Preventive Medicine 81 (2015) 433–437

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Influence of school community and fitness on prevalence of overweight in Australian school children

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ARTICLE INFO

Available online 30 October 2015

Keywords:
Childhood obesity
Prevention
Physical activity
Sports participation
Multi-level analysis
Social environment

ABSTRACT

The study objectives were (1) to determine the variation in prevalence of overweight between school communities, (2) to evaluate the relationship between cardiorespiratory fitness and the probability of being overweight among different school communities, and (3) to test whether this relationship varies between school communities. Using a repeated cross-sectional design, data from 31,424 (15,298 girls, 16,126 boys) Australian school children who had objective assessments of body composition and physical performance were used. Ninety-one schools located across 5 states and territories were included. Independent samples were taken across 12 school years (2000–2011). Analysis used generalised linear mixed models in R with a two-level hierarchical structure—children, nested within school communities. Predictor variables considered were: level 1—gender, age, cardiorespiratory fitness and year of measurement; level 2—school community. A total of 24.6% of the children were overweight and 69% were of low fitness. Variation in the prevalence of overweight between school communities was significant, ranging from 19% to 34%. The probability of being overweight was negatively associated with increasing cardiorespiratory fitness. The relationship was steepest at low fitness and varied markedly between school communities. Children of low fitness had probabilities of being overweight ranging between 26% and 75% depending on school community, whereas those of high fitness had probabilities of <2%. Our findings suggest that most might be gained from a public health perspective by focusing intervention on the least fit children in the worst-performing communities.

Introduction

Childhood overweight is considered to be a primary public health issue in children and is associated with a variety of adverse health, social and psychological consequences (Dietz & Robinson, 2005; Daniels, 2009). The prevalence of childhood overweight in Australia has increased rapidly from a level of about 7.5% in the mid-1960s to the epidemic level today of around 25% (Norton et al., 2006). At the same time, children's physical activity and physical fitness levels have been seen to decline (Dollman et al., 2005; Healthy Kids Australia, 2014). Despite much attention in published research, government reports and international calls for action (Lobstein et al., 2004; Bull et al., 2004; World Health Organisation, 2004), there has been limited success only in stopping either the spread of overweight or the downward trend in fitness within the school age population.

Most research focuses on the individual and interventions seek change within the individual or their immediate family (Waters et al., 2011). Although there has been some success using such a focus, childhood overweight has been demonstrated to have multifactorial drivers, not all of which are under the control of the individual (or their family). Thus, it has been proposed that more may be gained by adopting an ecological systems perspective (Huang et al., 2009; Penhollow & Rhoads, 2013), examining the physical, social and psychological development of children through the opportunities provided within their social circumstances. This approach has been widely applied in developmental and educational psychology research but has so far not received as much attention in relation to childhood overweight and physical fitness (Bronfenbrenner, 1993).

The purpose of this study was to address this limitation of previous research by examining the prevalence of overweight and low physical fitness in a large sample of Australian school children from the perspective of children within school communities. By school communities here, we mean the settings and people who provide, or can provide, opportunities for children to be physically active and to eat a balanced healthy diet. The central focus is the children themselves, as individuals and as a population, and the key setting is the school as this environment has a defining influence on children's development and their future prospects. The key perspectives are the adequacy and balance of opportunities provided to children. Specific questions addressed were: (1) What is the variation in the prevalence of overweight or obesity between schools? (2) How does fitness relate to the probability of being

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http://dx.doi.org/10.1016/j.ypmed.2015.10.013

overweight or obese and how does this relationship vary between schools?

Methods

Data for the present analysis were entirely cross-sectional, i.e. no individual child was included more than once in the data set analysed and were from a large sample of 31,424 Australian school children who had assessments of body composition and physical performance competences carried out as part of a service offered to Australian schools (in the Australian Capital Territory (ACT), New South Wales, South Australia, Queensland and Northern Territory) in the school years between 2000 and 2011 by SmartStart for Kids, a not-for-profit organisation specialising in healthy exercise, eating and lifestyle programmes for school children.

