Journal of
Obesity & Weight Loss Therapy

Short Communication Open Access

Applicability of Body Mass Index, Waist-to-Height Ratio, and Waist Circumference for Assessment of Cardiovascular Health in Postmenopausal Women

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Abstract

In our opinion there is a shortage of scientific reports on correlations between WHtR and serum lipid levels in elderly in postmenopausal women. The PubMed search results only in merely one study focused on WHtR variability as a function of serum lipid levels, total cholesterol (TC), triglycerides (TG), and high-density cholesterol (HDL-C). Additionally, all the reports on the correlations between WHtR and cardiovascular risks follow a standard approach by which WHtR is defined by the two ranges: WHtR < 0.5 and WHtR ≥ 0.5. Presently, a diversity of reports suggest that adverse changes in lipid levels are not connected with an increment in BMI but with an increase in WC. This clearly indicates a lack of direct association between body indexes and cardiovascular health level with body height. In this report we study the relations among Body Mass Index, Waist Circumference, Waist to Hip Ratio, Waist to Height Ratio, and serum lipid levels [TC, TG, HDL-C, LDL-C] in a healthy group of postmenopausal women. The results of this study allows to draw the following conclusions: (1) BMI and WC may be exchangably used for the prediction of cardiovascular health, (2) WHtR cutoff value in postmenopausal women requires adjustment for menopausal status and , most probably, age and gender.

Keywords: Obesity; Cardiovascular health; Body mass index; Waist circumference; Waist to hip ratio; Waist to height ratio

Introduction

Among parameters defining the health-related quality of life weight to height, the ratio is the oldest. Although the first instances of its applications were reported 183 years ago[1], its renaissance came in the early '70s of the last century and is owed to Keys and coworkers who introduced the term Body Mass Index (BMI) [2]. Since then, BMI became the primary descriptor of obesity in thousands of scientific reports. Notwithstanding its popularity, a variety of studies have found shortcomings in its clinical applicability and opened an advent for the search of new clinically viable indices of obesity. Among those employed in practice, the waist circumference (WC) [3], the waist-to-hip ratio (WHR) [4], and the waist-to-height ratio (WHtR) [5] provide an attractive alternative to BMI.

Over a decade ago, Aswell and Hsieh [6] delineated WHtR superior to Body Mass Index (BMI) for early warning of cardiovascular health risks. This observation was further confirmed by his study [5], indicating WHtR not only better than BMI but also WC and WHR for prediction of risk of cardiovascular diseases (CVD) in women. Notwithstanding the apparent clinical attractivity of WHtR, there is a dearth of reports on correlations between WHtR and serum lipid levels in elderly postmenopausal women. Thus there are only a few reports on relations between WHtR and serum lipid levels [7], total cholesterol (TC), triglycerides (TG), and high-density cholesterol (HDL-C) and all of those follow traditionally established WHtR threshold of 0.5 [5,8-10].

Although BMI cutoffs adopted by the World Health Organization indirectly relate to CVD risks, an analysis of scientific literature discloses shortcomings of such an approach, especially among older women. For example, it was shown that adverse changes in serum lipid levels are not inherently related with an increase in BMI [11]. It is due to a multitude of age-dependent factors, among which the menopausal transition plays a fundamental role [12-14]. Nevertheless, adverse changes in lipid levels and levels of water and fat-soluble vitamins [13] are negatively related to cardiovascular health (CVH) [15-17] and are always coupled to an increase in WC [18]. To extend our knowledge on correlation between WC, and its cutoff, as a function of the risk of cardiovascular diseases, we study and analyze relations among BMI, WC, WHR, WHtR, and serum lipid levels [TC, TG, HDL-C, LDL-C] in postmenopausal women.

