

Prevalence of overweight and obesity among selected schoolchildren and adolescents in Cofimvaba, South Africa

Olufunmilola Otitoola^{a,b}, Wilna Oldewage-Theron^{b,c}  and Abdul Egal^{b,*} 

^aDepartment of Nutrition and Dietetics, Federal Polytechnic, Ede, Nigeria

^bCentre for Sustainable Livelihoods, Vaal University of Technology, Vanderbijlpark, South Africa

^cDepartment of Nutritional Sciences, Texas Tech University, Lubbock, Texas, United States

*Corresponding author, email: abdul@vut.ac.za



Background: Childhood obesity has become a growing global epidemic. In South Africa, overweight and obesity during childhood and adolescence are rising. The objectives of this study were (i) to estimate the prevalence of overweight and obesity among selected students in Cofimvaba, a rural settlement in Eastern Cape province, South Africa, and (ii) to assess the accuracy of the mid-upper arm circumference (MUAC) and ultrasound triceps skin-fold thickness (TSF) methods of predicting these health parameters

Methods: A cross-sectional study was conducted on 211 students (109 girls and 102 boys) selected randomly from five public schools in Cofimvaba and aged 6–19 years. The weight, height, MUAC and TSF were determined by standard techniques. Data obtained were subjected to descriptive statistics, Pearson correlations and receiver operating characteristic (ROC) curve analysis. $P < 0.05$ was considered statistically significant.

Result: Overall 1.9% (1.8% girls and 2.0% boys) of the respondents were underweight, 14.8% (21.1% and 7.8% boys) were overweight and 2.8% (4.6% girls and 1.0% boys) were obese. The prevalence of overweight and obesity was significantly higher ($p < 0.05$) in girls than boys during adolescence but there was no gender difference in children (6–9 years). Most of the students (80.6%) had a healthy weight, with boys being significantly ($p < 0.05$) healthier than girls. The BMI showed significant strong correlations with MUAC ($r = 0.926$; $p < 0.001$) and TSF ($r = 0.643$; $p < 0.001$). ROC curve analysis gave an area under the curve (AUC) of 0.795 (95% CI, 0.761–0.889) and 0.835 (95% CI, 0.771–0.899) for MUAC and TSF respectively.

Conclusion: The study found a high prevalence of overweight children in the sample and a low prevalence of stunting and underweight. The adolescent girls are at a higher risk of being overweight and obese than the boys. MUAC and TSF can adequately predict overweight and obesity among the selected students.

Keywords: children and adolescents, Cofimvaba, MUAC, obesity, overweight, TSF

Background

Childhood obesity has become a growing global epidemic.¹ In 2010 it was estimated that 43 million children were overweight and obese with 81% of these coming from developing countries. It was projected that by 2020 almost 1 in 10 children worldwide and 1 in 8 children in Africa will either be overweight or obese. Childhood obesity has been reported to be higher among South African children (17.1% to 22.8%).² Adolescence (10–19 years), a transition phase between childhood and adulthood, is a critical period for the onset of obesity and for obesity-associated morbidity in later life.³

The South African National Health and Nutrition Examination Survey (NHANES-1) reported a combined overweight and obesity prevalence of 13.5% in children aged 6–14 years, which is higher than the 10% global prevalence in schoolchildren.⁴ The South African Primary School's Anthropometric and Health Survey (1994) and the Health of the Nation Study (2001/2004) estimated an increase in overweight individual from 1.2% to 13% and obesity from 0.2% to 3.3% from 1994 to 2004, respectively.⁵ It became clear that, although the prevalence of stunting decreased over the period, the trend of being overweight and obese increased. Successive studies have also confirmed this trend.⁶

Body mass index (BMI) is the internationally recommended criterion for defining overweight and obesity in children and

adults but it has some limitations.⁷ MUAC, used to determine under-nutrition in children using arm muscle and arm fat muscle, has recently been proposed as another significant indicator of overweight and obesity in children and adolescents.⁷ It is an easy and quick way to measure overweight and obesity and requires only an inexpensive flexible tape.⁷

Triceps skinfold thickness has also been shown to be a good indicator of the amount of body fat and is positively correlated with BMI. Although closely related to BMI, TSF has been reported to predict the amount of body fat better than BMI.⁸

Eastern Cape is the third largest province in South Africa but the second poorest, where 50% of households in the rural districts are food insecure.⁹ Studies on the prevalence of overweight and obesity in this rural area are scarcely documented. This study will therefore add valuable information in describing the prevalence of overweight and obesity in this region and also determine the accuracy of MUAC and ultrasound TSF to identify high BMI in children and adolescents.

