ORIGINAL ARTICLE

Anthropometric Parameters: Obesity and Metabolic Risks for Non-communicable Diseases among Adolescent Swimmers

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ABSTRACT

Objective: *To assess obesity and metabolic risks for non-communicable diseases among adolescent swimmers.*

Methods: *A cohort of 220 swimmers was selected at their respective swimming clubs* via *quota sampling and measured using various anthropometric parameters, which were then compared with standard cut-off points for the various age groups.*

Results: *The mean body mass index (BMI) was 21.23 ± 3.85 kg/m², the mean waist circumference was 69.8 ± 8.08 cm, and the mean body fat percentage was 21.20 ± 9.27%. These mean body composition variables fell within their respective recommended ranges according to the cut-off points. Height (*$p < 0.001$*), weight (*$p < 0.011$*), mid-upper arm circumference [MUAC] (*$p = 0.035$*) and visceral fat (*$p = 0.033$*) were statistically significant when compared between males and females. Chi-square analysis revealed that gender was statistically significantly associated with waist-to-hip ratio [WHR] (*$p < 0.001$*) and body fat percentage [BFP] (*$p = 0.003$*), while BFP was statistically significantly associated with BMI (*$p < 0.001$*), waist circumference (*$p < 0.001$*), WHR (*$p = 0.026$*), MUAC (*$p < 0.001$*) and skeletal muscle mass (*$p < 0.001$*).*

Conclusion: *The swimmers had an overall healthy body composition and were at low risk for developing non-communicable diseases. We recommend that Trinidad and Tobago develop anthropometric cut-off points for athletes and non-athletes.*

Keywords: Adolescents, anthropometric, metabolic risks, swimmers

Parámetros antropométricos: obesidad y riesgos metabólicos de las enfermedades no transmisibles entre los nadadores adolescentes

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RESUMEN

Objetivo: *Evaluar la obesidad y el riesgo metabólicos para no-enfermedades transmisibles entre los nadadores adolescentes.*

Métodos: *Una cohorte de 220 nadadores fue seleccionada mediante muestreo de cuotas en sus respectivos clubes de natación, y sometida a mediciones utilizando varios parámetros antropométricos, que fueron luego comparados con puntos límites estándar para los distintos grupos etarios.*

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DOI: 10.7727/wimj.2015.259

Resultados: *El índice de masa corporal (IMC) promedio fue 21.23 ± 3.85 kg/m², la circunferencia promedio de la cintura fue 69.8 ± 8.08 cm, y el porciento de grasa corporal promedio fue de 21.20 ± 9.27%. Estas variables promedio de la composición corporal estuvieron dentro de los rangos recomendados de acuerdo con los puntos límites. La altura (*$p < 0.001$*), el peso (*$p < 0.011$*), la circunferencia braquial medio-superior [CBMS] (*$p = 0.035$*), y la grasa visceral (*$p = 0.033$*) fueron estadísticamente significativas cuando se compararon hembras y varones. El análisis de chi-cuadrado reveló que el género se hallaba significativamente asociado estadísticamente con el índice cintura-cadera [ICC] (*$p < 0.001$*) y el porciento de grasa corporal [PGC] (*$p = 0.003$*), mientras que PGC se hallaba estadísticamente significativamente asociado con el IMC (*$p < 0.001$*), el índice cintura-cadera [ICC] (*$p < 0.001$*), la circunferencia de la cintura (*$p < 0.001$*), el ICC (*$p = 0.026$*), CBMS (*$p < 0.001$*), y la masa muscular esquelética (*$p < 0.001$*).*

Conclusión: *Los nadadores tenían una composición corporal sana en general y presentaban bajo riesgo de desarrollar enfermedades no transmisibles. Recomendamos que Trinidad y Tobago desarrolle puntos límites antropométricos tanto para los deportistas como para los no deportistas.*

Palabras clave: Adolescentes, antropométricos, riesgos metabólicos, nadadores

West Indian Med J 2018; 67 (1): 32

INTRODUCTION

The obesity epidemic is a critical public health challenge of the twenty-first century (1–3). According to the Centers for Disease Control and Prevention, United States of America (USA), more than one-third (34.9% or over 78.6 million) of the adults in the USA and 17% (12.7 million) of the children and adolescents aged 2–19 years in the USA were obese (4–6). This pandemic among adults appears to be foreshadowing a similar problem in children. The prevalence of obesity has doubled in children and tripled in adolescents over the last three decades and is a major health concern (7, 8). Children in the USA are not alone – rapidly rising rates of obesity threaten the health of an alarming number of children around the globe (2). Globally, an estimated 170 million children (aged below 18 years) were estimated to be overweight (9). Similarly, in the Caribbean region, there is a high incidence of overweight and obesity among young children and adolescents (10). The highest prevalence of childhood overweight is in upper- and middle-income countries and, when taken as a group, low-income countries have the lowest prevalence rate (2). However, overweight is rising in almost all countries, with prevalence rates growing fastest in lower- and middle-income countries (2).

