up (control = 26, intervention = 53). [e]Baseline (control = 25, intervention = 83), mid-point (control = 129, control = 173), follow-up (control = 82, intervention = 72). [f]Baseline (control = 19, intervention = 24), mid-point (control = 74, control = 94), follow-up (control = 109, intervention = 162). Participants (*n*). [g]Baseline (control = 491, intervention = 593), mid-point (control = 409, control = 516), follow-up (control = 407, intervention = 534). [h]Baseline (control = 491, intervention = 590), mid-point (control = 442, control = 573), follow-up (control = 415, intervention = 549). [i]Baseline (control = 491, intervention = 587), mid-point (control = 440, control = 562), follow-up (control = 410, intervention = 547). [j]Baseline (control = 491, intervention = 584), mid-point (control = 440, control = 562), follow-up (control = 409, intervention = 547). [k]Baseline (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				
									Difference in change between groups				
	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 study[58] 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 = ~ 0.80 kg m^{-2} per year; control = ~ 0.94 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.

ACKNOWLEDGEMENTS

We thank the PA4E1 staff who worked as project officers, research assistants and data collectors on the project. We are also indebted to the schools and students participating in the study. This study is funded through the NSW Ministry of Health, Heath Promotion Demonstration grant scheme. In kind, support for the study is also provided by the Hunter New England Local Health District. The project also received infrastructure support from the Hunter Medical Research Institute (HMRI).The study has been approved by the Hunter New England Human Research Ethics Committee (Ref No. 11/03/16/4.05), University of Newcastle (Ref No. H-2011-0210), NSW Department of Education and Communities (SERAP 2011111), Maitland Newcastle Catholic School Diocese and Broken Bay Catholic School Diocese. Anthony Okely is supported by a National Heart Foundation Career Development Fellowship.

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.

REFERENCES

1 Alberga AS, Sigal RJ, Goldfield G, Prud' homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes* 2012; **7**: 261–273.

2 Bibiloni MdM, Pons A, Tur JA. Prevalence of overweight and obesity in adolescents: a systematic review. *ISRN Obes* 2013; **2013**: 392747.

3 Scarborough P, Bhatnagar P, Wickramasinghe KK, Allender S, Foster C, Rayner M. The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: an update to 2006–07 NHS costs. *J Public Health* 2011; **33**: 527–535.

4 Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U *et al*. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 2012; **380**: 247–257.

5 Dumith SC, Gigante DP, Domingues MR, Kohl HW. Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol* 2011; **40**: 685–698.

6 Borraccino A, Lemma P, Iannotti R, Zambon A, Dalmasso P, Lazzeri G *et al*. Socio-economic effects on meeting PA guidelines: comparisons among 32 countries. *Med Sci Sports Exerc* 2009; **41**: 749–756.