Subjects and methods

Ethics and informed consent

Ethical clearance was obtained for the study from the Senate Research and Innovation Ethics Committee of the Vaal University

of Technology (20130520-3) and the Council of Scientific and Industrial Research (CSIR) (75/2013). Written permission was obtained from the School Management Board in Eastern Cape. The research was conducted according to the Medical Research Council's guidelines for research on human beings as well as the Helsinki Declaration agreement guidelines. Prior to the study a meeting was held with the parents of the children and they were informed about the purpose of the study and the assessment to be conducted on their wards. Those that agreed signed written informed consent (parents and adolescents) and assent (children) forms, respectively.

Study settings

The study was conducted in Cofimvaba, a rural community in the Chris Hani District Municipality in the Eastern Cape province of South Africa.¹⁰ It is situated 79 km east of Queenstown and has a land area of 21.19 km² and a predominant black population of over 9 000. Cofimvaba is characterised by high levels of poverty and unemployment with critical skill shortages, subsistence farming, food insecurity and HIV/AIDS. A low level of education among the adult population was observed with less than a third having some form of secondary education and only 4% postsecondary education.¹⁰

Study design and population

The sample size was calculated using the formula¹¹

$$\text{Sample size} = Z^2 * p * (1 - p) / c^2$$

where $Z = Z$ value of 1.96 for 95% confidence level, $p = 80\%$ expressed as a decimal (0.8 used for sample size needed) and $c =$ confidence interval of 6.5, expressed as 0.065.

$$\text{Sample size} = 1.96^2 * 0.8(1 - 0.8) / 0.065^2 = 146$$

Of the 21 schools ($n = 5\ 250$ learners) in Cofimvaba, five schools with a population of 1 250 learners aged 6–19 years old were purposively selected by the Department of Basic Education for inclusion in the study, representing 24% of the school-age children in that area. The inclusion criteria were boys and girls in the selected schools between the ages of 6 and 19 years. Students outside that age bracket who reported ill-health or did not present signed informed consent and assent were excluded from the survey. After screening for the inclusion and exclusion criteria, 523 learners were eligible for inclusion in the study from the 556 informed consent and assent forms signed. The sample was then stratified for gender and age and 240 learners were selected from those with informed consent and assent. Data collection was conducted in August 2013 for five days (Monday to Friday).

A total of 211 students aged 6–19 years, randomly selected from five schools using probability according to sample size, completed the survey. A validated well-structured pre-coded socio-demographic questionnaire was used to elicit information on the family characteristics including family size, parental marital status, accommodation type and permanent residency.

Anthropometric measures

The field workers for this study were recruited from the Department of Food and Consumer Sciences at the Walter Sisulu University and trained during two eight-hour sessions by a registered dietitian and a public health nutritionist. The four field workers were trained on the ethical and general research philosophies applicable to research on human beings, the importance of accurate measurement and how to complete

the socio-demographic questionnaire and 24-hour diet recall without interviewer bias (not reported in this study).

The children's ages obtained from school records were confirmed by the field workers. The bodyweight and height were measured by a registered dietitian and public health nutritionist according to standard procedures¹² with a calibrated Philips electronic scale, model HF350 (135 kg/100 g) (Philips, Amsterdam, The Netherlands) with a two-point decimal precision and a Seca stadiometer, respectively. All measurements, which were not to vary by more than 0.1 kg for weight and 0.1 cm for height, respectively, were taken twice and the average of the two measurements recorded.¹³ The height was measured to the nearest 0.1 cm using the stadiometer as each child stood erect and barefoot with heels touching the wall of the stadiometer. Weight was measured to the nearest 0.1 kg as the child stood still on the weighing scale barefoot with light clothes on having emptied his/her pockets. Body mass index was computed using the standard formula $\text{BMI (kg/m}^2\text{)} = \text{weight/height}^2$

The MUAC and TSF were measured by a public health nutritionist. The MUAC was measured on the upper left arm at the midway between olecranon and acromion process using a flexible plastic Seca tape (Seca, Hamburg, Germany). During these measurements, the flexible tape was wrapped round at the midpoint of the upper arm as each child stood in a comfortable position and looking straight ahead with shoulders in normal position and the arm hanging loosely by the side. The tape was examined to ensure it was not too tight or loose and measurement was done to the nearest 1 mm.