Obesity has serious physical, psychological and social consequences. Individuals who are obese, defined as having a body mass index (BMI) of ≥ 30 kg/m², are at greater risk of suffering from non-communicable diseases (NCDs), such as heart disease, hypertension, diabetes mellitus, breast cancer and colon cancer (11–13). Obese as compared to non-obese children and adolescents are more likely to become obese as adults and are at risk for health problems during their youth and adulthood (14–16). During their youth, obese children and adolescents are more likely to have risk factors associated with cardiovascular disease, such as hypertension, hypercholesterolaemia, hyperlipidaemia and Type 2 diabetes, which were once seen only in adults (11–13, 17). Moreover, in children and adolescents, overweight and obesity are associated with significant reductions in quality of life (18, 19). Given the high prevalence and the known long-term effects of childhood overweight, there is an urgent need for the detection of obesity and its co-morbidities during childhood and adolescence. The prevention of NCDs is vital in children and adolescents as this helps to lay the foundation for the development of healthy lifestyles throughout adulthood (20).

In diagnosing obesity and metabolic risks, individualized assessments of body composition are necessary to improve fitness and maintain health (21). Body composition is influenced by factors such as age, gender, race, genes, physical activity, diet, the environment and presence of disease (22). Sudden changes in body composition may be an indication of a health problem (23). Studies have used various direct and indirect anthropometric parameters to assess the nutritional status of children and adolescents (24–27). Large multinational studies, such as International Day for the Evaluation of Abdominal Obesity (28), INTERHEART (29), European Prospective Investigation into Cancer and Nutrition (30) and the US Cancer Prevention Study II Nutrition Cohort (31), have confirmed that measurement of abdominal obesity and central fat accumulation is an important tool in assessing risk of heart disease, risk of developing Type 2 diabetes and risk of death. Waist circumference (WC), skinfold thickness and mid-upper arm circumference (MUAC) are the indirect methods used to screen children and adolescents for obesity (32, 33). Body mass index is recognized as the gold standard for identifying individuals at increased risk of obesity-related co-morbidities (34). Epidemiologic studies have demonstrated a direct correlation between BMI and the risk of adiposity-related adverse health outcomes and mortality rate (35, 36). However, BMI is simply a ratio of weight in relation to height and is not a direct measurement of body fat. Hence, BMI provides no information about the distribution of body fat. In contrast, the measurement of WC provides information regarding fat topography. Therefore, WC is a good indicator of high-risk intra-abdominal or visceral fat accumulation and a good indicator of risk for obesity and its co-morbidities (34). Since WC correlates with abdominal fat mass (37) and is associated with hypertension, diabetes, coronary heart disease and dyslipidaemia (34–38), it is used as a marker for abdominal fat mass (34, 37). Mid-upper arm circumference is another indicator of obesity and was reported to reflect body fat tissue closely (33, 39). In light of the worldwide prevalence and importance of detecting NCDs in early life, this study assessed obesity and metabolic risks for NCDs among adolescent swimmers using anthropometric parameters.

SUBJECTS AND METHODS

Participants

Swimmers were recruited from private swimming clubs registered with the Amateur Swimming Association of Trinidad and Tobago *via* quota sampling. At the time of data collection, participants were registered with and trained by a competitive club. A total of 220 swimmers participated in the study. Ethical approval for the study was obtained from the Campus Research Ethics Committee of The University of the West Indies, St Augustine, Trinidad and Tobago. Additionally, consistent with ethical conduct for research involving human participants, informed consent in writing was obtained from participants and/or their parents/guardians.

