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Adiposity-Associated Anthropometric Indicators and Myocardial Infarction Risk: Keys for Waist to-Height-Ratio as Metric in Cardiometabolic Health

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Abstract: Objective: The aim was to realize an analysis to identify both the association and plausibility of adiposity-associated indicators on the risk prediction for myocardial infarction (MI) in men. Method: A case-control study in 246 Europoid men aged 30-74 years was conducted. Weight, height, waist and hip perimeters and skinfolds according to standardized protocols were measured. The areas under the ROC curves, the odds ratios and correlations for indicators were calculated. Result: Body mass index (BMI) [AUC: 0.687, 95% CI (0.619-0.715); OR: 3.5]. Waist circumference (WC) [AUC: 0.742, 95% CI (0.679-0.805); OR: 5.9]. Waist-to-height ratio (WHtR) [AUC: 0.780, 95% CI (0.721-0.839); OR: 8.4]. Endomorphy [AUC: 0.721, 95% CI (0.656-0.785); OR: 2.4]. Body fat percentage (%BF) [AUC: 0.774, 95% CI (0.714-0.834); OR: 10.2]. Lean body mass (LBM) [AUC: 0.490, 95% CI (0.413-0.568); OR: 1]. BMI correlated with %BF (0.84), endomorphy (0.80), WC (0.69), WHtR (0.72) and LBM (0.65). WHtR correlated with WC (0.97), %BF (0.92), endomorphy (0.62) and LBM (0.32). %BF correlated with WC (0.86) and endomorphy (0.78). The correlations between WHtR and adiposity-associated indicators were strong (all $r \geq 0.62$, $p < 0.001$). Conclusion: In MI men, adiposity-associated indicators show different discriminatory capability. BMI-defined obesity presents moderate discrimination and association bias that do not lent support their suitability as risk predictor. WHtR and %BF show the highest discriminative abilities and robust anthropometric reasons related with the true biological risk. WHtR is the real metric of risk and expression of unhealthy body fat for the identification of men with increased cardiometabolic risk.

Keywords: Obesity, Myocardial Infarction, Anthropometric Indicator, Body Fat, Cardiometabolic Risk, Risk Prediction, Public Health

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1. Introduction

Obesity is a public health problem with high prevalence worldwide [1]. Globally, adiposity is associated with several medical conditions, including cardiovascular diseases, mainly heart disease and stroke as the leading causes of death [1, 2]. Heart disease is responsible for 1 in 4 deaths in the U.S. (death rate: 165.0 per 100,000 US standard population), and more than half of the deaths that occur as a result of heart disease are in men[3]. Coronary heart disease is the most common type of heart disease, killing over 370,000 American people annually [3]. On the other hand, body mass index (BMI) is the anthropometrical metric proposed to define the ideal cardiovascular health, and has been associated with myocardial infarction (MI) in worldwide, included US population [4-8], but in spite of its wide use does not provide accurate information on the body composition and fat distribution. Thus, accurate estimation of the body fat distribution is highly relevant from a public health perspective, an aspect that has been endorsed by the American Heart Association Obesity Committee [9]. In addition, technological methods for assessing whole-body fat percentage (%BF) such as dual-energy X-ray absorptiometry (DXA) can support the criterion of a more accurate evaluation, however, it is impractical in clinical settings. To date, the diagnosis of BMI-defined obesity is the failure to considerer the impact of real adiposity on MI risk prediction [6-8]. Further, BMI has been found as a worse index than bioelectrical obesity indices as (%BF) to diagnose obesity in patients with coronary disease and stroke [10, 11]. Evidence is accumulating in support of the lifestyle behaviors and anatomical distribution of adipose tissue, particularly abdominal obesity, as strong indicators of metabolic syndrome, atherosclerotic cardiovascular disease (ASCVD) and mortality [5-8, 12-17]. Equally, the study previously published supports the body fat distribution as a strong indicator of risk in proving the different biological risk for both visceral and subcutaneous adipose tissue [17]. From the INTERHEART and Norwegian studies as well as in a recently analyzed American cohort from Minnesota, waist-to-hip ratio (WHR) has been confirmed as a strong indicator to explain population attributable risk and cardiovascular events [6, 7, 18]. However, we have revealed statistical error bias for WHR-associated risk if the cutoff was not biologically equivalent with other indicators such as waist circumference (WC) and waist-to-height ratio (WHtR) [8, 17]. Moreover, we have described the anthropometric reasons that do not lent support WHR as a real associated risk beyond WC and unlike WHtR [8, 17]. Additionally, in the study of body composition by somatotyping we have warned about the attributed spurious risk to both BMI and WHR. It is very important to know that in the implication of cardiometabolic risk from any indicator, the role of the each measurement or involved bodily component, as metabolically healthy or unhealthy is well different from each one, irrespective of the magnitude of statistical association [17].