7 World Health Organisation. *Planning Meeting in Health Promoting Schools Project: Background, development and strategy outline of the Health Promoting Schools Project*. WHO: Copenhagen, 1991.
8 Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). *BMJ* 2012; **345**: e5888.
9 Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. *CMAJ* 2009; **180**: 719–726.
10 Lavelle H, Mackay D, Pell J. Systematic review and meta-analysis of school-based interventions to reduce body mass index. *J Public Health* 2012; **34**: 360–369.
11 Sallis JF, Hinckson EA. Reversing the obesity epidemic in young people: building up the physical activity side of energy balance. *Lancet Diabetes Endocrinol* 2013; **2**: 190–191.
12 Institute of Medicine. *Educating the student body: taking physical activity and physical education to school*. National Academies Press: Washington, DC,USA, 2013.
13 Kriemler S, Meyer U, Martin E, van Sluijs EMF, Andersen LB, Martin BW. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *Br J Sports Med* 2011; **45**: 923–930.
14 Murillo Pardo B, García Bengoechea E, Generelo Lanaspa E, Bush PL, Zaragoza Casterad J, Julián Clemente JA *et al.* Promising school-based strategies and intervention guidelines to increase physical activity of adolescents. *Health Edu Res* 2013; **28**: 523–538.
15 Sutherland R, Campbell E, Lubans DR, Morgan PJ, Okely AD, Nathan N *et al.* A cluster randomised trial of a school-based intervention to prevent decline in adolescent physical activity levels: study protocol for the 'Physical Activity 4 Everyone' trial. *BMC Public Health* 2013; **13**: 57.
16 Sutherland R, Campbell E, Lubans DR, Morgan PJ, Nathan N, Wolfenden L *et al.* The Physical Activity 4 Everyone cluster randomised trial. 2-year outcomes of a school physical activity intervention among adolescents. *Am J Prev Med* (in press).
17 Moher D, Hopewell S, Schulz KF, Montori V, Gøtzsche PC, Devereaux P *et al.* CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *J Clin Epidemiol 2010* **63**: e1–e37.
18 Australian Bureau of Statistics. *Technical Paper: Census of Population and Housing: Socio-Economic Indexes for Australia (SEIFA)*. Commonwealth of Australia: Canberra, Australia, 2001.
19 Bandura A. *Social foundations of thought and action: A Social Cognitive Theory*. Prentice-Hall: Englewood Cliffs, NJ, USA, 1986.
20 Green LW, Richard L, Potvin L. Ecological foundations of health promotion. *Am J Health Promot* 1996; **10**: 270–281.
21 van Sluijs EM, McMinn AM, Griffin SJ. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. *BMJ* 2007; **335**: 703.
22 Dewar DL, Morgan PJ, Plotnikoff RC, Okely AD, Collins CE, Batterham M *et al.* The Nutrition and Enjoyable Activity for Teen Girls study: a cluster randomized controlled trial. *Am J Prev Med* 2013; **45**: 313–317.
23 Casey MM, Harvey JT, Telford A, Eime RM, Mooney A, Payne WR. Effectiveness of a school-community linked program on physical activity levels and health-related quality of life for adolescent girls. *BMC Public Health* 2014; **14**: 1.
24 Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD *et al.* Smart-phone obesity prevention trial for adolescent boys in low-income communities: the ATLAS RCT. *Pediatrics* 2014; **134**: e723–e731.
25 Bandura A. Health promotion by social cognitive means. *Health Educ Behav* 2004; **31**: 143–164.
26 Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions. How are we doing? How might we do better? *Am J Prev Med* 1998; **15**: 266–297.
27 Lubans D, Morgan P. Evaluation of an extra-curricular school sport programme promoting lifestyle and lifetime activity for adolescents. *J Sports Sci* 2008; **26**: 519–529.
28 Centers for Disease Control and Prevention (CDC) and President's Council on Fitness. Healthy People 2010. Chapter 22 Physical Activity and Fitness 2010. Available at http://hp2010.nhlbihin.net/2010Objs/22Physical.html#_Toc471793-048.h (accessed on 28 August 2012).
29 Centres for Disease Control and Prevention. *School Health Index: A Self-Assessment and Planning Guide. Middle school/High school version*. Centres for Disease Control and Prevention: Atlanta, GA, USA, 2005.
30 Lubans DR, Morgan PJ, Callister R, Collins CE, Plotnikoff RC. Exploring the mechanisms of physical activity and dietary behavior change in the program x intervention for adolescents. *J Adolesc Health* 2010; **47**: 83–91.
31 O'Connor TM, Jago R, Baranowski T. Engaging parents to increase youth physical activity a systematic review. *Am J Prev Med* 2009; **37**: 141–149.
32 Wilson KD, Kurz RS. Bridging implementation and institutionalization within organizations: proposed employment of continuous quality improvement to further dissemination. *J Public Health Manag Pract* 2008; **14**: 109–116.
33 Sallis JF, McKenzie TL, Conway TL, Elder JP, Prochaska JJ, Brown M *et al.* Environmental interventions for eating and physical activity: a randomized controlled trial in middle schools. *Am J Prev Med* 2003; **24**: 209–217.
34 Ward DS for Active Living Research. School Policies on Physical Education and Physical Activity. Research Synthesis. 2011. Available at www.activeliving research.org (accessed June 2012).
35 Connolly P, McKenzie TL. Effects of a games intervention on the physical activity levels of children at recess. *Res Q Exerc Sport* 2005; **60**: A60.
36 McKenzie TL, Sallis JF, Prochaska JJ, Conway TL, Marshall SJ, Rosengard P. Evaluation of a two-year middle-school physical education intervention: M-SPAN. *Med Sci Sports Exerc* 2004; **36**: 1382–1388.
37 Bravata DM, Smith-Spangler C, Sundaram V, Gienger AL, Lin N, Lewis R *et al.* Using pedometers to increase physical activity and improve health: a systematic review. *JAMA* 2007; **298**: 2296–2304.
38 Abraham C, Michie S. A taxonomy of behavior change techniques used in interventions. *Health Psychol* 2008; **27**: 379.
39 Lubans DR, Morgan PJ, Callister R, Collins CE. Effects of integrating pedometers, parental materials, and E-mail support within an extracurricular school sport intervention. *J Adolesc Health* 2009; **44**: 176–183.
40 Cleland CL, Tully MA, Kee F, Cupples ME. The effectiveness of physical activity interventions in socio-economically disadvantaged communities: a systematic review. *Prev Med* 2012; **54**: 371–380.
41 Greaves CJ, Sheppard KE, Abraham C, Hardeman W, Roden M, Evans PH *et al.* Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. *BMC Public Health* 2011; **11**: 1.
42 McKenzie T. SOFIT (System for Observing Fitness Instruction Time). *Generic Description and Procedures Manual* 2012.
43 Trost SG. State of the art reviews: measurement of physical activity in children and adolescents. *Am J Lifestyle Med* 2007; **1**: 299–314.
44 Grydeland M, Bergh IH, Bjelland M, Lien N, Andersen LF, Ommundsen Y *et al.* Intervention effects on physical activity: the HEIA study-a cluster randomized controlled trial. *Int J of Behav Nutr Phys Act* 2013; **10**: 1–13.
45 Okely AD, Cotton WG, Lubans DR, Morgan PJ, Puglisi L, Miller J *et al.* A school-based intervention to promote physical activity among adolescent girls: rationale, design, and baseline data from the girls in sport group randomised controlled trial. *BMC Public Health* 2011; **11**: 658.
46 Toftager M, Christiansen LB, Ersbøll AK, Kristensen PL, Due P, Troelsen J. Intervention effects on adolescent physical activity in the multicomponent SPACE study: a cluster randomized controlled trial. *PloS One* 2014; **9**: e99369.
47 Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci* 2008; **26**: 1557–1565.
48 Marfell-Jones MOT, Stew A. *International Standards for Anthropometric Assessment*. The International Society of the Advancement of Kinanthropometry: Australia, 2006.
49 World Health Organization. Global Database on Child Growth and Malnutrition: growth reference data for 5–19 years. 2007. Available at http://www.who.int/growthref/en/ (accessed on 10 December 2015).
50 Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ* 2007; **335**: 194.
51 Drenowatz C, Eisenmann JC, Pfeiffer KA, Welk G, Heelan K, Gentile D *et al.* Influence of socio-economic status on habitual physical activity and sedentary behavior in 8-to 11-year old children. *BMC Public Health* 2010; **10**: 214.
52 Gortmaker SL, Lee RM, Mozaffarian RS, Sobol AM, Nelson TF, Roth BA *et al.* Effect of an after-school intervention on increases in children's physical activity. *Med Sci Sports Exerc* 2012; **44**: 450–457.
53 Audrey S, Bell S, Hughes R, Campbell R. Adolescent perspectives on wearing accelerometers to measure physical activity in population-based trials. *Eur J Public Health* 2013; **23**: 475–480.
54 Lubans DR, Morgan PJ, Dewar D, Collins CE, Plotnikoff RC, Okely AD *et al.* The Nutrition and Enjoyable Activity for Teen Girls (NEAT girls) randomized controlled trial for adolescent girls from disadvantaged secondary schools: rationale, study protocol, and baseline results. *BMC Public Health* 2010; **10**: 652.
55 Murray DM, Stevens J, Hannan PJ, Catellier DJ, Schmitz KH, Dowda M *et al.* School-level intraclass correlation for physical activity in sixth grade girls. *Med Sci Sports Exerc* 2006; **38**: 926–936.
56 White IR, Horton NJ, Carpenter J, Pocock SJ. Strategy for intention to treat analysis in randomised trials with missing outcome data. *BMJ* 2011; **342**: d40.
57 Wong PC, Chia MY, Tsou IY, Wansaicheong GK, Tan B, Wang JC *et al.* Effects of a 12-week exercise training programme on aerobic fitness, body composition,

