Effect of school-based interventions on body composition of grade-4 children from lower socioeconomic communities in Gqeberha, South Africa

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Background. South African (SA) children from disadvantaged communities are plagued by a double burden of under- and over-nutrition. The resulting overweight and obesity on the one hand, and stunting on the other, are risk factors for chronic diseases in adulthood.
Objective. To determine the effect of school-based interventions on body composition of grade-4 children from lower socioeconomic communities in the Gqeberha region, SA.
Methods. A cluster-randomised controlled trial was carried out with children from 8 schools. Schools were randomly assigned, either to a 10-week school-based intervention (4 schools) or a control condition (4 schools). The intervention comprised several arms, with each intervention school receiving a different combination of the following measures: physical activity, health and hygiene education, and nutrition education with supplementation. Effects on children's body composition were evaluated using standardised, quality-controlled methods. Height and weight were assessed to calculate body mass index (BMI), and percentage body fat was measured via thickness of skinfolds (triceps and subscapular).
Results. Overall, 898 children (458 boys and 440 girls) aged 8 - 11 years participated in the trial. Children's BMI, BMI-for-age and percentage body fat increased significantly over time. Increases were similar in boys and girls. Body fat remained unchanged in underweight children, whereas increases occurred in normal weight and (particularly) overweight/obese peers. In normal-weight children, the physical activity intervention (either alone or combined with health education) mitigated increments in body fat levels. A similar pattern was observed in overweight/obese children, but only in the physical activity intervention cohort alone.
Conclusion. Our study shows that normal-weight children are at risk of becoming overweight and children who are already overweight/obese are at even greater risk of gaining weight. The physical activity intervention (alone or in combination with health education) can mitigate increases in body fat in normal-weight children as well as in overweight/obese children. Our findings reveal that school-based physical activity, nutrition and health and hygiene interventions can have beneficial effects on children's body composition. Further analyses are needed to examine how (school-based) physical activity interventions should be designed to improve children's health in lower socioeconomic areas.

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Since the start of the new millennium, the prevalence of wasting and stunting has considerably declined in nearly all low- and middle-income countries (LMICs).[1] This decrease has positive implications, as nutrition and optimal growth are important factors for children's health and ultimate stature.[2] However, over-nutrition is on the rise in LMICs that undergo rapid epidemiological transition.[1] In addition, the level of physical activity (PA) is decreasing in many countries, which favours the emergence of non-communicable diseases (NCDs). Physical inactivity is the fourth leading risk factor for mortality worldwide.[3] Owing to this epidemiological transition, LMICs have seen a reduction in PA and increased access to unhealthy fast foods, which has resulted in increased levels of overweight and obesity.[1] Childhood obesity is a risk factor for chronic diseases in adulthood, such as heart disease, diabetes and hyperlipidaemia.[4]

South Africa (SA) is undergoing a nutrition transition and is faced with a double challenge of overweight and obesity on the one hand and stunting in children and adolescents on the other hand, indicating major nutritional deficits and risks related to chronic disease in adulthood.[5] This double burden of malnutrition (under-nutrition and overweight/obesity) is related to economic inequalities.[1,5] Two decades ago, stunting was already reported as the most common nutritional disorder among young children in SA, affecting ~one in five children, while overweight was reported to affect ~one in 10 children.[6] When looking at secular trends among young South Africans, mild and moderate stunting still exists but its prevalence has decreased, while there has been a considerable increase in the prevalence of overweight and obesity.[7]

The Healthy Active Kids South Africa (HAKSA) 2018 report card emphasised that insufficient PA levels are a concerning aspect of SA youth.[8] In line with this view, studies revealed that only about half (50 - 52%) of SA children pursued the recommended 60 minutes of moderate-to-vigorous PA (MVPA) per day.[9,10] A study carried out in a rural part of SA showed that the co-occurrence of under- and over-nutrition is a particular concern regarding children and adolescents, and is most prevalent in low-socioeconomic classes of the population.[5] However, it is currently unknown whether this notion is generalisable to SA children living in urban or peri-urban settings. Overweight/obesity rates are still increasing, especially among girls, even in the presence of food insecurity.[8] As under- and over-nutrition both develop over time, the most effective means for controlling these conditions is through prevention. Regular participation in PA and nutrition-sensitive interventions have shown to be successful in reducing over- and under-nutrition, respectively, and could thus be used to improve children's health status.[11,12]

As children spend a considerable amount of time at school, the school environment has been identified as a suitable setting for the promotion of PA through physical education (PE) lessons.[13,14] However, in SA schools, the implementation of PE faces a number of challenges. For instance, PE is marginalised in the school curriculum, and therefore inadequately implemented. Indeed, there is a lack of qualified PE teachers, facilities and equipment are inadequate, and there are limited financial resources.[15] These factors are especially pronounced in poorer schools.[15]

Nutrition-specific and nutrition-sensitive interventions are needed to address the double burden of chronic under-nutrition and the increasing prevalence of overweight and obesity in SA children.[16] The aim of the present study was to investigate the effects of a 10-week school-based health intervention on the body composition of grade-4 children from lower socioeconomic communities in the Port Elizabeth region. The programme comprised four different intervention arms: (*i*) PA only; (*ii*) PA and health and hygiene education; (*iii*) health and hygiene education and nutrition education with supplementation; and (*iv*) PA, health and hygiene education and nutrition education with supplementation. As PA increases energy expenditure,[17] our expectation was that PA alone or PA combined with health/hygiene education may lead to lower body mass index (BMI) and body fat scores. By contrast, we assumed that the nutrition intervention in combination with health/hygiene education may result in increased BMI and body fat percentage. The reasoning behind this assumption is that although the nutrition intervention focused on healthy diets, it also included an energy-dense supplement, which contributed to increased energy intake. Finally, we expected that combining PA, nutrition intervention (with supplement) and health/hygiene education would not produce any clear effects, as PA increases energy expenditure, whereas the supplement contributes to increased energy intake. We are aware that the qualitative interpretation of our findings will depend on the children's initial nutritional status. Thus, while an increase of BMI and body fat might be interpreted as beneficial among underweight children, such an increment is not desired among normal-weight and overweight/obese children. Accordingly, one important goal of our study was to find out whether the intervention measures produced differential effects among underweight, normal-weight and overweight/obese children.