Ethical approval for the research carried out here was granted by ACT Health Human Research Ethics Committee's Low Risk Sub-Committee on 5th November 2014 (ETHLR14.264). All work on which the study is based was carried out with the prior approval of the appropriate local authorities who commissioned the service. Schools involved in collection of the original data gave their informed consent and all parents gave written informed consent for their children to take part. Data collection was carried out during normal school hours. School administrators and class teachers assisted with the coordination of the various class groups. Overall participation rate was 82%. Measurements were carried out by SmartStart for Kids' trained assessors, usually three in number, to accommodate small groups of children moving round a set of measurement stations. All data processed by the researchers carrying out the current analysis had been de-identified so that no individual child or participating school could be identified from any of the information available. However, each record in the data file contained both a school linkage key and an individual child key so that the original commissioners of the research would be able to consider the findings in context and respond appropriately if necessary.

Body weight status was represented by the body mass index (BMI = weight (kg)/height (m); (Daniels, 2009)). Height was measured using a standard stadiometer (Surgical and Medical Products, Seven Hills, New South Wales, Australia) calibrated in 1 mm increments and weight was measured to the nearest 0.1 kg using Tanita TBF-522 electronic weight and body fat monitor scales, calibrated and spot-weight checked regularly. Cardiorespiratory fitness was measured using the 20 m multi-stage fitness test (Ramsbottom et al., 1988). Instructions were played using a calibrated CD player. Children did the test in small peer groups. One member of the SmartStart for Kids evaluation team acted as lead/runner for each group and two other members independently recorded the final stage and shuttle reached by each child. Assessments were carried out using 1220 class groups in 91 schools over 12 school years (2000–2011).

Body weight categories for each child in each gender half-year age subgroup were defined using established international thresholds (Cole et al., 2000; Cole et al., 2007). Physical fitness categories were estimated as follows. For each gender and half-year age band in the range 4.5 to 15 years, the fitness range was divided into 8 equal segments and four cut-points were set at the end of the 1st, 3rd, 5th and 7th segments, allowing us to derive a working estimate of 5 fitness categories for each child in each gender/age combination. Category labels were chosen to reflect the link between physical activity and fitness, i.e. we derive our fitness from physical activity in a combination of volume and intensity and adaptation of the muscles and organs used in that activity (specificity). Thus, the physical fitness (activity) levels are better interpreted as 'the level of fitness that might be expected in a child who is CATEGORY'.

The response variable for the multi-level analyses was the binary indicator of whether a given child was overweight or obese (1) or not (0). Analyses were carried out using SPSS21 (descriptives) and R (multi-level models) (R Core Team, 2014). The analytical approach is described in detail by Szmaragd and Leckie (ibid p. 6–8 for the null model, i.e. considering only variation by school community and p 27–33 for the two-level random slope model) (Szmaragd & Leckie, 2008), and used the lme4 package for fitting linear and generalised linear mixed models in R (Bates et al., 2014). The data were considered to have a two-level hierarchical structure with 31,434 children at level 1, nested within 91 school communities at level 2. Predictor variables considered were: level 1—gender, age, cardiorespiratory fitness (hereinafter referred to simply as fitness) and year of measurement; level 2—school community.

Results

The number of schools assessed per year ranged from 9 to 30 with a mean of 19. The number of children per school ranged from 9 to 1572 (mean 345). The number of years a given school was assessed ranged from 1 to 11 (median 2). There were 226 school assessments and the number of children per assessment ranged from 9 to 644 (mean 139).

Table 1 summarises the body weight and physical fitness categories for the children included in the sample. A total of 3.8% were classified underweight, 24.6% were overweight or obese and 71.6% were in the normal range. These figures compare favourably with those reported nationally, where the proportion of overweight children (aged 2–17) was 24.6% (Australian Bureau of Statistics (ABS), 2013). Nearly 69% of children were classified as being in the bottom two physical fitness (activity) categories for each gender/age band, whereas only 6.4% of children were in the two highest categories.

