Submitted to *Pediatrics* 26 Jan 2006 – Under review and Decision pending

Preventing obesity in children through enhancing physical activity: the APPLE project

Rachael W. Taylor[1], Kirsten A. McAuley[2], Sheila M. Williams[3], Wyn Barbezat[1], Glen Nielsen[1], Jim I. Mann[1,2]

Department of Human Nutrition, University of Otago, Dunedin, New Zealand[1]
Edgar National Centre for Diabetes Research, University of Otago, Dunedin, New Zealand[2]
Department of Preventive and Social Medicine, University of Otago, Dunedin, New Zealand[3]

Address for correspondence:
Professor Jim Mann
Department of Human Nutrition
University of Otago
PO Box 56
Dunedin
NEW ZEALAND
Phone: + 64 3 479 7719
Fax: + 64 3 479 7958
Email: jim.mann@stonebow.otago.ac.nz

Running title: Preventing obesity through enhancing physical activity
Total word count: 2,900

ABSTRACT

OBJECTIVE: Community based lifestyle intervention offers the only means of reducing the global epidemic of childhood obesity and its consequences, yet few successful interventions have been reported. The objective was to determine whether a simple approach to increasing extra-curricular levels of activity could reduce excessive weight gain in children.

METHODS: A one-year controlled intervention study was conducted using standardised methods to assess outcomes. Two comparable relatively rural communities in Otago, New Zealand formed intervention and control settings. Height, weight, waist circumference and participation in physical activity (by accelerometry) were measured at baseline and 1 year in 384 children aged 5 to 12 years representing the majority of children in this age group in intervention and control communities. Community Activity Co-ordinators were employed at each school in the intervention area. Their brief was to widen exposure to activity and engage children not interested in traditional sporting activities by encouraging lifestyle-based activities and non-traditional sports during extra-curricular time at school, after school and during vacations. Simple dietary advice was offered. The entire community was encouraged to participate.

RESULTS: Average accelerometry counts at 1 year were 28% (95% CI: 11 to 47%) higher in intervention compared with control children after adjusting for age, sex, baseline values and school. Intervention children spent less time in sedentary activity (ratio 0.91, $P = 0.007$) and more time in moderate (1.07, $P = 0.001$) and moderate/vigorous (1.10, $P = 0.01$) activity. Adjusted mean BMI Z-score was lower in intervention relative to control children by -0.12 (95% CI: -0.22 to -0.02) units.

CONCLUSIONS: A simple intervention designed to maximise opportunities for physical activity during extra-curricular time at school and during leisure time through the provision of community based Activity Co-ordinators significantly increased participation in physical activity and slowed excessive weight gain in primary school aged children.

INTRODUCTION

Reducing the risk of obesity in childhood and adolescence offers the best chance of stemming the tide of the epidemic of type 2 diabetes and the comorbidities associated with overweight and obesity.[1] The increasing global prevalence of excess adiposity, especially amongst the young[2] confirms the failure, thus far, of public health measures aimed at preventing obesity. It is clear that educational approaches alone are insufficient to produce the behavioural change required to increase energy expenditure or reduce energy intake, the only possible means of reducing the prevalence of obesity.[3] Thus it has been suggested that the focus of attempts to reverse the global epidemic should move towards altering the obesity prone environment.[4-6] However, there is limited evidence that such an approach is effective.[7] Despite the urgency of the problem, it is inappropriate to invest in unproven preventive measures. There is an urgent need for controlled trials which attempt to modify behaviours which have been causally linked with obesity. Only television watching, consumption of sugary beverages, infant formula feeding[8] and more recently physical inactivity[9] probably meet the criteria required for a convincing association with the development of obesity.[3] Increasing demands on curriculum time in schools make the evaluation of the effectiveness of an extra-curricular approach to increasing physical activity in children opportune.[10] We report here the outcome following one year of a controlled community intervention designed to prevent obesity in children by enhancing extra-curricular opportunities for physical activity. To our knowledge this is the first of this type of community intervention to be undertaken in young children.

