Obesity anthropometric indicators associated with cardiometabolic risk in Portuguese children and adolescents

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ABSTRACT

The purpose of this study was to determine the association between cardiometabolic risk with body mass index and skinfold independently or in combination in youth. This cross-sectional study comprised a convenience sample of 450 children and adolescents (255 girls), aged 10 to 18 years old. Indicators of body composition were measured, and hemodynamic assessment completed. The association between body mass index and/or sum of skinfolds and cardiometabolic risk (z score of the sum of triglycerides/high density lipoprotein cholesterol, waist circumference, and mean blood pressure), was calculated using Generalized Linear Models Regression. The results showed that youngsters classified as overweight or obese with the highest skinfold measurements had the strongest association with cardiometabolic risk (< beta > : 2.60; IC 95%: 2.25–3.0) when compared with those exhibiting normal skinfold thickness (< beta > : 1.78; IC 95%: 1.30–2.20). Body mass index was most strongly associated with cardiometabolic risk (< beta > : 1.78; IC 95%: 1.3–2.2), in comparison to skinfold thickness, which was associated to a lesser extent (< beta > : 0.41; IC 95%: 0.34–0.49). Results of this cross-sectional study indicate that body mass index is more strongly associated with cardiometabolic risk than skinfold thickness. However when these two measures of overweight/obesity are combined, prediction of cardiometabolic risk is further improved. It is therefore important that public health professionals consider both body mass index and sum of skinfolds to better predict cardiometabolic risk in overweight and obese youth. Implications for future research include the use of longitudinal designs and inclusion of children from other racial/ethnic groups.

1. Introduction

Overweight and obesity in children and adolescents continues to be a public health concern (Faienza et al., 2016). This is particularly the case as obesity is considered the primary cause of cardiometabolic co-morbidities (Faienza et al., 2016; Cook et al., 2003). Alongside prevention of obesity, ensuring good cardiometabolic health in children and youth is a key public health priority. However, approximately 10% of adolescents already show clustering of three or more cardiometabolic (CM) abnormalities (Cook et al., 2003). In addition, one form of CM risk cluster, namely the metabolic syndrome, has been recognized as a robust indicator of cardiovascular problems in adulthood and early diagnosis is a priority for prevention of later cardiometabolic disease (Juonala et al., 2011; Popkin et al., 2013).

Anthropometric assessment has been widely used to screen children and youth for CM risk, principally because of their low-cost, ease of administration and non-invasive nature (Groeneveld et al., 2007; Andersen et al., 2015; Griffiths et al., 2013). Body mass index (BMI) is the most widely used such anthropometric index in epidemiological studies to determine metabolic risk (Andersen et al., 2015; Faienza et al., 2016; Barlow and Expert Committee, 2007; Cole et al., 1995; Sardinha et al., 2016). However, although BMI appears to be related to total body composition, use of BMI is not without problems as it is unable to distinguish fat and lean mass and its usefulness has been questioned (Barlow and Expert Committee, 2007; Sardinha et al., 2016). There are also several other anthropometric and body composition variables such as high percentage of fat, visceral fat and abdominal adipose tissue accumulation as well as other specific tissue fat

accumulation that have been associated with CM risk (Bosch et al., 2015; Neovius et al., 2009). Consequently, the use of different anthropometric indicators, either alongside or instead of BMI, such as skinfolds (SKF) and waist circumference (WC), might provide complementary information to better screen for CM risk in children and youth. Furthermore, these aforementioned methods are recognized as adequate to determine CM risk (Taylor and Hergenroeder, 2011; Aristizabal et al., 2015).