Procedure

The following anthropometric parameters were collected: height, weight, BMI, body fat percentage (BFP), MUAC, WC, hip circumference (HC), skeletal muscle mass (SMM), visceral fat (VF) and waist-to-hip ratio (WHR). Trained professionals conducted all anthropometric measurements. Height and body weight were measured according to the protocol of the International Society for the Advancement of Kinanthropometry (40). Height was measured to the nearest 0.1 cm in bare feet with swimmers standing upright against a mounted stadiometer. Weight was measured to the nearest 0.1 kg with swimmers lightly dressed (swim suits or trunks) using a bioelectrical impedance analysis (BIA) scale (Omron Full Body Sensor Body Composition Monitor and Scale, Model HBF-510, Illinois, USA). Body fat percentage, VF, SMM and BMI were measured using the BIA scale. Waist circumference, HC and MUAC were measured using a non-stretch measuring tape. Waist circumference was measured to the nearest 0.1 cm at the minimal respiration (at the mid-point between the lowest rib and the top of the iliac crest). Hip circumference was measured to the nearest 0.1 cm over minimal clothing at the maximal extension of the buttocks (at the level of the greatest protrusion of the gluteal muscles). Mid-upper arm circumference was measured to the nearest 0.1 cm at the mid-point between the tip of the shoulder and the tip of the elbow (olecranon process and the acromion). Body mass indices were compared with the World Health Organization's (WHO) simplified field tables for BMI-for-age for girls and boys aged 5 to 19 years [percentiles] (41) and with WHO's BMI classification for adults (42). The WC cut-off points developed by Fernández *et al* (43) and the MUAC cut-off points developed by Mazicioğlu *et al* (33) were used to compare measurements. The International Obesity Task Force (IOTF) cut-off points for BFP were used in this study (44). The reference data of the manufacturer of the BIA scale used in this study were used for the classification of VF and SMM percentages (45).

Statistical analysis

The Statistical Package for Social Sciences (SPSS) for Mac, version 21.0 (SPSS Inc, 2012, Chicago, Illinois, USA) was used for the analyses. Data were analysed using descriptive statistics. The parametric *t-test* was applied to test significance levels at $p < 0.05$ between genders, while Chi-square was used to determine associations between gender and anthropometric variables and between BFP and other anthropometric variables. The statistical significance was set at $p < 0.05$.

RESULTS

The study sample comprised of 220 swimmers: 122 (55.5%) were male and 98 (44.5%) were female. The mean age of the swimmers was 14.56 ± 2.54 years. The majority of the swimmers were of mixed descent. The highest level of education attained by most swimmers was secondary school. The majority of the swimmers were in the age group of 15–17 years. Additionally, the majority of the swimmers (125 or 56.8%) reported that they had never attended a nutrition class, course or seminar since starting to swim (Table 1).

The mean and standard deviations of the swimmers' anthropometric characteristics are presented in Table 2. The mean BMI was 21.2 ± 3.85 kg/m^2 and fell between the 3rd and 85th percentiles for children. Statistical analyses showed that the male swimmers were significantly taller than their female counterparts ($p < 0.001$). They also had a statistically significantly higher weight ($p = 0.011$) and MUAC ($p = 0.035$) than the female swimmers. There were no statistically significant differences between the genders in the other variables.

Table 3 shows the classification of the swimmers based on cut-off points. According to BMI, 4 (1.9%) swimmers were underweight, 39 (17.7%) were overweight and 19 (8.6%) were obese. Measurements of BFP placed 35 (17.6%) swimmers in the 'under fat' category, 109 (55.1%) 'normal fat' or optimal fat, 32 (16.2%) 'over fat' and 22 (11.1%) 'obese'. Based on WC for age, 215 (97.8%) swimmers were classified as 'low risk' and 5 (2.3%) as 'high risk'. For MUAC, only 24 (10.9%) swimmers were classified as having a 'normal weight' while 196 (89.1%) were classified as being 'overweight' or 'obese'.

Table 1: Demographic variables of the swimmers (n = 220)

Variable	Classification	n	%
Gender	Female	98	44.5
	Male	122	55.5
Ethnicity	African	70	31.8
	Indian	11	5.0
	Caucasian	7	3.2
	Asian	3	1.4
	Mixed	129	58.6
Age range (years)	11–12	61	27.7
	13–14	59	26.8
	15–17	70	31.8
	18–21	30	13.6
Highest level of education	Primary	16	7.3
	Secondary	175	79.5
	Tertiary	29	13.2
Number of nutrition classes/courses/ seminars attended	None	126	57.3
	1–3	76	34.5
	4 or more	18	8.2