Material and Methods

Participants

The study was performed on postmenopausal women for whom the menopausal status was defined by the time passed since the last period, i.e., the postmenopausal women are these for whom the last period occurred >12 months before this study [12,14]. Over 1,500 women living in Gdansk, Poland metropolitan area, were contacted and asked to participate in this study. Out of all eligible subjects, 450 refused to sign the consent form and 1,030 provided written consent. However, only 645 took part in the experiment. The study sample encompasses the age range between 56 and 83 years, with the mean age of 69.7 years, the average height of 160.57 cm, and the average body mass of 69.16 kg. A general practitioner performed the health interview on the day of laboratory measurements. The conducted health interview allowed to elucidate the women who did not and do not suffer from congestive heart disease or kidney disease, are not at risk of hypertension, and for whom the body mass is relatively stable, i.e., the body mass has not varied more than 2 kg over six months before this study. This protocol resulted in the final sample size equal to 600 subjects. The provincial medical chamber approved the study protocol.

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Received March 16, 2020; **Accepted** June 11, 2020; **Published** June 18, 2020

Citation: Zubrzycki IZ, Ossowski Z, Wiacek M (2020) Applicability of Body Mass Index, Waist-to-Height Ratio, and Waist Circumference for Assessment of Cardiovascular Health in Postmenopausal Women. J Obes Weight Loss Ther 10: 400.

Measures

Anthropometric measurements

Anthropometric parameters including body mass (BM), height (Ht), waist circumference (WC), hip circumference (HC), Body Mass Index (BMI), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) were collected during this study. The mass of a subject was weight to the nearest 0.2 kg and body height measured to the nearest 0.5 cm. All circumferences were measured accordingly to the WHO protocol [19] using a tailor's tape measure. Thus, waist circumference was measured at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest, and hip circumference was measured around the widest portion of the buttocks with the tape parallel to the floor. All circumferences were measured with an accuracy of 0.5 cm. BMI, WHR, and WHtR were calculated using the following formulas: BMI = BM (kg)/Ht^2 (m^2), WHR = WC (cm)/HC (cm), and WHtR = WC (cm)/Ht (cm) respectively.

Serum lipids

An analysis of serum lipid levels was performed accordingly to the ATP III [20] protocol. Analyses were performed on a 12-hour fasting subject resting in a sitting position for at least five minutes before phlebotomy. Total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG) were determined using an automatic biochemical analyzer (Roche Corvus' 8000 modular analyzer Series C701, Mannheim, Germany).

Statistical Analysis

The mean of samples and statistical inferences were estimated using bootstrap analysis. Clustering of the data consisted of two levels approach. At the first level hierarchical clustering was employed at the second level Two Step [21] clustering technique was used. In the hierarchical cluster, Ward's method was used for calculation of a distance between cluster pairs. The initial number of clusters was assessed using a dendrogram. The quality of clusters was assessed using a silhouette plot [22].

Statistical inferences were assessed using Bootstrap estimated [23] confidence intervals (CI) of the means. Bootstraps were obtained using repeated random samples of the same size as the original sample drawn with replacements from the original data. The number of bootstrap re-samples for the construction of CIs was equal to 10,000 [24-26]. The CIs were calculated by the bias-corrected and accelerated (Bca) method [23]. The statistically significant difference between the samples was defined as the absence of overlap between 95% CIs between samples. Correlations between parameters were investigated using a linear regression where an ordinate always refers to a predictor.

Results

Table 1 comprises descriptive statistics of the study sample. Table 2 describes the stratification of the study sample accordingly to currently defined standards for BMI, WC, WHR, and WHtR [5]. Table 3 outlines the stratification of the study sample as a function of a level of TC, TG, HDL-C, and LDL-C [20]. Table 4 encompass stratification of BMI as a function of WHtR-cluster, and Table 5 envelopes the results of WHtR-cluster dependent differences in serum lipid levels. Figure 1A-G represents the correlations between BMI, WC, HC, WHR, and WHtR.