Methods

Study design and participants

A cluster randomised controlled trial as part of the research project entitled 'Disease, Activity and Schoolchildren's Health (DASH)' was implemented.[18,19] The study reported here employed data from the baseline (T1) and post-intervention survey (T2).

The population under investigation consisted of children aged 8 - 11 years from socioeconomically disadvantaged schools in Port Elizabeth. Eight quintile 3 schools were selected based on the following criteria: (*i*) at least 100 children attending grade 4; (*ii*) geographic location; (*iii*) representation of target communities (predominantly coloured and black African communities); and (*iv*) commitment to support the project. In the SA context, quintiles are used to classify government schools according to their socioeconomic status (SES), ranging from quintile 1 (poorest), to quintile 5 (least poor) schools.[20] Quintile 1 - 3 schools are no-fee-paying schools that also benefit from the National School Nutrition Programme (NSNP), which provides children with one meal a day at school. The schools were situated in historically neglected, apartheid-demarcated black African and coloured areas that have been adversely affected by high unemployment rates and extreme poverty.

Overall, 1 009 children (with written informed consent from parents/guardians and children's assent) participated in the baseline assessment (T1). Subsequently, 111 children were excluded for a number of reasons, including changing schools, absenteeism and incomplete data. Complete data records were available for 898 children (458 boys and 440 girls).

Procedures

Permission to conduct the DASH study was sought from and granted by the Ethics Committee of Northwest and Central Switzerland (EKNZ) in Basel, Switzerland (ref. no. EKNZ 2014-179), the Nelson Mandela University's Research Ethics Committee (ref. no. H14-HEA-HMS002), the Eastern Cape Department of Health (DoH) and the Eastern Cape Department of Education (DoE) in SA.

Testing was conducted at the respective schools and was carried out class-wise during official school hours by trained researchers. Detailed explanations and demonstrations were provided prior to commencement of testing. The T1 data assessment was carried out between mid-February and end of March 2015. The intervention commenced after the holidays in mid-July 2015 and lasted until September 2015 (10 weeks in total). The T2 data assessment took place in October 2015. Measurement procedures were identical across schools during both time points. The following anthropometric variables were assessed: weight (kg), stature (referred to as height in this study) (cm), and skinfolds (mm) at two sites (triceps and subscapular). The measurement procedures are detailed in the DASH study protocol.[18] We calculated the BMI (height (in cm) divided by weight (in kg) squared) and body fat percentage (BF%) using the Slaughter equation,[21] as key measures of body composition. Age, gender and SES were used as potential covariates.

SES was measured with a 9-item self-report questionnaire about housing characteristics, ownership of durable assets (e.g. washing machine), and household-level living standards. Scores of the SES index range from 1 to 9, with higher scores reflecting higher family SES. Evidence for the validity of similar SES scales has been reported.[22]

Intervention

The interventions comprised PA, health and hygiene education, and nutrition education and supplementation. The interventions were readily integrated into the school curriculum in the Life Skills learning area. Intervention arms and control conditions are shown in Table 1. The procedure for intervention allocation is detailed in the DASH study protocol.[18,19] Independent of study arm allocation, the children received deworming medication during the study period, if indicated according to guidelines of the World Health Organization (WHO).[23] Interventions were implemented over a 10-week period in four randomly selected schools. The control schools continued to follow the standard school curriculum. To each school receiving a different combination of the intervention measures, we assigned a control school located in the same geographic area (township v. northern area). Our preliminary analyses revealed that the children of the eight different schools did not significantly (p>0.05) differ with regard to SES.

The PA intervention consisted of two weekly 40-minute PE lessons, one weekly 40-minute moving-to-music lesson, regular in-class PA breaks, and an adaptation of the school playground to provide a PA-friendly environment (painted games and PA stations). All PE lessons were aligned with the prescribed PE curriculum. Teachers were assisted by external PE specialists in conducting the intervention. The moving-to-music lessons were conducted by trained dance students from Nelson Mandela University.

For the health and hygiene as well as the nutrition education interventions, six 45-minute lessons were developed and taught by the classroom teacher during class time. The health and hygiene education intervention consisted of lesson plans about general health and hygiene, health-promoting posters and class activities for children. This included handwashing, where we encouraged each classroom to have a water bucket and soap for children to wash their hands regularly, especially after playing and using the toilet and before eating. The rationale for the inclusion of this component is linked to the general health and hygiene education, which is important for the prevention of intestinal parasitic and other infections. Regular handwashing habits improved in schoolchildren and modest effects were reported on children's nutritional status.[24] For the nutrition intervention, children were given the United Nations Children's Fund (UNICEF)-approved nutritional supplement, known as the Ready-to-Use Supplementary Food (RUSF), once a day.[25] The RUSF is a peanut butter-based supplement in vegetable oil that includes vitamins, minerals and protein, packaged in a small sachet (530 kcal per 100 g sachet). Lessons on healthy eating were also developed and relevant posters provided. The lessons included different food groups, the importance of eating a balanced meal, and encouraging children to bring a healthy lunchbox to school. The aim was to raise awareness about healthy diets and good nutrition habits.

