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Original Article

Gender Differences in Weight-Adjusted Waist Index in Elderly Inhabitants of a Geriatric Center

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Abstract

Introduction and aim: Weight-adjusted waist index (WWI) represents a novel anthropometric measure for assessing obesity. Bearing in mind that there is insufficient data in the literature regarding gender differences in WWI values, the aim of the current study was to examine gender differences in WWI values among older adults.

Materials and methods: The research was conducted at the Sarajevo Gerontological Center, Bosnia and Herzegovina. The study design was cross-sectional. It included 151 participants aged 65 years and older (66 males and 85 females). Anthropometric parameters as well as data on blood pressure were gathered. WWI was calculated by dividing waist circumference (in cm) by the square root of body weight (in kg). Differences between compared groups were analyzed using the Student *t*-test, Mann-Whitney U or chi-square test. The Spearman's test was used to assess correlations.

Results: Elderly women had significantly higher values of WWI compared to men. In elderly male participants, there was a statistically significant positive correlation between WWI and waist circumference, hip circumference, neck circumference, and mid-upper arm circumference, but no statistically significant correlation was found with BMI. In elderly female participants, statistically significant positive correlation between WWI and all tested anthropometric measures was found.

Conclusion: The differences in WWI values between genders observed in the present study highlight its gender-specific implications and underline the importance of considering gender when interpreting WWI in clinical and research settings. Further research is warranted to explore additional health implications and validate WWI utility across diverse populations and age groups.

Keywords

anthropometry, elderly, obesity, weight-adjusted waist index

INTRODUCTION

Obesity is defined as the excessive accumulation of adipose tissue in the body, which has a multifactorial etiology. Obesity was uncommon until the 1960s; however, beginning in the 1970s and continuing to this day, it has become increasingly prevalent, reaching epidemic proportions. Obesity leads to increased cardiac workload, lung function disorders, joint stress, and the onset of type 2 diabetes mellitus.[1]

Adipose tissue is metabolically active, producing, among others, two important hormones: leptin and adiponectin.[2] Leptin acts as an appetite suppressant, and individuals with genetically determined leptin deficiency suffer from severe obesity. Adiponectin, on the other hand, enhances insulin sensitivity and improves the functionality of pancreatic beta cells. Adiponectin exerts positive effects on adipose tissue by increasing mitochondrial density and reducing adipocyte size.[3]

Obesity also results in the secretion of other cytokines, such as IL-6 and TNF-α, contributing to a state of low-grade inflammation in obese individuals.[4] Excessive growth of adipose tissue can lead to tissue hypoxia and necrosis, promoting macrophage infiltration and persistent inflammatory conditions. Elevated levels of IL-6 are associated with increased risk of hypertension, atherosclerosis, and other cardiovascular diseases. TNF-α, a potent proinflammatory cytokine, is similarly linked to cardiovascular diseases and diabetes mellitus.[5]

Weight-adjusted waist index (WWI) represents a novel anthropometric measure for assessing obesity, introduced by Park et al. in 2018.[6] Recent studies highlighted the effectiveness of WWI in predicting morbidity and mortality among older adults. Central obesity, assessed through WWI, is a significant risk factor for numerous conditions, including cardiovascular diseases, type 2 diabetes mellitus, metabolic syndrome, and cognitive impairments.

The global trend shows that the number of older adults is increasing, including in Bosnia and Herzegovina, where 15.66% of the population in the Federation of Bosnia and Herzegovina and 20.17% in the Republic of Srpska are 65 and older as of 2019. In the United States, the number of older adults is projected to double in 40 years, from 40.2 million in 2010 to 88.5 million by 2050.[7]

Several theories attempt to explain the aging process, attributing it to molecular cross-linking, the presence of aging genes in DNA, damage caused by free radicals, telomere shortening, and changes in immune system function.[8] Aging is characterized by physiological changes that may result in mild, benign, or significant alterations in organism function, accompanied by increased prevalence of comorbidities and changes in nutritional status, including malnutrition or obesity. Malnutrition may be a consequence of therapy with multiple medications for various conditions, which can lead to gastrointestinal issues and taste changes.[9]

The prevalence of sarcopenic obesity among older adults is rising. Sarcopenic obesity involves a decrease in bone and muscle mass with an increase in predominantly visceral fat. Sarcopenia may be accelerated by concurrent obesity and can lead to earlier onset of disability, morbidity, and mortality.[10]

The study of the association between body mass index (BMI) levels and the risk of cardiovascular diseases (CVD) reveals that BMI is significantly higher in survivors of CVD compared to those who have succumbed to the same, thereby explaining the obesity paradox. Conversely, WWI values, reflecting weight and waist circumference, are lower in CVD survivors compared to non-survivors. This underlines the limitations of BMI as an anthropometric measure since it does not account for waist circumference, which reflects visceral obesity predominant in older adults, nor does it consider the distribution and proportion of fat and muscle tissue.[6]

The increase in fat accumulation with advancing age is often not linked to increased food intake, which may even decrease, but rather to reduced energy expenditure and physical activity. This correlates with stable, unchanged energy intake leading to fat accumulation. Hormonal changes also play a role in fat accumulation and redistribution.[11] The obesity paradox suggests that obesity does not necessarily shorten a patient's lifespan and can even be beneficial in certain cases. The existence of this paradox questions the validity of BMI as an anthropometric measure.[12]

AIM

Given that WWI is a recent anthropometric parameter and there is insufficient data in the literature regarding gender differences in WWI values, the aim of the current study was to examine gender differences in WWI values among older adults.