The association between CM risk and overweight/obesity (OW/OB) is not simple and trying to distinguish which solitary anthropometric measure of obesity might be best associated with CM risk in children and youth may not be as effective as understanding if combining anthropometric measures might be better associated with CM risk. Indeed, in prior studies, different anthropometric methods showed differential associations with key indices of cardiometabolic health including high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), total cholesterol, triglycerides (TG) and C-reactive protein (Gracia-Marco et al., 2015). Further, Samouda et al. (2015) showed that complementing anthropometric measures of regional adiposity with BMI Z scores could improve the prediction of CM risk factors in youth. It is therefore reasonable to hypothesize that a sum of BMI and SKF could be a more effective indicator of overall adiposity in children and youth. However, few studies to date have examined if this might be the case. This study sought to determine the association between CM risk with BMI and SKF independently or in combination in youth.

2. Methods

2.1. Participants

This is a cross sectional study, using a quantitative approach, carried out as part of a longitudinal research project. The study comprise the follow up of different Portuguese schoolchildren and adolescents cohorts since 1998 until 2010 (Aires et al., 2010; Martins et al., 2009). A convenience sample, comprising 450 students (255 girls and 195 boys), aged 11–17 years old from two different schools in Porto-Portugal, participated in this study. Prior to data collection, schools approved the study protocol and informed written consent was obtained from the participants' parents/guardians. The Scientific Board of PhD Program in Exercise and health approved the project at Porto University (Portugal). The subjects signed consent forms and their identities were kept confidential. All study procedures were carried out following the Helsinki Declaration (World Medical Association, 2013).

The minimum sample size was calculated on G power software considering a statistical analysis to F tests family omnibus r^2 (a multiple regression), with a 0.05 to alfa error probability, and 0.95 to power test and a medium effect size F^2 Cohen of 0,20, suggesting a minimum sample size of 105 participants. The study was executed with a total date of 450 youths, stratified by gender.

2.2. Anthropometric measures

Height and mass were measured in all subjects who were dressed in lightweight clothing and after having breakfast. Body mass was measured to the nearest 0.10 kg, using an electronic weight scale (Seca 708 portable digital beam scale) and body height was measured to the nearest mm in bare or stocking feet with the participant standing upright against a Holtain Stadiometer. BMI was calculated as kg/m². WC was measured to the nearest mm with a metallic tape at the superior border of the iliac crest.

Skinfolds were taken from the triceps, subscapular and medial calfusing Harpenden Skinfold Calipers and following established protocols (Heyward, 1998). Each skinfold was measured twice consecutively, on the right side of the body. If measurements differed by > 5%, a third measure was taken. To minimize errors in this evaluation, two

researchers (men measured boys; woman measured girls) with five years of experience in anthropometry measurements were responsible for this test in all procedures of this study. The average of three skinfolds (triceps, subscapular and midcalf) thickness measurements was calculated as a final value, determining the sum of skinfolds (ESKF).

2.3. Cardiometabolic risk factors

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured by an automated oscillometric sphygmomanometer (DINAMAP model BP 8800) using a standard technique (Duarte et al., 2000). The subjects were at rest, in sitting position, with the right arm at heart level. The first and second measurements were taken after 5 and 10 minute resting. The average of these two measurements was used for data analysis. Mean arterial pressure (MAP) was calculated as: [(SBP − DBP) / 3] + DBP.

For determination of HDL-C and TG, after 12-14 h of fasting, capillary whole blood samples were collected from the earlobe using a 35 µl lithium heparin-coated capillary tube and immediately assayed using the Cholestech LDX Analyzer (Cholestech Corporation- Hayward, CA, USA). TG and HDL-C values were used for determining the TG/HDL-C ratio (Giannini et al., 2011).

2.4. Statistical analyses

The data was evaluated using the Shapiro Wilk Normality Test and outliers were analyzed considering the box-plot for all variables. Descriptive analysis was expressed considering average and standard deviations. We separated all analyses by gender because we have previously found significant correlations between males, females and cardiometabolic variables (data not shown).WC, TG/HDL-C and MAP were continuous variables in the data base, so we tested Pearson's correlations among those variables. Results were considered significant when p < 0,05. After each variable (WC, TG/HDL-C and MAP) was transformed in standard deviation united (Z score) in a descriptive statistic method, they were summed up in a new Z score, called Z Cardiometabolic Risk, which was used as a dependent variable in the next regression analysis.