Although a wide variety of anthropometric methods to estimate body habitus or somatotype in adults has been developed, including those of Framingham study, hip circumference (HC) does not a essential measurement [19, 20]. However, WHR derived from cross-sectional and prospective larger studies [6, 7, 18] is still strongly considered as a referent risk predictor in spite of previous revelations and not causal relationship of HC with body composition in MI men [17]. On the other hand, WHtR has been described as the best predictor of %BF, and visceral adipose tissue was found to be as an independent predictor of cardiovascular events in Caucasian individuals [21, 22]. Moreover, in a large recent study, a new anthropometric indicator of %BF, foundated on WHtR inverse, also has been validated by DXA in American adult individuals [23]. In the current situation, BMI and WHR reflect information bias and they show limited accuracy to estimate the whole-body fat and to predict faithfully MI risk [8, 17]. Further, BMI as proxy of obesity closely linked to weight factor may not have the validity relative to use of a standard method of reference to assess the real abdominal adiposity as risk-enhancing factor for ASCVD [17, 24]. Moreover, BMI categories misclassify the cardiometabolic health of US adults, and the overweight category has been associated with significantly increased risk of developing cardiovascular disease at an earlier age [25, 26]. The aim was to assess the relative importance of measurements and adiposity anthropometric indicators including %BF on the MI risk prediction in a sample of Europoid men. We evaluated the discriminatory capability by comparing the Receiver Operating Curves (ROC). Furthermore, we determined the correlations between anthropometric indicators in differentiating those that estimate some bodily components by measuring lean body mass (LBM), body fat mass (BFM), endomorphy and abdominal obesity.

2. Method

Study participants were recruited from a Hospital Complex in the Health Area of Caceres in Spain**.** Cases were selected from a post-myocardial infarction Cardiac Rehabilitation Program. The minimum sample size for calculating was of 91 cases and at least 1 control per case, with an obesity exposition for adult population of 22%, a level of safety of 0.99 and a statistical power of 0.99. The odds ratio (OR) to detect was of 3. A sample of 246 subjects, men of Europid ethnicity, aged 30-74 years, from 2012 database and new additions during 2018 was evaluated. Case data were collected in the first fitting days after hospital diagnosis. Exclusion criteria were nonage, physical disability or any chronic disease. One control age-matched (± 5 years) was recruited per case at two Health Centers (60%), a wellness center (20%) and a department of workers of the State General Administration (20%). Exclusion criteria for controls were identical to those described for cases, with the additional criterion that controls had no previous diagnosis of coronary disease or history of exertional chest pain.

All subjects signed an informed consent approved by the Ethical Committee of the Hospital, according to the principles of the Declaration of Helsinki and Data Protection. Anthropometric measures. Measurements were made according to standard international protocols [27, 28]. Weight was measured (kg) wearing light underwear. Height was measured (cm) without shoes and the head was positioned in the Frankfort plane. Skinfolds (mm): triceps, subscapular and supraspinale were measured on the right side. WC and HC were measured to the nearest 0.1 cm. WC was determined in a horizontal plane in the perimeter passing through the navel and just above the upper most lateral border of the right iliac crest at the midaxillary line, and at the end of a normal expiration. HC was measured at the maximum perimeter around the buttocks with feet together and without gluteus contraction. Technical error of measurement for each dimension with an anthropometric tolerance for skinfolds about 5%, for perimeters 1%, and for height and weight 0.5%, was calculated.