blood lipids and C-reactive protein in adolescents with obesity. *Ann Acad Med Singapore* 2008; **37**: 286–293.

58 Marcus MD, Hirst K, Kaufman F, Foster GD, Baranowski T. Lessons learned from the HEALTHY primary prevention trial of risk factors for type 2 diabetes in middle school youth. *Curr Diab Rep* 2013; **13**: 63–71.

59 Wardle J, Brodersen NH, Cole TJ, Jarvis MJ, Boniface DR. Development of adiposity in adolescence: five year longitudinal study of an ethnically and socio-economically diverse sample of young people in Britain. *BMJ* 2006; **332**: 1130–1135.

60 Summerbell CD, Waters E, Edmunds LD, Kelly S, Brown T, Campbell KJ. Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2005; **20**: CD001871.

61 Doak CM, Visscher TLS, Renders CM, Seidell JC. The prevention of overweight and obesity in children and adolescents: a review of interventions and programmes. *Obes Rev* 2006; **7**: 111–136.

62 Simon C, Schweitzer B, Oujaa M, Wagner A, Arveiler D, Triby E *et al*. Successful overweight prevention in adolescents by increasing physical activity: a 4-year randomized controlled intervention. *Int J Obes* 2008; **32**: 1489–1498.

63 Lubans DR, Morgan PJ, Okely AD, Dewar D, Collins CE, Batterham M *et al*. Preventing obesity among adolescent girls: one-year outcomes of the nutrition and enjoyable activity for teen girls (neat girls) cluster randomized controlled trial. *Arch Pediatr Adolesc Med* 2012; **166**: 821–827.

64 Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obesity Rev* 2009; **10**: 110–141.

65 Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the projected obesity trends in the USA and the UK. *Lancet* 2011; **378**: 815–825.

66 Javed A, Jumean M, Murad MH, Okorodudu D, Kumar S, Somers VK *et al*. Diagnostic performance of body mass index to identify obesity as defined by body adiposity in children and adolescents: a systematic review and meta-analysis. *Pediatr Obesity* 2015; **10**: 234–244.

Supplementary Information accompanies this paper on International Journal of Obesity website (http://www.nature.com/ijo)