METHODS

Subjects

The APPLE (A Pilot Programme for Lifestyle and Exercise) Project is a community-based demonstration project based in Otago, New Zealand which commenced in August 2003. The nature of the community-based project precluded randomisation, but control and intervention areas were selected on the basis of comparability with regard to socio-demographic variables (2001 New Zealand census, Department of Statistics) and were separated geographically. It was also not possible to blind participants or researchers. Five hundred and seventy-two children aged 5 to 12 years attend the seven primary schools in our intervention and control areas. They were predominantly Caucasian (81.8%, 17.3% Maori and 0.9% Pacific Island) from middle-class backgrounds (Ministry of Education 2003 School Decile ratings of 3-7). Ethical approval for the study was obtained from the University of Otago Ethics Committee.

Intervention components

Barriers to healthy eating and physical activity were explored prior to the development of the intervention.[11] These community consultations led to the development of several intervention initiatives which were introduced at various stages of the two-year project. At all times, the focus of the intervention was on encouraging healthy eating and activity in all children, rather than highlighting weight or obesity as issues. The main initiative in the first year was the provision of Community Activity Co-ordinators (ACs) attached to each intervention school (n = 4), who developed a community-based activity programme. Their main role was to encourage all children to be a little more physically active every day by increasing the variety and opportunities for physical activity, beyond that which was currently provided in each school. Wherever possible, the focus was on encouraging lifestyle-based activity rather than structured sports only, both to widen exposure to a variety of activities and to engage those children not interested in traditional sporting activities. Such activities included golf, taekwondo, community walks, beach hikes, school triathlons, line dancing, children's games from other countries, parent and child team sports. As members of their local community, ACs encouraged increased involvement of parents and others in the community. They were employed for 20 hours per week, providing activity programmes for 8 hours and promoting activity in the community or undertaking administrative duties in the remainder of their time.

Additional initiatives introduced in the second year include activities promoting reduction of intake of sugary drinks, increase in fruit and vegetable consumption, reduction of television time and short activity breaks in class. In addition, physical activity was enhanced by providing sport and play equipment during lunchtime.

Physical measurements

All measurements were made in duplicate during school hours at baseline and one year. Height was measured using a portable stadiometer (Wedderburn, Dunedin) to the nearest 0.1cm and weight by electronic scales (Tanita TI1618) to the nearest 0.1kg. Waist circumference was measured using a Rabone Metal Diameter tape at the level of the right iliac crest. All measurements were completed with the children wearing light clothing and no shoes using the same equipment and procedures as used in the recent New Zealand National Children's Nutrition Survey.[12] Duplicate measures of pulse rate and blood pressure were obtained with children in a supine position after 5 minutes resting quietly using an automated sphygmomanometer (Dinamap).[13] Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared and Z-scores calculated according to 2000 Center for Disease Control reference norms.[14]

Physical activity was measured using Mini-Mitter (Bend, OR) unidirectional Actical accelerometers worn around the waist which provide an objective independent assessment of physical activity.[15] Because of funding constraints, the accelerometers were worn by each child for 1 (26%) to 2 (74%) days at baseline and 2 (68%) to 5 (32%) days at follow-up. Children were instructed to put the accelerometer on as soon as they woke and to take it off just before bed. Several belts were provided for each child so that the accelerometers could still be worn during bathing and swimming. Due to variation in sleeping patterns in children, accelerometry data were analysed for each child from 8am to 8pm. We further analysed these data according to two time periods, school (9am-3pm on weekdays) and home time (8am-9am and 3-8pm on weekdays and 8am-8pm on weekend days) to ascertain if the activity intervention, which occurred predominantly during school hours, had any effect on home-based activity. The amount of time spent in sedentary (minimal body movements in a sitting or reclined position e.g. computer use), light (low level of exertion in the standing position e.g. cleaning), moderate (medium exertion in the standing position e.g. walking) and vigorous (high level of exertion in the standing position e.g. running) activity was calculated according to the threshold cut-offs validated by Puyau et al.[15] A 7-day recall of physical activity and television time was completed by questionnaire.[12]