Fig. 1 summarises the null model, which is a two-level model with an intercept and school community effects only. Plotted points represent the estimated deviation of each school from the global mean (intercept) and the vertical lines represent the 95% confidence intervals of this estimate for each of the 91 schools. Schools to the left where the 95% confidence interval does not overlap the horizontal line at zero have significantly lower probabilities of children being overweight or obese whereas those on the right that do not overlap the horizontal line at zero have significantly higher probabilities of children being overweight or obese.

Adding fitness as an explanatory variable improved the model fit markedly (random intercept, random slope model). The fitted relationships between the probability, p, of being overweight or obese and fitness by school are shown in Fig. 2. To produce this plot, the linear log odds of being overweight or obese outputs from the model were converted to the probability scale using the transformation $p = 1/(1 + e^{-L})$, where L is the original log odds transformation used to perform the fit, i.e. $L = \ln(p/(1 - p))$, where ln denotes the natural logarithm.

It is clear from this figure that there was considerable variation between school communities in the relationship between being overweight or obese and fitness. Variation was greatest at low fitness levels (left of figure) but converged to a low level at the highest fitness levels, coupled with low probabilities of being overweight or obese (right of figure). Children of the lowest fitness level had probabilities of being overweight or obese ranging between about 26% (best-performing

Table 1
Body weight and physical activity (fitness) categories (Australia, 2000–2011).

Weight category[a]	Gender				Total	
	Female		Male			
	N	%	*N*	%	*N*	%
Severe thinness	11	0.1	10	0.1	21	0.1
Moderate thinness	54	0.4	46	0.3	100	0.3
Mild thinness	552	3.6	508	3.2	1060	3.4
Normal range	10,600	69.3	11,896	73.8	22,496	71.6
Overweight	3027	19.8	2637	16.4	5664	18.0
Obese	1054	6.9	1029	6.4	2083	6.6
Total	15,298	100	16,126	100	31,424	100
Physical fitness (activity) category[b]						
Sedentary	994	6.5	1816	11.3	2810	8.9
Light active	10,151	66.4	8643	53.6	18,794	59.8
Moderate active	3420	22.4	4384	27.2	7804	24.8
Heavy active	681	4.5	1214	7.5	1895	6
Vigorous active	52	0.3	69	0.4	121	0.4
Total	15,298	100	16,126	100	31,424	100

[a] Thresholds for each weight category were determined from published cutoffs for each gender half-year age group (Cole et al., 2000; Cole et al., 2007).
[b] Physical fitness (activity) levels to be interpreted as 'the level of fitness that might be expected in a child who is CATEGORY'

