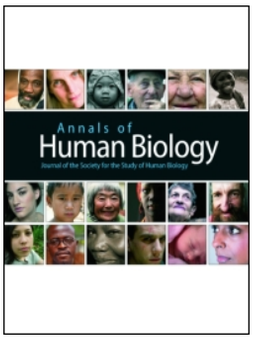

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RESEARCH PAPER

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Relationships between different nutritional anthropometric statuses and health-related fitness of South African primary school children

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ABSTRACT

Background: A double burden of both under- and over-nutrition exists among South African children.
Aim: To describe associations between nutritional statuses and health-related fitness test performances.
Subjects and methods: Height and weight of 10 285 children (6–13 years; $n = 5604$ boys and 4681 girls) were measured and used to calculate body mass index (BMI) and prevalence of overweight and obesity, stunting, wasting and underweight. Physical fitness scores for standing long jump, shuttle run, sit-and-reach, sit-up (EUROFIT) and cricket ball throw were assessed. Age- and gender-specific *z*-scores were calculated for these variables. Physical fitness for each nutritional status group was compared to children of normal weight.
Results: Compared to normal weight children, overweight and obese children scored lower on all fitness tests ($p < .001$), except cricket ball throw ($p = .235$) and sit-and-reach ($p = .015$). Stunted and underweight children performed poorer than normal weight children on most fitness tests ($p < .001$), except sit-and-reach (stunted: $p = .829$; underweight: $p = .538$) and shuttle run (underweight: $p = .017$). Performance of wasted children was not as highly compromised as other under-nourished groups, but they performed poorer on the cricket ball throw ($p < .001$).
Conclusions: When compared to normal weight children, both under- and over-nourished children performed poorer on some, but not all, health-related fitness tests.

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KEYWORDS
South African primary school children; obesity; overweight; stunting; wasting; underweight; health-related fitness

Introduction

Physical fitness during childhood and adolescence is a strong predictor of future health; with cardio-respiratory fitness associated with adiposity and cardio-respiratory and muscular fitness associated with cardiovascular disease risk factors (Ortega et al., 2008). However, the physical fitness of children has declined in many countries in the past few decades (Tomkinson et al., 2003). Further to this, there has been a rapid increase in overweight and obesity among children, especially in urbanised populations and economically developed countries (Katzmarzyk et al., 2015; Wang & Lobstein, 2006). Associated with the nutrition transition, childhood overweight and obesity has also increased in some developing nations, including South Africa (Armstrong et al., 2011b; de Onis et al., 2010; Filozof et al., 2001; Puoane et al., 2002; Rivera et al., 2002). On the African continent there was an increase in the prevalence of overweight and obesity from 4.0% in 1990 to 8.5% in 2010 (de Onis et al., 2010). The prevalence of stunted children in Africa over this time period barely changed from 40.3% in 1990 to 38.2% in 2010 (de Onis et al., 2011). This dual burden of under- and over-nutrition may manifest at the community, household, or individual level, and presents complex challenges to governments and health organisations when trying to implement programmes that effectively target opposite ends of the malnutrition spectrum (Tzioumis & Adair, 2014). We previously showed that over the 10 year period from 1994–2004 there was a secular decline in the levels of stunting but a concurrent increase in overweight and obesity among South African children (Armstrong et al., 2011b). However, despite these decreases, stunting is still a problem among young black South African children (Said-Mohamed et al., 2015), and information is scarce on how under-nutrition is associated with health-related fitness.

With increasing evidence of the nutrition-transition in developing countries (Adamo et al., 2010; Armstrong et al., 2011b; Jinabhai et al., 2003; Popkin, 2001) it is important to consider the relationship between both under- and over-nutrition and health-related fitness in children from developing nations. We hypothesised that both under- and over-nutrition would have a negative impact on health-related fitness. Therefore, the purpose of this study was to determine whether differences in nutritional status were associated with health-related fitness test performance of South African primary school children.

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Supplemental data for this article can be accessed here.