BMI was categorized as normal weight or overweight and obese according to Cole et al. (1995) cut-points. Regarding ESKF, we used the 75 percentile adjusted by age and gender, to categorize the group at risk of being obese (P75). These methods were used based on previous data with the same population (Guerra et al., 2006). Using this data a new variable was created based on BMI and ESKF, comprising four categories: 1) No risk where both BMI and ESKF were classified as in the healthy zone; 2) risk zone according to ESKF (p > 75) and normal BMI; 3) risk zone according to BMI (overweight and obese) and normal ESKF and 4) risk aggregated, this category included those who were classified in the risk zone for both BMI and ESKF.

The association between body composition and cardiometabolic risk (dependent variable) was tested through different Generalized Linear Regression Models. We considered "Healthy" as the reference category to be compared to BMI or ESKF with BMI + ESKF regarding variance and strength of the association with the dependent variable (β coefficient). The best regression model was determined using the minor value of Akaike's and Bayesian's criteria. An alpha level of < 0.05 was considered for all analyses and all analysis was completed using the Statistical package for Social Sciences (SPSS) version 24.0 (IBM Corp, Armonk, NY).

3. Results

Table 1 shows continuous and categorical sample descriptive analysis. Homogeneity was observed in the average values of age, body mass, height, WC, TG/HDL-C, MPA and Z cardiometabolic risk. The occurrence of participants at risk with BMI + ESKF was higher than

Table 1
Sample's characteristic, descriptive and occurrence analysis, 2010.

Variables	Boys		Girls		Total	
Continuous	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Age	195	13.75 (2.01)	255	14.07 (1.94)	450	13.93 (1.98)
Body mass	195	55.93 (12.63)	251	53.80 (10.15)	446	54.73 (11.34)
Height	195	1.63 (0.11)	249	1.58 (0.07)	444	1.60 (0.10)
WC	195	73.9 (8.67)	255	75.2 (8.28)	450	74.6 (8.47)
TG/HDL-C	195	1.4 (0.78)	255	1.4 (0.75)	450	1.4 (0.76)
MPA	189	82.2 (10.05)	245	83.8 (9.62)	434	83.1 (9.83)
Z CM risk	189	− 0.19 (2.02)	245	0.14 (1.93)	434	− 0.005 (1.97)

Variables	Boys		Girls		Total	
Categorical	N	%	N	%	N	%
BMI + ESFK	31	15.9	35	13.7	66	14.7
ESKF	17	8.7	23	9.0	40	8.9
BMI	21	10.8	27	10.6	48	10.7
Healthy	125	64.1	164	64.3	289	64.2
Total	194	99.5	249	97.6	443	98.4
Missing	1	0.5	6	2.4	7	1.6

n: subjects number; %: proportion subjects; WC: waist circumference; ESKF: average of skinfolds; BMI: body mass index; TG: triglycerides; HDL-C: high density lipoprotein cholesterol; MPA: mean pressure arterial; Z CM risk: score Z cardiometabolic risk.

with ESKF or BMI categories separately, but these values were lower than Healthy.

Table 2 shows associations of BMI and ESKF to CM risk in girls. The association between BMI + ESKF was observed in both crude and adjusted models. OW/OB girls measured by BMI + ESKF showed a stronger association with CM risk score (β: 2.6 IC 95% 2.0; 3.20) compared to those assigned to the no risk group. OW/OB measured by BMI (β: 1.9 IC 95% 1.27; 2.53) also had a statistically significant association with CM risk, while OW/OB by ESKF (β: 0.4 IC 95% − 0.27; 1.07) did not show significant association.