Table 2: Anthropometric variables of the swimmers

Anthropometric variable	Mean ± standard deviation			*p*-value[a]
	Male (n = 122)	Female (n = 98)	Total (n = 220)	
Age (years)	14.9 ± 2.67	14.2 ± 2.34	14.5 ± 2.54	
Height (m)	1.7 ± 0.11	1.6 ± 0.072	1.7 ± 0.10	< 0.001*
Weight (kg)	61.7 ± 15.68	54.5 ± 11.18	58.5 ± 14.28	0.011*
Body mass index (kg/m^2)	21.5 ± 3.91	21.0 ± 3.78	21.2 ± 3.85	0.522
Waist circumference (cm)	71.4 ± 8.17	67.9 ± 7.60	69.8 ± 8.08	0.357
Hip circumference (cm)	88.6 ± 9.88	89.7 ± 9.79	89.1 ± 9.84	0.687
Mid-upper arm circumference (cm)	28.4 ± 5.85	26.3 ± 3.50	27.4 ± 5.04	0.035*
Waist-to-hip ratio (cm)	0.8 ± 0.042	0.8 ± 0.043	0.8 ± 0.05	0.243
Body fat percentage (%)[b]	15.7 ± 6.93	27.3 ± 7.52	21.2 ± 9.27	0.538
Visceral fat[c]	5.3 ± 3.29	3.4 ± 0.73	4.8 ± 2.90	0.033*
Skeletal muscle mass (%)[c]	41.4 ± 3.60	31.2 ± 5.64	38.3 ± 6.36	0.160

[a] *p*-values are for differences in the variables between male and female swimmers.
[b] Body fat percentages were not obtained for 22 swimmers.
[c] Visceral fat and skeletal muscle mass percentage were obtained for only 30 swimmers.
* $p < 0.05$

Chi-square analysis revealed that gender was statistically significantly associated with WHR ($p < 0.001$) and BFP [$p = 0.003$] (Table 4). Body fat percentage was significantly associated with BMI ($p < 0.001$), WC ($p < 0.001$), WHR ($p = 0.026$), MUAC ($p < 0.001$) and SMM ($p < 0.001$).

DISCUSSION

The present study investigated body composition and the risk for NCDs in adolescent swimmers training competitively in Trinidad and Tobago, based on various anthropometric parameters. Normal weight (*ie* between the 3rd and 85th percentiles for age) was observed in the majority of the swimmers; this may be attributed to their regular participation in swimming. These findings were similar to the results of a study conducted by Juzwiak *et al* which evaluated the body composition and dietary intake of 44 adolescent tennis players (46). The researchers found that the majority of the athletes in their study were within normal weight. Similarly, in a study by Gibson *et al* which evaluated the nutrition status of junior elite female soccer athletes, the researchers also found that the majority of the athletes in their study were within normal weight (47).

A comparison of BMI with WHO standards revealed that most swimmers were within the recommended range for adolescent athletes and therefore were at low risk for developing NCDs. However, 17.7% and 8.6% of the swimmers were considered overweight and obese, respectively, which suggested that the swimmers may have a high percentage of muscle mass since only five swimmers had a high WC, which put them at risk for developing NCDs. In a study which assessed the accuracy of BMI as a measure of percentage fat in college athletes and non-athletes, Ode *et al* concluded that BMI incorrectly classified athletes with normal body fat as overweight and that separate standards should be established for athletic populations (48). Therefore, the BMI results of the present study should be viewed with caution since BMI measures excess weight rather than excess fat and hence should not be used alone as a diagnostic tool to assess health but rather as an indicator of potential health problems. Our study showed that BMI and BFP were statistically significantly associated. Ochiai *et al* (26) also demonstrated that BMI and adiposity were notably related and may be useful in identifying excess body fat in adolescents and the increased risk for developing NCDs. It is important to note that although BMI is the most common measure of obesity, it does not take into account body composition (49). Additionally, it can be misleading in athletes with a high proportion of lean muscle mass (49). However, one limitation of the present study was that the hydration status of the athletes was not measured, which may have affected the accuracy of the results.

Sarria *et al* (50) and Himes (51) reported that WC and BMI had the same accuracy when identifying overweight/obesity in children. In contrast, researchers postulated that WC was a more accurate measure of the distrubution of body fat than BMI (52, 53). In that context, using the cut-off point for WC (43), we found that the majority of the swimmers were at 'low risk' for developing obesity and its co-morbidities, such as metabolic syndrome, Type 2 diabetes and cardiovascular

Table 3: Distribution of the swimmers using the cut-off points for anthropometric variables from specified groups