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Methods

The basic anthropometry and physical fitness of 10 285, 6–13 year old children ($n = 5604$ boys and 4581 girls) from primary schools in South Africa were assessed during the Discovery Vitality Health of the Nation Study from 2001–2004. The study design, selection of schools and subjects and testing protocols have been described elsewhere (Armstrong et al., 2006, 2011a). Briefly, a minimum of five randomly selected schools of varied socioeconomic status from each of five South African Provinces (Western Cape, Eastern Cape, Gauteng, KwaZulu Natal and the Free State) were invited to participate in the study. If a school chose not to participate another school was randomly selected as a replacement. This sampling method resulted in a diverse mixture of socioeconomic and ethnic backgrounds. Socioeconomic status was calculated according to variables such as average income, unemployment rate and level of education/literacy level in the school catchment area.

The research team trained the fieldworkers in each province and quality control was ensured through members of the research team acting as observers during the testing phase of the project. Height and weight of each child was measured and used to calculate BMI, and nutritional anthropometric indicators of under- and over-nutrition (Armstrong et al., 2006). Each child was invited to participate in five tests of physical fitness including: standing long jump, shuttle run, sit-and-reach, sit-up and cricket ball throw (Armstrong et al., 2011a). While no information on test–re-test reliability was collected during this study, most tests were from the validated EUROFIT test battery. Demographic data including age, gender and ethnic group were also recorded. Written consent was required from the parent or guardian and verbal assent from each child prior to participation. Further to this, each Provincial Education Department and the Human Research Ethics Committee of the University of Cape Town approved this study. Further details of the data and access policies can be obtained from the lead author.

Statistical methods

We first excluded all subjects with missing data for BMI, those younger than 6 years of age and those older than 13 years of age. Measures of under-nutrition were calculated according to the WHO 2007 definitions (WHO Multicentre Growth Reference Study Group, 2006) and used to classify children according to stunting (height-for-age < -2 *z*-score), wasting (BMI-for-age < -2 *z*-score), stunting and wasting (height-for-age < -2 *z*-score and BMI-for-age < -2 *z*-score), and under-weight (weight-for-age < -2 *z*-score, restricted to 6–9 year olds as per WHO 2007 definitions (WHO Multicentre Growth Reference Study Group, 2006)). Measures of over-nutrition, including overweight and obesity, were calculated according to the International Obesity Task Force definitions (Cole et al., 2000). Summary statistics of the overall proportions of children within each nutritional status category were calculated, adjusted for age. Summary fitness test score data were calculated for each nutritional status group, adjusted for age and gender.

Z-scores were calculated for each fitness test according to gender and age group. This controlled for test-specific differences related to age and gender, thereby allowing for standardised comparisons of physical fitness between the children. Summary statistics were then calculated for each fitness test, according to each over- or under-nutrition measure vs normal weight children (i.e. those without nutritional deficiencies). For example, for overweight and obese children combined, comparisons were made against children not classified in any of the under-nourished groups (i.e. not including stunted, wasted or underweight children). For the shuttle run, for which a higher score represents a poorer performance, the sign of the *z*-score was reversed to allow for consistency. Pairwise correlations were calculated to provide an overview of the associations between ethnicity, socioeconomic status, and the different fitness test variables. Bonferroni adjustments for multiple comparisons were made, testing at the 0.05 significance level. Correlations were squared to calculate the coefficients of determination.

Linear regression models were used to assess whether there were differences between the physical fitness test scores of children with under- or over-nutrition, compared to the normal weight group. Likelihood ratio tests were conducted to determine whether there were interactions between nutritional statuses and socioeconomic status or ethnicity. Significance was assessed using a Bonferroni correction for multiple comparisons, testing at the 0.05 significance level. Regression models were used to assess whether there were differences in fitness test *z*-scores according to nutritional status, testing at the 0.05 significance level and using a Bonferroni correction for multiple comparisons. These models were adjusted for socioeconomic status and ethnicity. The use of fitness test *z*-scores, calculated according to age and gender, meant that both age and gender were already taken into account in the models. As data were collected from 61 different schools, these models were also adjusted for school clusters. To assess overall model quality, regression models were run using raw fitness test scores, first minimally adjusted for age, gender and school clusters. Fully adjusted models were then run with the addition of socioeconomic status and ethnicity. Statistical analyses were performed using STATA version 14.0 (version 14.0, Statacorp, College Station, TX).