The triceps skinfold thickness, which provides a measure of subcutaneous fat, was measured with the aid of a BodyMetrix (BX2000) according to the manufacturer's user guide (BodyMetrix/Intelamatrix, Brentwood, USA). The child stayed in an upright position with the arm hanging loosely by the side, and the ultrasound gel was applied to the posterior surface of the left arm, midway between the olecranon and the acromion process. The tip of the BodyMetrix was used to massage the ultrasound gel on the posterior surface for 1 minute and then pressed firmly for another 30 seconds to measure. The body fat was calculated in percentage from mid-upper arm circumference and triceps fold thickness.¹⁴

Data analysis

Anthropometric data for the students were analysed using the World Health Organization's (WHO, 2010) Anthroplus version 1.0.2 statistical software.¹⁵ Overweight and obesity were defined using age- and gender-specific international cut-off points for BMI.¹⁶ Data obtained were subjected to descriptive analysis, t-tests to detect difference between means, Pearson's correlations to evaluate relationships between anthropometric indices and ROC curves were generated and area under the curve (AUC) calculated to determine the global accuracy measure for MUAC and TSF in predicting overweight and obesity. All analyses were done using SPSS version 20 (IBM Corp, Armonk, NY, USA) and a p value < 0.05 was considered as statistically significant.

Results

Socio-demographic and anthropometric characteristics of the respondents

In total, 211 learners aged 6–19 years completed the study. As shown in Table 1, most of the respondents (74.4%) were

Table 1: Socio-demographic characteristics of the respondents

Factor	n (%)	Overweight by BMI for age (%)	Overweight by MUAC for age (%)
Gender:			
Female	109 (51.9)	25.7*	12.8*
Male	102 (48.3)	8.8	2.0
Age:			
6–9 years	54 (25.6)	20.4	9.3
10–19 years	157 (74.4)	16.6	7.0
Family size:			
< 6 persons	176 (83.3)	17.0*	3.5
≥ 6 persons	35 (16.7)	36.3	11.1
Accommodation:			
Shared	158 (74.9)	20.9	8.5
Not shared	53 (25.1)	8.5	2.0
Permanent residence:			
Yes	189 (89.6)	18.1	6.4
No	22 (10.4)	15.0	10.0

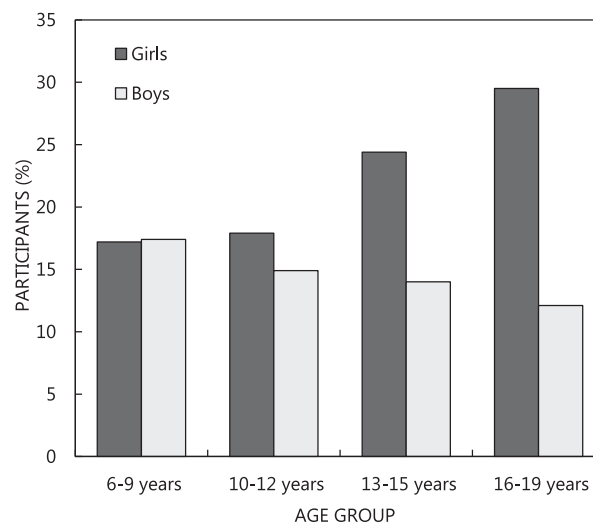
Table 2: Means of anthropometric profiles of the respondents

Factor	Girls (n = 109)	Boys (n = 102)
Age (years)	12.17 ± 3.79	12.80 ± 3.37
Height (m)	144.49 ± 16.62	150.34 ± 19.19*
Weight (kg)	42.52 ± 16.72	41.91 ± 14.90
BMI (kg/m ²)	19.47 ± 4.00	17.88 ± 2.67*
MUAC (cm)	22.21 ± 4.20	21.00 ± 3.36
TSF (mm)	8.86 ± 5.56	4.94 ± 1.28*
Percentage body fat (%)	22.10 ± 10.2	14.3 ± 3.7*

adolescents (aged 10–19 years old) and the gender was spread 51.7% female versus 48.3% male. Also, 74.9% lived in shared accommodation, 89.6% were permanent residents and 83.3% lived in houses with five or fewer persons.