BMI dividing body weight by square height (kg/m^2), WHR and WHtR (waist, hip and height in cm) were calculated. BMI ≥25-29.9 was defined as overweight and ≥30 as general obesity. Endomorphy rating was calculated according to the Heath-Carter Instruction Manual [20]. The equation to calculate endomorphy was: Endomorphy= - 0.7182 + 0.1451 (X) - 0.00068 (X^2) + 0.0000014 (X^3).

Where X = (sum of triceps, subscapular and supraspinale skinfolds) x (170.18/height).

Endomorphy rating of 0.5 to 2.5 were considered low, 3 to 5 were moderate, and 5.5 to 7 were high. %BF was calculated according to the formula from Woolcott and Bergman for men: 64 - (20 * height (m)/WC (m)) [23]. LBM was calculated by subtracting BFM of total body weight: LBM= weight – BFM (kg). BFM is the transformation from %BF to unit of mass =%BF*100/weight (kg).

Statistical analysis Data were computed using SPSS® software (version 20.0 IBM for Windows). Descriptive statistics as means, standard deviations are provided. Normal distributions were assessed using Kolmogorov Smirnov test. Student-test as parametric and Chi-square as no parametric test were applied to establish differences. Bivariate analysis was used for calculating Pearson´s correlation coefficients (r). Sensitivity and specificity by ROC analysis were assessed. The total area under the curve (AUC) was tested with no parametric differences and their values were used for identifying the strength of association for each indicator. The cutoff were defined there where sensitivity plus specificity was the highest. The odds ratio (OR) of prevalence of indicators according to different cutoff was calculated by using contingency tables and binary logistic regression analysis. The confidence interval was set at 95% in all cases. A value of $p<0.01$ was considered significant.

3. Result

Anthropometric characteristics of study participants are shown in table 1. The main risk anthropometric indicators present differences at the significance level. Both indicators of general obesity and abdominal obesity show strongly significant differences. Indicators measured by skinfolds (endomorphy) as well as % BF also show significant differences. Among units of length and mass, HC, weight and LBM do no show anthropometric differences (p = 0.07, p = 0.21 and p= 0.8 respectively).

Table 1. *Anthropometric characteristics of the study participants.*

Variable	MI (n=123)	95% CI	Control (n=123)	95% CI	p
Age (years)	53.7 ± 9.7	52.04 – 55.5	51.7 ± 9.4	50.1– 53.4	0.09
Weight (kg)	81.9 ± 13.3	79.5 – 84.3	79.0 ± 12.0	76.9 – 81.2	0.07
Height (cm)	169.4±7.3	168.1– 170.7	173.5 ± 6.8	172.3 – 174.8	<0.01
HC (cm)	99.1 ± 13.1	96.8-101.5	97.5 ± 6.4	96.3 – 98.6	0.21
BMI (kg/m^2)	28.5 ± 4.0	27.8 – 29.2	26.2 ± 3.4	25.5 – 26.8	<0.01
WC (cm)	101.7 ± 20.5	97.9 – 105.3	91.3 ± 10.2	89.5 – 93.1	<0.01
WHR	1.02 ± 0.13	0.9 – 1.04	0.93 ± 0.06	0.92 – 0.94	<0.01
WHtR	0.60 ± 0.11	0.58 – 0.62	0.52 ± 0.05	0.51 – 0.53	<0.01
Endomorphy	4.6 ± 1.2	4.3 – 4.8	3.6 ± 0.9	3.4 – 3.8	<0.01
%BF	29.8 ± 4.6	29 – 30.6	25.5 ± 4.0	24.8 – 26.3	<0.01
BFM (kg)	36.7 ± 5.1	35.8 – 37.7	32.6 ± 4.8	31.7 – 33.4	<0.01
LBM (kg)	45.2 ± 16.3	42.3 – 48.1	46.4 ± 14.4	43.8 – 49	0.8

Abbreviations: BF: Body fat; BFM: Body fat mass; BMI: Body mass index; HC: Hip circumference; LBM: Lean body mass; MI: Myocardial infarction; WC: waist circumference; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio.
p: Significance level.

The AUC to establish the differences between groups were calculated according to sensitivity and specificity at each point of the ROC curve (table 2). It is worth noting that an inferior limit less than 0.5 included in the confidence interval would indicate lack of association.