Statistical analysis

Mean, standard deviations (SDs) as well as mean difference scores (T2 minus T1) were calculated as descriptive statistics, separately for (*i*) girls and boys and (*ii*) underweight, normal-weight and overweight/obese children assigned to the experimental and control groups of the four match-paired schools. To examine whether BMI-for-age and BF% changed differently in girls v. boys and in underweight, normal weight v. overweight/obese children, we carried out repeated measures analyses of covariance (ANCOVAs), with the within-factor time (T1 v. T2), the between factor gender (girls v. boys) or nutritional status (underweight, normal-weight v. overweight), and treatment as a covariate (experimental v. control). Additionally, simple repeated measures ANOVAs were carried out to examine changes in each single comparison group, with the within-factor time (T1 v. T2). All statistical analyses were carried out with SPSS 26 (IBM Corp., USA), and the level significance was set at p<0.05 across all analyses. As statistical significance does not always imply that the observed mean changes are of practical importance, η^2 was calculated for each comparison. To interpret effect sizes, we followed Cohen's[26] recommendations: η^2 ≥0.01 (small effect), η^2 ≥0.059 (moderate effect), and η^2 ≥0.138 (large effect). Finally, to take into account the nested and multivariate nature of the data (learners assessed in classes; interrelatedness between assessed predictors), we performed mixed linear regression analyses with random intercepts for school classes, separately for normal weight and overweight/obese children (owing to the low number, no separate analyses were possible for underweight children). More specifically, we used age, gender, SES, baseline scores and treatment to determine the multivariate association with BMI-for-age and BF% at T2. Separate analyses were performed for each of the four match-paired schools (receiving a different intervention arm v. control condition).

Results

Descriptive statistics for the total sample

In the total sample, a significant increase was observed for the following: BMI (T1: M=17.0, SD=3.0; T2: *M*=17.7, *SD*=3.3, F(1 897)=536.1, p<0.001, η^2=0.374); BMI-for-age (T1: M=-0.0, SD=1.2; T2: M=0.1, SD=1.2, F(1 897)=148.8, p<0.001, η^2=0.143); and BF% (T1: M=15.9, SD=7.0; T2: M=17.2, SD=8.9, F(1 897)=70.5, p<0.001, η^2=0.073).

Descriptive statistics for boys and girls

Table 2 shows the means and SDs of the measured BMI and estimated BMI-for-age scores separately for boys and girls at T1 and T2 for

Table 1. Grouping of schools from socioeconomically disadvantaged areas in Gqeberha, South Africa, with the relevant interventions allocated in February and March 2015

Experimental group	Control group	School area
School E1 (*n*=90)	School C1 (*n*=113)	Township area
Physical activity intervention	Deworming medication	
Deworming medication		
School E2 (*n*=99)	School C2 (*n*=97)	Northern area
Physical activity intervention	Deworming medication	
Health and hygiene education intervention		
Deworming medication		
School E3 (*n*=92)	School C3 (*n*=151)	Township area
Health and hygiene education intervention	Deworming medication	
Nutrition intervention (with supplement*)		
Deworming medication		
School E4 (*n*=170)	School C4 (*n*=86)	Northern area
Physical activity intervention	Deworming medication	
Health and hygiene education intervention		
Nutrition intervention (with supplement*)		
Deworming medication		

n = number of children.
*Ready-to-use supplementary food.

each of the treatment and match-paired control groups, as well as the mean difference in BMI-for-age scores. Significant (and meaningful) changes were observed in 10 of 16 subgroups. In the total sample, BMI-for-age did not change differently from T1 to T2 in boys (T1: M=-0.1, SD=1.2; T2: M=0.1, SD=1.2) compared with girls (T1: M=0.0, SD=1.2; T2: M=0.2, SD=1.2), $F(1\ 886)=3.4$, $p=0.066$, $\eta^2=0.004$. In line with these data, a statistically significant increase in BMI-for-age was found both for boys, ($F(1\ 456)=9.1$, $p=0.003$, $\eta^2=0.020$) and girls ($F(1\ 438)=23.8$, $p<0.001$, $\eta^2=0.051$).

The descriptive statistics for BF% are summarised in Table 3.

While we observed increasing body fat levels in 7 of 16 subgroups, changes were not significantly different in boys (T1: M=13.3, SD=6.0; T2: M=14.4, SD=8.3) compared with girls (T1: M=18.6, SD=6.9; T2: M=20.1, SD=8.6), ($F(1\ 886)=1.6$, $p=0.211$, $\eta^2=0.002$). Overall, a significant increase in BF% was observed both for boys ($F(1\ 456)=18.0$, $p<0.001$, $\eta^2=0.038$) and girls, ($F(1\ 438)=82.8$, $p<82.8$, $\eta^2=0.159$).

Descriptive statistics for underweight, normal-weight and overweight/obese children

Table 4 shows the means and SDs of the measured BMI and the estimated BMI-for-age scores separately for underweight, normal-weight and overweight/obese children at T1 and T2 for each of the treatment and the match-paired control groups. Table 4 also displays the mean difference in the BMI-for-age scores. Significant (and meaningful) changes were observed in the majority of subgroups. In the total sample, BMI-for-age scores changed differently from T1 to T2 in underweight (T1: M=-2.5, SD=0.5; T2: M=-2.1, SD=0.8), normal weight (T1: M=-0.3, SD=0.7; T2: M=-0.1, SD=0.7) and overweight/obese children (T1: M=1.8, SD=0.7; T2: M=1.9, SD=0.8) ($F(2\ 885)=12.7$, $p<0.001$, $\eta^2=0.028$). Separate repeated measures ANOVAs showed that the increase was statistically significant only for normal-weight children ($F(1\ 689)=33.7$, $p<0.001$, $\eta^2=0.047$), whereas no significant changes were observed in underweight ($F(1.37)=1.03$, $p=0.316$, $\eta^2=0.027$) and overweight peers ($F(1\ 164)=0.5$, $p<0.475$, $\eta^2=0.003$).