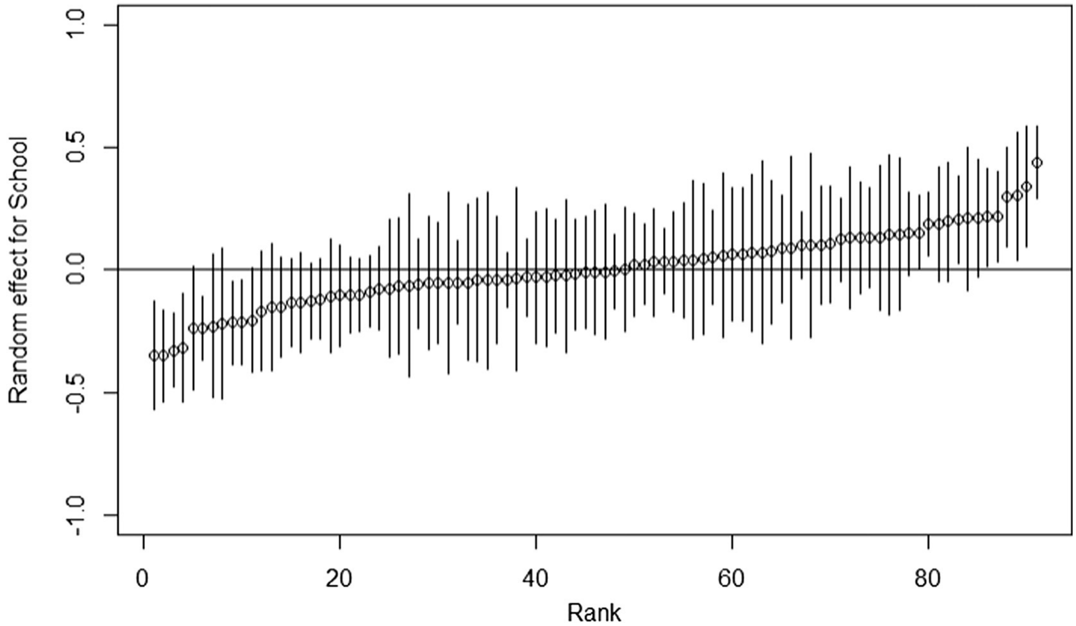

Fig. 1. School community effects (null model) on log odds of being overweight or obese ranked (by likelihood of children being overweight or obese) in order of school community (Australia, 2000–2011). Open circles represent the deviation in log odds from the population average (horizontal line at 0) for each school community. Vertical lines represent the 95% confidence limits for each estimate. Children in schools to the left are less likely to be overweight or obese while those on the right are more likely to be so.

school communities) and about 75% (worst-performing school communities), whereas children of the highest fitness had probabilities of being overweight or obese of less than 2% regardless of school community. On average, moving low fit children from a fitness score of 1 to 2 would produce a 14% (from 52% to 38%) reduction in their probability of being overweight or obese, whereas moving from a fitness score of 11 to 12 would produce only a 2% (from 3% to 1%) reduction.

Age (older children more likely to be overweight or obese), gender (girls more likely to be overweight or obese) and year of measurement (children in later years less likely to be overweight or obese) when examined individually made small but significant improvements to the model fit but were not significant when fitness was included in the model.

Discussion

The sustained and widespread high prevalence of overweight and obesity, at about 1 in every 4 children, and the low general level of fitness, with over two-thirds of children in the lowest fitness categories, confirm that modern Australian children of school age have poor levels

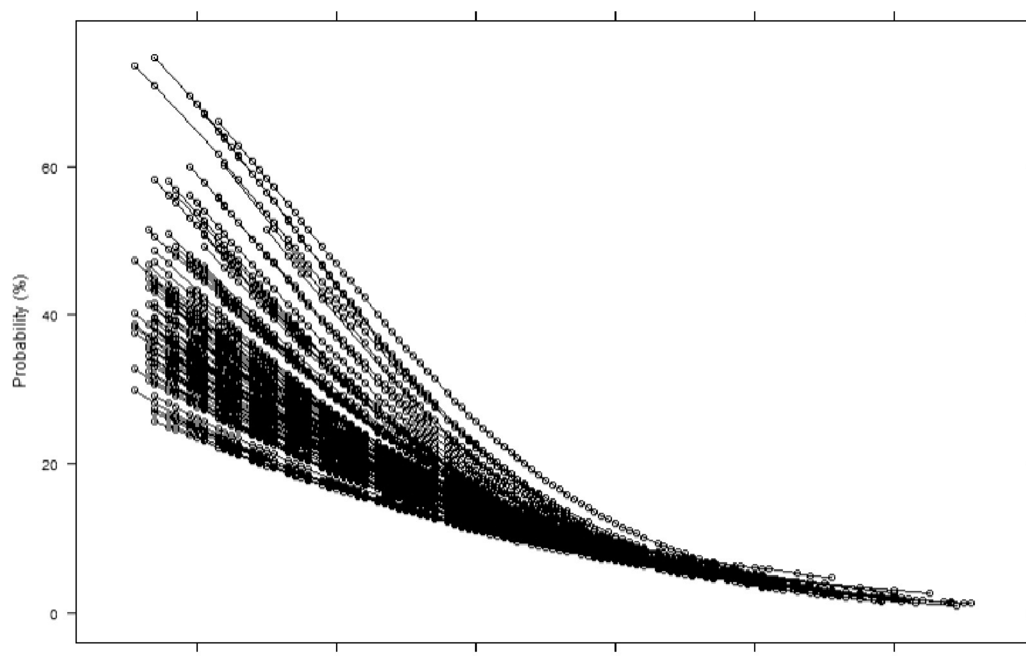

Fig. 2. Probability of being overweight or obese by school community and cardiorespiratory fitness (Australia, 2000–2011). Lines shown represent the model fits for each of the 91 school communities included in the study.

