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ORIGINAL ARTICLE
BODY COMPOSITION, NUTRITION AND SUPPLEMENTATION

The mediating effect of physical fitness on long term influences of overweight in primary school girls' academic performance

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ABSTRACT

BACKGROUND: Overweight and obesity contribute to multiple health risks in children, while also impacting negatively on educational performance. Physical fitness can impact outcomes beyond health related measures therefore it can play a mediating role in combating the negative effects of being overweight.
METHODS: One hundred and seventy-two primary school girls aged 6-13 years old from the North West Province of South Africa formed part of this random stratified longitudinal research design in which three follow-up measurements took place over seven years. Body Mass Index was used to compile obesity profiles, while the progressive aerobic cardiovascular endurance run (PACER) was used to determine cardiovascular fitness. Academic school achievements for grades 1, grade 4 and grade 7, as well as national and provincial values were correlated with academic performance. Data were analyzed by a repeated measure over time ANOVA as well using a latent growth curve model from the structural equation modelling framework (SEM).
RESULTS: No differences ($P>0.05$) were found in the academic performance of obese and normal weight girls, although obese girls showed poorer physical fitness values ($P<0.05$). The SEM model was a good fit for all requirements (RMSEA, 0.60; CMIN DF, 2.837; CFI, 0.966). VO_2max had a standardized indirect mediation effect (-132) while body composition showing a standardized direct effect (0.183) with academic achievement. Physical fitness showed a mediation effect with regard to obesity and academic achievement in grade 7 girls.
CONCLUSIONS: Although the academic performance of obese girls did not show impairment before the age of 12 years, physical fitness had a reversible effect on relationships between obesity and academic achievement. This substantial influence of physical fitness should be used strategically in preventive intervention programs necessary to enhance cognitive functioning, academic performance and brain health among overweight children.

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KEY WORDS: Overweight; Obesity; Physical fitness; Academic performance.

Worldwide, 41 million children under the age of 5 are overweight or obese.[1] In addition, obesity is the most common chronic condition in children.[2] Previously overweight and obesity was characterized as a problem that only occurs in developed countries,[3] but research[4, 5] shows that this trend is also increasing in low and middle-income countries. It is reported that the prevalence of overweight and obesity increased from 11% to 19% in southern Africa over the period 2000-2013.[3] According to the national SANHANNES-1 study (South African National Health and Nutrition Examination Survey), South Africa shows a prevalence of 22.7% for overweight and obesity among preschool children between the ages of 2-5.[6] South African girls birth-14 years also tend to be heavier and taller, and more overweight and obese compared to boys.[6] Current statistics, furthermore, show increases in this epidemic of

overweight and obesity in South Africa, similar to the rest of the world. However, the deduction can be made that the increase in childhood obesity in South Africa as currently reported in studies, does not even reflect the true magnitude of the problem, as the appearance and increase of the problem seem to differ widely in terms of ethnicity, age, Socio Economic Status (SES) and gender.[5, 7]

Overweight and obesity are defined as the excessive accumulation of body fat that may adversely affect health.[2] Excess weight gain and obesity have short and long-term consequences that are largely associated with health risks such as cardiovascular diseases, diabetes, cancer, metabolic syndrome, sleep apnea, asthma, poor self-esteem, depression, hypertension, cancer, and growth inhibition in children.[1, 7-9] Long-term consequences of childhood obesity may even lead to premature death.[9] Apart from the health risks associated with excess weight gain and obesity, these conditions can also affect other dimensions of children's well-being with long-term and equally important consequences. These consequences include academic underperformance and reduced health-related physical fitness in developing children.[10, 11] In this regard Wang *et al.*[12] provide evidence that obesity-related changes in metabolism can lead to the impairment of cognitive brain function, and that childhood obesity may contribute to a decrease in executive functioning, math- and reading skills as well as poor attention span. Poor cognition is further associated with overweight and obesity because high-fat diets can limit cognitive functioning.[12] Du Toit *et al*.[11] reports a negative correlation between higher body fat and lower aerobic fitness in relation to academic achievement among girls aged 11-12 years old. An overview study also shows that physical fitness components, especially aerobic capacity, correlated positively with academic achievement.[13] The relationship between academic achievement and physical activity has long been investigated and it is found that physical activity activates the brain through an increase in blood supply to essential areas in the brain, which again stimulates the learning process.[14] Furthermore, it appears that aerobic fitness and muscle endurance may improve cognition and oxygen intake in obese individuals in the long term.[12] A systematic review confirms a positive relationship between academic achievement and physical fitness.[15] The majority of studies in this review made use of the Fitnessgram (The Cooper Institute, Dallas, TX, USA) and the PACER aerobic test to analyze the role of physical fitness in academic performance in children aged 5-13 years old. This review also confirms that this relationship is in some instances only applicable to girls. However, contradictory findings about these relationships can also be found in literature. Smith *et al.*[16] highlights inconsistent results regarding the benefits that physical fitness, more specifically muscle strength and muscle endurance, brings about with regard to cognitive abilities in children aged 4-19 years old.

Researchers who investigated the relationship between obesity and academic achievement reported that adolescent girls (13.7 years) who moved from normal to overweight status over a period of 3 years, showed poorer academic achievement in math and reading skills.[17] Similar results are also reported for younger girls over a four year period, moving from nursery school to grade 3.[18] Martin *et al.*[19] concludes that obesity in young children displays a poor link with cognition although this relationship strengthens over time and that it can exert a greater impact later on in the child's life.