The descriptive statistics for BF% are summarised in Table 5. Significant changes were found in about half of the subgroups. All significant changes pointed towards increasing body fat levels. Changes were significantly different in underweight (T1: M=9.8, SD=2.7; T2: M=10.1, SD=3.5), normal weight (T1: M=13.9, SD=4.3; T2: M=14.6, SD=4.9) and overweight/obese children (T1: M=25.8, SD=7.8; T2: M=29.6, SD=11.4) ($F(2\ 885)=35.1$, $p<0.001$, $\eta^2=0.073$). While no significant change was observed in underweight children ($F(1.37)=0.0$, $p=0.853$, $\eta^2=0.001$), significant increases occurred in normal-weight ($F(1\ 689)=63.0$, $p<0.001$, $\eta^2=0.084$) and overweight peers ($F(1\ 164)=42.2$, $p<0.001$, $\eta^2=0.205$).

Effects of intervention among normal-weight children

The effects of the mixed linear regression analyses for normal-weight children are summarised in Table 6. Across both outcomes (BMI-for-age and BF%), baseline scores were the strongest predictor of T2 scores. Moreover, in the treatment arm where PA, health/hygiene and nutrition (including the supplement) were combined, children of the control group had lower BMI-for-age scores at follow-up compared with peers assigned to the experimental group. Regarding BF%, in the PA alone and PA combined with health/hygiene education treatment arms, the control groups had significantly higher BF% at T2 if compared with the respective experimental groups.

Effects of intervention in overweight/obese children

The effects of the mixed linear regression analyses for overweight/

Table 2. Observed BMI (kg/m²) of each experimental group and corresponding paired control group in schoolchildren from Gqeberha, South Africa, in 2015

		BMI		BMI-for-age (zBMI)				
		T1	T2	T1	T2			
Group	Treatment, *n*	M (SD)	M (SD)	M (SD)	M (SD)	Mean difference in zBMI	*p*-value	η^2
E1 - C1								
Boys	Control, *n*=57	16.9 (1.6)	17.3 (1.7)	0.2 (0.8)	0.3 (0.8)	+0.1	0.169	0.034
	Experimental, *n*=42	17.3 (2.1)	17.7 (2.4)	0.2 (1.0)	0.2 (1.1)	0.0	0.841	0.001
Girls	Control, *n*=56	17.7 (3.6)	18.5 (4.0)	0.4 (1.3)	0.5 (1.3)	+0.1*	0.014*	0.105*
	Experimental, *n*=42	18.4 (4.8)	18.8 (4.8)	0.4 (1.2)	0.5 (1.1)	+0.1	0.379	0.017
E2 - C2								
Boys	Control, *n*=45	17.1 (2.9)	17.5 (3.2)	0.2 (1.3)	0.2 (1.3)	0.0	0.367	0.019
	Experimental, *n*=50	17.4 (3.2)	17.9 (3.7)	0.3 (1.3)	0.3 (1.4)	0.0	0.769	0.002
Girls	Control, *n*=52	16.9 (2.7)	17.5 (2.7)	0.0 (1.2)	0.1 (1.2)	+0.1*	0.037*	0.083*
	Experimental, *n*=49	16.7 (2.1)	17.6 (2.3)	0.0 (1.0)	0.3 (0.9)	+0.3*	0.002*	0.181*
E3 - C3								
Boys	Control, *n*=80	16.9 (3.3)	17.5 (3.8)	−0.2 (1.1)	0.0 (1.2)	+0.2*	<0.001*	0.182*
	Experimental, *n*=49	17.8 (4.0)	18.6 (4.2)	0.1 (1.2)	0.4 (1.1)	+0.3*	<0.001*	0.361*
Girls	Control, *n*=71	17.9 (3.1)	18.5 (3.2)	0.3 (1.1)	0.4 (1.0)	+0.1*	0.022*	0.072*
	Experimental, *n*=43	18.1 (3.5)	19.4 (4.1)	0.4 (1.3)	0.7 (1.2)	+0.3*	<0.001*	0.501*
E4 - C4								
Boys	Control, *n*=46	15.6 (1.5)	15.8 (1.9)	−0.8 (1.0)	−0.8 (1.1)	+0.0	0.488	0.011
	Experimental, *n*=89	16.4 (1.9)	17.4 (2.3)	−0.4 (1.1)	0.0 (1.1)	+0.4*	<0.001*	0.572*
Girls	Control, *n*=40	15.7 (2.6)	16.5 (2.7)	−0.7 (1.2)	−0.5 (1.2)	+0.2*	<0.001*	0.274*
	Experimental, *n*=81	16.2 (2.6)	17.2 (2.8)	−0.5 (1.2)	−0.2 (1.2)	+0.3*	<0.001*	0.622*

n = number of children; M = mean; SD = standard deviation; BMI = body mass index; zBMI = standardised body mass index.
*Statistically significant differences (*p*<0.05).

obese children are summarised in Table 7. Baseline scores were the strongest predictor of the T2 scores for both outcomes (BMI-for-age and BF%). Moreover, in the PA-alone treatment arm, the control group had significantly higher BF% at T2 compared with peers assigned to the experimental group. No further treatment effects were observed.

