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RESEARCH ARTICLE

Waist-to-Height Ratio is an Optimal Metric in Predicting Myocardial Infarction Risk. Other Anthropometrics Widely used by Cardiology to Promote Cardiovascular Health Present Association Biases

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ABSTRACT

Among the components of Life's Essential 8, body mass index is the anthropometric used in the scoring algorithm of cardiovascular health. Concerning myocardial infarction, the waist-to-hip ratio may show more predictive value than body mass index, waist circumference, and waist-to-height ratio, and has showed a greater excess risk of myocardial infarction in women than in men. However, bias has occurred in global research because of inadequate comparisons with the high-risk body composition. Hence, cardiology may have been confused for a long time because bias-related errors were always overlooked. This situation occurred when risk association was distorted by over- or under-estimating some simple measurements over others. Our aim was to determine whether the historical risk associated with some anthropometrics might provide a bias in causal inferences. Our study design was a review on data of the body of literature. We created new anthropometric variables, which were always omitted in previous large studies. In most studies, mathematical inequalities between the simple measurements in anthropometrically healthy subjects were overlooked, including disparities between lean and fat masses. That way, in omitting the difference in means between the simple measurements of length and body mass components, association findings and causality cannot be assumed. No anthropometric will be equivalent for estimating the same high-risk body composition if the difference in means between the simple measurements present an unbalanced distribution, and besides, being associated as confounding factors. Therefore, after describing new anthropometric variables termed as "x" and demonstrating that the simple measurements showed means of differences differentially distributed between healthy and unhealthy cases worldwide, association biases for the body mass index, waist-to-hip ratio or waist circumference alone may be endorsed, indicating the importance of these results. From a new anthropometric perspective, the waist-to-height ratio may indicate the concrete volume of an abdominal three-dimensional disc in direct-inverse relationship with waist-body height without showing association biases. This index may represent a new construct by defining a risk abdominal volume and avoiding potential confounding factors. In a paradigm shift, only the waist-to-height ratio meets causality criteria as the optimal index to predict myocardial infarction risk and to promote cardiovascular health.

Keywords: Cardiovascular disease; myocardial infarction; abdominal obesity; anthropometric; waist-to-height ratio; risk prediction; bias; public health.

1. INTRODUCTION

The American Heart Association defined a novel construct of cardiovascular health to promote a paradigm shift on disease treatment to one inclusive of positive health promotion and preservation across the life course in populations and individuals[1].

Among the components of Life's Essential 8, body mass index (BMI) was the anthropometric included in the scoring algorithm range[1]. BMI remains a universalized anthropometric in cardiovascular health promotion. Moreover, when predicting myocardial infarction (MI) risk, BMI has shown a moderate association, while the waist-to-hip ratio (WHR) is the strongest indicator worldwide[2-5]. Thus, BMI and WHR are the anthropometrics proposed in the construct of cardiovascular health and the INTERHEART risk score, respectively[1,6]. On the other hand, an accurate estimation of the body composition (BC) as well as body fat distribution is more relevant from a scientific perspective, which has also been endorsed by the American Heart Association [7]. In light of this, how can a high-risk BC for any type of cardiovascular disease (CVD) be measured using simple anthropometric measurements?

Interestingly, epidemiologic association do not always equate to causation in incidences of CVD and MI. Thus, an important limitation of anthropometric studies is the potential for confounding bias that arises because risk assignment is not random. Therefore, the observed associations may be attributable to differences other than the risk being investigated, and causality cannot be assumed. Similarly, differences in BC between groups with similar baseline confounding variables may result in bias if the true risk assignment does not account for covariates that predict the true risk[8,9]. Hence, a major limitation when using observational data to estimate causal effects is confounding factors. These confounding factors can be adjusted with multivariate models. However, the distribution of anthropometrics as confounding factors may be different between healthy and unhealthy subjects, and model extrapolation can be erroneous. In this sense, the causal effect estimated with regression models can vary depending on different assumptions and omissions from the model. Moreover, any observed association may be spurious, indirect or real. Therefore, any anthropometric epidemiologically may be associated with CVD and MI; however, this may demonstrate over- or under-estimations if confounding factors are present.

As a result, the risk assignment for anthropometrics – such as BMI, WHR, and the waist circumference (WC) – may be systematically biased for causal inferences if they do not capture the true risk or if the values for the simple body measurements do not present a balanced distribution between healthy and unhealthy cases[8,9]. Hence, the notion of mathematical equivalence for the different simple measures should be respected between groups being compared. If not, the lack of a balanced distribution between the simple measurements will be particularly prone to the generation of biases in outcomes [8,9]. In this approach, a nuclear observation relates to the anthropometric knowledge of the mathematical relationships and differences between the simple body measurements in anthropometrically healthy subjects and normal weight (<25 kg/m²) range[10] (Table 1). In Table 1, mathematical expressions and accurate values are result of scientific knowledge after investigating anthropometric variables from another perspective. Thus, data of mathematical inequalities between each two different simple measurements and other anthropometrics – such as fat free mass (FFM), fat mass (FM), and fat mass-to-fat free mass ratio (FMFFMR) or FM%-to-FFM% ratio – were collated. Similarly, variables, where body weight is distributed by unit of height: [Height (cm)–100] or [Height (m²)] as in BMI formula, were added.

Table 1: Anthropometrics, natural mathematical inequalities and absolute difference between some simple measurements in anthropometrically healthy subjects from any ethnically-based or sex-specific large population

1. Ht>HC>WC: Ht/HC>1: HC>Ht/2: HC/(Ht/2)>1: WHR<WHtR x 2: WHR/WHtR<2
2. WC<Ht/2: WC/(Ht/2)<1: Ht>WC x 2: WHtR<0.5: WC/Ht<1
3. HC>WC: WC/HC<1: WHR<1 (<0.90 in men and <0.85 in women)
4. Weight (kg)<Ht (cm): Weight/Ht<0.5: Weight/(Ht-100)<1: Weight/(Ht (m)^2) [BMI] <24.9: FFM+FM/(Ht-100)<1: FFM+FM/(Ht (m)^2 [BMI]<24.9
5. WHD: HC–WC=X: |x|>0: |+x|> in women than in men
6. HCHt/2D: HC–height/2=X: |x|>0
7. WCHt/2D: WC–height/2=X: |x|>0 : |-x|>0
8. Height–WC=X: |x|>0: 2WC>height: 2WC–height>0
9. Height–HC=X: |x|>0: 2HC>height: 2HC–height>0
10. FM%<25-30% (men-women). FFM%>70-75% (women-men). FM%/FFM%<0.33-0.42 (men-women). FFM>FM: FMFFMR<1: FM–FM=X: |x|>0: |+x|> in men than in women. FFM–FM/(height)–100)=X: |x|>0: FFM–FM/(Ht (m)^2=X: |x|>0:

BMI indicates body mass index in kg/m^2; FFM, fat free mass in kg or % as appropriate; FM, fat mass in kg or % as appropriate; FMFFMR, fat mass-to-fat free mass ratio; HC, hip circumference in cm; HCHt/2D, absolute difference between hip and half of height in cm; Ht, height in cm; WC, waist circumference in cm; WCHt/2D, absolute difference between waist and half of height in cm; WHD, absolute difference between hip and waist in cm; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; X, new anthropometric variable as the absolute difference between the corresponding measurements; |x|, absolute value for "x".