Statistical analysis

All data was analysed using STATA (StataCorp, Stata Statistical Software, Release 8.0 College Station, TX, Stata Corporation; 2003). Power calculations were based on estimates for the correlation between repeated measures of BMI and the intraclass correlation between schools from an earlier study in Dunedin.[16] These suggested that our study had the potential to detect an effect of 0.3 SD in BMI or 0.13 Z-score (the principal outcome measure) if the analysis adjusted for baseline values and clustering. This sample size is equivalent to a randomised trial with 174 people in each arm. Differences between intervention and control participants at baseline were analysed using unpaired t-tests for continuous variables and chi-squared tests for categorical variables. Variables not normally distributed were transformed before analysis and the raw data presented. Because schools not students were the sampling unit, generalised estimating equations were used to analyse the data for individual outcomes adjusting for individual covariates with school nested within experimental condition.[17] Adjustments were made for baseline measures, age and gender for both the accelerometry data and the health outcomes. Further adjustment was made for baseline television watching and participation in physical activity for the health outcomes.

RESULTS

Five hundred and thirteen children (87% control, 92% intervention) had baseline measurements. This analysis concerns the 384 children (76% control, 75% intervention) available for repeat measurements at the end of the first year of intervention. Of the remaining 129 children, 3 (one family) withdrew from the study, 17 moved away from the area and the remainder left primary school to attend high school. Average time between measurements was 380 days. Table 1 presents the baseline characteristics. No differences were observed in age, gender distribution, pulse rate, blood pressure or television exposure but intervention children were more physically active and leaner at baseline. The children spent most (61%) of their waking hours in sedentary or light activities. On average, 254 minutes per day were spent in moderate activity and 17 minutes in vigorous activity. Intervention children spent a similar proportion of time to control children in sedentary/light activities but slightly more time in moderate (18 minutes) and vigorous (6 minutes) activity (P <0.05).

Table 2 demonstrates that the intervention had a significant impact on time spent physically active. After adjusting for baseline values, age and sex, accelerometry counts per minute were 28% (95% CI: 11 to 47%) higher in intervention compared with control children. Average accelerometry counts were higher in intervention children both during school hours (38%; 95% CI: 18 to 62%) and home-time activity (20%; 95% CI: 4 to 37%). Table 2 shows the amount of time spent in different intensity categories. After adjustment for confounders, intervention children spent 9% less time (95% CI: 3 to 15%) in sedentary activity relative to control children and 7% more time in activity of moderate intensity (95% CI: 3 to 12%). These ratios translated to observed differences of 10 minutes less of sedentary activity and 20 minutes more of moderate activity over the 12-hour period measured (8am-8pm). Intervention children also tended to spend more time in activities that were light and vigorous in nature, although neither of these categories quite reached statistical significance. Overall, moderate/vigorous activity was 10% (95% CI: 2 to 18%) or 26 minutes more in intervention compared with control children.

Table 3 shows the effect of the intervention on various outcome variables. The primary outcome, change in BMI Z-score, was lower in intervention compared with control children by -0.12 units (P <0.05). Although the risk of being overweight or obese[18] at year end in intervention compared with control children (odds ratio 0.55; 95% CI: 0.19 to1.48) did not achieve statistical significance, more intervention children who were overweight at baseline tended to be classified as normal weight at year-end (12 of 49, 24%) than control children (10 of 65, 15%). Furthermore, 10 of 158 (6%) intervention children became overweight during the year compared with 13 of 112 (12%) control children. No intervention effect was observed on waist circumference, blood pressure or pulse rate (Table 3). However, commensurate with the increase in activity recorded by the accelerometers, intervention children spent 6% (1-9%) less time watching television, despite no formal promotion to do so.

DISCUSSION

Our study has shown that a simple approach to enhancing opportunities for children to be physically active during extra-curricular time at school and after-school can slow the rate of excessive weight gain in primary school aged children. As a result of employing part-time Activity Co-ordinators in schools, intervention children were spending on average 26 more minutes per day in activities of a moderate or vigorous nature than control children. Moreover, change in mean BMI Z-score was significantly lower in intervention children by -0.12 units. A small shift in the mean BMI Z-score has the ability to translate to large differences in terms of population health.[19]