Discussion

The present study examined the effect of various school-based interventions on the body composition of grade-4 children from lower socioeconomic communities in the Gqeberha region, SA. The key findings are that in the total sample, BMI, BMI-for-age and BF% increased significantly during the study period. Our findings correlate with previous observations made elsewhere in SA.[27] This increase is expected in children during the period of development as they reach puberty.[28] However, other factors could have also played a role. A study by Kruger *et al*.[29] found that children living in urban areas or informal settlements close to a town/city are exposed to a western and urbanised lifestyle with increased prevalence of overweight/obesity. These increases were similar in boys and girls and similar results were reported in other studies in North-West Province[27] and Johannesburg and Gqeberha, in SA,[30] among primary schoolchildren. Another study conducted on rural SA children found girls to have a larger BMI increase than boys and attributed these differences to energy needs, growth rate and behavioural differences such as higher PA levels in boys, especially during adolescence.[28]

BMI-for-age scores increased more strongly in normal-weight children compared with underweight and overweight/obese children. This means that many normal-weight children are at risk of becoming overweight or obese, which raises concerns as evidence from a longitudinal cohort reported that obesity in childhood may continue into adulthood[31] and higher BMI in childhood, even in the absence of apparent overweight, is associated with coronary heart disease in adulthood.[32] However, whereas body fat remained relatively unchanged in underweight children, statistically significant increases occurred in normal-weight and overweight/obese peers. The increase was particularly large in the latter group. This means overweight/obese children may be at greater risk. A study reported that the odds of being overweight in adulthood were 6.2 times greater in overweight than in normal-weight children.[31] Intervention measures to counteract the increase in overweight/obesity are important, and strategies for the inclusion of PA programmes in schools and after-school community PA programmes are recommended.[33]

With regard to the effects of the different intervention arms, only partial support was found for our assumptions. Nevertheless, our findings suggest that in normal-weight children, a 10-week PA intervention (either alone or in combination with health education) has the potential to mitigate increases in body fat levels that are typically observed during this period of life. Similar results were reported in a 10-month intervention study conducted in Gauteng Province, SA[33] and in other countries.[34] Results were similar in overweight/obese children. However, in this group, the pattern was less consistent as the treatment effect was only observed in the PA alone condition (but not if PA was combined with health and hygiene education). Other factors might explain the partial PA effects found among overweight/obese children. Truter *et al*.[35] reported that aerobic capacity decreased progressively in overweight and obese compared with normal-weight participants in their study. In the other intervention arms, with one exception, treatment was not associated with BMI-for-age or body fat. In the intervention arm where all measures (PA, health and hygiene, nutrition intervention with supplement) were combined, BMI-for-

Table 3. BF% of each experimental group and corresponding paired control group in schoolchildren from Gqeberha, SA, in 2015

		BF%				
		T1	T2			
Gender	Treatment, *n*	M (SD)	M (SD)	Mean difference in BF%	*p*-value	η^2
E1 - C1						
Boys	Control, *n*=57	12.7 (4.1)	15.5 (5.3)	+2.8*	<0.001*	0.447*
	Experimental, *n*=42	15.3 (7.2)	16.0 (7.4)	+0.7	0.237	0.034
Girls	Control, *n*=56	19.3 (7.1)	24.3 (11.5)	+5.0*	<0.001*	0.407*
	Experimental, *n*=42	21.9 (9.8)	20.6 (7.5)	−1.3	0.064	0.071
E2 - C2						
Boys	Control, *n*=45	14.7 (7.3)	14.6 (8.7)	−0.1	0.807	0.001
	Experimental, *n*=50	14.2 (7.5)	14.7 (9.0)	+0.5	0.191	0.035
Girls	Control, *n*=52	18.9 (5.8)	21.2 (7.9)	+2.3*	<0.001*	0.286*
	Experimental, *n*=49	17.1 (4.9)	17.2 (5.8)	+0.1	0.763	0.002
E3 - C3						
Boys	Control, *n*=80	13.4 (6.4)	14.6 (10.2)	+1.2*	0.032*	0.057*
	Experimental, *n*=49	14.5 (6.4)	17.9 (12.0)	+3.4*	0.003*	0.169*
Girls	Control, *n*=71	19.7 (6.1)	22.6 (9.0)	+2.9*	<0.001*	0.254*
	Experimental, *n*=43	20.2 (7.8)	22.8 (9.3)	+2.6*	<0.001*	0.258*
E4 - C4						
Boys	Control, *n*=46	10.5 (4.1)	10.7 (4.2)	+0.2	0.490	0.011
	Experimental, *n*=89	12.2 (4.2)	12.3 (5.4)	+0.1	0.674	0.002
Girls	Control, *n*=40	15.6 (5.5)	16.3 (6.0)	+0.7	0.231	0.037
	Experimental, *n*=81	16.6 (5.7)	16.0 (5.7)	−0.6	0.266	0.015

BF% = body fat percentage; *n*=number of children; M = mean; SD = standard deviation.
*Statistically significant differences ($p<0.05$).

Table 4. Observed body mass index (kg/m²) of each experimental group and corresponding paired control group in schoolchildren from Gqeberha, South Africa, in 2015