* Mathematical expressions and values derive from the anthropometric knowledge, where the mean values (standard deviation) were measured in the anatomy of anthropometrically healthy adults and normal weight range.

Source: Original table built by the author who has the copyright. Data are result of an own investigation. Partial data have been published by the author, and new variables are now added.

Mathematically, the absolute value of each simple measurement (weight, FFM, FM, height, WC and hip circumference [HC]) depends on the bodily components involved in each dimension, but never estimates an identical high-risk BC[8,9]. Evidence supports that WC is a metrics linked to visceral adipose tissue and, together with the waist-to-height ratio (WHtR), can better predict CVD, MI, and cardiometabolic risks[2-5,8,9,11-24]. However, from the INTERHEART and other studies about MI, WHR appeared to show the best predictive value compared with BMI, WC, and WHtR, as appropriate[2-5,8,9]. Additionally, data from the UK Biobank revealed that WHR showed a greater excess risk of MI in women than in men[5]. Similarly, in this population cohort, South Asian individuals had substantially higher risk of atherosclerotic CVD compared with individuals of European ancestry[25]. On the other hand, WHtR, whole-body fat percentage, and technologically–measured adiposity could also be good indicators for predicting cardiovascular risk factors and cardiovascular events[5, 8,9,11-23,26-28]. Nevertheless, when predicting CVD or cardiometabolic risk, the magnitude of the association for different anthropometrics in all-important studies was not always a coincidence[2-5,12-16]. In this regard, the association of anthropometrics and CVD and MI is not interchangeable with the relationships between anthropometric and non-anthropometric risk factors[2-5,12-19,25]. Interestingly, despite the existing discrepancies in the association of anthropometrics and CVD and MI outcomes, when the simple measurements were differentially distributed between healthy and unhealthy individuals, bias errors were never typically addressed and discussed[2-5,8,9,20-25]. To the author`s mathematical knowledge, each proper fraction (ratio <1) never represents the same whole as that measured by the corresponding numerator. In contrast, when a ratio is ≥1, the numerator and fraction represent the same whole with respect to the concerned measurements in the fraction; therefore, the mathematical object depends exclusively on the

numerator (e.g., weight/(height (cm)–100>1)[8,9]. Nevertheless, when some anthropometric is represented under this mathematical expression, any improper fraction and their numerator may represent the same whole, but not necessarily referring to the highest risk BC, at least after knowing that some anthropometrically-omitted bodily components may hide the true high-risk BC[8,9,17,27-29]. The objective of this research was to determine whether the historical associations of anthropometrics and MI might provide some bias in results; therefore, constraining causal inferences.

2. METHOD AND STUDY DESIGN

This research has been conducted using published data sources. Our study design was a review on anthropometric data of the body of literature. Moreover, we mathematically created new anthropometric variables. Similarly, from mathematical functions validated by DEXA in adult individuals, other variables – such as FM and FFM (or their corresponding percentages) – were established and calculated[27,28]. Thus, new metrics and their corresponding risk cut-offs for differentiating bodily components were established. Mean values (standard deviation) of the simple measurements in different studies were used for calculating variables or recalculating new metrics. The difference in means between two simple measurements becomes a new variable termed "x", and measures the absolute difference or modulus |x| as a result of subtracting one simple measurement or their mean from one another. Absolute value describes the distance from zero that a number is on the number line, without considering direction or sign. In addition, the difference in means between the mean values of the simple measurements in a parallel group analysis is equal to the mean of the differences in two groups in a paired analysis. In this approach, we have described "x" as a variable to indicate each absolute value result of the difference between HC–WC, WC–height/2 (or 2WC–height as its mathematical equivalence) and HC–height/2 (or 2HC–height as its mathematical equivalence). Additionally, FFM–FM and its difference by unit of height: FFM–FM/height $(m)^2$ or FFM–FM/height (cm)–100 were added. Complementary, FMFFMR and FM%-to-FFM% ratio were created.

After collating variables (see Table 1), an update on epidemiologic risk cut-offs in different studies worldwide was carried out. The cut-offs were defined through different measures of association and body of scientific evidence, but representing mean values (standard deviation) and significant differences between the corresponding metrics. A standard difference that higher than 0.5 will be taken to indicate a considerable difference for each "x" variable between two simple measurements ($|x|>0.5$). Similarly, a significant difference between two simple measurements will be taken to indicate a considerable difference for the ratios or ratio of ratios ($p<0.05$). If, after checking risk cut-offs for associations systematic differences between measurements remain, this will be an indication that a spurious risk has been assigned by over-or under estimating some simple measurements over others.

3. RESULTS

Results of this research are shown in Table 2. The risk cut-offs for the most widely used anthropometrics are collated. Similarly, the new anthropometrics and the corresponding uncovered risk cut-offs are presented. In all risk cut-offs an inequality between the corresponding simple measurements was significantly found ($|x|>0.5$ and $p<0.05$ as appropriate). Height and height/2 showed null association or more frequently inverse. HC showed null association or weak positive or weak inverse, as appropriate, and poor discriminatory power. Weight showed poor discriminatory ability. The |x| values for HC–WC and FFM–FM were always slanted towards the healthy status, therefore, showing an inverse association. Rest of anthropometrics were positively associated.

Table 2: Update on epidemiologic risk cut-off points for the associations of anthropometrics and cardiovascular disease and myocardial infarction worldwide. Mathematical relationships between the different simple measurements and ratios or ratio of ratios (2-5,8-10,16-21,23-26,28,30-33).