Anthropometric variable	Cut-off description	Female (n = 98)	Male (n = 122)
		n (%)	
Body mass index[1]	Underweight	3 (1.4)	1 (0.5)
	Normal weight	72 (32.7)	86 (39.1)
	Overweight	17 (7.7)	22 (10.0)
	Obese	6 (2.7)	13 (5.9)
Waist circumference[2]	Low risk	95 (43.2)	120 (54.6)
	High risk	3 (1.4)	2 (0.9)
Body fat percentage[3]	Under fat	8 (4.0)	27 (13.6)
	Normal fat	52 (26.3)	57 (28.8)
	Over fat	21 (10.6)	11 (5.6)
	Obese	13 (6.6)	9 (4.5)
Mid-upper arm circumference[4]	Normal weight	13 (5.9)	11 (5.0)
	Overweight/Obese	85 (38.6)	111 (50.5)

[1] World Health Organization (41, 42).
[2] Fernández *et al* (43).
[3] McCarthy *et al* (44).
[4] Mazicioğlu *et al* (33).

Table 4: Association between anthropometric variables using Chi-square

Variable	Gender		Body fat percentage	
	Chi-square	*p*	Chi-square	*p*
Body mass index	2.877	0.411	96.177	< 0.001*
Waist circumference	0.495	0.482	25.686	< 0.001*
Waist-to-hip ratio	26.040	< 0.001*	14.297	0.026*
Mid-upper arm circumference	1.009	0.315	38.832	< 0.001*
Body fat percentage	13.926	0.003*	–	–
Visceral fat	0.443	0.506	6.724	0.081
Skeletal muscle mass	4.180	0.243	27.133	< 0.001*

* $p < 0.05$

diseases. Many studies have pointed out a strong positive relationship between WC and BFP (24, 54). This was also supported by our study which showed a statistically significant association between WC and BFP. Additionally, Mehdad *et al* (24) identified WC as a good indicator for adiposity in adolescents. Both BMI and WC were endorsed by the American Heart Association as primary tools for measuring adiposity (55). However, WC is used less frequently. Waist circumference was also suggested to be the easiest and best indicator for screening for metabolic syndrome in adolescents (56) but may misjudge total and trunk fat (24, 57).

Swimmers who fell at or below the 2nd percentile cut-off were considered under fat, between the 2nd and 85th percentiles were considered to have normal fat, between the 85th and 95th percentiles were considered over fat and those who fell at or above the 95th percentile were considered obese (44). Over half of the participants fell within the 'normal fat' category, which may have a positive effect on their health. Juzwiak *et al* also reported that participants in their study fell within the recommended body fat range (46). Our results showed that females had a higher body fat percentage when compared to males, which was expected, and that gender was statistically significantly associated with BFP (58). Body fat percentage plays a more important role in differentiating between healthy and obese individuals, as it has a greater ability to differentiate between lean mass and fat mass compared to BMI (59). Additionally, swimmers usually have a higher BFP when compared to athletes participating in other sporting disciplines (25).

A study conducted by Neovius *et al* showed that WHR was only weakly correlated to BFP, while BMI and WC showed strong positive correlations to BPF (54). Taylor *et al* (60) found that WC was better than WHR at predicting adiposity in adolescents. This was supported by our results which showed that WC had a stronger association with BFP than WHR did. Results also showed that WHR was statistically sigificantly associated with gender.

According to Dasgupta *et al*, MUAC is a good predictor of malnutrition in adolescents (61). Maziciolǧlu *et al* concluded that it could be utilized in the screening of adolescents for obesity and fat distribution (33). In this study, MUAC was shown to be statistically significantly correlated to BFP. Mid-upper arm circumference is widely used as an indicator of severe and moderately acute undernutrition for children aged up to five years. However, researchers had identified and recommended MUAC as a variable tool to screen children and adolescents for obesity (32, 33, 62, 63). In our study, we found that the majority of swimmers were categorized as overweight/obese. This may have been due to the swimmers having a high muscle mass, causing their MUAC to be greater than that of the average adolescent. As such, MUAC may not be a suitable indicator of obesity for athletic adolescents. Additionally, the cut-off values did not take into account adolescents above the age of 17 years.

We concluded that based on BMI, WC, BFP and VF, the swimmers in this study had a healthy body composition and, therefore, were at low risk for developing NCDs. Although this study provided some baseline data for athletes, it is recommended that Trinidad and Tobago develop its own cut-off values for WC, BMI and MUAC for both athletes and non-athletes since anthropometric data for athletes in Trinidad and Tobago are non-existent.

ACKNOWLEDGEMENTS

The authors wish to thank Dr George Legall for his statistical assistance and the swimmers for participating in the study.

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