		BMI		BM-for-age (zBMI)				
		T1	T2	T1	T2			
Group by nutritional status	Treatment, *n*	M (SD)	M (SD)	M (SD)	M (SD)	Mean difference in zBMI	*p*-value*	η²
E1-C1								
Underweight†	Control, *n*=1	13.3 (-)	13.5 (-)	−2.3 (-)	−2.1 (-)	+0.2	-	-
	Experimental, *n*=1	11.5 (-)	12.4 (-)	−3.7 (-)	−2.9 (-)	+0.8	-	-
Normal-weight†	Control, *n*=87	16.2 (1.2)	16.7 (1.4)	−0.1 (0.7)	0.0 (0.7)	+0.1*	0.013*	0.071*
	Experimental, *n*=65	16.4 (1.2)	16.9 (1.5)	−0.1 (0.7)	−0.1 (0.8)	0.0	0.558	0.005
Overweight/obese	Control, *n*=25	21.2 (3.3)	22.2 (3.5)	1.8 (0.7)	1.9 (0.7)	+0.1	0.277	0.049
	Experimental, *n*=24	22.2 (5.0)	22.4 (5.3)	1.7 (0.6)	1.6 (0.7)	−0.1	0.108	0.113
E2-C2								
Underweight†	Control, *n*=4	13.0 (0.7)	13.5 (0.5)	−2.5 (0.4)	−2.3 (0.3)	+0.2	-	-
	Experimental, *n*=2	13.7 (0.2)	17.6 (3.9)	−2.2 (0.1)	−0.3 (1.9)	+1.9	-	-
Normal-weight†	Control, *n*=69	16.0 (1.3)	16.4 (1.5)	−0.3 (0.7)	−0.2 (0.7)	+0.1	0.068	0.048
	Experimental, *n*=78	16.1 (1.3)	16.6 (1.4)	−0.2 (0.7)	−0.1 (0.8)	+0.1	0.027*	0.062*
Overweight/obese	Control, *n*=24	20.7 (2.5)	21.3 (2.8)	1.7 (0.7)	1.7 (0.7)	0.0	0.632	0.010
	Experimental, *n*=18	21.6 (2.9)	22.8 (3.3)	2.0 (0.8)	2.1 (0.8)	+0.1	0.151	0.117
E3-C3								
Underweight†	Control, *n*=2	13.7 (0.4)	14.2 (0.3)	−2.3 (0.2)	−2.0 (0.3)	+0.3	-	-
	Experimental, *n*=4	13.8 (0.5)	15.0 (0.4)	−2.1 (0.2)	−1.5 (0.1)	+0.6	-	-
Normal-weight†	Control, *n*=120	16.1(1.3)	16.8 (1.5)	−0.3 (0.7)	−0.2 (0.7)	+0.1*	<0.001*	0.213*
	Experimental, *n*=66	16.6 (1.3)	17.4 (1.6)	−0.1 (0.7)	0.1 (0.7)	+0.2*	<0.001*	0.400*
Overweight/obese	Control, *n*=30	22.3 (4.0)	23.1 (4.6)	1.9 (0.8)	1.9 (1.0)	0.0	0.991	0.000
	Experimental, *n*=21	23.2 (4.5)	24.8 (4.7)	2.0 (0.6)	2.2 (0.5)	+0.2*	0.002*	0.415*
E4-C4								
Underweight	Control, *n*=12	13.4 (0.6)	13.7 (0.8)	−2.4 (0.4)	−2.4 (0.5)	0.0	0.659	0.018
	Experimental, *n*=13	13.4 (0.8)	14.2 (1.0)	−2.6 (0.5)	−2.1 (0.6)	+0.5*	<0.001*	0.671*
Normal-weight	Control, *n*=68	15.6 (1.2)	16.1 (1.3)	−0.7 (0.7)	−0.5 (0.8)	+0.2*	0.001*	0.168*
	Experimental, *n*=138	15.9 (1.2)	16.9 (1.4)	−0.5 (0.7)	−0.2 (0.7)	+0.3*	<0.001*	0.595*
Overweight/obese	Control, *n*=6	20.9 (2.5)	21.5 (3.0)	1.6 (0.4)	1.6 (0.5)	0.0	0.607	0.057
	Experimental, *n*=18	21.1 (2.1)	22.9 (2.4)	1.7 (0.5)	2.0 (0.5)	+0.3*	<0.001*	0.529*

BMI = body mass index; zBMI = standardised body mass index; *n* = number of children; M = mean; SD = standard deviation.
*Statistically significant differences ($p<0.05$).
†Analyses not performed in subgroups with less than 10 cases.

age scores increased more strongly from T1 to T2 in the experimental than in the control group. In the context of the present study, however, this finding should not be negatively interpreted, as for children assigned to this intervention, the baseline BMI-for-age scores were below average, both in children in the experimental and the control group.

Our investigation is one of only few studies in which different school-based health promotion interventions were compared to examine their effectiveness among children in SA. We conducted a comparison of different intervention arms and made use of pair-matched groups (with similar SESs) for each intervention arm. The strengths of the study are its relatively large sample size. The study considered gender and nutritional status as potential moderating factors, and we controlled for age, gender, SES and the nested nature of our data when examining the effects of the intervention. Moreover, it took place in disadvantaged areas and the SES of participating children was relatively homogenous. Thus, our study focused on a target group that has been described as particularly vulnerable to conditions associated with poverty, such as under- and over-nutrition combined with low PA.

Several limitations are offered for discussion. First, the intervention period was relatively short, lasting for only 10 weeks, because the study schedule had to take into consideration school holidays, mid-term assessments and end-of-term examinations pertinent to the schools. Second, our findings should not be generalised to other populations (e.g. higher SES and rural children). We also acknowledge that despite the fact that some intervention measures (e.g. health and hygiene education) were not directly associated with children's energy balance, it might be that they have an indirect effect on the outcomes. As shown previously, good hygiene behaviour might reduce the risk for soil-transmitted helminth infections.[24] On the other hand, research showed that soil-transmitted helminth infections are significantly associated with children's nutritional status.[36] Third, although a cluster-randomised study design was adopted, it is conceivable that other factors might have influenced our findings as the number of locations per intervention arm was small. This may be the reason why the observed effects were not consistently found across all paired groups. Possible confounders include the children's dietary

Table 5. BF% of each experimental group and corresponding paired control group in schoolchildren from Gqeberha, South Africa, in 2015