Despite interest in physical activity as a means of preventing obesity,[3] few comparable controlled trials have investigated the effectiveness of enhancing activity in children. A recent review concluded that the evidence base for interventions targeting physical activity for obesity prevention is insufficient to make recommendations[20] and few studies have been published subsequently. Fitzgibbon et al[21] reported that mean BMI Z-score was significantly reduced at 1 year (-0.23, P = 0.006) in preschool children following a brief (14-week) intervention. While a promising finding in terms of long-term effectiveness, such an approach may not be feasible in older children given that it appears the activity sessions were compulsory. By contrast, we found a significant benefit on weight in a population of school-aged children in optional extra-curricular and community-based activities. Coleman et al[22] reported a reduced prevalence of overweight but no change in mean BMI in low income Mexican schools following an intervention designed to increase the proportion of physical education time in moderate/vigorous activity and reduce the fat content of school cafeteria meals. Other recent activity-based interventions have either not evaluated weight outcomes[23,24] or data are unavailable at present.[25]

The relative contributions of physical inactivity and inappropriate dietary intake to the high rates of childhood obesity have not been established. While our data do not provide an answer, they suggest the possibility of a relatively simple measure to stem the tide of the epidemic. High demands on curriculum content and variation in perceived importance of physical activity in schools have undoubtedly led to reduced activity during the school day. Increased availability of sedentary activities also contributes to the decline in energy output, hence the need to explore alternative options for increasing physical activity.[10] Part-time physical activity co-ordinators were employed to develop lunchtime and after-school programmes as well as stimulating community endeavours to increase physical activity. They were not intended to replace any involvement by teachers in children's physical activity. Lunch-time activities including games from other countries, aerobics, line-dancing and "wheels" days (children were allowed to ride their bicycles, scooters and skateboards around school grounds) were particularly successful. Community activities introduced as part of the APPLE programme such as parent and child taekwondo, children's club golf, and community walks as fundraisers have already been institutionalised into the community. Total numbers of children attending each session were recorded and reports from the activity co-ordinators indicates that most children were involved in the additional activities. Thus it is unlikely that the results are due to small numbers of children participating in all activities. Although almost three-quarters of parents considered that after-school programmes would help increase their children's level of physical activity and all schools agreed in principle[11], this was the least successful aspect of the intervention. Barriers cited by the schools included commitment to other school run activities, keeping children to bus transport timetables and additional safety concerns. Given the findings that children are less active after school than at lunchtime[12], it is conceivable that such an intervention could have a more marked impact than what was achieved if the barriers could be lessened or removed. Moreover, the potential for additional impact should be apparent by the end of the second follow-up when interventions aimed at reducing sugary drink intake, reducing television viewing and increasing fruit and vegetable consumption have been implemented for a year.

There are no universally agreed cut-offs for defining physical activity levels in children[26] and data in adults demonstrate how different cut-offs can result in substantially different estimates of time at different intensities of activity.[27] Thus the estimates of time spent in the various intensity groupings are somewhat arbitrary. However, the relatively small amount of time spent by our subjects in vigorous activity is consistent with that reported in other studies. Reported time spent in moderate activity is more variable with our children appearing to have rather higher levels of activity reported from some studies[26,28] though consistent with data from another.[29] A likely explanation is that accelerometry data collected for 2-3 days may be insufficient to represent habitual activity in children.[30] It is also conceivable that we may have captured more moderate activity due to collecting data in 15-second epochs rather than the 1-minute epochs typically used, when considering the intermittent nature of activity in young children. Despite this limitation this relatively simple and inexpensive approach significantly increased participation in physical activity and slowed excessive weight gain in primary school aged children. This is the first of this type of study to be undertaken in young children and offers some hope in reducing obesity in the population.