Anthropometric	Men	Women	Association findings**
Weight (kg)	(W>(Ht-100)*	(W>(Ht-100)*	(-) or weak positive
Height (cm)	(Ht>HC>WC)*	(Ht>HC>WC)*	(-) or inverse
HC (cm)	(HC>WC>Ht/2)*	(HC>WC>Ht/2)*	(-)/weak positive or weak inverse
Height/2 (cm)	(WC>Ht/2)*	(WC>Ht/2)*	(-) or inverse
HHt/2R: HC/(Ht/2)	**>1** (HC>Ht/2)*	**>1** (HC>Ht/2)*	Moderate positive
HCHt/2D (HC – Ht/2): "X"	**|x|>0***	**|x|>0***	Moderate positive
WC (cm)	>94 (102): (WC>Ht/2)*	>80 (88): (WC>Ht/2)*	Strong-moderate positive
BMI (kg/m²)	>26.5 (<30): W>(Ht-100)*	>25.5 (<30): W>(Ht-100)*	Moderate positive
FFM+FM/(Ht (m)-100)	>1*	>1*	Moderate positive
FFM+FM/(Ht (m)²)	>24.9*	>24.9*	Moderate positive
FMFFMR	<1*	<1*	Moderate positive
FM%	>26.5-27*	>35*	Strong-moderate positive
FM%-to-FFM% ratio	>0.33 (<1)*	>0.42 (<1)*	Moderate positive
FFM–FM: "X"	**|x|>0***	**|x|>0***	Moderate inverse
FFM– FM/(Ht–100): "X"	**|x|>0***	**|x|>0***	Moderate inverse
FFM–FM/(Ht (m)²: "X"	**|x|>0***	**|x|>0***	Moderate inverse
WHR	≥0.90 **<1** (HC>WC)*	≥0.85 **<1** (HC>WC)*	Strong positive
WHD (HC–WC): "X"	**|x|>0***	**|x|>0***	Moderate inverse
WHtR	**≥0.5** (WC>Ht/2)*	**≥0.5** (WC>Ht/2)*	Strong-moderate positive
WHt/2R: WC/(Ht/2)	**>1** (WC>Ht/2)*	**>1** (WC>Ht/2)*	Strong-moderate positive
WCHt/2D (WC–Ht/2): "X"	**|x|>0***	**|x|>0***	Strong-moderate positive
WHR/WHtR	**<2** (WHR<WHtR x 2)*	**<2** (WHR<WHtR x 2)*	Strong-moderate positive

BMI indicates body mass index; FFM, fat free mass in kg or % as appropriate; FM, fat mass in kg or % as appropriate; FMFFMR, fat mass-to-fat free mass ratio; HC, hip circumference; Ht, height; HCHt/2D, absolute difference between hip and half of height; HHt/2R, hip-to-height/2 ratio; W, weight in kg; WC, waist circumference; WCHt/2D, absolute difference between waist and half of height; WHD, absolute difference between hip and waist; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; WHt/2R, waist-to-height/2 ratio; "X", absolute difference between the corresponding simple measurements.

*Significant difference between the mean values of the referenced simple measurements ("x" variable) and a non-equivalent relationship in the ratios was always found: $|x|>0.5$ or $p<0.05$ as appropriate. ** Each anthropometric, simple measurement, ratio, ratio of ratios, or "x" values in the corresponding risk cut-offs represent the mean values (standard deviation) in Caucasian population. Absolute values for simple measurements or BMI and WHR cut-offs may vary in Asian population, but without modifying for inequalities or direction of "x" values between the simple measurements.

***Measures of association such as odds ratios, hazard ratios, receiver operating characteristic curves or other statistical models were used as appropriate. Means (standard deviation) or medians, tertiles, quartiles, quintiles, sensitivity/specificity and universally categorized or defined cut-off points were used in all the comparisons where appropriate

(-): Null or no association

a Ethnically-specific risk cut-offs are taken into account when reflecting the inequality between simple measurements, and the subsequent non-equivalent risk in the ratios, ratios of ratios and "x" values. b Mathematical inequalities and differences were extracted from the differences between the mean values (standard deviation) described or inferred in most studies worldwide.

Source: This original table refers to both cardiovascular disease and myocardial infarction, and partially has been published by the author, who has the copyright. The new anthropometric variables and others are now added.

4. RECENT FINDINGS AND PARADIGM SHIFT ON THE ASSOCIATIONS OF ANTHROPOMETRICS AND CVD/MI

For the first time, by using propensity score and stratification methods, an association bias of WHR has been demonstrated in Spanish men with MI by selecting spurious-risk in the stratum between the risk cut-off and 0.999 value[20]. Similarly, in assessing CVD and MI risk, bias in research occurred worldwide when the high-risk BC was not well compared due to imbalances between the means of the simple measurements and their corresponding difference in means being overlooked[8,9,20,26]. Interestingly, as described in this study, each subject presented an anthropometrically-measurable variable, which an absolute value |x| was the result of substracting WC from HC[20].

After investigation, most of the risk cut-offs for the association of anthropometrics and CVD and MI worldwide showed an imbalance between the means of the simple measurements and corresponding ratios [2-5,8-10,16-21,23-26,28,30-33] (see Table 2). Consequently, the association findings for each metric and causality for the true risk cannot be assumed. For example, a mean WC of 96.5 and a mean HC of 98.3 may indicate a difference in means of 1.7, where the mean WC ≠HC: mean HC>WC: mean WHR<1: x=1.7: |x|>0 and significant difference (|x|>0.5) [8,9,20]. Following the example, a mean of difference for HC minus WC (97.5 vs. 91.4) =6.1 (x=6.1) in the healthy group and x= -2.7 (99 vs. 101.7) in the cases group indicates you a mean of differences of 1.7 (6.1+ (-2.7)/2 =1.7): x=1.7: |x|>0: unbalanced distribution, and "x" slanted towards the healthy status (inverse association)[20]. In anthropometric research, how much difference there is between the means of the healthy group and the cases group is often omitted. Thus, in most observational studies, excepting the cited study[8,9,20], the corresponding "x" variable for HC–WC was always omitted.

From the associations of CVD and MI risk when making causal inferences in most studies, WHR appeared to be biased with respect to WC and WHtR. This occurred due to an unbalanced distribution of the difference between means of the simple measurements in any WHR risk cut-off <1 and when the mean WHR/WHtR was of <2 (mean HC>height/2) (see Table 2). For example, a mean HC of 98.3 and mean height/2 of 85.7 may indicate a difference in means of 12.6, where the mean HC ≠height/2: mean HC>height/2: x=12.6: |x|>0 and significant difference (|x|>0.5)[20]. Following the example, a mean of difference for HC minus height/2 (97.5 vs. 86.7) =10.8 (x=10.8) in the healthy group and x=14.3 (99 vs. 84.7) in the cases group indicates you a mean of differences of 12.6 [(10.8+14.3)/2 =12.6]: x=12.6: |x|>0: unbalanced distribution and "x" slanted towards the cases status. Thus, either for HC–WC or HC–height/2, the imbalance was significantly slanted toward one of the groups with a mean |x|>0, and it created a protective overestimation of HC with respect to WC and height[8,9,20,26] (see Table 2). This mathematically demonstrated that any WHR-associated risk beyond that of WC and WHtR was a spurious-risk providing a false causal inference, and was anthropometrically impossible[8,9,20,26,33].