		BF%				
		T1	T2			
Nutritional status	Treatment, *n*	M (SD)	M (SD)	Mean difference in BF%	*p*-value*	η²
E1 - C1						
Underweight†	Control, *n*=1	7.3 (-)	8.0 (-)	+0.7	-	-
	Experimental, *n*=1	8.1 (-)	9.1 (-)	+1.0	-	-
Normal-weight†	Control, *n*=87	13.6 (4.1)	16.3 (4.8)	+2.7*	<0.001*	0.398*
	Experimental, *n*=65	15.1 (4.2)	15.4 (4.5)	0.3	0.258	0.020
Overweight/obese	Control, *n*=25	24.5 (6.7)	32.8 (12.2)	+8.3*	<0.001*	0.594*
	Experimental, *n*=24	29.4 (10.9)	27.0 (8.5)	−2.4	0.094	0.117
E2 - C2						
Underweight	Control, *n*=4	12.0 (3.4)	12.5 (3.4)	+0.5	-	-
	Experimental, *n*=2	13.7 (5.2)	15.1 (9.3)	+1.4	-	-
Normal-weight†	Control, *n*=69	14.5 (4.2)	14.9 (5.2)	+0.4	0.131	0.033
	Experimental, *n*=78	13.6 (4.1)	13.4 (3.9)	−0.2	0.475	0.007
Overweight/obese	Control, *n*=24	24.9 (7.2)	28.3 (10.2)	+3.4*	0.003*	0.328*
	Experimental, *n*=18	24.6 (7.5)	27.3 (9.9)	+2.7*	0.014*	0.305*
E3 - C3						
Underweight†	Control, *n*=2	8.2 (1.2)	8.1 (0.3)	−0.1	-	-
	Experimental, *n*=4	9.6 (3.0)	12.4 (3.1)	+2.8	-	-
Normal-weight†	Control, *n*=120	14.1 (4.3)	15.1 (5.6)	+1.0*	<0.001*	0.108*
	Experimental, *n*=66	14.7 (4.6)	16.4 (4.4)	+1.9*	<0.001*	0.360*
Overweight/obese	Control, *n*=30	26.0 (71.3)	32.2 (13.3)	+6.2*	<0.001*	0.347*
	Experimental, *n*=21	26.7 (7.9)	34.0 (14.7)	+7.3*	0.009*	0.296*
E4 - C4						
Underweight	Control, *n*=12	9.8 (2.6)	9.7 (3.2)	−0.1	0.917	0.001
	Experimental, *n*=13	9.3 (1.8)	8.9 (2.4)	−0.4	0.386	0.063
Normal-weight	Control, *n*=68	12.5 (4.8)	12.9 (4.6)	+0.4	0.232	0.021
	Experimental, *n*=138	13.4 (3.8)	13.2 (4.6)	−0.2	0.323	0.007
Overweight/obese†	Control, *n*=6	22.9 (5.6	24.9 (8.6)	+2.0	-	-
	Experimental, *n*=18	24.5 (5.9)	24.6 (4.7)	+0.1	0.955	0.001

BF% = body fat percentage; *n* = number of children; M = mean; SD = standard deviation.
*Statistically significant differences ($p<0.05$).
†Analyses not performed in subgroups with less than 10 cases.

habits and activities during break-time and after school, as it can only be assumed that the latter remained the same during the intervention. Finally, the sample size calculations were not based on the outcomes considered in the present paper. Accordingly, some subgroups had low numbers (e.g. underweight children), which meant statistical significance testing and intervention effects could not be performed. The power calculation was originally driven by the goal to achieving sufficient precision in estimating the prevalence of soil-transmitted helminth infections (in line with the overall purpose of the DASH study to survey the distribution of selected intestinal parasite infections). Hence, the sample size was not estimated to establish the minimal/optimal sample size for the specific research questions addressed in the present paper. *A posteriori* power analyses (based on G*Power 3.1) showed that using repeated measures ANOVAs with a within-subject design (alpha error = 0.05, power = 0.80, number of measurements, correlation among repeated measures = 0.50), at least 34 participants would have been needed to detect a moderate effect (f = 0.25). In the present study, however, some subgroups were smaller, which entails the risk that at least some of the analyses were underpowered.

Conclusion and practical implications for schools

The study reported an increase in BMI-for-age and body fat percentage in the group, with boys and girls showing a similar increase. An increase in children's body composition was also observed and this included normal weight (BMI-for-age) and overweight/obese children (BF%). This increase is an important public health issue among SA children because childhood overweight/obesity can track into adulthood. A significant decrease in the BF% of normal-weight children exposed to the PA intervention (alone or combined with health education) was reported, highlighting the importance of regular participation in PA to reduce fat mass and encourage favourable body composition in children. In addition, the PA intervention showed partial effects on overweight/obese children's BF% compared with their counterparts in the control groups that increased body fat. Given that both under- and over-nutrition are important public health issues among SA children, measures that are readily tailored to specific population groups are warranted. In order to identify the right measures, *a-priori* analyses of the children's health state can be helpful. For instance, in areas where

Table 6. Prediction of BMI-for-age and BF% at T2 with sociodemographic background, baseline values and treatment among normal-weight children from Gqeberha, SA, in 2015

