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 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.

S Afr J Child Health 2021;15(1):89-98. https://doi.org/10.7196/SAJCH.2021.v15.i2.1762
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. 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. 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.

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. 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. These factors are especially pronounced in poorer schools.

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. 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, 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. 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. 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 subcapular). The measurement procedures are detailed in the DASH study protocol. We calculated the BMI (height in cm) divided by weight (in kg) squared) and body fat percentage (BF%) using the DASnehmer equation, 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.

**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. 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). 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. 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. 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, η² was calculated for each comparison. To interpret effect sizes, we followed Cohen's recommendations: η² ≥0.01 (small effect), η² ≥0.059 (moderate effect), and η² ≥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, η²=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, η²=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, η²=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

| 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 hygiene education intervention |               |                      |
| Deworming medication |               |                      |
| School E3 (n=92)   | School C3 (n=151)   | Township area        |
| Health 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 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, η²=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, η²=0.020) and girls (F(1,438)=23.8, p<0.001, η²=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, η²=0.002. Overall, a significant increase in BF% was observed both for boys (F(1,456)=18.0, p<0.001, η²=0.038) and girls (F(1,438)=82.8, p<0.001, η²=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, η²=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, η²=0.047), whereas no significant changes were observed in underweight (F(1,37)=1.03, p=0.316, η²=0.027) and overweight peers (F(1,164)=0.5, p=0.475, η²=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, η²=0.073). While no significant change was observed in underweight children (F(1,37)=0.0, p=0.853, η²=0.001), significant increases occurred in normal-weight (F(1,689)=63.0, p<0.001, η²=0.084) and overweight peers (F(1,164)=42.2, p<0.001, η²=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 group 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/obese children are summarised in Table 7. Across both outcomes (BMI-for-age and BF%), baseline scores were the strongest predictor of T2 scores. For BMI-for-age, the intervention 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 group had significantly higher BF% at T2 if compared with the respective experimental groups.

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

| Group | Treatment, n | BMI (M, SD) | BMI-for-age (zBMI) (M, SD) | Mean difference in zBMI (M, SD) | p-value | η² |
|-------|--------------|-------------|---------------------------|-------------------------------|---------|----|
| 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.[25] This increase is expected in children during the period of development as they reach puberty.[26] However, other factors could have also played a role. A study by Kruger et al.[27] 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[28] and Johannesburg and Gqeberha, in SA,[29] 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.[30]

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.[33] 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.[34]

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[35] and in other countries.[36] 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.[37] 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

| Gender | Treatment, n | BF% | T1 M (SD) | T2 M (SD) | Mean difference BF% | p-value | \( \eta^2 \) |
|--------|--------------|-----|----------|----------|---------------------|---------|---------|
| Boys E1 - C1 | Control, n=57 | BF% | 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 |
| | | | 19.3 (7.1) | 24.3 (11.5) | +5.0* | <0.001* | 0.407* |
| | | | 21.9 (9.8) | 20.6 (7.5) | -1.3 | 0.064 | 0.071 |
| Boys E2 - C2 | Control, n=45 | BF% | 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 |
| | | | 18.9 (5.8) | 21.2 (7.9) | +2.3* | <0.001* | 0.286* |
| | | | 17.1 (4.9) | 17.2 (5.8) | +0.1 | 0.763 | 0.002 |
| Boys E3 - C3 | Control, n=80 | BF% | 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* |
| | | | 19.7 (6.1) | 22.6 (9.0) | +2.9* | <0.001* | 0.254* |
| | | | 20.2 (7.8) | 22.8 (9.3) | +2.6* | <0.001* | 0.258* |
| Boys E4 - C4 | Control, n=46 | BF% | 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 |
| | | | 15.6 (5.5) | 16.3 (6.0) | +0.7 | 0.231 | 0.037 |
| | | | 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).
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 paired groups. Possible confounders include the children's dietary and exercise habits as well as their socioeconomic status. Moreover, 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 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. On the other hand, research showed that soil-transmitted helminth infections are significantly associated with children's nutritional status. 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 habits and exercise habits as well as their socioeconomic status.
Table 5. BF% of each experimental group and corresponding paired control group in schoolchildren from Gqeberha, South Africa, in 2015

| Nutritional status   | Treatment, n | T1 M (SD) | T2 M (SD) | Mean difference in BF% | p-value* | \( \eta^2 \) |
|----------------------|--------------|-----------|-----------|------------------------|----------|-----------|
| 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 (7.3)| 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.

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

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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.

**Declaration.** The funders played no role in the study design, data collection, analysis or interpretation, or decision to publish.

**Acknowledgements.** The authors are grateful to the children and parents/guardians for their willingness to participate in the study.

**Author contributions.** RdUR, MG, IM, HS, PS, NP-H, JU, UP and CW designed the study; established the methods and wrote the original study protocol. All other authors contributed to the development of the study protocol. SN, LA, JD, SG, NJ, IM and DS conducted the fieldwork of the study. SN, LA, JD, SG, NJ, IM, HS and DS managed data entry, cleaning and preparation of the database. Statistical analysis was done by JB and MG. SN wrote the first draft of the manuscript with support from MG, RdUR and CW. SN, RdUR, LA, JD, SG, MG, NJ, IM, DS, HS, PS, NP-H, JU, UP and CW provided comments on the drafts and read and approved the final version of the paper prior to submission. SN, RdUR and CW are guarantors of the paper.