Table 2. *Analysis ROC for the association of anthropometric indicators in myocardial infarction men.*

Anthropometric variables	AUC	Error	95% CI	p
BMI	0.689	0.034	0.622-0.757	<0.001
BFM	0.718	0.033	0.654-0.782	<0.001
WC	0.743	0.032	0.680-0.805	<0.001
Inverse height	0.671	0.035	0.603-0.739	<0.001
Weight	0.569	0.037	0.497-0.642	0.06
HC	0.519	0.037	0.447-0.592	0.59

Anthropometric variables	AUC	Error	95% CI	p
WHR	0.790	0.030	0.730-0.849	<0.001
WHtR	0.780	0.030	0.722-0.839	<0.001
Inverse WHtR	0.220	0.030	0.161-0.279	<0.001
LBM	0.476	0.038	0.402-0.550	0.808
Endomorphy	0.724	0.033	0.660-0.788	<0.001
%BF	0.774	0.030	0.715-0.834	<0.001

Abbreviations: AUC: Area under the curve; BF: Body fat; BFM: Body fat mass; BMI: Body mass index; HC: Hip circumference; LBM: lean body mass; WC: waist circumference; WHR: Waist to-hip-ratio; WHtR: Waist-to-height ratio.
p: Significance level.

The cut-off point, sensitivity, specificity, OR and confidence interval for risk indicators are shown in table 3.

Table 3. *Cut-off points, sensitivity, specificity and odds ratio for the anthropometric indicators associated to myocardial infarction men.*

Variables	Cut-off points	Sensitivity	Specificity	OR	95% CI	p
BMI (kg/m^2)	≥30	0.322	0.918	3.5	2.3-10.3	<0.001
WC (cm)	≥94.4	0.711	0.605	5.9	3.4-10.3	<0.001
Inverse height	≥1/169.9	0.604	0.631	3.7	2.1 – 6.4	<0.001
WHR	≥0.95	0.803	0.697	8.7	4.7-16.1	<0.001
WHtR	≥0.54	0.777	0.746	8.4	4.7-15.1	<0.001
%BF	27.2	0.769	0.754	10.2	5.7-18.5	<0.001
Endomorphy	≥3.9	0.682	0.581	2.4	1.4-4.2	<0.001
BFM	33.3	0.694	0.607	3.9	2.3-6.8	<0.001

Abbreviations: BF: Body fat; BFM: Body fat mass; BMI: Body mass index; WC: Waist circumference; WHR: Waist to-hip-ratio; WHtR: Waist to-height-ratio.
p: significance level

The different ROC curve patterns are plotted in figure 1 and 2.