The age of the studied sample is between 56 and 83 years of age, the body height between 147 and 178 cm, body mass between 43.3 and 102.5 kg, waist circumference between 59 and 114 cm, hip circumference between 73 and 128 cm, BMI between 18.97 and 39.88, the waist-to-hip ratio between 0.68 and 1.02, and the waist-to-height ratio between 0.39 and 0.70. There are 256 women within the healthy

Variables	Age (yrs)	Height (cm)	Mass (kg)	BMI (kg/m²)	WC (cm)	HC (cm)	WHR	WHtR
Mean	66.94	160.57	69.16	26.83	85.21	102.48	0.83	0.53
Median	65	161	68.85	26.78	85.5	102	0.82	0.53
Std. Deviation	5.74	6.04	11.34	4.31	9.8	9.87	0.077	0.062
Minimum	56	147	43.3	18.97	59	73	0.68	0.39
Maximum	83	178	102.5	39.88	114	128	1.02	0.7
Body Mass Index (BMI), Waist Circumference (WC), Hip Circumference (HC), Waist-to-Hip Ratio (WHR), and Waist-to-Height Ratio (WHtR).								

Table 1: Anthropometric parameters of a study sample.

Parameter	Class	Range	Frequency
BMI (kg/m²)	Obesity class II	35.0–39.9	3
	Obesity class I	30.0–34.9	18
	Pre-obesity	25.0–29.9	38
	Normal weight	18.5–24.9	43
WC (cm)	High	>80	37
	Normal	≤ 80	65
WHR	Normal	≤ 0.85	102
WHtR	High	>0.5	71
	Normal	≤ 0.5	31

Table 2: Sample stratification accordingly to current golden standards for Body Mass Index (BMI), Waist Circumference (WC), Waist-to-Hip Ratio (WHR), and Waist-to-Height Ratio (WHtR).

Fraction	Level	Range (mmol/L)	Frequency
TC	High	≥ 6.206	48
	Border	5.172 ≤ x < 6.206	26
	Desirable	< 5.172	28
TG	Very high	≥ 5.64	4
	High	2.25 ≤ x < 5.64	10
	Borderline-high	1.69 ≤ x < 2.25	10
	Normal	<1.69	78
HDL-C	High	≥ 1.55	79
	Normal	1.03 ≤ x < 1.55	22
	Low	<1.03	1
LDL-C	Very high	≥ 4.88	11
	High	4.12 ≤ x < 4.88	17
	Border	3.34 ≤ x < 4.12	33
	Near optimal	2.58 ≤ x < 3.34	22
	Optimal	<2.58	19
TC - Total Cholesterol (mmol/L), TG – triglycerides (mmol/L), HDL-C – high-density lipoprotein cholesterol (mmol/L), LDL-C – low-density lipoprotein cholesterol (mmol/L).			

Table 3: Sample stratification accordingly to the National Cholesterol Education Program.

Cluster	Mean	Bootstrap				Difference
		Bias	Std. Error	BCa 95% Confidence Interval	Upper	
				Lower		
1	22.5	-0.0007	0.31	21.88	23.1	a
2	26.9	0.0012	0.33	26.25	27.56	b
3	32.57	0.0098	0.65	31.37	33.87	c

Table 4: BMI stratification as a function of WHtR cluster.

Cluster number/Fraction		Bootstrap (10000 repeats)					Difference
		Mean (mmol/L)	Bias	Std. Error	BCa 95% Confidence Interval		
					Lower	Upper	
1	TC	6.32	-0.0007	0.21	5.9	6.73	a
2	TC	5.76	-0.0017	0.22	5.31	6.19	a
3	TC	5.79	0	0.23	5.33	6.22	a
1	TG	1	0.0004	0.08	0.87	1.15	a
2	TG	1.27	0.0003	0.08	1.3	1.41	a
3	TG	1.27	-0.0021	0.1	1.08	1.45	a
1	LDL-C	3.79	-0.0005	0.2	3.41	4.18	a
2	LDL-C	3.47	-0.0026	0.16	3.18	3.77	a
3	LDL-C	3.55	0.0013	0.21	3.13	3.96	a
1	HDL-C	2.12	-0.0003	0.06	2.01	2.23	a
2	HDL-C	1.86	0.0002	0.06	1.75	1.97	b
3	HDL-C	1.67	-0.0004	0.07	1.54	1.8	c
TC:Total Cholesterol (mmol/L), TG:triglycerides (mmol/L), HDL-C: High-density lipoprotein cholesterol (mmol/L), LDL-C:Low-density lipoprotein cholesterol (mmol/L). a, b, c – similarity of the clusters. The same letter for different clusters defines the lack of statistically significant differences between specific clusters.							