Based on these mathematical observations, only equivalence may exist when the mean HC=height/2 (or mean 2HC=height) [|x|=0 in both], coincides with a mean of WHR/WHtR=2 [mean WHR=WHtR x 2: mean WHR minus WHtR =WHtR]. For example, 0.90 vs. 0.45, 0.95 vs. 0.475, 0.97 vs. 0.485, 0.98 vs. 0.49 etc., for mean values of WHR vs. WHtR, where WHR is always equal to twice WHtR. However, this situation epidemiologicaly never happens, and besides, anthropometrically is impossible [8,9,20,26,33]. On the other hand, most studies may demonstrate that if the WHtR risk cut-off is >0.5, there is no balance between the mean WC and height/2 (mean WC>height/2: difference between means =x: |x|>0: unbalanced distribution. For example, a mean WC of 96.5 and mean height/2 of 85.7 (mean height of 171.4: WHtR=0.56) may indicate a difference in means of 10.8, where the mean WC ≠height/2: mean WC>height/2: mean WHtR>0.5: x=10.8: |x|>0 and there is a significant difference (|x|>0.5)[8,9,20]. Following the example, a mean of difference for WC minus height/2 (91.4 vs. 86.7: WHtR=0.52) =4.7 (x=4.7) in the healthy group and x=16.9 (101.6 vs. 84.7: WHtR=0.60) in the cases group indicates you a mean of differences of 10.8 [(4.7+16.9)/2 =10.8]: x=10.8: |x|>0: unbalanced distribution[20]. In this situation, and since in healthy people WC usually is lower than height/2 (see Table 1), the imbalance with a mean |x|>0 was significantly slanted towards the cases status, creating a risk overestimation for WC in the tallest people and an underestimation in the shortest. Therefore, any WC-associated risk above WHtR measures becomes a spurious-risk for providing a false causal inference in any study and is impossible anthropometrically.

After reviewing differences in means from selected studies worldwide (e.g., INTERHEART, CONOR, UK Biobank, a Swedish cohort, and others in Caucasian

and Asian populations), the mean |x|values recalculated and inferred feasibly were always unbalanced; therefore, they never compared the same |x| value between healthy and cases[2-5,8,9,20-28,31] (see Table 2). Undisputably, there was always imbalance between the simple measurements. All mean |x| values were >0.5, even though different individuals in both groups might present "x" as a positive, zero or negative value. This situation generated a generalised confounding bias due to the constant association of non-causal and confounding factors, which provided an over- or under- estimate of some anthropometrics. Thus, all the risk comparisons were marked for different mean |x| values, and therefore showed association biases. Surprisingly, in the recent Rotterdam study about anthropometrics and risk of new-onset atrial fibrillation association biases were also found[32]. After analysing the study, all mean |x| values for the difference in means of WC–HC (x=5.6 in men and 14.7 in women; |x|>0 in both), WC–height/2 (x=8.7 in men and 7.6 in women; |x|>0 in both) and HC–height/2 (x=13.7 in men and 22.3 in women; |x|>0 in both) were unbalanced (|x|>0 in all); therefore, comparing for different biological risk[32].

Anthropometrically, either height or weight, or even HC may be associated factors, but not causally related to CVD and MI. Thereby, in the Rotterdam study, only an inferred WHtR of 0.54 in both sexes may meet the best anthropometric criteria in predicting atrial fibrillation risk. In this anthropometric situation, height would not be a predominant causal risk factor, but a volume factor modulating the causal risk[7-9,17]. Similarly, considering weight as the predominant risk factor in women may be a bias error. After using validated formulas, mean FM and FFM in the Rotterdam study were recalculated[27, 28]. Thus, a different mean FFM between men (mean BMI =26.5) and women (mean BMI =27.1) was verified: 59.5 kg (72.4%) vs. 43.3 kg (60.6%), respectively (significantly different)[32]. Hence, with the same mean value of WHtR=0.54 in both sexes you are comparing for different means of FFM–FM: |x|=36.8 in men vs. |x|=15.2 in women, and for different means of FM%-to-FFM% ratio [0.38 (27.6%/72.4%) in men vs. 0.65 (39.4%/60.6%) in women][32]. Interestingly, some studies (e.g., the UK Biobank, Rotterdam and a case-control Spanish study) showed the same risk cut-off for FM%-to-FFM% ratio in men (value of 0.38), although they assessed MI and atrial fibrillation as diferent types of CVD[5,28,32,].

From a mathematical and geometric perspective, a two-dimensional area (cm^2) calculated using a WC is not the same as a three-dimensional volume (cm^3) measured using a WC as area of the base and WHtR cm as an unit of height[8,9,17,20,33] (Figure 1).