References

1. Lobstein T, Baur L, Uauy R, for the IASO International Obesity TaskForce. Obesity in children and young people: a crisis in public health. *Obes Rev* 2004;5 Suppl 1:4-85.
2. Speiser PW, Rudolf MC, Anhalt H, Camacho-Hubner C, Chiarelli F, Eliakim A, et al. Consensus statement: Childhood obesity. *J Clin Endocrinol Metab* 2005;90:1871-1887.
3. Reilly JJ. Physical activity and obesity in childhood and adolescence. *Lancet* 2005;366:268-269.
4. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 1999;29:563-570.
5. Swinburn B, Egger G. Preventive strategies against weight gain and obesity. *Obes Rev* 2002;3:289-301.
6. Jain A. Treating obesity in individuals and populations. *BMJ* 2005;331:1387-1390.
7. French SA, Story M, Jeffery RW. Environmental influences on eating and physical activity. *Annu Rev Public Health* 2001;22:309-335.
8. Whitaker RC. Obesity prevention in pediatric primary care: four behaviors to target. *Arch Pediatr Adolesc Med* 2003;157:725-727.
9. Kimm SY, Glynn NW, Obarzanek E, Kriska AM, Daniels SR, Barton BA, et al. Relation between the changes in physical activity and body-mass index during adolescence: a multicentre longitudinal study. *Lancet* 2005;366:301-307.
10. Jago R, Baranowski T. Non-curricular approaches for increasing physical activity in youth: a review. *Prev Med* 2004;39:157-163.
11. Williden M, Taylor RW, McAuley KA, Simpson JC, Oakley M, Mann JI. The APPLE project: an investigation of the barriers and promoters of healthy eacting and physical activity in children aged 5-12 years. *Health Educ J* 2005 (In press).
12. Parnell W, Scragg R, Wilson N, Schaaf D, Fitzgerald E. NZ Food NZ Children: Key results of the 2002 National Children's Nutrition Survey. Wellington, New Zealand: Ministry of Health, 2003:1-267.
13. Wattigney WA, Webber LS, Lawrence MD, Berenson GS. Utility of an automatic instrument for blood pressure measurement in children. The Bogalusa Heart Study. *Am J Hypertens* 1996;9:256-262.

14. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC Growth Charts for the United States: methods and development. Data from the National Health Survey. *Vital Health Stat 11* 2002:1-190.
15. Puyau MR, Adolph AL, Vohra FA, Zakeri I, Butte NF. Prediction of activity energy expenditure using accelerometers in children. *Med Sci Sports Exerc* 2004;36:1625-1631.
16. Williams SM. Body mass index growth curves for use in New Zealand. *N Z Med J* 2000;113:308-311.
17. Gortmaker SL, Peterson K, Wiecha J, Sobol AM, Dixit S, Fox MK, et al. Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. *Arch Pediatr Adolesc Med* 1999;153:409-418.
18. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international study. *BMJ* 2000;320:1240-1243.
19. Lazarus R, Wake M, Hesketh K, Waters E. Change in body mass index in Australian primary school children, 1985-1997. *Int J Obes Metab Dis* 2000;24:679-684.
20. Reilly JJ, McDowell ZC. Physical activity interventions in the prevention and treatment of paediatric obesity: systematic review and critical appraisal. *Proc Nutr Soc* 2003;62:611-619.
21. Fitzgibbon ML, Stolley MR, Schiffer L, Van Horn L, KauferChristoffel K, Dyer A. Two-year follow-up results for Hip-Hop to Health Jr.: a randomized controlled trial for overweight prevention in preschool minority children. *J Pediatr* 2005;146:618-625.
22. Coleman KJ, Tiller CL, Sanchez J, Heath EM, Sy O, Milliken G, et al. Prevention of the epidemic increase in child risk of overweight in low-income schools: the El Paso coordinated approach to child health. *Arch Pediatr Adolesc Med* 2005;159:217-224.
23. Simon C, Wagner A, DiVita C, Rauscher E, Klein-Platat C, Arveiler D, et al. Intervention centred on adolescents' physical activity and sedentary behaviour (ICAPS): concept and 6-month results. *Int J Obes Relat Metab Disord* 2004;28 Suppl 3:S96-S103.
24. Salmon J, Ball K, Crawford D, Booth M, Telford A, Hume C, et al. Reducing sedentary behaviour and increasing physical activity among 10-year-old children: overview and process evaluation of the 'Switch-Play' intervention. *Health Promot Int* 2005;20:7-17.