		BMI-for-age (T2)				Body fat (%)		
Group	Predictor	*B*	Estimate (95% CI)	*p*-value	Predictor	*B*	Estimate (95% CI)	*p*-value
E1 - C1	Age	−0.1	−1.0 - 0.9	0.919	Age	0.36	−0.19 - 0.91	0.194
	Girls (cf. boys)	−0.8	−0.25 - 0.09	0.329	Boys (cf. girls)	−0.42	−1.64 - 0.81	0.503
	SES	−0.1	-0.90 - 0.7	0.815	SES	−0.23	−0.74 - 0.27	0.366
	Baseline for age at T1	0.87	0.75 - 1.00	<0.001*	Baseline for age at T1	0.88	0.74 - 1.03	<0.001*
	Control group (cf. experimental group)	0.03	−0.14 - 0.20	0.731	Control group (cf. experimental group)	2.35	1.34 - 3.36	<0.001*
E2 - C2	Age	−0.4	−0.12 - 0.05	0.400	Age	0.43	−0.10 - 0.96	0.111
	Girls (cf. boys)	−0.14	−0.26 - -0.02	0.019	Boys (cf. girls)	−2.27	−3.24 - −1.29	<0.001
	SES	0.02	−0.02 - 0.05	0.314	SES	0.07	−0.13 - 0.27	0.493
	Baseline for age at T1	0.91	0.82 - 1.00	<0.001*	Baseline for age at T1	0.75	0.64 - 0.87	<0.001*
	Control group (cf. experimental group)	−0.04	−0.16 - 0.08	0.515	Control group (cf. experimental group)	0.83	0.09 - 1.58	<0.001*
E3 - C3	Age	0.00	−0.01 - 0.01	0.659	Age	0.00	−0.05 - 0.05	0.975
	Girls (cf. boys)	−0.07	−0.15 - 0.02	0.136	Boys (cf. girls)	−1.36	−2.30 - −0.42	0.005
	SES	0.01	−0.01 - 0.03	0.449	SES	0.09	−0.07 - 0.25	0.255
	Baseline for age at T1	0.92	0.85 - 0.98	<0.001*	Baseline for age at T1	0.92	0.82 - 1.03	<0.001*
	Control group (cf. experimental group)	−0.09	−0.19 - 0.01	0.052	Control group (cf. experimental group)	−0.63	−1.44 - 0.18	0.128
E4 - C4	Age	−0.01	−0.6 - 0.3	0.635	Age	0.23	−0.23 - 0.68	0.326
	Girls (cf. boys)	−0.03	−0.10 - 0.05	0.523	Boys (cf. girls)	−0.30	−1.21 - 0.61	0.515
	SES	−0.01	−0.03 - 0.01	0.355	SES	0.02	−0.18 - 0.21	0.858
	Baseline for age at T1	0.95	0.92 - 0.99	<0.001*	Baseline for age at T1	0.88	0.80 - 0.97	<0.001*
	Control group (cf. experimental group)	−0.24	−0.33 - -0.16	<0.001*	Control group (cf. experimental group)	0.53	−0.35 - 1.40	0.237

BF% = body fat percentage; BMI = body mass index; B = beta; CI = confidence interval; c.f. = compared with; SES = socioeconomic status.
*Statistically significant differences ($p<0.05$).

overeating has replaced under-nutrition as a health problem, a focus on PA is appropriate, whereas the provision of a nutritional mass supplement should be targeted at undernourished children. School-based PA interventions should be in accordance with the global recommendation of pursuing at least 60 minutes of MVPA per day, and could be achieved through regular PE lessons at school, activity during break-time and after-school extramural activities.

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Table 7. Prediction of BMI-for-age and BF% at T2 with sociodemographic background, baseline values and treatment, among overweight/obese children from Gqeberha, SA, in 2015

	BMI-for-age (T2)				BF (%)			
	Predictor	*B*	Estimate (95% CI)	*p*-value	Predictor	*B*	Estimate (95% CI)	*p*-value
E1 - C1	Age	0.00	−0.15 - 0.16	0.953	Age	1.43	−1.70 - 4.55	0.362
	Girls (cf. boys)	0.04	−0.21 - 0.30	0.725	Boys (cf. girls)	−4.97	−10.29 - 0.34	0.066
	SES	0.10	−0.13 - 0.33	0.387	SES	−2.28	−6.76 - 2.21	0.312
	Baseline for age at T1	0.98	0.81 - 1.15	<0.001*	Baseline for age at T1	0.77	0.52 - 1.03	<0.001*
	Control group (cf. experimental group)	0.20	−0.01 - 0.41	<0.001	Control group (cf. experimental group)	10.09	5.93 - 14.3	<0.001*
E2 - C2	Age	−0.03	−0.20 - 0.14	0.710	Age	−0.28	−2.69 - 2.13	0.814
	Girls (cf. boys)	0.02	−0.17 - 0.22	0.818	Boys (cf. girls)	−1.72	−4.50 - 1.06	0.217
	SES	−0.01	−0.07 - 0.05	0.730	SES	−0.10	−1.00 - 0.78	0.816
	Baseline for age at T1	0.95	0.82 - 1.08	<0.001*	Baseline for age at T1	1.26	1.07 - 1.45	<0.001*
	Control group (cf. experimental group)	−0.10	−0.29 - 0.10	0.308	Control group (cf. experimental group)	0.80	−1.99 - 3.59	0.566
E3 - C3	Age	−0.12	−0.26 - 0.02	0.087	Age	−2.08	−5.41 - 1.25	0.215
	Girls (cf. boys)	0.20	−0.04 - 0.44	0.098	Boys (cf. girls)	4.26	−1.62 - 10.14	0.151
	SES	−0.01	−0.06 - 0.05	0.816	SES	0.18	−1.06 - 1.42	0.768
	Baseline for age at T1	1.05	0.88 - 1.22	<0.001*	Baseline for age at T1	1.43	1.04 - 1.82	<0.001*
	Control group (cf. experimental group)	−0.20	−0.44 - 0.04	0.093	Control group (cf. experimental group)	−0.62	−6.31 - 5.07	0.827
E4 - C4†	Age	-	-	-	Age	-	-	-
	Girls (cf. boys)	-	-	-	Boys (cf. girls)	-	-	-
	SES	-	-	-	SES	-	-	-
	Baseline for age at T1	-	-	-	Baseline for age at T1	-	-	-
	Control group (cf. experimental group)	-	-	-	Control group (cf. experimental group)	-	-	-

BF% = body fat percentage; MI = body mass index; B = beta; CI = confidence interval; SES = socioeconomic status.
*Statistically significant differences ($p<0.05$).
†Analyses not performed due to low number of overweight/obese children in the E4 - C4 group ($n=24$).

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