Results

For the full study population of 6–13 year old children (10 285), 8.1% (828) were stunted, 5.4% (561) were wasted and 0.7% (75) were stunted and wasted, according to the WHO 2007 norms (WHO Multicentre Growth Reference Study Group, 2006). According to the IOTF norms (Cole et al., 2000), 15.4% (1564) were overweight or obese. In the full sample, 72.3% (7432) of children were of normal weight and used as the comparison group. Of the 6–9 year old children

Table 1. Mean fitness test scores for each nutritional status group adjusted for age and gender. Values are expressed as mean ± standard deviation and sample size (*n*).

	Sit-and-reach	Standing jump	Sit-ups	Shuttle run	Ball throw
Normal weight[a]	22.8 ± 7.9 (7399)	160.0 ± 23.0 (7385)	16.4 ± 5.3 (7422)	22.4 ± 2.1 (7392)	21.7 ± 6.7 (7371)
Overweight/obese	22.1 ± 7.9 (1561)	150.3 ± 23.0 (1560)	14.3 ± 5.3 (1561)	23.0 ± 2.1 (1560)	21.6 ± 6.7 (1550)
Stunted	22.2 ± 7.8 (825)	141.4 ± 22.9 (825)	13.9 ± 5.2 (828)	23.4 ± 2.1 (824)	18.8 ± 6.6 (821)
Wasted	21.8 ± 8.0 (560)	158.5 ± 23.2 (559)	16.2 ± 5.2 (561)	22.5 ± 2.0 (559)	19.8 ± 6.7 (558)
Stunted and wasted	20.8 ± 8.0 (75)	140.8 ± 23.1 (74)	13.6 ± 5.2 (75)	23.1 ± 2.1 (75)	17.2 ± 6.7 (74)
Underweight[b]	22.3 ± 7.1 (219)	126.7 ± 22.7 (219)	11.1 ± 5.3 (219)	24.3 ± 2.3 (217)	12.3 ± 5.2 (218)
Normal weight[c]	23.0 ± 7.1 (2933)	140.4 ± 22.6 (2922)	13.7 ± 5.3 (2933)	23.4 ± 2.3 (2909)	15.1 ± 5.2 (2906)

[a]Age and gender adjusted in comparison to overweight or obese group in full 6–13 year age range.
[b]Restricted to 6–9 year olds.
[c]Age and gender adjusted in comparison to underweight group, restricted to 6–9 year olds.

(3957), 5.8% (219) were underweight, and 74.2% (2938) were of normal weight.

Table 1 presents mean fitness test scores according to nutritional status. Sit-and-reach scores tended to be similar regardless of nutritional status. There were larger differences between standing jump, sit-ups and ball throw scores according to nutritional status. There was a moderate-to-strong correlation between socioeconomic status and ethnicity (Supplementary Table S1), with an R^2 value of 0.46. There were weak positive correlations between both socioeconomic status and ethnicity, when compared to standing jump, sit-ups and shuttle run (Supplementary Table S1). Likelihood ratio tests indicated very few significant interactions between nutritional status and socioeconomic status and between nutritional status and ethnicity, for the various fitness test outcomes (Supplementary Table S2). The regression models were strong for all fitness test outcomes, except sit-and-reach (Supplementary Table S3). Ball throw scores seemed to be largely influenced by gender and age, as the addition of ethnicity and socioeconomic status to the model had very little effect on the overall model R^2 values (Supplementary Table S3).