Table 5: Differences in serum lipid levels stratified by WHtR clusters.

BMI range, 390 within the normal WC range, 600 within the normal WHR range, and 177 within the normal WHtR range. One hundred sixty-five women are within the desirable TC range, 480 within the normal TG range, 120 within the normal HDL-C range, and 130 within the optimal LDL-C range.

There are the following relations between BMI, WC, HC, WHR, and WHtR: a) WC → f(BMI), R2adj=72%, F(1,100)=248.848, p=.0, b) HC → f(BMI), R2adj=40%, F(1, 100)=85.263, p=.0,c) WHR → f(BMI), R2adj=8.1%, F(1,100)=8.603, p=.04,d) WHtR → f(BMI), R2adj=80%, F(1,100)=370.969, p=.0,e) HC → f(WC), R2adj=46%, F(1,100)=85.263, p=.0,f) WHtR → f(HC), R2adj=44%, F(1,100)=78.899, p=.0, and g) WC → f(WHtR), R2adj=90%, F(1, 100)=895.342, p=.0

Clustering of WHtR values lead to three clusters: 1) 0.39 ≤ cluster 1 < 0.50, 2) 0.50 ≤ cluster 2 < 0.58, and 3) 0.58 ≤ cluster 3 ≤ 0.7. Cluster 1 encompasses BMI between 21.88 kg/m^2 and 23.10 kg/m^2, cluster 2 between 26.25 kg/m^2 and 27.56 kg/m^2, and cluster 3 between 31.37 kg/m^2 and 33.87 kg/m^2. There is a significant difference among all the clusters (Table 4).

There are no statistically significant differences in TC, TG, and LDL-C as a function of the WHtR cluster. However, there are statistically significant differences in HDL-C levels. Thus, WHtR cluster 1 encompasses HDL-C levels between 2.01 mmol/L and 2.23 mmol/L, cluster 2 between 1.75 mmol/L and 1.97 mmol/L, and cluster 3 between 1.54 mmol/L and 1.80 mmol/L.