As indicated in Table 2, there was no significant gender difference in the means of age, weight and MUAC. Although the boys were significantly taller ($p < 0.05$) than the girls (144.49 ± 16.62 versus 150.34 ± 19.19), the girls had significantly higher BMI (19.47 ± 4.00 versus 17.88 ± 2.67), TSF (8.86 ± 5.56 versus 4.94 ± 1.28) and percentage body fat (22.10 ± 10.2 versus 14.3 ± 3.7) than boys. Of all socio-demographic characteristics studied, only gender had significant effect on the weight status of the respondents. The girls had a higher prevalence of being overweight both by BMI and MUAC. Other socio-demographic profiles had no significant effect on the weight status of the learners.

The prevalence of overweight and obesity among the respondents is shown in Figure 1. Using the age and gender specific international cut-off points, 1.8% (3.1% girls and 0% boys) of those aged 6–9 years were underweight. Among the adolescents, 1.9% (2.6% girls and 1.3% boys) were underweight. Overall, 1.9% (1.8% girls and 2.0% boys) of the respondents were underweight, 14.8% (21.1% girls and 7.8% boys) were overweight and 2.8% (3.1% girls and 1.0% boys) were obese. The prevalence of overweight and obesity was significantly higher

**Figure 1:** Prevalence of overweight/obesity in Cofimvaba students aged 6–19 years.

($p < 0.05$) in girls than boys during adolescence but no gender difference ($p > 0.05$) was observed in children aged 6–9 years. Most of the respondents (80.6%) had healthy weights and boys were significantly healthier than girls (89.2% versus 72.5%; $p = 0.014$). As shown in Figure 1, while the trend of overweight increased in girls it reduced in boys from childhood to late adolescence.

Difference in TSF and anthropometry according to weight status

Overweight/obese girls had significantly higher values for BMI (18.0 ± 2.7 versus 23.7 ± 4.1), MUAC (20.9 ± 3.3 versus 26.0 ± 4.5), ultrasound TSF (7.7 ± 4.8 versus 12.3 ± 6.2) and % body fat (20.5 ± 9.7 versus 26.7 ± 10.5) than their non-overweight counterparts (Table 3). The same trend was observed for overweight/obese boys.

Correlation between MUAC/TSF and other anthropometric characteristics

Table 4 shows the correlation coefficients of MUAC/TSF with other anthropometric characteristics by gender and age groups. MUAC had strong positive correlations with age ($r = 0.789$ versus $r = 0.736$; $p < 0.001$) and height ($r = 0.819$ versus $r = 0.781$; $p < 0.001$) and very strong positive correlations with weight ($r = 0.959$ versus $r = 0.919$; $p < 0.001$) and BMI ($r = 0.951$ versus $r = 0.888$; $p < 0.001$). Ultrasound TSF had positive correlations with age, height, weight, BMI and MUAC but when stratified into gender there was no significant correlation with age, height and weight in boys. Also, when stratified into age groups, no significant correlation was observed for TSF and height in either children (6–9 years) or adolescents (10–19 years).

Association of MUAC and ultrasound triceps with obesity

Table 5 indicates the accuracy of MUAC and ultrasound triceps skinfold thickness (TST) to predict overweight and obesity in children and adolescents. The area under the curve obtained showed that MUAC and TST had a high level of accuracy (AUC > 0.70) in identifying overweight and obesity in both girls and boys. Across age groups an AUC of 0.763–0.94 ($p < 0.05$) and 0.728–0.924 ($p < 0.05$) was obtained for MUAC and TSF respectively. The overall AUC of 0.795 (95% CI 0.761–0.889) for MUAC and 0.835 (95% CI 0.771–0.899) for TSF showed that both

Table 3: Difference in TSFT and anthropometry according to weight status

Weight status	n	BMI (kg/m ²)	MUAC (mm)	Ultrasound TSFT (mm)	Body fat (%)
Female					
Non-overweight	81	18.0 ± 2.7	20.9 ± 3.3	7.7 ± 4.8	20.5 ± 9.7
Overweight/obese	28	23.7 ± 4.1	26.0 ± 4.5	12.3 ± 6.2	26.7 ± 10.5
Total	109	19.5 ± 4.0	22.2 ± 4.2	8.8 ± 5.6	22.1 ± 10.2
p-value		0.000	0.000	0.000	0.005
Male					
Non-overweight	93	17.5 ± 2.2	20.7 ± 3.1	4.7 ± 1.1	14.1 ± 3.4
Overweight/obese	9	21.8 ± 3.9	24.1 ± 4.6	7.1 ± 1.4	18.0 ± 4.4
Total	102	17.7 ± 2.7	21.0 ± 3.4	4.9 ± 1.3	14.4 ± 3.7
p-value		0.000	0.003	0.000	0.002