The performance of overweight and obese children combined was significantly poorer than normal weight children on all except the sit-and-reach and the ball throw test, for which there was no difference between the groups (Sit-and-reach: $p = .015$; Standing long jump: $p < .001$; Sit-ups: $p < .001$; Shuttle run: $p < .001$; Ball throw: $p = .235$) (Figure 1). Normal weight children outperformed stunted children on all physical fitness tests except the sit-and-reach test, for which the two groups showed an equal performance (Sit-and-reach: $p = .829$; Standing long jump: $p < .001$; Sit-ups: $p < .001$; Shuttle run: $p < .001$; Ball throw: $p < .001$) (Figure 2). The wasted children threw the cricket ball a shorter distance than their normal weight counterparts (Ball throw: $p < .001$). There were no differences between the wasted group and the normal weight group for the remaining physical fitness tests (Sit-and-reach: $p = .473$; Standing long jump: $p = .580$; Sit-ups: $p = .428$; Shuttle run: $p = .124$) (Figure 3). Children who were both stunted and wasted performed poorer on the standing long jump ($p < .001$) and ball throw tests ($p < .001$), but similarly on the other tests (Sit-and-reach: $p = .276$; Sit-ups: $p = .069$; Shuttle run: $p = .747$), when compared to normal weight children (Figure 4). There were no differences between the physical fitness scores of the underweight and normal weight children for the sit-and-reach ($p = .538$) and shuttle run ($p = .017$) tests. However, the underweight children were outperformed on the standing long jump ($p < .001$), sit-up ($p < .001$) and ball throw ($p < .001$) tests (Figure 5).

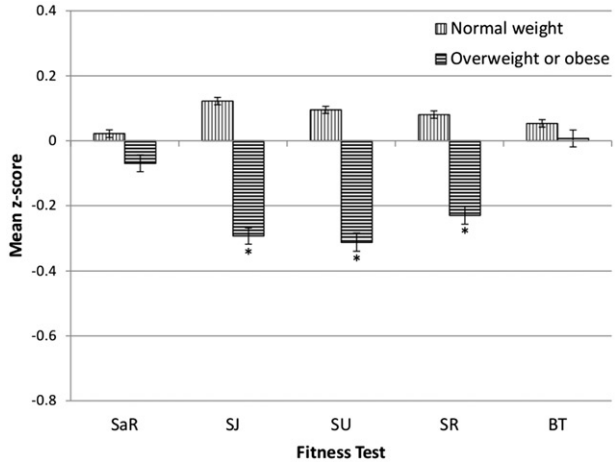

Figure 1. The differences between the physical fitness test scores of children (6–13 years) classified as normal weight compared to those classified as overweight or obese (≥ IOTF cut-off for overweight) (IOTF definitions of overnutrition (Cole et al., 2000)). SaR, sit-and-reach; SJ, standing long jump; SU, sit-up; SR, shuttle run; BT, cricket ball throw, significant differences indicated with *.

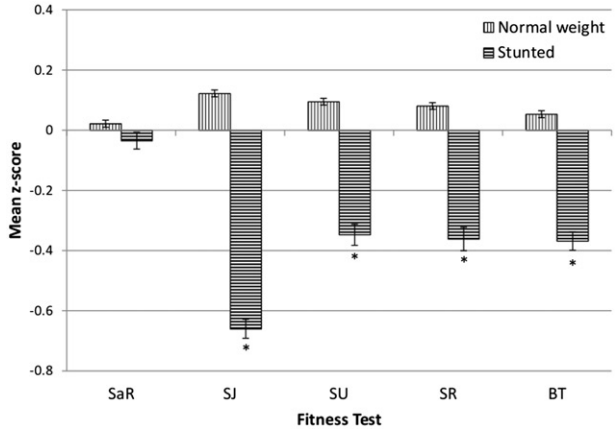

Figure 2. The differences between the physical fitness test scores of children (6–13 years) classified as normal weight compared to those classified as stunted (≤ −2 SD of height-for-age) (WHO, 2007 definitions (World Health Organisation (WHO), 2008)). SaR: sit-and-reach; SJ: standing long jump; SU: sit-up; SR: shuttle run; BT: cricket ball throw, significant differences indicated with *.