Armstrong *et al.*[4] reports similar increases in overweight and obesity trends among South African girls, as those reported worldwide over the past decade. A recent longitudinal study reports an increase in overweight and obesity by 4.2% over the 3-year period between six and nine years old in South African girls.[7] The Ellisras Longitudinal Growth and Health study[20] also shows significant increases in obesity among girls aged 13.5-14.9 years old, where increases from 10.4% to 15.5% over a period of 16 months were found. Therefore, it is important to investigate the relationship between BMI (Body Mass Index) and academic achievement during early childhood as poor academic achievement can lead to poor educational achievement during adulthood as well as threatening psychosocial development during adulthood.[21] Longitudinal studies that analyze relationships between repeated measurements of children and adolescents' weight status and academic achievement are, therefore necessary for a greater understanding of this relationship over the long term.

In addition, a South African study reports that high (BMI) values in adolescent girls exert a negative impact on physical fitness and motor skills over the long term.[22] However, the relationship between academic achievement and physical fitness are only reported cross-sectionally with regard to South African girls.[11]

Some studies, focusing on girls aged 6-13, have been published which examined the long-term relationships between overweight and obesity, academic achievement and physical fitness.[14, 16, 23, 24] However, controversial findings are still reported regarding these relationships, while longitudinal studies focused mainly on the prevalence of overweight and obesity.[4, 7] Some longitudinal studies

that studied relationships between body composition and academic achievement or physical fitness are also found, but these studies are again limited to the role of specific socio-economic status groups in these relationships.[20, 22] From these limitations, a gap in existing research has been identified regarding the long-term role of overweight and obesity in academic performance as well as the possible mediation effect that aerobic fitness can exert on such relationships, especially in primary school girls. The main purpose of this study was to determine whether there was a longitudinal relationship between overweight and obesity and academic performance of girls in their primary school years (7-13 years) in the North West Province of South Africa, and how health-related physical fitness can affect this relationship. Obesity is expected to exert a negative impact on academic achievement and health-related physical fitness of primary school girls while physical fitness can bring about a mediation effect on this relationship.

Materials and methods

Research design

The study has a longitudinal study design, which forms part of the North West Child Health, Integrated with Learning and Development (NW-CHILD study), which represents the full primary school phase of seven school years. Baseline measurements took place in 2010, in grade 1 and in children with two follow-up measurements in 2013 and 2016. The sample was randomized and stratified according to school district, school quintile and gender, in collaboration with the Statistical Consultation Service of the North-West University (NWU). To determine the sample, a list of all schools in the NW Province (NWP) was obtained from the Department of Basic Education. The NWP is divided into eight school districts, each comprising 12 to 22 districts, with approximately 20 schools in each district (minimum 12 and maximum 47). South Africa uses a poverty classification system to categorize different schools in different quintile statuses based on socio-economic status-(SES) factors. In this study, the socio-economic school status (also known as quintiles) was used as categorization of SES of participants. The Department of Basic Education use a poverty classification to categorize schools in different quintiles. Schools in the NWP are classified in 5 quintiles, where quintile 1 represents schools with low SES and quintile 5 schools with high SES. Quintile 1 and 2 schools are the poorest schools. They are exempt from school fees[25] and have feeding schemes that provide support to learners during the school day. Only the girls who participated in the NW-CHILD study were included for the purpose of this study. Twenty schools that represented each of the 5 different school quintiles formed part of the study. Ethical approval was obtained from HREC, the NWU Ethics Committee (00070-09-A1), as well as at the Department of Basic Education of the North West Province. Principals of each of the twenty schools that were part of the study had to give continued permission for the follow-up measurements of the study. Both parents/guardians and the participants also had to consent before participation in the study was allowed. The research was conducted during school hours and according to the Helsinki Declaration and "Ethics in Health Research: Principles, Processes and Structures."

Research group

In 2010, 880 children were recruited for participation in the study; 816 (418 boys and 398 girls) with a mean age of 6.81 years (SD=0.38) participated. Three years later in 2013, only 79.1% of the original sample of girls was available (N.=282) for the first follow-up, representing a 19.9% dropout. The mean age in grade 4 was 9.84 years (SD=0.38). In grade 7 (2016), only 198 girls, representing a 50.3% (N.=200) dropout rate over the 7-school year period, participated in all three measurements from 2010-2016. Only this group was used for the purpose of this study, which included data of a six-year follow-up period.