Table 4: Correlation coefficients of MUAC/TSF with other anthropometric indicators

Factor	Girls (n = 109)	Boys (n = 102)	6–9 years (n = 54)	10–19 years (n = 157)	Total (n = 211)
Mid-upper arm circumference					
Age	0.789**	0.736**			0.771**
Height	0.819**	0.781**	0.363**	0.602**	0.789**
Weight	0.959**	0.919**	0.828**	0.912**	0.931**
BMI	0.951**	0.888**	0.870**	0.923**	0.921**
Triceps	0.694**	0.236**	0.503**	0.564**	0.508**
Triceps skinfold thickness					
Age	0.607**	NS			0.339**
Height	0.555**	NS	NS	NS	0.240**
Weight	0.682**	NS	0.452**	0.453**	0.478**
BMI	0.695**	0.416**	0.854**	0.621**	0.643**
MUAC	0.694**	0.236**	0.503**	0.564**	0.508**

** $p < 0.001$; NS = not significant, $p > 0.05$.

Table 5: Accuracy of MUAC and ultrasound triceps to predict overweight and obesity

Age group	Mid-upper arm circumference				Ultrasound triceps skinfold thickness			
	Area	SE	p-value	95% CI	Area	SE	p-value	95% CI
6–9 years, girls	0.763	0.119	0.036	0.529–0.997	0.860	0.089	0.004	0.686–1.000
6–9 years, boys	0.944	0.058	0.006	0.631–1.000	0.924	0.075	0.009	0.776–1.000
10–19 years, girls	0.934	0.029	0.000	0.877–0.982	0.728	0.060	0.002	0.611–0.845
10–19 years, boys	0.899	0.081	0.003	0.740–1.000	0.903	0.064	0.003	0.777–1.000
Total	0.795	0.048	0.000	0.761–0.889	0.835	0.033	0.000	0.771–0.899

MUAC and TSF had excellent accuracy to predict overweight and obesity in the respondents.

Discussion

The results from this study showed that 1.9% of the learners aged 6–19 years were underweight. The prevalence of underweight was lower than the 10% underweight prevalence reported among South African children aged 1–9 years in the NFCS 2005.¹⁷ The 4.2% prevalence of underweight observed in girls aged 10–12 years was similar to the 4% reported among female primary students aged 10–12 years in rural KwaZulu-Natal.¹⁸ Also, the underweight prevalence was similar to the underweight prevalence of 4.6% girls and 5.2% boys reported among students aged 10–16 years in rural Limpopo using the US Centre of Disease Control and Prevention (CDC) cut-off points¹⁹ but contrary to the 66% prevalence of underweight reported among school children in eThekweni district in KwaZulu-Natal using the WHO guidelines for adults, where

BMI < 18.5 kg/m² was regarded as underweight.¹⁸ This explains why adult guidelines are not an appropriate reference for children and adolescents as levels of underweight in the KwaZulu-Natal study may have been overestimated.

This study shows a high prevalence of overweight and obesity (16.9%) among the adolescents, which is consistent with previous findings in South Africa.^{20–23} The report of the 2008 national surveys showed the prevalence overweight/obesity to be 25% in adolescents aged 14–19 years.⁶ In a study conducted among children aged 9–13 years in the Northwest province, 22% of the participants were either overweight or obese. A systematic review of overweight and obesity among South African children reported trends of high prevalence across races, provinces, urban and rural settlements.²⁴ Studies have attributed high prevalence of overweight in rural areas to the consumption of diets rich in starch and fats, sedentary lifestyle and reduced physical activities.^{24,25}

In this study, overweight and obesity consistently increased in girls and decreased in boys with age. A similar trend was observed by Grobbelaar *et al.*²⁶ who found that while overweight/obesity increased in girls from 0% in 4–8-year-olds to 26.7% in 14–18-year-olds, it reduced in boys from 16.7% to 0% of the same age range.²⁶ Previous studies have found significant age differences in the prevalence of overweight and obesity.^{21,22} The proportion of those who were overweight and obese was higher in girls than in boys. This is consistent with the earlier studies.^{24,26–30} Studies have linked the development of obesity in girls to the onset of menarche^{24,31,32} and lower prevalence of overweight and obesity in boys to higher levels of physical activity.^{31,32} Other factors suggested to be responsible for the gender disparity in overweight prevalence included differences in energy needs, behavioural and cultural beliefs.²⁴