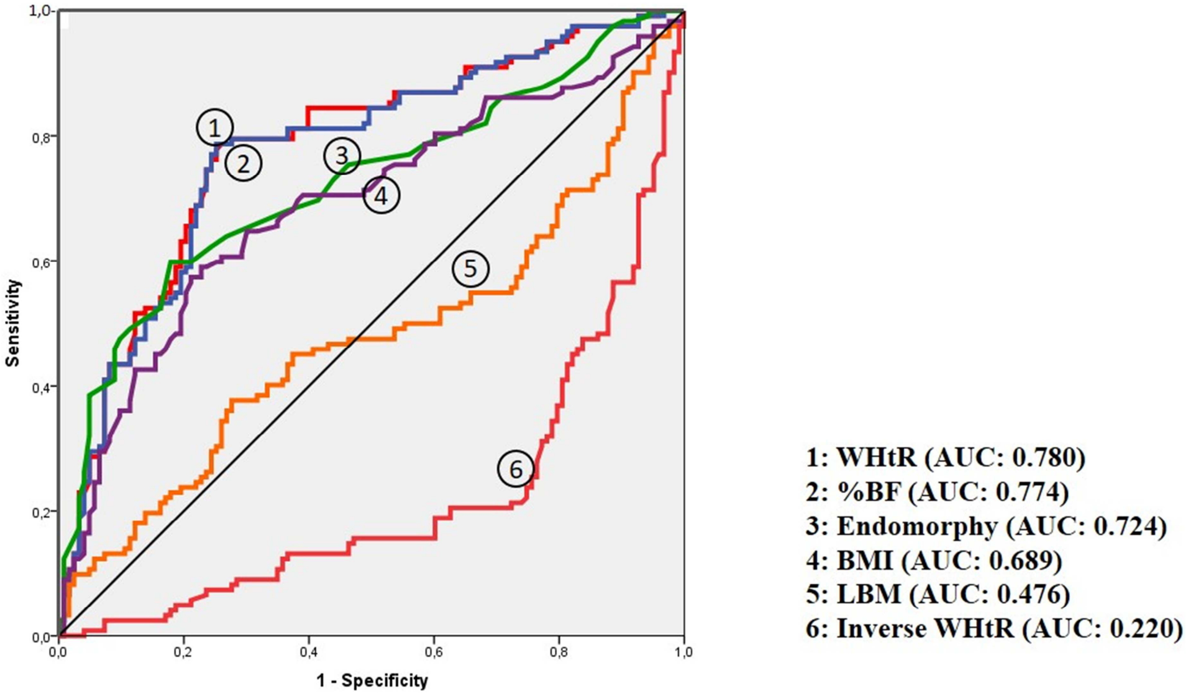

Figure 1. *Graph representing of the ROC curves for calculated indicators. AUC denotes area under the curve, BF body fat, BMI body mass index, LBM lean body mass and WHtR waist-to-height ratio.*

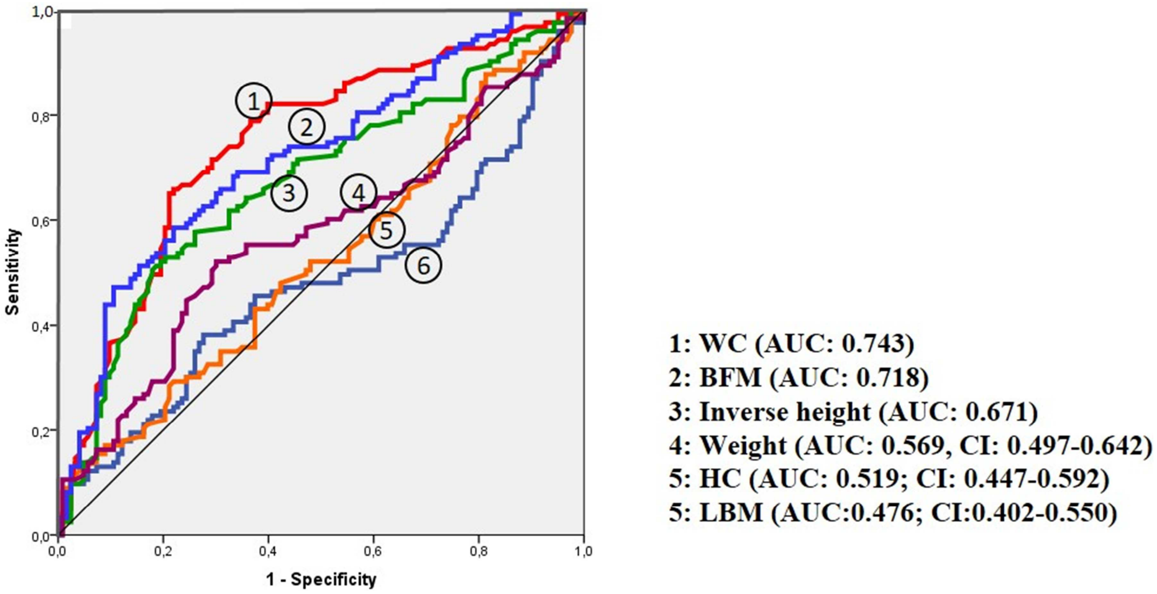

Figure 2. *Graph representing of the ROC curves for indicators represented by units of measure (length and mass). AUC denotes area under the curve, BFM body fat mass, LBM lean body mass, HC hip circumference and WC waist circumference.*

The correlation coefficients for the main variables in MI men are given in table 4. BMI correlated with endomorphy, LBM and %BF (0.80, 0.65 and 0.84 respectively). The correlations for WHtR with WC, endomorphy, LBM and %BF were 0.97, 0.62, 0.32 and 0.92 respectively. WHtR was notably correlated with adiposity-associated risk indicators. LBM correlated strongly with BMI and weakly with both skinfold and central obesity variables (all r <0.5).