In boys (Table 3), the association between BMI + ESKF was observed in both crude and adjusted models. OW/OB boys measured by BMI + ESKF showed stronger associations with CM risk (B: 2.700 IC 95% 2.11; 3.20). Similarly, in girls, OW/OB measured by BMI (B: 1.600 IC 95% 0.90; 2.30) also showed a significant association, while OW/OB boys measured by ESKF (B: 1.300; IC 95%: 0.56; 2.05) showed a statistically significant, but lower association with CM risk.

Table 2
Cardiometabolic risk association with body composition indicators in girls, 2010.

	Risk categories	Z cardiometabolic risk			
		B	IC 95%	Wald Chi-square	P
Model 1	Intercept	− 0.400	(− 0.72; − 0.20)	12.0	0.001
	BMI + ESKF	2.400	(1.8; 3.07)	61.4	0.001
	ESKF	0.580	(− 0.14; 1.3)	2.46	0.117
	BMI	1.790	(1.1; 2.4)	26.2	0.001
Model 2	Intercept	− 5.300	(− 6.7; − 3.8)	52.9	0.001
	BMI + ESKF	2.600	(2.0; 3.2)	83.6	0.001
	ESKF	0.400	(− 0.27; 1.07)	1.35	0.245
	BMI	1.900	(1.27; 2.53)	35.1	0.001
	Age	0.300	(0.24; 0.44)	45.4	0.001

ESKF: average of skinfolds; BMI: body mass index; Model 1: female unadjusted (AIC: 960.1; BIC: 977.4); Model 2: female age adjusted (AIC: 920.6; BIC: 941); reference category of independent: healthy BMI and ESKF.

Table 3
Cardiometabolic risk association with body composition indicators in boys, 2010.

	Risk categories	Z cardiometabolic risk			
		B	IC 95%	Wald Chi-square	p
Model 1	Intercept	− 0.800	(− 1.19; − 0.56)	29.8	0.001
	BMI + ESKF	2.400	(1.78; 3.10)	48.6	0.001
	ESKF	1.500	(0.67; 2.46)	11.7	0.001
	BMI	1.300	(0.44; 2.1)	8.8	0.003
Model 2	Intercept	− 7.800	(− 9.2; − 6.3)	110.4	0.001
	BMI + ESKF	2.700	(2.11; 3.20)	83.9	0.001
	ESKF	1.300	(0.56; 2.05)	11.9	0.001
	BMI	1.600	(0.90; 2.30)	19.9	0.001
	Age	0.500	(0.39; 0.60)	89.9	0.001

ESKF: average of skinfolds; BMI: body mass index; Model 1: male unadjusted (AIC: 762.4; BIC: 778.6); Model 2: male age adjusted (AIC: 691.3; BIC: 710.3); reference category of independent variables: healthy BMI and ESKF.

4. Discussion

The present study examined the association between BMI and SKF with CM risk in youth, both independently and in combination. Few studies to date have examined whether the combination of BMI and SKF into a single risk screen adds value to using either BMI or SKF in isolation in youth. The key finding of the present study is that when BMI and ESKF are combined it demonstrates a stronger association with CM risk compared to either BMI or SKF alone. When BMI was considered in isolation, it was more strongly associated with CM risk than when ESKF was used in isolation.

The results presented here are important in the context of public health monitoring. Given the link between obesity and CM comorbidity and the rising prevalence of obesity worldwide, understanding which anthropometric measures might be most associated with CM risk is useful in understanding which measures might be most effective for public health monitoring. There remains an increasing need for low-cost and non-invasive methods for use in clinical practice and community health to indicate this disease and CM risk in youth. The studies that have addressed the relationship between these methods and CM risk factors to date are equivocal (Griffiths et al., 2012; Browning et al., 2010; Lara et al., 2012; Wheelock et al., 2017). To date, the majority of studies have focused on understanding whether measures of central adiposity, such as WC, are more effective in predicting CM risk compared to measures of overall adiposity, such as BMI and SKF. Several studies also suggest that BMI is a reliable indicator of CM risk in childhood and adolescence (Wheelock et al., 2017; Ali et al., 2014), and this method has been widely used in epidemiological studies. There are however considerable limitations to the use of BMI in children and adolescents, notably the assumption that BMI is linearly related to fatness. Data suggest this is not the case in children and adolescents and that it may not be the most robust measure of fatness in this population (Nevill and Holder, 1995). Likewise, as expected, in the present study BMI was more related to CM risk score than ESKF. However, BMI does not allow the differentiation between lean mass and fat mass (Erfle and Gamble, 2015). In the present study, this aspect was noticed by the result indicating that there is a greater association with CM risk when youth are at risk using, both BMI and SKF. Despite this, few prior studies have considered if combining anthropometric measures adds to the prediction of CM risk in youth.