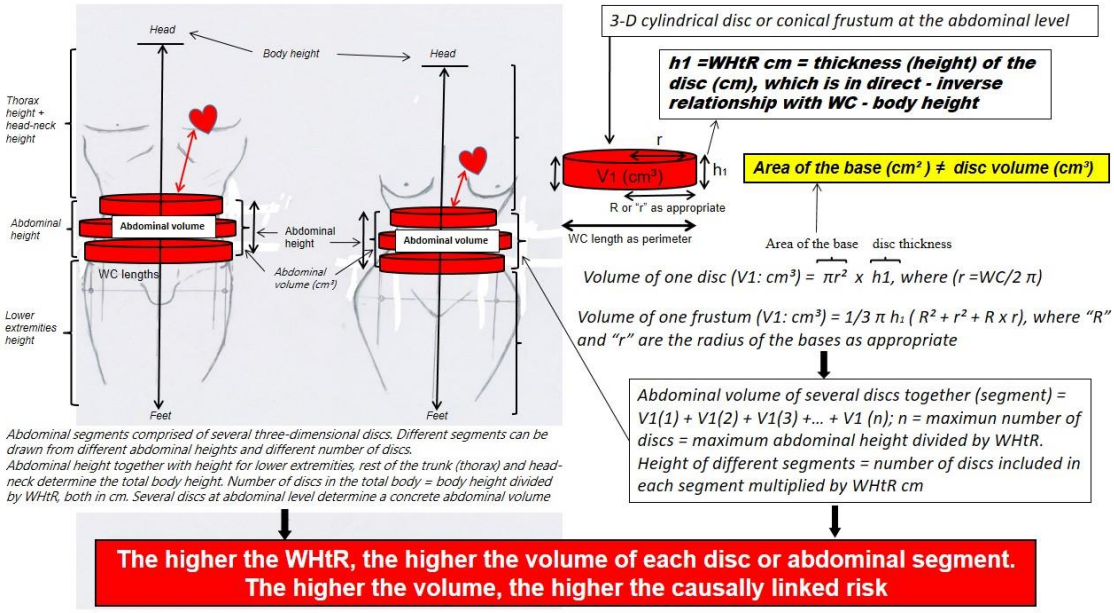

Figure 1. Geometry and volume of solids applied in the human body. Abdominal discs and segments are drawn. Volumes of one or several three-dimensional discs segmented at abdominal level are explained. h1 indicates height of each disc/frustum; R, radius of the major base if appropriate; r, radius of the base or minor base if appropriate; V1, volume of each disc/frustum; WC, waist circumference at different levels; WHtR, waist-to-height ratio.

Subsequently, only when WC presents a balanced distribution with respect to height (2WC=height: WC=height/2: WHtR risk cut-off =0.5), then WC and WHtR refer to the same whole as a mathematical object, where 2WC/height and WC/(height/2) are equivalent fractions with de same value (both ratios =1: improper fractions). However, this situation epidemiologically never happens. By contrast, in any WHtR risk cut-off >0.5, area and volume measurements will never mathematically express the same whole-risk nor the same whole-body fat percentage[8,9,27,28,33]. Thus, when assigning true risk, only WHtR from a risk cut-off above 0.5 better captures a high-risk BC[8,9,17,28,33] (see Figure 1).

Regarding BMI, most studies have showed a BMI risk cut-off representing the category of overweight (>24.9 to <30 kg/m^2)[2-5,8-10,19-26,28,30-33] (see Table 2). Moreover, after a logical deduction, the mean FFM is always higher than FM; therefore the "x" variable representing the difference is higher than zero (|x|>0). However, in this anthropometric situation [(FFM+FM)/(height (m)–100>1], it is only possible to say that either BMI or body weight represent the same whole, but never refers to the highest risk BC, which may depend on other more predictive variables capturing the true risk[8,9,33]. Similarly, while FMFFMR was of <1 and FM%-to-FFM% ratio of >0.33 or >0.42 (in men or in women, respectively; <1 in both) FM, as the numerator, and FMFFMR, as a proper fraction, may never express the same whole as a mathematical object. Thus, BMI-associated risk may not be fully explained either by an improper fraction (weight/height (m)–100>1) or by a proper fraction (FMFFMR<1). In both cases, BMI and the ratio between two opposite metabolical components hide the true relationship with high-risk BC. In this sense, BMI might partially capture a spurious-risk derived from an uncontrolled measure by omitting an unbalanced distribution of the corresponding "x" variable in the compared groups (see Tables 1 and 2).

Effectively, after analysing adiposity anthropometrics in a Spanish study in men with MI[28], a mean FFM of 45.8 kg (72.4%) and mean FM of 34.6 kg (27.6%) indicated a difference in means of 11.2: mean FFM>FM: mean FM%-to-FFM% ratio of 0.38: mean FMFFMR =0.75 (<1): x=11.2: |x|>0 and significant difference (p<0.05)[28]. Following this example, a mean of difference for FFM–FM (45.2 vs. 36.7) =8.5 (x=8.5) in the cases group and x=13.8 (46.4 vs. 32.6) in the healthy group, indicating a mean of differences of 11.2 [(13.8+8.5)/2 =11.2]: x=11.2: |x|>0: unbalanced distribution and "x" slanted towards the healthy status (inverse association)[28] (see Table 2). This study compared both components of the weight by separation. Among several novel findings, total FFM as lean body mass showed no significant differences between groups (45.2 vs. 46.4: area under the curve: 0.476). However, when currently analysing FFM by unit of height (FFM/height (cm)–100) a significant difference may be found (0.65 vs. 0.63: p<0.05), and relative FFM as confounding factor is directly associated with the MI group. This means that relative FFM was differentially distributed between both groups, generating a protective overestimation of the musculoskeletal component with respect to FM[28]. Similarly, when recalculating bodily components in baseline characteristics of participants in the UK Biobank[5,27,28], we may find a mean FM% of 27.6% in men and 37.5% in women, and mean FFM% of 72.4% and 62.5% (in men and in women, respectively). That way, the mean FM%-to-FFM% ratio was of 0.38 in men and 0.60 in women, therefore, in a risk cut-off of <1, where both components were always unbalanced while associating different risk: hazard ratio =1.28 in men (mean BMI of 27.8) and of 1.22 in women (mean BMI of 27.0)[5].

In this approach, while the anthropometric profile from somatotype, BMI, WHR, and WHtR may be similar or approximate in most studies, the "x" variable for FFM–FM may always show an unbalanced distribution and inverse association (see Table 2). Thus, after determining that mean FFM is consistently much higher than mean FM in all anthropometrically healthy subjects (mean FM%-to-FFM% ratio <0.33-0.42), and FM% is strongly associated with MI, any imbalance between both components: FFM–FM >0, FMFFMR<1 and FM%-to-FFM% ratio >0.32-0.43 will result in a biased measure for BMI-associated risk[2-5,17,20-33] (see Tables 1 and 2).

To note, after revising large studies and its difference in means for the simple measurements, our recent findings about confounding biases may be endorsed, indicating the future importance of these current results.

5. DISCUSSION

This research demonstrates that measures of BMI, WHR, and WC present each confounding bias leading to a biased association of the anthropometrically-measured risks. The findings were consistent across time and different anthropometrics, and besides, depending no on the degree of association reported in different studies [2-5,8-10,16-21,23-26,28,30-33].

General and abdominal obesity are well-established independent risk factors for development of many CVD, including MI, stroke, atrial fibrillation etc. However, the CVD and MI

causal risk may conceptually derive from visceral fat and a high-risk BC maintained over time. In this regard, BMI has always showed a moderate association with MI, and with any reported BMI risk cut-off we always found increased abdominal obesity rather than a mean BMI >30 kg/m² may be collated[2-5,8-10,16-21,23-26,28,30-33]. In this sense, BMI differentiates not the true bodily components of risk and may present a paradoxical and biased information that distorts their true relationship with CVD and MI risk[8,9,17,20,28,29,33].