Research procedures

Stature (cm), body mass (kg) and skin folds (sub scapula, medial calf, and triceps, in mm) were taken according to the protocol for the International Society for the Advancement of Kinanthropometry (ISAK),[26] by three trained kinanthropometricts with level 2 training certificates. A portable Harpenden stadiometer (Holtain Ltd, Crymych, UK) was used to determine the stature to the nearest 0.1 cm. Body mass was determined with an electronic scale to the nearest 0.1 kg (BF 511, Omron). Body mass and stature were measured without shoes and wearing light clothes. The subscapular, calf and triceps skinfold were taken by a Harpenden skinfold calliper to the nearest 0.1 mm. For the technical error of measurement (TEM) all skinfolds were taken 2-3 times, and the mean or median value was then used to ensure validity and reliability. The Body Mass Index (BMI) was calculated by using weight and stature measurements of each participant by determining the ratio between stature and mass (mass [kg]/height^2 [m]).The international cut-offs for BMI as developed by Cole *et al*.[27] were used to classify the group into different Body Mass

Index (BMI) groups. Accordingly, the participants were divided into five weight categories namely: underweight and stunted (UW/ST), normal weight, overweight (OW), obese (OB), and a combined overweight and obese (OW/OB) group. Influences of underweight was not a focus of the study but it was important to make sure that the normal weight group was free of stunted or underweight children as inclusion of such participants in this group might have confounded the results. Cut-offs compiled by Lohman[28] were used to calculate the sum of two skinfolds (triceps and subscapular). These two skin folds show the strongest connection with body fat percentages in children.[28] Furthermore, the fat percentage and fat free body mass were also determined using the OMRON, BF 511, body composition bioelectrical impedance monitor. Secondary sex characteristics served as indicators of maturational differences between the girls. Breast development and the onset of menarche were used as indicators of sexual maturity. Participants were questioned by the Kinderkineticist regarding the onset of menarche and biological development was determined according to Tanner's 5 phases of development, where 0 would represent no development and 5 would be fully developed breasts.[29] Tanner's criteria was also assessed by the same Kinderkineticist for all the participants throughout the duration of the study. All measurements were performed in a private area before any physical fitness tests were conducted.

Physical fitness

The PACER (progressive aerobic cardiovascular endurance run) test was used to determine aerobic endurance during the two follow-up tests (2013, 2016).[30] This test was not used during the baseline measurements in 2010 because it is not considered a suitable test for use in children younger than nine years of age.[30] The PACER test is part of the Fitnessgram Test Protocol and consists of a multi-level shuttle run test that evaluates aerobic endurance. The test consisted in running back and forth between two lines (20 m apart) following an audio signal. The test started at a slow pace that gradually increases. The test finished for each child when they could not reach the line with the audio signal on two consecutive occasions or when they stopped due to fatigue, and the total number of completed laps was recorded. Age and gender specific VO_2max values were then calculated to categorize each child into a fitness zone.[30]

Academic achievement

In 2010 when the participants were in grade 1, basic academic literacy skills were evaluated by class teachers who used The Mastery of Basic Learning Areas assessment method. Numeric skills (mathematics) as well as reading and writing skills (standard of handwriting and pencil grip) were noted (CAPS Foundation, 2011) and evaluated on a scale of one to four, where 1 indicated no mastery, 2 partial mastery, 3 if the skill has been mastered and 4 indicates exceptional mastery. These categories were converted to percentages to enable comparisons with the grade 4 and 6 scores that were available as percentages. The academic percentages are interpreted as follows: 80-100% reflect excellent achievement; 70-79% meritorious achievement; 60-69% described significant achievement; 50-59% adequate achievement; 40-49% average achievement; 30-39% basic achievement and 0-29% indicated that the learning outcome "was not reached."

In 2013 and 2016, academic progress reports of the participants were requested from the schools of their mid-year June exams. The six learning areas in these reports include: 1) mathematics; 2) home language; 3) second language; 4) natural sciences; 5) social sciences and technology; 6) life orientation, as well as a grade point average (Department of Basic Education's Curriculum and Assessment Policy Statements [CAPS], CAPS Intermediate, 2011).

The results of the Annual National Assessment (ANA) which took place in September 2013, in which the participants' language and mathematical abilities were assessed nationally, were also available for the research (Department of Education, 2014). In 2016, the ANA was replaced by the similar North West Provincial Assessment (NWPA), as the ANA was not written in 2016. The NWPA assessed the participants in North West Province's in languages (Afrikaans, English, Setswana) and Mathematics to determine problems in this regard on a provincial level. Academic achievement in only languages and math were used in this study.

Statistical analysis

The Statistica-computer programme[31] were used to analyze the data for descriptive purposes as percentages, minimum and maximum values, and standard deviations. Significant relationships that emerged during the study were determined by two-way summary tables. A repeated measure over time ANOVA was calculated, followed by a *post-hoc* Bonferroni adjustment, to determine statistically significant relationships over time between obesity, academic achievement, and physical fitness. The non-parametric Freedman test was also used to verify parametric statistics if the numbers of participants decreased over time. In the analysis, corrections were made for school status (quintile)

and physical fitness. For Structural Equation Modelling, we used AMOS 23 software (Arbuckle, 2014).[32] A latent growth curve analysis was followed within a Structural Equation Modelling (SEM) framework to assess the longitudinal interrelations between overweight and obesity and academic performance and also the mediation effect of physical fitness on this relationship. To describe the model fit, the comparative fit index was used. For the model fit to be characterized good, the comparative compliance criteria had to meet three requirements, namely: RMSEA= Root-mean-square error of approximation <0.1; CFI= Comparative fit index with a 95% CI>0.95; CMIN/DF=χ^2 minimum sample discrepancy divided by degrees of freedom (χ^2/degrees of freedom) <5.[33]