25. Yin Z, Hanes J, Jr., Moore JB, Humbles P, Barbeau P, Gutin B. An after-school physical activity program for obesity prevention in children: the Medical College of Georgia FitKid Project. *Eval Health Prof* 2005;28:67-89.
26. Ekelund U, Sardinha LB, Anderssen SA, Harro M, Franks PW, Brage S, et al. Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *Am J Clin Nutr* 2004;80:584-590.
27. Strath SJ, Bassett DR Jr., Swartz AM. Comparison of MTI accelerometer cut-points for predicting time spent in physical activity. *Int J Sports Med* 2003;24:298-303.
28. Reilly JJ, Coyle J, Kelly L, Burke G, Grant S, Paton JY. An objective method for measurement of sedentary behavior in 3- to 4-year olds. *Obes Res* 2003;11:1155-1158.
29. Pate RR, Freedson PS, Sallis JF, Taylor WC, Sirard J, Trost SG, et al. Compliance with physical activity guidelines: prevalence in a population of children and youth. *Ann Epidemiol* 2002;12:303-308.
30. Vincent S, Pangrazi R. Does reactivity exist in children when measuring activity levels with pedometers? *Pediatr Exerc Sci* 2002;14:56-63.

Contributors

R.W. Taylor, K.A. McAuley and J.I. Mann (Principal Investigators) participated in the study conceptualisation and ongoing project management. S.M. Williams completed all statistical analyses, W. Barbezat was the Project Co-ordinator and G. Nielsen completed accelerometry analyses. All authors contributed to the writing of the manuscript.

Conflict of interest statement

All authors declare that they have no conflict of interest and that they have no competing interests.

Acknowledgements

This research was supported by funding from the Health Research Council, the National Heart Foundation, the Community Trust of Otago, the University of Otago, and the Otago Diabetes Research Trust.

Table 1 Baseline characteristics of participants with repeat measures (n = 384)

	Intervention		Control		
	n		*n*		*P* value
Age	207	8.0 (1.7)	177	7.9 (1.5)	0.655
Gender (% female)	207	45.9	177	50.3	0.391
BMI Z-score	207	0.58 (0.82)	177	0.83 (0.89)	0.004
Prevalence of overweight or obese[18] *n* (%)	207	49 (24%)	177	65 (37%)	0.010
Waist circumference	207	59.3 (7.6)	177	62.1 (9.7)	0.002
Pulse rate (counts/minute)	205	89 (12	177	88 (12)	0.366
Systolic blood pressure (mmHg)	205	104 (14)	177	103 (14)	0.579
Diastolic blood pressure (mmHg)	205	59 (8)	177	58 (8)	0.122
Average accelerometer counts/minute	162	1165 (505)	141	976 (467)	0.001
Television (hours/day)	163	1.5 (0.8)	153	1.6 (0.9)	0.338

n = number with each measurement   Values are mean (SD) unless otherwise stated

Table 2 The effect of the intervention on overall activity and intensity of activity presented as ratios of intervention (I) to control (C) children adjusted for age, sex, baseline differences and school

	Ratio of I:C (95% CI)
Average accelerometry counts	1.28 (1.11, 1.47)
Time in sedentary activity	0.91 (0.85, 0.97)
Time in light activity	1.14 (0.99, 1.32)
Time in moderate activity	1.07 (1.03, 1.12)
Time in vigorous activity	1.42 (0.87, 2.31)
Time in moderate/vigorous activity	1.10 (1.02, 1.18)

Table 3 Differences (95% CI) in outcome variables at one year (Intervention relative to control) adjusting for confounding variables

	Difference (95% CI) adjusted for age, sex, baseline value, school	**Difference (95% CI) adjusted for age, sex, baseline value, school, TV and exercise**
BMI Z-score	-0.10 (-0.19, 0.00)	-0.12 (-0.21, -0.02)
Waist circumference (cm)	0.2 (-0.8, 1.3)	-0.1 (-1.1, 0.9)
Pulse rate (counts)	0.9 (-2.5, 4.3)	1.9 (-1.1, 5.0)
Systolic blood pressure (mmHg)	-2.0 (-5.2, 1.1)	-2.2 (-4.4, 0.7)
Diastolic blood pressure (mmHg)	-0.6 (-2.2, 1.1)	-0.5 (-1.8, 0.8)