On the other hand, as learned from mathematical fractions, only when the numerator and denominator take the same value, the numerator and fraction would express the same whole in mathematical terms[8,9,33]. Thus, if, and only if, the mean FFM=FM: FMFFMR=1: FFM–FM=X: (|x|=0), can one say that FFM and FM estimate the same whole-risk as a mathematical object. In this approach, only in a theoretical situation where the mean of |x|=0, would FFM and FM be equivalent for a same risk, and therefore, body weight anthropometrically could be valid as adding 50% for each component. However, it only might occur where there is a hight mean general obesity. Only when FFM=FM =weight/2, and a theoretical final weight was =[initial weight (100%)+(initial weight/2) (50%)], an increase of 50% over initial weight would imply a final weight of 150% without gaining FFM. However, this situation and a mean body fat excess that is so high is unlikely in any population study. For example, for a mean BMI of 27.3 kg/m² and mean initial weight of 80 kg [FM (20 kg) + FFM (60 kg)], only when mean final weight was 80+(80/2)=120 kg, would FM and FMM meet the criteria of equality: FM (60 kg) =FFM (60 kg) = final weight/2 (50% of final weight =(120/2)=60 kg), but having a mean BMI of 40.9 kg/m² and mean height of 171.2 cm. This situation would occur only if FM increases and FFM does not move. Effectively, increasing 3 or 2.3 times (for men or women, respectively) to an initial FM in normal (<25-30%) range (see Table 1)[29] can one equal to an initial FFM in normal (>70-75%: women-men) range if FFM does not move (FMFFMR ≈1). Obviously, if the absolute value of an initial FFM increases or decreases FM should increase more or less to up a value of equality (50% for each component: FM%-to-FFM% ratio =1). In the opposite case, only in a severe sarcopenia in underweight (BMI <18.5 kg/m²) range might there be a mean body weight that is anthropometrically valid with a body weight adding 50% for each component (FFM=FM). Similarly, decreasing 2.3 or 3 times (for women or men, respectively) to an initial FFM in normal (>70-75%) range (see Table 1)[29] can one equal to an initial FM in normal (<25-30%) range if initial FM does not move (FMFFM ≈1: FM =FFM =weight/2). Obviously, if the absolute value of an initial FM increases or decreases FFM should decrease more or less to up a value of equality (50% for each component: FM%-to-FFM% ratio =1). However, this situation and a mean FFM so low is clinically possible, although epidemiologically unlikely, and not causally related to CVD risk, at least without gaining FM. By contrast, in all epidemiologic studies we always found a BMI risk cut-off in overweight range and the corresponding "x" variable for FFM–FM was always >0: (|x|>0): unbalanced distribution, and FM%-to-FFM% ratio of >0.33 or >0.42 (<1 in both sexes) (see Table 2). Therefore, this mathematically demonstrates that in any BMI risk cut-off—without reflecting a high degree of obesity or even underweight and the mean being always FFM>FM—both bodily components may never be equivalent for estimating the same whole risk. Hence, in this anthropometric situation, BMI will always show confounding and association bias.

It is noteworthy, from the Framingham studies and others investigating coronary disease and high cardiometabolic risk, that somatotype has indicated that high mesomorphy rating, moderate endomorphy rating, low ectomorphy rating (higher volume by a unit of height), and whole-body fat percentage may be associated with cardiovascular events to a different degree[8,9,17,27,28,33]. It would justify a higher FFM by each unit of height (height (cm)–100) in the cases group, and therefore unbalanced distribution[8,9,17,28]. Thus, since FM and FFM may be anthropometrically measured[27,28], an unbalanced distribution for the mean "x" variable between groups may be a confounding factor. Hence, in any BMI risk cut-off in the overweight/low obesity degree range, and with FMFFMR<1, body weight may envolve a protective overestimation of FFM with respect to FM, and an association bias when assigning causal risk to BMI may occur. It is clear by using BMI alone or their cut-off categories, you might assign a false risk score to individuals with high musculoskeletal component as in some athletic specialities and men with MI[8,9,17,28,33,34]. In this line, the higher the |x| value for a mean FFM–FM in men (|+x| value far from zero and FMFFMR far from one), the higher the probability of bias for BMI when compared to women who have a different mean |+x| value close to zero. This is because men usually have lower FM%-to-FFM% ratio and a higher |+x| value than women[5,8,27-29] (see Tables 1 and 2).

Regarding abdominal obesity, it is well-known that dividing one whole number by another is not the same as subtracting one number from another, and this is mathematically explained[8,9,20]. Thus, between

two consecutive risk abstract values for WHR<1 (e.g. between 0.95 and 0.96), you may account for ten "x" values between 5 and 4.1, which may misclassify the risk for 0.95. As already published, we may have points of risk for WHR<1, but without involving risk from the distance between HC–WC[20]. Between any WHR risk cut-off <1 (e.g., 0.93) and 0.99 value (HC–WC is always >0:|x|>0) you may have different individuals and an infinite number of fractions receiving risk-code, but not necessarily referring to the same high-risk BC as measured from WC. For example, 95.1/102 vs. 95.5/102.1 vs. 96.2/102.8 vs. 96.5/103.5 etc. =0.93 (ten values between 0.930 and 0.939): "x" for HC–WC between 7 and 6.1. As another example, 94.8/95 vs. 95.7/96 vs. 97/97.2 vs. 101/101.5 etc. =0.99 (ten values between 0.990 and 0.999): "x" for HC–WC between 1 and 0.1. Broadly, there would be seven values for WHR between 0.93 and 0.99 and infinite fractions for values of "x" between 7 and 0.1; HC>WC in all, but not receiving a true risk if the WC risk cut-off is ≥96 in each set. This is because fractions of equal value do not refer to the same whole risk as a mathematical object. On these bases, in the distribution curves for WHR spurious risk points may be assigned to provide association bias due to a protective overestimation of HC with respect to WC[9,20].

After comparing WC with WHtR, association bias for WC may be explained too[8,9,33]. Thus, between 0.51 and any WHtR risk cut-off up to 0.99 value (e.g. ≥0.55), you could find different individuals and an infinite number of fractions receiving the same binary code for WHtR (non-risk), but not necessarily referring to the same risk-code from the WC risk cut-off. For example, 96.7/175.8 vs. 92.5/168.2 vs. 98.8/179.6, 94 vs. 169.5 etc. =0.55. Here, there would be no risk code for WHtR<0.55, while WC shows different risk codes if their risk cut-off was >96 and WC>height/2. The higher the WHtR, the higher the probability of selecting false-positive points for WC compared to those true negatives below the WHtR risk cut-off. Similarly, an association bias for WHR with respect to WHtR may occur due to an imbalance in the "x" variable for HC–height/2. In this case, individuals at risk selected from a WHR risk cut-off (false positives) are true negatives from the WHtR risk cut-off [8,9,33]. In this approach, any WHR-associated risk above WC and WHtR overestimates the protective effect of HC in relation to WC and height. In this line, the higher the |x| value for a mean HC–WC in women (|+x| value far from zero and WHR more far from one), the higher the probability of bias for WHR when compared to men who have a different mean |x| value close to zero. This is because women usually have a lower WHR and higher |+x| value than men[2-5,8,9,30-33] (see Tables 1 and 2).