Results

Descriptive information of the anthropometric composition (stature, mass, BMI and fat percentage) of the group during each of the three-year follow-up measurements is presented in Table I. A total of 198 girls were part of the group, indicating a 50.3% drop out of participants from 2010 to 2016. All body composition variables increased over the 6-year follow-up period, although it was expected due to increases in age from 6.8 years in grade 1, to 9.9 years in grade 4 and 12.8 years in grade 7. The obesity prevalence increased from 13.13% in grade 1 (8.5% overweight, 4.54% obese) to 20.2% at the age 12.8 years (13.3% overweight; 7.07% obese). From Table I it appears that academic performance in grade 1 was higher than in grade 4 and grade 7. In grade 1, the assessment scale is based on categorical symbols from 1-4, compared to the use of percentages in grades 4 and 7. These scores had to be converted to percentages for comparative purposes which might have influenced this observation. In this group, academic school achievement for math dropped significantly from grade 1 to grade 7 (76.46% to 52.00%), while a similar drop was also observed in the grade-point average (74.42% to 59.59%, Table I). Academic performance in language also dropped significantly (±15%) from grade 1 to grade 4 after which a reverse trend showing an increase of 4.5% was observed in grade 7.

The group was divided in into 5 BMI categories at each time point for comparative purposes, namely an underweight group, normal weight, overweight, obese and a combined OW and OB (OW/OB) group. The mean body composition and academic percentages as obtained in each of these different BMI categories, are indicated in Table II for grades 1, grade 4 and grade 7.

TABLE I.—*Descriptive information of body composition and academic performance changes from grade 1 to grade 7 (N.=198).*

	M±SD	Min	Max
Stature (cm)			
Gr.1	119.04±6.23	107.90	134.70
Gr. 4	135.83±7.15	113.00	155.10
Gr. 7	153.83±7.28	136.60	85.90
Body Mass (kg)			
Gr.1	21.17±5.37	15.50	68.60
Gr.4	32.52±10.01	20.50	113.10
Gr.7	47.89±4.16	28.80	154.00
BMI (kg/m^2)			
Gr.1	15.53±2.59	12.50	38.40
Gr.4	17.55±4.65	12.26	61.24
Gr.7	20.07±5.00	13.90	57.50
Body Fat (%)			
Gr.1	15.44±4.96	7.59	31.81
Gr.4	20.92±9.08	5.40	59.10
Gr.7	24.71±8.40	10.10	47.60
∑ Skinfolds (mm)			
Gr.1	16.56±6.67	8.25	55.25
Gr.4	20.60±10.57	7.50	72.00
Gr.7	24.87±13.46	9.00	101.50
Academic performance (%)			
Gr.1			
Language	73.35±17.37	25.00	100.00
Math	77.28±17.35	25.00	100.00
Grade Point Average	74.53±16.48	25.00	100.00
Gr.4			
Language	59.57±16.09	12.00	93.00
Math	61.46±16.25	25.00	95.00
Grade Point Average	61.41±13.30	25.17	92.80
Gr.7			
Language	64.06±11.53	18.00	91.50
Math	51.21±16.12	12.00	97.00
Grade point Average	59.17±11.07	20.33	92.56

M: mean; SD: standard deviation; Min: minimum value; Max: maximum value; BMI: Body Mass Index; Body fat: fat percentage (%); ∑ Skinfolds: sum of skinfolds.

Table II shows a decrease in school math achievements in all BMI groups from grades 1 to grade 4, and again from grade 4 to grade 7. Decreases in percentages were also similar in both the normal weight and the OW/OB group over the follow-up period. All groups showed a decrease in school language performance from grade 1 to grade 7 although a slight reverse trend was noticeable from grade 4 to grade 7 in all groups. The grade point average also declined in all groups from grade 1 to grade 4 with a further, although slighter drop during the final measurements in grade 7. Analysis of changes in the provincial math results also revealed only slight differences in the changes of the normal group (49.57% to 50.35%) and OW/OB group (53.00% to 54.96%) from grade 4 to grade 7 and scores remain almost similar in both groups in the different grades.

TABLE II.—*Descriptive body composition and academic values per BMI categories in grades 1, 4 and 7 (N.=198).*

	Grade 1				Grade 4		
	UW/ST N.=37	Normal N.=135	OW N.=17	OB N.=9	OW/OB N.=26	UW/ST N.=44	Normal N.=116
Age (years)	6.82±0.33	6.80±0.39	7.03 ±0.31	6.68±0.28	6.91±0.34	9.83±0.34	9.84±0.39
School assessments (%)							
Math	68.24±20.96	78.73±16.93	79.14±13.21	80.56±11.02	79.81±12.29	57.79±16.68	62.24±16.62
Language	66.55±18.88	74.81±17.27	72.79±14.14	80.56±11.02	71.15±18.29	55.71±13.43	59.60±17.09
Grade Point Average	67.11±18.63	76.12±16.28	75.00±10.62	80.56±11.02	76.92±10.88	57.64±11.33	61.43±14.26
Provincial Marks (%)							
Math		-	-	-	-	45.70±16.32	49.57±19.90
Language		-	-	-	-	47.84±20.06	60.21±19.68
Length			1				
Stature (cm)	111.81±2.82	120.32±4.85	21.32±6.39	125.09±8.60	122.63±7.29	127.40±3.51	137.51±5.52
Mass (kg)	18.22±1.61	21.61±2.76	27.29±2.86	37.26±12.87	30.74±9.04	25.10±2.92	30.66±4.41
BMI (kg/m2)	14.57±1.01	14.89±1.23	18.54±0.89	23.40±5.78	20.22±4.09	15.301.63	16.29±1.88
PACER (levels)	-	-	-	-	-	18.57±8.49	19.70±9.04
VO2 max (mL/kg/min)	-	-	-	-	-	41.49±3.28	41.43±2.95
Fat percentage (%)	13.89±3.54	14.24±3.63	22.76±4.32	25.92±4.30	23.86±4.50	15.82±5.85	18.39±6.09
Skin folds (mm) (Σ subscapular +triceps)	14.45±1.01	14.91 ±4.17	25.66±6.60	32.64±10.75	28.08±8.73	14.40±4.02	17.42±5.61