of general conditioning. This, of course, is not new. Obesity prevalence trends in Australia have been summarised recently in an evidence brief prepared by the Australian National Preventive Health Agency (2014), while Dollman et al. (2005) have reviewed the downward trends in children's physical activity opportunities and behaviours, which presumably contribute to the declines in aerobic fitness observed here and described in the latest *Report Card on Physical Activity for Children and Young People* in Australia (Healthy Kids Australia, 2014).

What our research does add, however, is a specific focus on the role that the school and its community has on children's lifestyle behaviours and physical development. The variation seen here between the school communities flags a marked inequity in lifestyle development opportunities for children across different school communities. For example, the data from Fig. 1, considering only the level 2 (school community) effects, represents a variation from 19% probability of being overweight or obese (best school community) to 34% (worst school community) with an underlying school population average of 25%. The variation becomes even more marked when fitness is taken into consideration. Children of low fitness in all school communities have a much higher likelihood of being overweight than children of high fitness. This disparity is exacerbated in the worst-performing school communities, where the likelihood of being overweight for children of low fitness could be as high as 3 out of every 4 children.

We have been careful here to refer to school communities rather than to individual schools per se. Given the retrospective nature of this analysis (and de-identification of individuals and schools), we were unable to gather specific information on home, school and community environments and opportunities for children to be sedentary or active and to eat healthily (high nutrient content, low caloric foods and drinks) or unhealthily (low nutrient content, high caloric foods and drinks). Thus, we are unable to explain the factors contributing to the variation between school communities. It is likely that some of the variation may be explained by differences in practice and policy between schools, particularly in regard to physical education provision, use of active play in recess periods and canteen and lunch box policy. But, more likely given the wide variation reported here, the bulk of the explanation will be related to factors and exposures outside the direct control of the schools. Thus, schools alone should not be charged with redressing the loss in physical activity and fitness and the gain in caloric intake faced by children in Australia today, and over recent decades. However, we propose that a focus on the school community is important because it recognises the societal drivers of collective behaviours and offers the potential to identify problems early, to target public and personal resources effectively and to monitor change in response to intervention. For example, practices and policies in the best-performing schools (in relation to body weight, physical activity and fitness) could be adopted across all schools. Similarly, safe routes within, say, a kilometre around all schools could provide the opportunity for children to walk, cycle or scoot to and from school, offering roughly half of their daily guideline amount of physical activity.

The public health implications of our findings are twofold. Firstly, the general fitness of school age children should be increased, particularly for those children in the lowest categories of fitness, i.e. the majority of children in this sample. The cardiovascular benefits of physical activity and fitness are well established and have been reviewed recently by Myers et al. (2015). The fact that so many children have low levels of fitness must be a concern for both their short-term and long-term health prospects. Pratt et al. (2015) have reviewed the global evidence on whether population levels of physical activity can be increased. Their conclusions are positive and in broad agreement with those of earlier reviews (Heath et al., 2012; Foster et al., 2005), but success will be challenging because it requires engagement and action across multiple levels of influence and by multiple sectors of the community. A guiding socio-ecological framework, strong policy, consistent investment in public health programmes, multi-sectoral support and actions, good surveillance and an evaluation framework guiding ongoing investment were identified as the features that characterized each of the success stories in this review.

The second implication is that the greatest gains in public health, through increasing fitness and potentially reducing the prevalence of overweight, would be made by focusing on the worst-performing school communities and the least fit children in these communities. This is because the non-linear slopes of the probability versus fitness relationships depicted in Fig. 2 are steepest in the top left region of the figure, i.e. greatest gain for the least expenditure of effort. This would have the added advantage of simultaneously reducing some of the current inequity of opportunity in the school community sector of society.