It is well known, WC would be the only simple measurement that meets the causality criteria as an intermediate link in the chain of causation when assessing true-risk or cardiovascular incidences, unlike weight, HC and height[2-28,33]. In this line, FFM, HC and height may be predictive factors of the outcome when showing significant associations, and although they might be causatives, they may not be. In addition, while the mean WC, HC and height/2, and the mean FFM and FM mathematically do not take the same value, we will always find an unbalanced distribution between these referred measurements. Thus, all differences in means for all the corresponding "x" variables were always higher than zero and, besides, significantly different (|x|>0.5) (see Table 2). This demonstrates that the concerned anthropometrics (BMI, WHR, WC, and WHtR) may never measure the same equivalent risk in mathematical terms[8,9,20,26,28,33]. This is because with a difference in means being different to zero (ratio between means of the simple measurements being different to one), the high-risk BC measured by each anthropometric will always be different. Moreover, when the "x" variables are different for each group, the compared risk between groups will always be different. Therefore, by omitting known confounding factors in the data analyses and ignoring mathematical inequalities in measurements of anthropometrically healthy subjects (see Table 1), a confounding bias occurred when associating anthropometrics and CVD and MI worldwide[2-5,9,17,20-26,28,30-33].

Considering another insight, technological methods and WC might have similar overall performance in predicting cardiometabolic and MI risk[8,9,18,33]. However, if the WHtR risk cut-off is >0.5 and height is inversely associated with the cases group, risk overestimation will occur for WC concerning height[8,9,17,26,33]. Additionally, any WC-associated risk above WHtR would be false due to a confounding bias that distorts the true relationship with the CVD and MI risk[8,9,17,20,33]. WHtR may detect increased intra-abdominal volume and cardiometabolic risk before a cardiovascular incident occurs or BMI reaches a degree of general obesity[2–5,10–26,28,30-33].

From a geometric perspective, we have explained that WHtR represents the relative abdominal volume of any three-dimensional disc/frustum segmented at abdominal level[8,9,20]. By deduction, if several discs are considered together at the abdominal level, the corresponding volume of a segment whose height is equal to the number of discs multiplied by WHtR (cm) can be calculated

(see Figure 1). Thus, based on the geometry and volume of solids, we may propose the following principle: Any three-dimensional cylindrical disc segmented at the abdominal level involves a CVD and MI risk in direct–inverse relationship with WC–body height from a defined WHtR risk cut-off >0.5. The magnitude of this risk is equivalent to the volume of a disc/frustum or abdominal segment determined from WC as an area of the base (s) and a thickness or height of each disc/frustum equal to WHtR (cm), regardless of BMI or WHR.

Even though an abdominal disc and visceral area do not form a perfect circle, the statement mentioned above is always fulfilled. The higher the volume of the abdominal disc or several discs together (segment), the higher the excess risk causally related to CVD and MI. This is in consonance with technological methods where a higher abdominal area involves a higher visceral fat-to-subcutaneous fat ratio[8,9,33]. Similarly, a higher volume of intra-abdominal fat will always correspond with WHtR and technological methods, at least while fat accumulation may be homogeneously distributed without reaching very high obesity. Therefore, any WHtR risk cut-off >0.5 will always detect increased abdominal obesity volume and MI risk before BMI reaches the general obesity range (see Table 2).

Based on our principle, WC does not meet any reasons for determining the highest risk in mathematical terms, at least if the WHtR risk cut-off is >0.5 and <1. In this approach, two equal risk values for WC in different individuals may determine different volumes and CVD risk levels only if WHtR quantifies a different risk volume in each individual[8,9,20]. In any population, for a same WC risk cut-off you can determine different volumes if height is significantly associated, and only finding true risk in a determined WHtR risk cut-off >0.5. Thus, a different relative risk volume may be calculated from a same WC and different personalized height (WC/height=WHtR cm as a unit of height directly associated with the risk[8,9,20,33] (see Figure 1).

It is important to note that additional comments based on other external publications in any quartile rank cannot be added. This is because no other study addressing or identifying biases was found except those derived from our own internal investigation[8,9,17,20,26,28,33]. BMI, WHR, WC and WHtR certainly present different degrees of association with CVD and MI, but they mathematically and anthropometrically never measure the same unhealthy BC. Thus, the biological risk captured from each measure may always be different[8,9,17,20,26,28,33,34]. From this perspective, by measuring a relative abdominal volume is not the same as weight management or measuring abdominal obesity from WC and/or WHR. Weight and abdominal obesity management are endorsed by different statement and guidelines on CVD prevention[1,6,7,35-42]. Nevertheless, each anthropometric is a well different tool to control cardiovascular health. This is because relative volume of risk and body mass or abdominal obesity area without accounting for volume factor may never indicate the same high-risk BC. In this line, the anthropometric somatotype in MI patients indicates a higher volume by unit of height than in healthy controls[17]. Likewise, the musculoskeletal component is in consonance with a high mesomorphy rating and high body weight by unit of height[9,17,28]. Thus, since FFM and FM components present different body densities (g/cm^3), and FM (with lower density) always occupies more volume, only a volume measure focusing on the unhealthy body fat may justify a high biological risk beyond that of BMI. As said above, only in a high degree of mean obesity FM and FFM may take the same mean value for estimating the same whole-risk. Since FFM is clearly higher than FM in healthy people (see Table 1), any FMFFMR risk cut-off <1 (see Table 2) would imply unbalanced distribution between both components ((|x|>0) and, therefore, BMI providing association biases from any epidemiologically established risk cut-off (Table 2). It is noteworthy that BMI-defined obesity is not the same as a BMI risk cut-off for predicting CVD and MI risk. Thus, BMI as an arithmetic fraction cannot be comparable to WHtR or whole-body fat as causal links to detect early risk.