Table 4. *Correlations between anthropometric variables of Europoid men with myocardial infarction (N = 123).*

Variables	BMI	WC	WHR	WHtR	Endomorphy	%BF	LBM
BMI	1	0.69 (*)	0.52 (*)	0.72 (*)	0.80 (*)	0.84 (*)	0.65 (*)
WC	0.69 (*)	1	0.76 (*)	0.97 (*)	0.59 (*)	0.86 (*)	0.49 (*)
WHR	0.52 (*)	0.76 (*)	1	0.75 (*)	0.48 (*)	0.79 (*)	0.24 (*)
WHtR	0.72 (*)	0.97 (*)	0.75 (*)	1	0.62 (*)	0.92 (*)	0.32 (*)
Endomorphy	0.80 (*)	0.59 (*)	0.48 (*)	0.62 (*)	1	0.78 (*)	0.45 (*)
%BF	0.84 (*)	0.86 (*)	0.79 (*)	0.92 (*)	0.78 (*)	1	0.30 (*)
LBM	0.65 (*)	0.49 (*)	0.24 (*)	0.32 (*)	0.45 (*)	0.30 (*)	1

Data are correlation coefficients.

Abbreviations: BF: Body fat; BMI: Body mass index; LBM: Lean body mass; WC: Waist circumference; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio;

*: Correlation is significant at the.01 level.

4. Discussion

The present study shows that adiposity-associated indicators in MI men present different discriminatory capability. Prior studies have shown the association of both general and abdominal obesity with MI although BMI-defined obesity and WHR have presented statistical error bias on their predictive ability [5-8, 17]. In addition, statistical association for any indicator is not the same as epidemiological causality and implicit risk. Therefore, some anthropometric indicators could show confusing in its true putative risk [17]. To our knowledge, the anthropometric risk associated to MI would depend on adiposity-associated risk rather than the indicators may be responsible for all or much of the statistical association. In this line, BMI does not discriminate between musculoskeletal component and body fatness in attributing partially a spurious risk to mesomorphy component [17]. Thus, BMI in depending on various components (muscle, bone, fat and residual mass) it underestimates abdominal obesity risk. Moreover, whether mesomorphy does not show causal association, BMI could provide a biased association because of overestimation of risk for musculoskeletal component [17]. This study is in agreement with previous one about body composition, and the different discriminative association for BMI-defined obesity and %BF by measuring WC and height has been proved [17, 23]. Even relative body fatness (expressed by endomorphy) in measuring three skinfolds, shows better discrimination than BMI according to somatotype of MI patients [8, 17]. These observations could confirm the different biological risk for both visceral and subcutaneous fat depots what is in agreement with body composition and higher association of %BF-defined obesity in coronary disease men [10, 11, 17]. This is important, since subcutaneous adipose tissue is less deleterious than intra-abdominal fat accumulation, which influences cardiometabolic processes and ASCVD risk [6-8, 10-18, 29-31].

The study supports the distribution of adipose tissue as notable risk predictor although all variables with WC measurements shown higher discrimination than indicators with skinfolds distribution (endomorphy) or body fatness integrated in BMI. In strict anthropometric sense WC as proxy of abdominal obesity is the true focal component of risk, and the only one among simple measurements in reflecting cardiometabolic risk, ASCVD risk and mortality [5-8, 11-18, 29-34]. In this line, we have exposed the role of WC and height as physical dimensions in relation to a body volume index through WHtR [8, 17]. Thus, the data strengthen the ability of WHtR to predict MI risk actually being WC and height measurements the foundated anthropometric basis for estimating %BF [23]. In results, %BF shows the same discriminative power as WHtR actually drawing inverse WHtR the same reciprocal ROC curve as %BF but associated to healthy control status. The question is the scientific deduction, %BF comes from equations of statistical models and WHtR provides a real index of biological risk volume by unit of height, with too little - too much dependence on musculoskeletal component – visceral adiposity [8, 17]. On the other hand, the differences of associated risk between simple measurements or unit of measure (e.g. length, mass) such as WC, height, HC, weight, BFM and LBM are fundamental anthropometric keys for the understanding of the true risk for each compound indicator. These findings reproduce previous studies [8, 17] in revealing statistical bias for BMI and WHR (ROC curve not shown). Both indicators depend at time on peripheral body fat (with lesser discriminative risk) and partially of both weight and LBM (without associated risk) in underestimating abdominal obesity. Anthropometric evidence supports that HC does not influence body composition but vice versa [17], and this study verifies absence of discriminative risk. Besides, the normal human body is structured generally with a HC higher than WC (WHR <1) and a height lower than HC x 2. This anthropological fact along with the discriminative risk for inverse height provide a cutoff and statistical risk for WHR without real equivalence respect to WC and WHtR. This situation causes a protective overestimation for HC respect to WC and height that result in spurious risk for WHR association [8, 17].