This study finds a very strong relationship between MUAC and BMI, thus confirming previous studies that MUAC correlated very well with BMI^{7,33,34} and could be used to identify not only underweight but also overweight and obesity. Similarly, an association was observed between ultrasound TSF and BMI, which also confirmed previous findings.⁸ The AUC obtained for both MUAC and TSF shows an excellent accuracy level to predict high BMI or overweight and obesity.

Study limitation

The study considered only children attending schools in Cofimvaba, and care must be taken when generalising results from the study.

Conclusion

This study reported low prevalence of underweight and higher prevalence of overweight and further confirmed that MUAC as well as ultrasound TSF can be an alternative tool to BMI for determining overweight and obesity in children and adolescents. A tilt towards overweight is apparent among the girls in this rural community. Considering the consequences of overweight and obesity, nutrition intervention and physical activities aimed at promoting healthy lifestyles are recommended for life-long benefits.

Disclosure statement – No potential conflict of interest was reported by the author(s).

ORCID

Wilna Oldewage-Theron  <http://orcid.org/0000-0001-8975-5693>

Abdulkadir Egal  <http://orcid.org/0000-0003-0303-6319>

References

- Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry*. 2012;24(3):176–188. doi:10.3109/09540261.2012.688195
- De Onis M, Lobstein T. Defining obesity risk status in the general childhood population: which cut-offs should we use? *Int J Pediatr Obes*. 2010;5:458–460. PMID:20233144. doi:10.3109/17477161003615583
- Freedman DS, Khan LK, Serdula MK, et al. Inter-relations among childhood BMI, childhood height, and adult obesity. The Bogalusa heart study. *Int J Obes Relat Metab Disord*. 2004;28(1):10–16. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/14652621> doi:10.1038/sj.ijo.0802544
- Shisana O, Labadarios D, Rehle T, et al. South African national health and examination survey (NHANES-1). Cape Town: HSRC Press; 2013.
- Armstrong ME, Lambert MI, Lambert EV. Secular trends in the prevalence of stunting, overweight and obesity among South African children (1994–2004). *Eur J Clin Nutr*. 2011;65(7):835–840.
- Reddy SP, Resnicow K, James S, et al. Underweight, overweight and obesity among South African adolescents: results of the 2002 national youth risk behaviour survey. *Pub Health Nutr*. 2008;12(2):203–207. PMID:18547451. doi:10.1017/S1368980008002656
- Tang A, Dang K, Deitcher M, et al. Use of cut-offs for mid upper arm circumference (MUAC) as an indicator or predictor nutrition and health related outcomes in adolescents and adults: a systematic review. *Food and Nutrition Technical Assistance (FANTA)*. 2013. Available from: http://www.fantaproject.org/sites/default/files/resources/MUAC%20systematic%20review%20_Nov%2019.pdf
- Planninsec J, Fosnaric S. Body mass index and triceps skinfold thickness in pre-pubertal children in Slovenia. *Coll Anthropol*. 2009;33(2):341–345. Available from: <https://www.semanticscholar.org/paper/Body-mass-index-and-triceps-skinfold-thickness-in-Planin%C5%A1ec-Fo%C5%A1nari%C4%8D/22d3c5143a06a361694be0d819b2458285ad20d7>
- Rogan M. Food poverty, hunger and household production in rural Eastern Cape households. *Dev S Afr*. 2018;35(1):90–104. doi:10.1080/0376835X.20171358602
- South African Statistics. Community Survey, 2016. [online]. Available from: www.stats.gov.za/communitiesurvey2016. 2018/07/easterncape.pdf
- The Survey System. Sample size calculator [cited 2013 Mar 31]. Available from: www.surveysystem.com/sscalc.htm
- Lohman TG, Roche AF, Martorell M. Anthropometric standardisation reference manual. Champaign (IL): Human Kinetics; 1988.
- Gibson R. Principles of nutritional assessment. 2nd ed. New York: Oxford University Press; 2005, p. 282.
- Frisancho AR. Anthropometric standards for the assessment of growth and nutritional status. Ann Arbor: University of Michigan Press; 1990.
- Anthro⁺ plus version 1.0.2. World Health Organization. c2010. Available from: www.who.int/growthref
- Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: international survey. *Bri Med J*. 2000;320:1240–1246.
- Labadarios D, Swart R, Maunder EMW, et al. National food consumption survey fortification baseline (NFCB-FB-I) South Africa, 2005. *S Afr J Clin Nutr*. 2008;21(2):245–300.
- Puckree T, Naidoo P, Pillay P, et al. Underweight and overweight in primary school children in KwaZulu-natal, South Africa. *Afr. J Prim Health Care Fam Med*. 2011;3(1):1–6.
- Toriola AL, Moselakgomo VK, Shaw BS, et al. Overweight, obesity and underweight in rural black South African children. *S Afr J Clin Nutr*. 2012;25(2):57–61.
- Steyn NP, Labadarios D, Maunder E, et al. Secondary anthropometric data analysis of the national food consumption survey in South Africa: The double burden. *Nutr*. 2005;21:4–13. PMID:15661473. doi:10.1016/j.nut.2004.09.003
- Jinabhai CC, Taylor M, Sullivan KR. Implications of stunting, overweight and obesity among South African primary school children: a possible nutrition transition? *Eur J Clin Nutr*. 2003;57(2):358–336.
- Kruger R, Kruger HS, MacIntyre UE. The determinants of overweight and obesity among 10- to 15-year-old schoolchildren in the North West Province, South Africa – the THUSA BANA study. *Pub Health Nutr*. 2006;9(3):351–358. PMID:16684387. doi:10.1079/PHN2006849
- Cameron N, Getz B. Sex differences in the prevalence of obesity in rural African adolescents. *Int J Obes*. 1997;21:775–782. PMID:9376890. doi:10.1038/sj.ijo.0800472
- Rossouw HA, Grant CC, Viljoen M. Overweight and obesity in children and adolescents: the South African problem. *S Afr J Sci*. 2012;108(5/6):1–7. doi:10.4102/sajs.v108i5/6.907
- Romieu I, Laure Dossus L, Barquera S, et al. Energy balance and obesity: what are the main drivers? On behalf of the IARC working group on energy balance and obesity. *Cancer Causes Control*. 2017;28(3):247–258. Published online Feb 17, 2017. doi:10.1007/s10552-017-0869-z
- Grobbelaar HH, Napier CE, Oldewage-Theron WN. Nutritional status and food intake data on children and adolescents in residential care facilities in Durban. *S Afr J Clin Nutr*. 2013;26(1):29–36.
- Vignerova J, Humenikova L, Brabec M, et al. Long-term changes in body weight, BMI and adiposity rebound among children