Data are expressed ad mean±SD.
UW/ST: Underweight and stunted combination; Normal: normal weight group; overweight group: OW; obese group: OB; OW/OB: combination group of overweight and obesity; M: mean; SD: standard deviation.

The normal group also showed similar ANA and NWPA language percentages in grades 4 and grade 7 (60.21% to 60.39%) while all overweight groups experienced lowering values. Both school and national math assessments revealed slightly higher math scores in the OW/OB group compared to the normal weight group in grades 4 and 7 although these differences became smaller in grade 7. Although no significant differences (P>0.05) were found between any of the academic assessments over the period from grade 1 to grade 7 between the different BMI groups (excluding the underweight group that did differ from the other groups in some instances although not the focus of this study), the results revealed higher marks in most academic assessments of the OW/OB group compared to the normal group.

The PACER test is reported as a valid indirect test for determining VO_2 max values. The values that are obtained with the PACER test can be used to classify a participant according to age and gender-specific cut-off points inside or outside a "Healthy Fitness Zone" (HFZ). In grade 4, the VO_2 max values of OW (38.41 mL/kg/min), OB (38.28 mL/kg/min) and OW/OB participants (38.36 mL/kg/min) were all below the HFZ (≤37.4-40.1), while participants in the normal weight group (41.43 mL/kg/min) fell within the healthy fitness zone (≥40.2). In grade 7, similar results were obtained, although all groups presented with lowering values. The VO_2 max (40.86 mL/kg/min) of the normal weight group was, however, still within the HFZ. These results implicate that the overweight groups have a health risk from the age of nine years regarding their cardiovascular fitness. The OB group also achieved the lowest PACER levels during both time point measurements (2013 and 2016), that highlights a negative relationship between obesity and cardiovascular fitness.

Fat percentage of all groups increased from 2013-2016. Both fat percentage and the sum of skinfolds were higher in all the overweight groups compared to in the normal weight group. Higher increases were also observed in the fat percentages of the OW (22.76% to 32.21%), OB (25.92% to 39.26%) and the OW/OB group (23.86% to 34.48%) compared to in the normal weight group (14.24% to 18.39%) where an increase of only four percent were seen. In comparison, all overweight groups showed increases of ten percent and more over the follow-up period.

The group was also divided into an underweight, normal weight and a combined overweight and obese group for comparative purposes and the academic achievement differences between these groups are graphically presented in Figure 1A-F. The obese group is denoted by a square

Grade 4			Grade 7				
OW N.=24	OB N.=13	OW/OB N.=37	UW/ST N.=36	Normal N.=122	OW N.=26	OB N.=14	OW/OB N.=40
9.99±0.38	9.81±0.37	9.93±0.38	12.86±0.33	12.86±0.39	12.82±0.33	12.91±0.37	12.86±0.39
65.25±0.87	59.69±18.84	63.30±4.18	45.17±14.96	52.45±16.40	50.35±13.88	57.07±17.55	62.70±15.38
64.79±13.01	62.38±18.29	63.95±14.87	59.79±13.24	64.59±10.72	66.35±12.72	65.79 ±9.98	66.15±11.71
65.18±10.37	67.07±12.52	65.81±0.99	53.91±11.02	60.11±10.70	59.65±11.51	63.22±10.35	60.90±11.12
53.13±18.56	52.77±18.08	53.00±18.13	44.83±18.91	50.35±21.17	47.97±17.94	67.95±20.56	54.96±20.98
61.70±15.15	63.69±22.02	62.57±17.71	55.11±14.12	60.39±12.29	59.45±15.39	60.31±12.11	59.75±14.17
141.38±6.53	139.19±7.44	140.61±6.85	145.89±3.54	155.79±5.90	155.95±6.19	155.74±10.09	155.88±7.65
43.01±4.30	54.92±19.59	47.19±13.15	36.02±4.75	44.98±6.64	59.87±6.39	81.54±22.72	67.45±17.54
21.49±1.19	29.12±9.83	24.17±6.84	17.13±1.93	18.51±2.17	24.74±2.20	32.63±7.46	27.50±6.02
11.18±3.13	10.33±3.26	11.00±3.16	21.92±14.62	23.73±12.97	15.85±6.92	11.54±5.34	14.41±6.69
38.41±1.09	38.28±1.30	38.36±1.15	38.94±5.18	39.62±4.67	36.83±2.59	35.19±2.02	36.28±2.52
32.21±3.68	39.26±8.74	34.48±6.66	19.84±5.70	22.34±6.11	34.81±5.07	40.25±4.26	36.62±5.42
34.11 ±4.28	45.00±13.46	37.94±9.99	16.90±5.02	20.78± 6.99	38.67±8.87	55.28 ±19.05	44.49±15.35