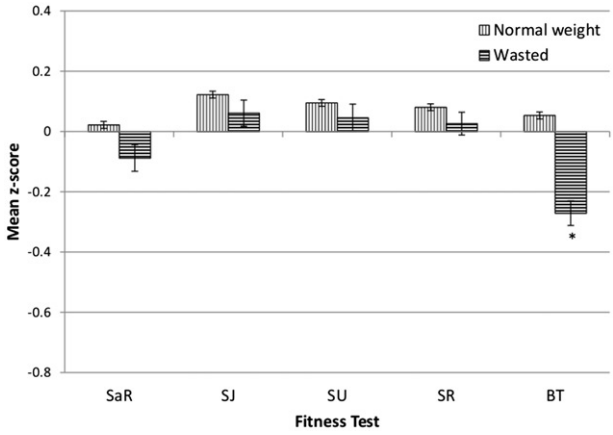

Figure 3. The differences between the physical fitness test scores of children (6–13 years) classified as normal weight compared to those classified as wasted (≤ -2 SD of BMI-for-age) (WHO, 2007 definitions (World Health Organisation (WHO), 2008)). SaR: sit-and-reach; SJ: standing long jump; SU: sit-up; SR: shuttle run; BT: cricket ball throw, significant differences indicated with *.

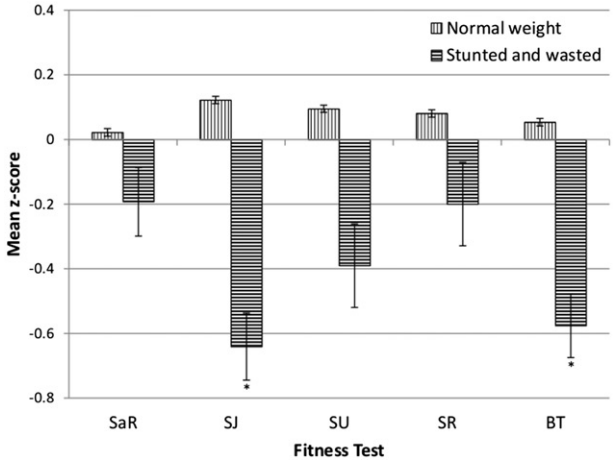

Figure 4. The differences between the physical fitness test scores of children (6–13 years) classified as normal weight compared to those classified as both stunted and wasted (≤ -2 SD of height-for-age and ≤ -2 SD of BMI-for-age) (WHO, 2007 definitions (World Health Organisation (WHO), 2008)). SaR: sit-and-reach; SJ: standing long jump; SU: sit-up; SR: shuttle run; BT: cricket ball throw, significant differences indicated with *.

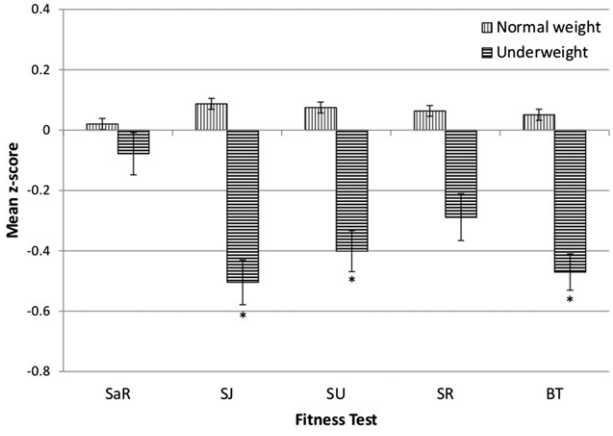

Figure 5. The differences between the physical fitness test scores of children (6–9 years) classified as normal weight compared to those classified as underweight (≤ -2 SD of weight-for-age) (WHO, 2007 definitions (World Health Organisation (WHO), 2008)). SaR, sit-and-reach; SJ: standing long jump; SU: sit-up; SR: shuttle run; BT: cricket ball throw, significant differences indicated with *.