In this regard, universal recommendations for BMI, WHR and WC determining overweight/obesity, or abdominal obesity and substantially increased risk of metabolic complications[1,6,7,10,35,37-42] may turn out to be fallacious if they ignore the "x" variables and the volume factor in the accumulated intra-abdominal fat[8,9,17,20,28,33]. Moreover, weight management through BMI, when ignoring abdominal volume, will always provide a distortion in cardiovascular health assessment, at least while body fat excess may be homogeneously distributed[8,9,33]. Despite this recognition, some other concepts can be clarified. Firstly, since an FFM measure may not be an intermediate between the exposure and outcome, and BMI underestimates abdominal obesity, any unbalanced distribution for FFM–FM may provide a confounding bias for BMI-associated risk[9,17,20,26,28,29,33,34]. From BMI you cannot differentiate bodily components and their proportions, for it is impossible to ensure a total relationship with a realistic risk, at least from a BMI risk-cut-off, where FFM is always higher than FM.

Secondly, from two parallel two-dimensional areas, WC and WHR estimate the same realistic risk exclusively depending on WC as the numerator, although without accounting for abdominal obesity volume. Nevertheless, WHR will always show a higher association than WC due to overestimating the protective effect of HC with respect to WC. Therefore, any WHR-captured risk above WC is partially a spurious risk[8,9,20,33]. In this arithmetic relationship, HC cannot be an intermediate between the exposure and outcome; anthropometrically, HC is irrelevant for a realistic risk[9,17,20,26,28,33]. Lastly, WC and WHtR would express the same CVD and MI risk if the mean WHtR=0.5 (WC =height/2) and height showed no association, which epidemiologically, is unlikely. In any case, only from the arithmetic relationship of WHtR can you only define a relative abdominal volume that captures the highest biological risk dimension [8,9,20,33] (see Figure 1). Mathematically and anthropometrically, a scientific statement will always hold true: Neither BMI nor WHR or WC may predict CVD and MI risk better than WHtR, at least from a risk abdominal volume measure and causal inference.

After considering a geometrical perspective, height is not an intermediate for causality, unlike WHtR as volume measure[8,9,17,20,33]. Similarly, WC and height are the basic anthropometrics for estimating the whole-body fat percentage, but without considering height as a CVD causal risk factor[8,9,27,28,33]. Having reached this point, a classification of WHtR categories between normality and a severe degree or even morbidity (0.4<0.5/≥0.5 ≤0.55/>0.55≤0.60/0.60+1) may be important because it refers to a different risk abdominal volume as WHtR directly increases[8,9,20,33]. Thus, after proposing BMI, and WHR, or even WC alone, as good predictors of ideal cardiovascular health trajectory[1,6,7,35-42], a wealth of anthropometric evidence for the referred metrics may not be found, at least without accounting for WHtR and by omitting potential confounding factors. In this sense, if you want to optimise cardiovascular health outcomes and removing anthropometric confounding biases, a new concept may be necessary. WHtR anthropometrically may represent a new construct by defining a risk abdominal volume and avoiding potential confounding factors. Surprisingly, in spite of several studies warning of anthropometric biases[8,9,17,20,26,33], most publications in this field[4,5,7,10,24,25,30,32,36-42] omitted the disparities and difference in means between the simple measurements; therefore, association biases for some anthropometrics were never well removed. In the advancement of science, an abundance of knowledge and critical thinking are needed. Thus, association biases discovered in this research and our exposed conceptual lines are consistent. Therefore, relative volume and differentiation between bodily components are fundamental anthropometric concepts necessary for understanding CVD and MI risk. Consequently, high mesomorphy, moderate endomorphy, low ectomorphy, shorter stature, “x” variables for HC–height/2 and WC–height/2, and WHtR>0.5 are justifiably associated with CVD and MI. Therefore, they all show the best consistency and convergence of the anthropometric knowledge and biological risk linked to CVD and MI, at least without showing discrepancies[8,9,17,20,26-28,33].

In summary, from anthropometry and mathematics this research leads to an important discovery in the area of cardiovascular epidemiology. The "x" variables as associated confounding factors were always hidden in the epidemiologic data sets somehow. In spite of being not intermediate links in the chain of causation, its systematic omission in most analyses always produced association biases between the concerned metrics.

Our research work has several strengths. First, this research included a novel methodology and new anthropometric variables demonstrating that BMI, WHR and WC may capture spurious risk. Second, this research reviewed different study types, in which thousands of CVD and MI cases were selected worldwide. Finally, this research revealed mathematical misconceptions that may demonstrate a different-equal risk assignment between individuals who have equal-different high-risk BC. Furthermore, the findings in this research are unique and innovative, and they have no mathematical limitations. The findings determine good generalisability to other population studies. After comparing thousands of cases in previous works, no further new studies are requered. Only an update is necessary by recalculating the data sets and taking into account the new variables and bodily components in each of the published studies.

6. CONCLUSIONS

After discovering confounding biases in the associations between anthropometrics and CVD and MI, WHtR rather than BMI, WHR, and WC may be considered the optimal metric for identifying people at risk. New anthropometric variables termed as “x” or the absolute difference between two simple body measurements—such as HC–WC, WC–height/2 (or 2WC–height), HC–height/2 (or 2HC–height) and FFM–FM—were described. Its omission in most previous epidemiologic studies and overlooking bodily components differentiation led to confounding biases resulting in a distortion of the true relationships with CVD and MI risk by over- or

under-estimates of some anthropometrics. In public health promotion, any anthropometric that is proposed without accounting for WHtR and known "x" variables in the epidemiologic data set will always provide biased information. A misleading information from epidemiologic data may be verified when demonstrating the lack of a balanced distribution for the simple measurements and their difference in means between groups being compared and after collating confounding biases for the concerned metrics.

7. RECOMMENDATIONS

Once association biases have been demonstrated elsewhere by omitting known anthropometric variables in the epidemiologic data, cardiology and cardiovascular epidemiology should be rectified to improve understanding in clinical practice and cardiovascular research. For decades, the associations of anthropometrics showed causality-related errors. We have identified historical and systematic errors and new anthropometric variables demonstrating biased measures constraining causal inferences. In this approach, reputable scientific societies and institutions, and even the World Health Organization, should consider bias errors when proposing anthropometrics and anthropometrically-measured BC in the scores and recommendations for an ideal cardiovascular health.

It is time to shift the arithmetic and anthropometric perspective to identify people at risk of CVD and MI without incurring confounding bias. At the same time, a paradigm shift in anthropometric indicators when predicting CVD and MI risk or promoting and preserving cardiovascular health seems necessary. We propose propensity score methods and the need to account for the WHtR and new "x" variables in all future anthropometric research studies.

8. Conflict of Interest

The author declares that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

9. Author Contributions

AM contributed to the conception and design of the research. AM discovered new anthropometric variables. AM contributed to the acquisition, calculate, analysis, and interpretation of the data. AM drafted the manuscript and substantially revised the submitted version. The author critically revised the final manuscript.

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