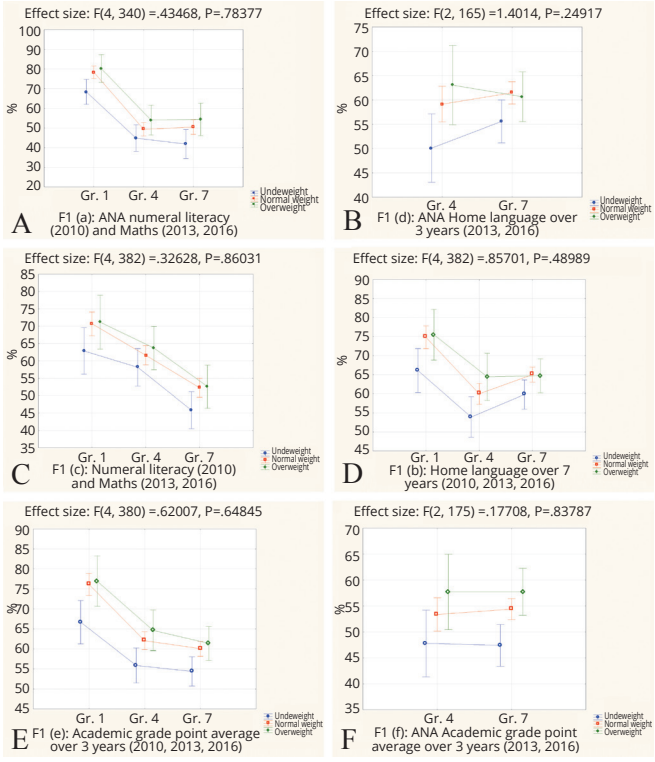

Figure 1.—A-F) Academic performance of normal weight, underweight and overweight BMI groups in math, language and grade point averages.

sign. All figures show that the underweight group had the lowest academic achievement scores at each time point, which was also significantly lower in most cases while the obese group showed in the highest mean scores up to grade 4. Thus, we can conclude that Home language, grade point average, ANA math average and ANA grade point average of the underweight group is significantly lower than the obese group. After grade 4 the trend changed as interaction effects are observed between the obese and normal weight groups, especially in language achievements (Figure 1B, D). This can however only be interpreted as trends as the interaction effects were not significant (Figure 1B, D).

This study furthermore tested the theoretical assumption that physical fitness, more specifically cardiovascular fitness, will exert a mediating effect on the relationship between obesity and academic achievement. Structural Equation Modelling was used for this analysis as displayed in Figure 2. The Goodness of Fit Comparative Measure was used to test this hypothesis. The model that was developed is characterized good with regards to all requirements as seen in Table III (RMSEA: 0.60; CMIN/DF: 2.837; CFI: 0.966).[33] Figure 2 depicts that VO_2 max has a negative relationship with biological development (-0.137) and body composition (-0.359). In contrast, VO_2 max shows a statis-

tically significant relationship with academic performance (0.367). Figure 2 also indicates a standardized indirect effect of body composition on academic performance with a negative relationship (-132) (Table IV). Furthermore, a standardized direct effect with a positive relationship (0.183) between body composition and academic achievement are also seen. Biological development and body composition show a positive correlation (0.538) with statistical significance as part of the comparative fit.

The goodness of fit criteria measures was all well suited to the data of the group in grade 7, at age 12 as can be seen in Table III. The cut-off points for all three requirements were met, namely RMSEA (root square of GKR estimate) (0.060; 0,059), CMIN/DF (χ^2/degrees of freedom) (2.837; 2.774), CFI (comparative compliance measure with a 95% confidence interval) (0.966; 0.966).

TABLE III.—*Comparative compliance measures (goodness of fit).*

Predictor	CMIN/DF	CFI	RMSEA (with 95% CI)
School performance	2.837	0.966	0.060 [0.40; 0.81]
Departmental performance	2.774	0.966	0.059 [0.39; 0.80]

RMSEA: root-mean-square error of approximation; CFI: comparative fit index (comparative compliance criteria with a 95% confidence interval); CMIN/DF: χ^2 minimum sample discrepancy divided by degrees of freedom (χ^2 squared/degrees of freedom).

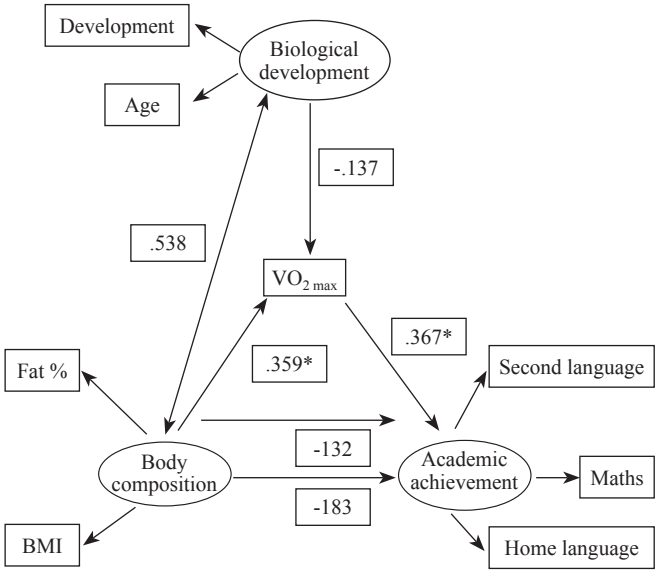

Figure 2.—Standardized effects *via* the structural equation model.