Much has already been achieved in this area but, clearly, on the evidence of the data gathered here and elsewhere (Kohl et al., 2012), much remains to be done. Hills et al. (2015) provide an excellent and timely overview of the key issues and challenges. This draws heavily on the work of the Centers for Disease Control and Prevention in the United States promoting the concept of Comprehensive School Physical Activity Programs (Centers for Disease Control and Prevention, 2013). A Comprehensive School Physical Activity Program (CSPAP) is 'a multi-component approach by which school districts and schools use all opportunities for students to be physically active, meet the nationally recommended 60 min of physical activity each day, and develop the knowledge, skills, and confidence to be physically active for a lifetime'. The building blocks for such programmes to be successful are: (1) staff involvement, (2) physical activity during school, (3) physical education, (4) physical activity before and after school and (5) family and community engagement. We could add the need for Comprehensive School Nutritional Education and Behaviour Programs with similar building blocks (Briggs et al., 2010). What is clear is that, as a society, Australia—along with many other societies globally—is a long way short of realising either of these objectives. Fundamentally, as a society, we need to value a lifetime commitment to regular physical activity and maintaining healthy body weight more highly and to put in place systems that enable these behaviours to become the norm. In all likelihood, this will entail top-down adequate and sustained leadership and support from government and marshalling of the resources on the ground, i.e. located in and providing support for communities to achieve the required behaviour changes. Furthermore, we would advocate a strong focus on the primary school years since these are the years when many of the lifestyle behaviours that track into later life are formed (Telama et al., 2014).

Two strengths of our study were the large sample size drawn from schools located in five of Australia's states and territories collected over a sustained period and the objective measurement of all data using a small team of independent, trained observers. Although not a stratified representative random selection from a defined population, our sample must capture many of the characteristics of children aged between 4.5 and 15 years in Australian schools. Indeed, the proportions of children in all weight categories were very similar to those reported nationally for 2- to 17-year-old children (Australian Bureau of Statistics (ABS), 2013). In addition, our use of multi-level analysis allowed us to explore the independent effects of school community on the likelihood of children being overweight or obese, to adjust for these in the models fitted to the data and to compare the variation within and between schools. Notwithstanding these strengths, there were some limitations that should also be considered in the interpretation of our findings. Firstly, as already mentioned, our sample was not a representative random sample from the population of interest. This limits the generalizability of the findings. Secondly, we did not have any data related to dietary intake of the children in our sample. This obviously has a role in the development of overweight or obesity and its absence limits the variance that could be explained by fitted models. Thirdly, it was not feasible to gather data on variables at the home, school or community level that may have allowed us to examine their separate influences on childhood overweight. A further limitation relates to the validity of the shuttle run test as a measure of cardiorespiratory fitness. We did not have any means to criterion reference the multi-stage fitness test and accept that the measurements here represent performance-based estimates of this characteristic. Criterion-related validity of this test in children has been shown to be moderate to good at around 0.78 (Mayora-Vega et al., 2015). Finally, our research design was essentially cross-sectional, albeit repeated annually over 12 years with a different sample of children. Thus, we are not able to infer direct causation in the relationship between fitness and the probability of being overweight, although this could be confirmed by intervention if change in fitness was accompanied by the expected change in likelihood of being overweight or obese.

Conclusions

The likelihood of children being overweight or obese varied markedly between school communities. Strong associations were observed between fitness and the likelihood of being overweight or obese and this relationship varied widely between school communities. Our findings suggest that most might be gained from a public health perspective by focusing intervention on the least fit children in the worst-performing school communities. Greater focus in research should be given to changing the wider environmental drivers of beneficial lifestyle behaviours such as maintaining regular physical activity and a healthy body weight.

Acknowledgments

We acknowledge the contribution of the SmartStart for Kids team in conducting the assessments and collating the data on which this research was based. We recognise, too, the valuable contribution of the 91 schools that gave us permission to involve their schools, in many cases over several years, the children who participated and their parents. Funding was provided by the ACT Government Directorate of Health for the data gathered in primary schools in the Australian Capital Territory in 2010 and 2011 as part of an evaluation of a screening service and after school programme for children with poor physical function or body composition.

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