**Funding.** This study was conducted within the scope of the Swiss-South African Joint Research Program (SSAJRP). Financial support was provided by the Swiss National Science Foundation (SNF; project no. IZLSZ3 149015) and the South African National Research Foundation (NRF; project no. 87397). SN was funded by the Department of Research Development, Nelson Mandela University and the National Research Foundation (NRF); Grant UID 100042. The funders played no role in the study design, data collection and data analysis, data interpretation, preparation of the manuscript and decision to publish. The corresponding author had the responsibility for the decision to submit for publication.

**Conflicts of interest.** None.

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**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**

| Group | Predictor | Estimate (95% CI) | p-value | Predictor | Estimate (95% CI) | p-value |
|-------|-----------|-------------------|---------|-----------|-------------------|---------|
| E1 - C1 | Age | −0.1 | 95% CI | 0.919 | Age | 0.36 | 95% CI | 0.194 |
| | Girls (cf. boys) | −0.8 | 95% CI | 0.329 | Boys (cf. girls) | −0.42 | 95% CI | 0.503 |
| | SES | −0.1 | 95% CI | 0.815 | SES | −0.23 | 95% CI | 0.366 |
| | Baseline for age at T1 | 0.87 | 95% CI | <0.001* | Baseline for age at T1 | 0.88 | 95% CI | <0.001* |
| | Control group (cf. experimental group) | 0.03 | 95% CI | 0.731 | Control group (cf. experimental group) | 2.35 | 95% CI | <0.001* |
| E2 - C2 | Age | −0.4 | 95% CI | 0.400 | Age | 0.43 | 95% CI | 0.111 |
| | Girls (cf. boys) | −0.14 | 95% CI | 0.019 | Boys (cf. girls) | −2.27 | 95% CI | <0.001 |
| | SES | 0.02 | 95% CI | 0.314 | SES | 0.07 | 95% CI | 0.493 |
| | Baseline for age at T1 | 0.91 | 95% CI | <0.001* | Baseline for age at T1 | 0.75 | 95% CI | <0.001* |
| | Control group (cf. experimental group) | −0.04 | 95% CI | 0.515 | Control group (cf. experimental group) | 0.83 | 95% CI | <0.001* |
| E3 - C3 | Age | 0.00 | 95% CI | 0.659 | Age | 0.00 | 95% CI | 0.975 |
| | Girls (cf. boys) | −0.07 | 95% CI | 0.136 | Boys (cf. girls) | −1.36 | 95% CI | 0.005 |
| | SES | 0.01 | 95% CI | 0.449 | SES | 0.09 | 95% CI | 0.255 |
| | Baseline for age at T1 | 0.92 | 95% CI | <0.001* | Baseline for age at T1 | 0.92 | 95% CI | <0.001* |
| | Control group (cf. experimental group) | −0.09 | 95% CI | 0.052 | Control group (cf. experimental group) | −0.63 | 95% CI | 0.128 |
| E4 - C4 | Age | −0.01 | 95% CI | 0.635 | Age | 0.23 | 95% CI | 0.326 |
| | Girls (cf. boys) | −0.03 | 95% CI | 0.523 | Boys (cf. girls) | −0.30 | 95% CI | 0.515 |
| | SES | −0.01 | 95% CI | 0.355 | SES | 0.02 | 95% CI | 0.858 |
| | Baseline for age at T1 | 0.95 | 95% CI | <0.001* | Baseline for age at T1 | 0.88 | 95% CI | <0.001* |
| | Control group (cf. experimental group) | −0.24 | 95% CI | <0.001* | Control group (cf. experimental group) | 0.53 | 95% CI | 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).

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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

| Predictor                  | Estimate (95% CI) | p-value | Predictor                  | Estimate (95% CI) | p-value |
|----------------------------|------------------|---------|----------------------------|------------------|---------|
| **E1 - C1**                |                  |         | **E2 - C2**                |                  |         |
| Age                       | 0.00             | -0.15 - 0.16 | 0.953                     | 1.00             | -0.20 - 0.14 | 0.710 |
| Girls (cf. boys)         | 0.04             | -0.21 - 0.30 | 0.725                     | -0.01 - 0.01     | -0.20 - 0.10 | 0.308 |
| SES                       | 0.10             | -0.13 - 0.33 | 0.387                     | 0.95             | 0.82 - 1.08  | <0.001* |
| Baseline for age at T1   | 0.98             | 0.81 - 1.15  | <0.001*                   | 1.05             | 0.88 - 1.22  | <0.001* |
| Control group (cf.        | 0.20             | -0.01 - 0.41 | <0.001*                   | Control group    | -0.20 - 0.44 | 0.093 |
| experimental group)       |                  |         |                           | (cf. experimental group) |         |
| **E3 - C3**                |                  |         | **E4 - C4**                |                  |         |
| Age                       | -0.12            | -0.26 - 0.02 | 0.087                     | Age              | -0.02 - 0.04 | 0.998 |
| Girls (cf. boys)         | 0.20             | -0.04 - 0.44 | 0.816                     | -0.20            | -0.44 - 0.04 | 0.093 |
| SES                       | -0.01            | -0.06 - 0.05 | 0.816                     | Boys (cf. girls) | -0.20 - 0.01 | 0.417 |
| Baseline for age at T1   | 1.05             | 0.88 - 1.22  | <0.001*                   | Boys (cf. girls) | 1.05     | 0.88 - 1.08  | 0.015 |
| Control group (cf.        | -0.20            | -0.44 - 0.04 | <0.001*                   | Control group    | -0.20 - 0.10 | 0.308 |
| experimental 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).
†Statistically significant differences (p<0.01).

Analyses not performed due to low number of overweight/obese children in the E4 - C4 group (n=24).

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Accepted 17 November 2020.