TABLE IV.—*Relationships between body composition and academic.*

Relationship between body composition and academic performance		
Standardized total effect	Standardized direct effect	Standardized indirect effect
0.052	0.183	0.132

Discussion

In this sample, 13.13% were obese in grade 1, 18.6% in grade 4 and 20.2% in grade 7. These prevalence's not only show sizeable increases over the primary school period of 7 school years, but also signifies that excess weight gain at an early age, can become a permanent condition with associated negative effects, as reported by various studies.[1, 7-12] Obesity is reported as a world reality among children with associated psychosocial consequences due to educational disadvantages identified in these children.[7, 22] As preventative and reversal strategies are essential to combat obesity, it is important to better understand the possible relationship between educational performance and mediating factors such as physical fitness, that are associated with obesity. This study aimed at determining the long-term influence of overweight on academic achievement and the possible mediating effect of physical fitness on the academic performance of primary school girls.

Contrary to what was expected, no significant academic achievement differences were found between normal weight and obese participants. The overweight and obese groups mostly achieved higher academic values during the follow-up measurements, although none of these differences were significant. However, Figure 1B, D show a trend change from grade 4 onwards, reflecting a decrease in language skills in the obese group when compared to the normal weight group. These differences were also still insignificant in the grade 7 year, at the mean age of 12 years. While the expectation was that obese children would fare worse, many contradictions about the possible relationship between obesity and academic achievement are also reported in the literature. In line with these findings, various studies also reported no differences. Kaestner *et al*.[34] reported that obese girls aged 5-12 years old achieved similar academic achievements as those who maintained a normal weight. In a study on Taiwanese children that moved from normal weight to overweight or obese after grade 1, Chen *et al*.[35] could also not find any relationships between obesity and academic achievement over a long-term period of 6 years. Furthermore, Black *et al*.[36] also confirmed that the academic performance of girls between 8-13 years old, in subjects such as math and languages, were not affected by obesity or BMI when corrections were made for

socio-demographic factors. Similar results are also supported by Datar *et al*.[37] when corrected for SES. Therefore these findings are contradictory to studies which indicated that overweight and obesity negatively affect academic performance.[12, 15, 16] In this regard, several longitudinal studies have confirmed significant negative relationships between academic achievement and overweight and obesity.[36, 38-40] The Longitudinal Study of Australian Children (LSAC), which included five follow-ups from 2004-2012, has shown that according to the last three measurements in grade 3, grade 5 and grade 7, BMI is negatively associated with academic achievement in girls.[36] A literature review also reveal several studies that report negative influences of overweight in adolescent children at the age of 14 years, while the same trends are also found in obese girls aged 13-14 years old.[41]

However, it is important to note that minor or non-significant relationships between obesity and academic achievement do not necessarily indicate that obesity is not an important factor contributing to academic achievement.[37] According to researchers, the influence of obesity on neurologic networks and structures must be present over a long period of time for it to create a negative academic effect.[34] In addition, researchers[35] also indicate that different forms of analysis of variables, different analytical techniques, and differences in cultures (ethnicity) and age can also contribute to a better understanding of the inconsistency between findings of studies. Wang *et al*.[40] believe that studies which make use of BMI as an indicator of obesity may also not be sensitive enough to capture the cognitive effects of obesity. Reasons such as discrimination by peers and bullying can also cause obese children to withdraw from interactions with peer groups, thus spending more time alone, which provides them with more time to spend on academic commitments, leading to equal or even better academic achievement than children who maintain a normal weight.[34] According to Kaestner *et al*.,[34] the effect of discrimination on the basis of weight is also greater as girls grow older, and which may give rise to different results at an older age, and which consequently makes it important to investigate these relationships and correlations in older children as well. A noteworthy finding was that the underweight group performed the poorest in all academic comparisons. This group was not the focus of this study as was discussed earlier, but more research is recommended in this regard as research shows in this regard that long-term growth impairment is related to cognitive impairment and poorer school attendance which was confirmed by our results.[42, 43]

A second main finding of the study is that physical fitness has emerged as a mediating factor that can exert both beneficial and detrimental influences on academic achievement. The results revealed that cardiovascular fitness had a mediating effect on the academic achievement of girls who were both obese and unfit during the final measurements in grade 7, where lower academic achievement was found in overweight and obese unfit girls, compared to in obese and non-obese fit girls. Sardinha *et al*.[44] investigated the relationship between cardiovascular fitness and weight status on academic achievement of 1531, grade 7 children (boys=787; girls=744) over a two-year period. Their study confirmed statistically significant differences between weight status and cardiorespiratory fitness, where children who maintained a normal weight for age as well as better cardiorespiratory fitness, performed better academically.[44] Bezold *et al*.[45] also reported that girls who had undergone a significantly noticeable increase in physical fitness over a 3-year period (grade 6-8) performed better academically compared to those who have not shown any change in their fitness levels. The effects of a decrease in physical fitness are also reported in the study where the decrease in physical fitness resulted in reduced academic achievement.[45]

Only a few studies have used the SEM method to analyze the relationship between academic achievement, BMI and physical fitness where hypothesis testing determined the mediating effect of aerobic fitness on academic achievement. All criteria in the SEM model (goodness or fit) were well-suited to the hypothesis that confirms this mediating effect of aerobic fitness in obese girls. Similar results were also reported by Garcias-Hermoso *et al*.[46] who found that the effect of BMI on academic performance may be partially or completely mediated by physical fitness and muscle strength. Although their study was performed on slightly older children with a mean age of 13.8 years,[46] it is consistent with the findings of this study on girls of 12.8 years of age.