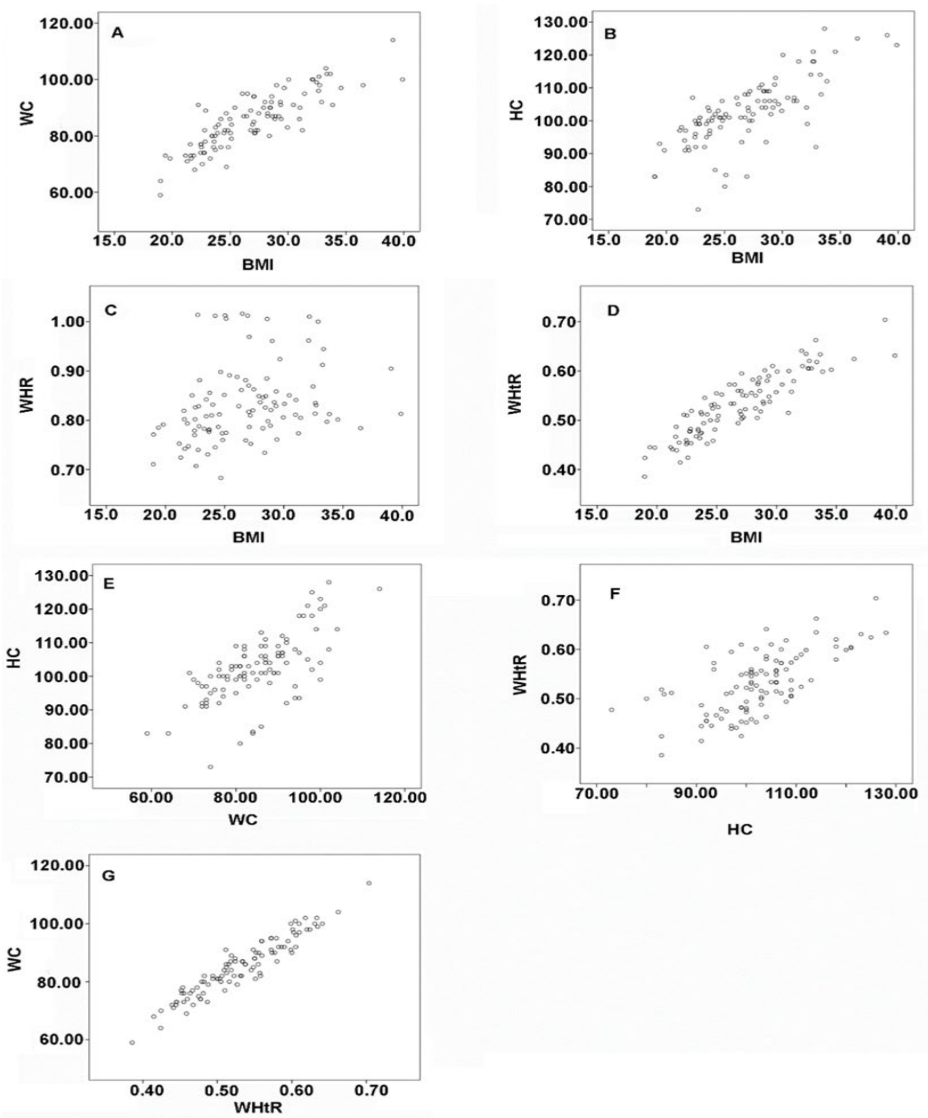

Figure 1 A-G : The correlations between BMI, WC, HC, WHR, and WHtR. For the clarity of the picture, only every sixth point is shown on the graph.

Discussion

To extend our understanding of the relevancy of WHtR for the screening of cardio-metabolic risks in elderly (postmenopausal) women we analyzed relations between the waist-to-height ratio (WHtR), serum lipid levels, and BMI in the sample comprising postmenopausal women between 56 and 83 years of age.

A brief review of parameters currently used for prediction of CVD risk reveals that height is the intrinsic parameter of the most popular body indexes, i.e., WHtR and BMI. Although, the recent meta-analysis of the clinical suitability of anthropometric factors used for the prediction of cardio-metabolic risks [3] presented WHtR better than WC or BMI, some of the recent studies discovered indexes which do not incorporate the body height parameter, i.e., WC and WHR, to be potentially more informative for prediction of CVD risk than WHtR [27-29].

This study confirms that an increase in WC is positive and strongly correlated with an increase in BMI and that both WC and BMI may be exchangably used for the assessment of obesity-associated health related risks in postmenopausal women. However, the results presented in this study reinforce the necessity for additional validation of WHtR as the overall mean for the prediction of CVD risk.

Currently, all the reports follow the traditional approach [5,9,30], of WHtR equal to 0.5 as the cutoff standard for health-related changes. The results of this study allow us to postulate that introduction of an additional threshold equal to 0.58 may improve clinical viability of WHtR/ Hence the novel definition of thresholds for WHtR ought to follow the following scheme: WHtR < 0.5 - optimal, $0.50 \leq$ WHtR < 0.58 - borderline, and $0.58 \leq$ WHtR – high. Such a stratification seems to be more appropriate for the prediction of CVD risk among postmenopausal women. The thesis of two WHtR thresholds proposed by this study is strengthened through a strong correlation between WHtR and WHO-BMI obesity scale: WHtR cluster 1 (optimal) encompasses "normal" BMI range, WHtR cluster 2 (borderline) encompasses "pre-obese" range and WHtR (night) encompass cluster 3 "obese I" BMI range.

In brief, the results presented in this study lead to the following conclusions: (1) BMI and WC may be exchangably used for prediction of the cardiovascular health in postmenopausal women, (2) WHtR cutoff value ought to be further studied and adjusted, if required, for the specific gender and age group.

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