However, there is no consensus regarding the best anthropometric indicator to determine CM risk (Griffiths et al., 2012; Browning et al., 2010; Lara et al., 2012). Thus, our central goal was to understand whether anthropometric aggregation might be used for better screening of CM risk. The stronger association with CM risk with the combined use of BMI and SKF does agree with prior research related to this topic.

For example, Samouda et al. (2015) suggested that adding anthropometric measures of regional adiposity to BMI Z scores improves the prediction of lipid profile and insulin resistance. Another recent study in adolescents showed that the addition of five indices of body composition, such as the ESKF, BMI, Waist-to-height ratio (WHtR), WC and lean mass was more strongly associated with SBP, maximum oxygen uptake, insulin resistance, C-reactive protein, total cholesterol, HDL-C and TG (Gracia-Marco et al., 2015). Furthermore, other work has shown that if the percentage of body fat, BMI and WHtR are used separately, then there was a weak identification of individual cardiovascular risk factors, while the use of a cluster increased their discriminatory power (Neovius et al., 2009).

In addition, we found a slightly different influence of ESKF on CM risk compared to BMI. Our findings identified a statistically significant association between ESKF and CM risk in boys, but not in girls. These results suggest that ESKF better explains the variance of CM risk in boys than girls but such an assertion may arise due to differences in maturation between boys and girls in the sample. As girls usually have greater body fatness than boys (Crocker et al., 2014; Bergmann et al., 2007). In practice evaluation there is a limitation of SKF measures because it can be challenging to pick up only fat mass when there are abundant subcutaneous fatness. In addition, these differences between boys and girls could probably be explained by several difficulties associated with SKF measurements.

Discrepancies among studies may also be related to methodological differences in data collection or even in the data preparation, such as the use of z-scores. Furthermore, our CM risk score included WC, which may strengthen the correlations. The inclusion of WC is justified because of a growing body of research includes this method as a CM risk indicator (Andersen et al., 2015; Sardinha et al., 2016). However, recent study have not included WC within their determination of CM risk (Ramírez-Vélez et al., 2017).

Several limitations of this study should be taken into consideration. The convenience sample employed does not allow a generalization of results to a whole population and the cross-sectional design does not allow us to establish causality. Secondly, the data are only applicable to the Portuguese population. Future research examining whether the combination of BMI and ESKF is more useful in other ethnic and racial groups would be useful. Finally, percentiles were used as no SKF cutoff to classify risk was available.

Despite this, the present study contributes to the evidence base in regard to anthropometric measures of OW/OB, showing that the cluster of both BMI and ESKF might be more effective to indicate CM risk compared to BMI or EKSF alone in youth. In summary, as an empirical implication our data suggests that the evaluation of CM risk would be more accurate using more than one anthropometric indicator.

5. Conclusion

Our results showed that BMI had a stronger association with CM risk than ESKF. We also found that BMI and ESKF together improved the prediction of CM risk in children and adolescents. These findings are useful for clinicians and public health practitioners in determining which anthropometric indicators may be most applicable for screening of overweight, obesity and all related comorbidities in this population. A logical next step would be to examine if the use of BMI and ESKF together provides a better means to predict CM risk longitudinally. Future studies should include longitudinal studies and larger sample sizes. Also, additional exploration of the research question with other racial and ethnic groups should be considered.

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