Several studies confirm that cardiorespiratory fitness is an important predictor of academic achievement.[14, 44, 45, 47] It appears that cardiorespiratory fitness and muscle endurance can improve cognition and the ability to improve oxygen absorption in obese individuals over the long term.[12] According to Santana *et al.*,[48] aerobic fitness shows positive relationships with academic achievement in girls, regardless of the BMI, body fat percentage and SES. A systematic literature review which reviewed similar components over the long term also confirms a positive link between academic achievement and physical fitness where

most studies also used the Fitnessgram and categorization in the HFZ in girls aged 5-13 years old.[19]

The results also highlighted a health risk in overweight girls (Table II) where the combined overweight and obese group (38.36 mL/kg/min) already performed below the HFZ (healthy fitness zone; VO_2 max ≥40.2 mL/kg/min) from as early as 9.8 years old. A decrease in their aerobic fitness is also observed at 12.8 years of age (36.29 mL/kg/min) and the OW/OB group again performed below the HFZ (VO_2 max ≤37.0 mL/kg/min) (Table II). The separated obese group presented with even worse cardiorespiratory fitness levels at both 9.8 and 12.8 years. Attention should, therefore, be paid to the improvement of cardiorespiratory fitness of obese girls to prevent the proliferation of this trend over the long term. If obese girls can become fitter over the long term, there is a possibility that the observed tendency that older obese girls do not perform as well as in grade 4 (Figure 1) might be reversed through higher physical fitness. Improvement of aerobic fitness is a fairly easily modifiable negative influence that can be addressed by appropriate physical activity and fitness programs; thus exercising can have a reversible effect on health and possible long-term academic achievement.

Although this research did not uncover a significant negative relationship between obesity and academic achievement among girls between nine and 12 years, such relationship become possible with worsening effects later in the child's life. Physical fitness can be a long-term counterstrategy in these potential future relationships. However, as stated in the above discussion, there are still conflicting results regarding the relationship between obesity and academic scores which necessitate further research in this regard.

Strengths and limitations of the study

The strength of this study lies primarily in the longitudinal nature of the analyses as well as the various variables that could be associated with each other by means of the structural equation model for hypothesis testing. The study included a large group of primary school girls who were randomly selected, representing the population composition of South Africa throughout the primary school period with longitudinal follow-up measurements over a 7-year school period. No studies have previously been conducted in this regard where academic achievement, body composition, and physical fitness were analyzed, especially not in South African girls over the long term. However, there were also limitations that need to be highlighted that could affect the results. Only an indirect measurement of cardiovascular fitness was used, therefore the maximum aerobic capacity (VO_2 max) of the participant could have been underestimated due to factors such as body composition and motivation.[49] Furthermore, the conditions at all schools were not always equally beneficial to perform the aerobic test, especially at low quintile schools where there were not always sports areas with level surfaces. A significant dropout rate over the follow-up period of the study may have affected the generalization of the findings.

Conclusions

The protective effect of aerobic physical fitness on cognitive functioning has clearly emerged from the findings of this study which necessitate attention to this important link that was established. Although overweight does not show an inhibitory effect on early academic achievement, it already affects girls' health from the age of 9 years as was seen in their significantly low physical fitness levels during the first follow-up of the study in the grade 4 year. Therefore, preventive strategies should be put in place to combat obesity in young South African females.

Although withdrawal from physical activity at a young age may be beneficial to make more time available for academics, the effects of such withdrawals can lead to unhealthy physical fitness levels where these children will not obtain the reversible long-term effect of this health benefit. The Department of Basic Education should, therefore, implement preventive strategies such as implementing more physical activity programs at schools that are important not only for sport but also for children's health. This will provide opportunities for girls who want to be physically active, but who do not participate in school sports. Furthermore, it is also important for children and especially parents to be informed about the benefits of healthy living and physical fitness in order to encourage children to become more physically active. Lifestyle habits start at home, therefor parents need to set an example and to participate in physical activity, such as cycling or walking with their children. It is also the responsibility of physicians in collaboration with the Department of Basic Education to support schools and to provide elucidation about the importance of physical activity, especially physical fitness for health with benefits in terms of cognitive outcomes.

It is recommended that similar studies be conducted on adolescent girls to determine this mediating effect of physical fitness in older girls, as well as to conduct similar studies in other provinces of South Africa. Research by Kaestner *et al*.[34] indicates that sleep disorders, the development of other health-related conditions associated with

high body mass such as asthma, lower physical activity, depression, bullying, and discrimination are all factors that can strengthen this connection in the future.[34] Therefore preventative strategies should be put in place to combat obesity in young South African females. The longitudinal relationship of underweight to academic achievement should also receive more research attention.

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