Discussion

We found that normal weight South African children generally performed better on tests of health-related fitness then their over- or under-nourished counterparts, although wasted children performed similarly to normal weight children. This is in agreement with studies considering older children and adolescents which have suggested a non-linear relationship between BMI and health related fitness (Huang & Malina, 2007; Mak et al., 2010). Studies have indicated that over-nutrition may affect the physical fitness of children, with overweight and obese children performing more poorly on physical fitness tests then normal weight children, when required to move their bodyweight through space (Brunet et al., 2007; Ceschia et al., 2016; Dumith et al., 2010; Prista et al., 2003; Raudsepp & Jürimäe, 1996; Sacchetti et al., 2012; Shang et al., 2010; Tokmakidis et al., 2006; Truter et al., 2010). Walking and running at the same speed requires a greater absolute energy expenditure in obese children when compared to normal weight children (Maffels et al., 1993). Additionally, when expressed as a multiple of resting metabolic rate, the energy cost of exercise is greater in obese than in normal weight children (Maffels et al., 1993). Therefore, it would be expected that obese children would be disadvantaged in comparison to normal weight children when tasks require them to move their greater body mass against gravity, such as standing long jump, shuttle run and timed sit-up test. Our results indicated that this was the case among South African children and was in agreement with the majority of other studies in different populations (Brunet et al., 2007; Ceschia et al., 2016; Dumith et al., 2010; Prista et al., 2003; Raudsepp & Jürimäe, 1996; Sacchetti et al., 2012; Shang et al., 2010; Tokmakidis et al., 2006; Truter et al., 2010). While our model was unable to explain much of the variance in sit-and-reach scores according to over-nourished vs normal weight children, our results were in agreement with other studies indicating that flexibility was not affected by over-nutrition (Ceschia et al., 2016; Dumith et al., 2010; Malina et al., 2011; Pongprapai et al., 1994; Sacchetti et al., 2012; Tokmakidis et al., 2006). The cricket ball throw is a test of upper arm power and motor co-ordination in which the overweight or obese child is less disadvantaged by their excess weight, thereby explaining their ability to perform on par with normal weight children. Our results are similar to those of others also testing upper body strength and power (Ceschia et al., 2016; Dumith et al., 2010; Sacchetti et al., 2012).

The relationships between under-nutrition and health-related fitness are less well studied. We found no difference between the flexibility of the under-nourished vs the normal weight groups, but our models were unable to explain much of the variance between these groups. Results from other studies were mixed for sit-and-reach (Malina et al., 2011; Monyeki et al., 2005; Prista et al., 2003).

We found that stunted children were the most disadvantaged, performing poorer than normal weight children on four out of the five fitness tests, followed by underweight children, who performed poorer than normal weight children on three out of the five fitness tests. Wasted children

performed similarly to normal weight children. Prista et al. (2003) showed that under-nourished children were disadvantaged on tests of strength. Monyeki et al. (2007) found that activities requiring short-term, high energy release, such as the standing long jump, were negatively affected by muscle wasting in a group of malnourished South African children. Malnutrition and nutritional deprivation during the growth of children may cause structural, metabolic and functional changes in skeletal muscle which manifest as a decrease in the size and number of fast-twitch muscle fibres, yet slow-twitch fibres are spared (de Jonge et al., 1996; Essen et al., 1981; Jeejeebhoy, 1986; Malina & Bouchard 1991; Russell et al., 1984). Different muscle fibre types affect different aspects of physical performance and these changes would result in a reduced capacity to perform exercise tasks of relatively short duration, as noted among the groups of stunted, stunted and wasted and underweight children in our study. Results from previous studies are mixed, with some (Malina et al., 2011; Prista et al., 2003), but not others (Monyeki et al., 2005; Shang et al., 2010) showing poorer performance in standing long jump for under-nourished compared with normal weight children. Two studies (Malina et al., 2011; Monyeki et al., 2005) showed no difference for sit-up performance between under-nourished and normal weight children, while one (Prista et al., 2003) showed a poorer performance among under-nourished children.

The strengths of this study include the large sample size and the diverse range of children from a variety of ethnic and socioeconomic groups, sampled from multiple regions across South Africa. Information on the diet and nutrition of the children was not collected, which may have added additional insight to the interpretation of results.

Our results support our original hypotheses and show that both under- and over-nutrition generally had a negative impact on the health-related physical fitness of South African children a decade ago, with these youth now starting to become the economically viable sector of the South African population. While stunting in young South African children has decreased over the past few decades, it is still a problem, especially among young black children (Said-Mohamed et al., 2015). Both nutritional status and health-related fitness may be important indicators of health, equity and development in South African children. Therefore, continued and periodic evaluation of both under- and over-nutrition, as well as health-related fitness of South African youth may be important for monitoring the progress of nutritional policies and physical activity programmes in schools.

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Disclosure statement

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