- and adolescents in the Czech Republic. *Econ Hum Biol.* 2007;5(3):372–382.
28. Wee BS, Poh BK, Bulgiba A, et al. Risk of metabolic syndrome among children living in metropolitan Kuala Lumpur: a case control study. *BMC Pub Health.* 2011;11:333.
29. Aounalian-Skhiri H, Traissac P, Ati JE, et al. Nutrition transition among adolescents of a south- Mediterranean country: dietary patterns, association with socio-economic factors, overweight and blood pressure. a cross-sectional study in Tunisia. *Nutr J.* 2011;10:38.
30. Gaskin PS, Walker SP. Obesity in a cohort of black Jamaican children as estimated by BMI and other indices of adiposity. *Eur J Clin Nutr.* 2003;57(3):420–426.
31. Mukuddem-Petersen J, Kruger HS. Association between stunting and overweight among 10–15-y-old children in the North West Province of South Africa: the THUSA BANA study. *Int J Obes.* 2004;28:842–851. PMID:14758345. doi:10.1038/sj.jco.0802586
32. Chung AE, Skinner AC, Steiner MJ, et al. Physical activity and BMI in a nationally representative sample of children and adolescents. *Clin Pediatr (Phila).* 2012;51(2):122–129.
33. Fakier A, Petro G, Fawcus S. Mid upper arm circumference: a surrogate for body mass index in pregnant women? *S Afr Med J.* 2017;107(7):606–610.
34. Tonder EV, Mace L, Steenkamp L, et al. Mid upper arm circumference (MUAC) as a feasible tool in detecting adult malnutrition. *S Afr J Clin Nutr.* 2018: 1–6. doi:10.1080/16070658.2018.1484622

Received: 28-11-2018 Accepted: 15-02-2020