According to our reasoning, the validity for any indicator depends on strength of their formula to reflect adiposity-associated risk although keeping in mind the discriminative ability as well as epidemiological causality and real equivalence between anthropological measurements and their own discriminative risks. Therefore, risk evaluation will have more strength with those anthropometric formulas that properly may translate a higher, verifiable, and plausible biological risk. To our knowledge, this is the first time that anthropometrically-predicted %BF provide a clear discriminative association in MI men by using a validated model in US adult population [23].

In the present research work, WHtR and %BF show the highest discriminative abilities related with an unhealthy body composition, although conceptually are different. We have proposed WHtR as risk volume concept where WC and inverse height always would be proportional to the individual biological risk [17]. Furthermore, WHtR as proxies of risk adiposity is the only one among anthropometric indicators that three-dimensionally may express a measure of volume at the same as technological methods. However, the new estimator of %BF in depending on other numerical variables from statistical models, and in spite of being a more intuitive concept could not translate the authentic and accuracy biological risk of the individual.

Lastly, results of this study provide critical perspectives on obesity criteria and cardiometabolic risk. BMI and WHR are misleading indices with biased statistical association and without anthropometric accuracy. Subcutaneous fat measures show a moderate discriminative power. WC alone does not indicate proportionality and it is individually insufficient. HC and height measurements are not comparable in their dimension of risk neither in anthropometric implications on the body composition and unhealthy fat distribution. It is time to recognize WHtR as the best MI risk predictor and the strongest anthropometric factor within metabolic syndrome criteria and as risk-enhancing factor for ASCVD [8, 12-17, 24]. WC as nuclear and verifiable adiposity factor and height as risk modulator factor provide the real metric in MI risk prediction, at least in middle-aged adult men with homogeneous body fat distribution and raised %BF. In public health education and promotion, a heart-healthy lifestyle across the life-course (smoking cessation, healthy diet pattern, regular physical exercise and energy balance) is for recommendation, and WHtR as clinical control tool of a healthier body composition rather than total body weight or WHR would be clearly better. Anyway, a pending question in research is to determine validated geographic region-specific and ethnicity-specific cutoff values for both WHtR and anthropometrically-estimated %BF. In our sample from a geographic-region specific, which population was subsumed between the 27,000 participants from 52 countries in the INTERHEART study [6], WHtR ≥0.54 and BF≥27.2 percentage are the cut-off points of reference in discriminating MI European men.

One potential limitation of this study is that the cross-sectional design did not allow showing long-term epidemiological causality between MI and associated indicators. Another limitation is that our results cannot be generalized by the sample size. Despite this, the disclosures could be extrapolated to all subjects with an anthropometric profile similar to those of other from larger studies. The new data referenced help to better understanding a profile related with adiposity and cardiometabolic risk. The relevance of these results extends the knowledge for the large number of infarcted people whose degree of adiposity measured by several anthropometric indicators could be very close to those of these values. Future studies should confirm this possibility.

5. Conclusion

In MI men, adiposity-associated indicators show different discriminatory capability. BMI-defined obesity presents moderate discrimination and anthropometric bias in association that do not lent support their suitability as risk predictor. WHtR and %BF by measuring waist circumference and height show the highest discriminative abilities and robust anthropometric reasons related with the true biological risk. In public health, we propose WHtR as the better and real metric of biological risk volume, abdominal adiposity proportional to individual height and clinical expression of unhealthy body fat for the identification of adult men with increased cardiometabolic risk.

Conflict of Interest

The authors declare that they have no competing interests.

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