MATERIALS AND METHODS

The research was conducted at the Sarajevo Geriatric Centre in Bosnia and Herzegovina and included 151 participants aged 65 years and older (66 males and 85 females). The study design was observational, cross-sectional, with cross-testing.

The study was conducted based on medical history and objective physical examination. Written consent for voluntary participation in the study was obtained from all participants, in accordance with the Helsinki Declaration as revised in 2013. The local Ethics Committee approved the study protocol (approval form No. 13-712/19 of 24.05.2019, Sarajevo). Specific forms/questionnaires were designed for data collection from participants. The form included general information (name, age, gender, education level), data on blood pressure values, pulse rate, a section for entering data obtained from anthropometric measurements (height, weight, BMI, neck circumference, waist circumference, hip circumference, and mid-upper arm circumference), lifestyle-related information (alcohol consumption, smoking, and physical activity), information regarding falls in the past year, family history (cardiovascular diseases, diabetes mellitus, and obesity), and space for recording any ongoing therapy used by the participants. The equipment used for measurements included a scale, portable stadiometer, measuring tape for anthropometric measurements, mercury sphygmomanometer, and stethoscope.

Height and body weight of each participant were measured to calculate BMI. Height was measured in centimeters using a portable stadiometer (Seca® 213). Participants stood on a horizontal surface with their feet together, wearing shoes. A horizontal head cover was placed on top of the head. Two centimeters were deducted, from the recorded value, to compensate for the mentioned footwear. Body weight was measured in kilograms using a digital scale (BS-03; Shenzhen J and E Electronics Co., Ltd.), with participants wearing light, casual clothing. BMI for each participant was calculated using the formula BMI=weight (kg)/ height^2 (m).

Neck circumference (NC) was measured with the head positioned in the Frankfort horizontal plane, using a non-elastic, calibrated, flexible tape, placed around the middle of the neck at the level of the laryngeal prominence. The upper part of the tape was positioned just below the laryngeal prominence, perpendicular to the neck axis. Waist circumference (WC) and hip circumference (HC) were measured in a standing position using a calibrated tape. During measurement, participants stood with feet together and breathed normally. Waist circumference was measured directly above the navel, while hip circumference was measured at the widest part of the buttocks.

After measuring body weight and waist circumference (measured just above the navel using a calibrated tape), the weight-adjusted waist index was calculated. It is computed by dividing waist circumference (in cm) by the square root of body weight (in kg).

Arterial blood pressure was measured using a standard mercury sphygmomanometer (SCH 11B; Smart Care) with participants in a seated position. Prior to measurement, participants rested for 5 minutes. The arm was positioned at heart level, and the cuff of the sphygmomanometer was placed around the upper arm and inflated. Using a stethoscope, the systolic blood pressure (SBP) was recorded at the pressure when the first Korotkoff sound was heard, and the diastolic blood pressure (DBP) was recorded when the Korotkoff sounds disappeared. Arterial blood pressure was recorded in millimeters of mercury (mmHg).

Statistical analysis

The data distribution of variables was assessed using Kolmogorov-Smirnov or Shapiro-Wilk tests. For normally distributed numerical variables, differences between compared groups were analyzed using the Student *t*-test. Non-normally distributed numerical variables were presented as median and interquartile range, and differences between groups were assessed using the Mann-Whitney U test. Categorical variables were presented as percentages, and differences in the frequency of categorical variables between groups were evaluated using the chi-square test. Spearman's correlation coefficient test was used to determine the correlation between variables. A level of $p<0.05$ was considered statistically significant. Statistical analyses were performed using SPSS, v. 19:0 (Chicago, IL, USA).

RESULTS

The results presented in **Table 1** show that statistically significant gender difference was found in the values of age ($p=0.01$), height ($p<0.001$), weight ($p=0.014$), BMI ($p<0.001$), hip circumference ($p=0.022$), and neck circumference ($p<0.001$). No statistically significant gender difference was determined in values of waist circumference ($p=0.503$), mid-upper arm circumference ($p=0.073$), systolic blood pressure ($p=0.956$), diastolic blood pressure ($p=0.577$) as well as in pulse values ($p=0.989$).

Results presented in **Fig. 1** show that in elderly male participants, mean WWI was 11.32±1.01, while in elderly female participants, mean WWI was 11.87±1.09. Mean WWI gender difference was statistically significant ($p<0.002$) with women having significantly higher values of WWI compared to men.

The results presented in **Table 2** show that in elderly male participants, statistically significant positive correlation between WWI and waist circumference, hip circumference, neck circumference, and mid-upper arm circumference was determined ($p<0.001$), while statistically significant correlation was not determined between WWI and BMI ($p=0.496$) in elderly male participants. In elderly female participants, statistically significant positive correlation between WWI and BMI ($p=0.003$), waist circumference ($p<0.001$), hip circumference ($p=0.006$), neck circumference ($p<0.001$), and mid-upper arm circumference was determined ($p=0.007$).

Table 1. Baseline characteristics of study participants

Variables	Men n=66	Women n=85	P
Age (years)	76.50 (70.00-85.00)	83.00 (75.00-86.00)	0.01
Height (cm)	176.81 (7.97)	162.67 (7.37)	0.001
Weight (kg)	76.00 (69.50-84.00)	70.00(65.00-78.00)	0.014
Body mass index, (kg/m^2)	24.15 (22.05-26.70)	26.50 (23.85-29.75)	0.001
Waist circumference, (cm)	99.23 (11.78)	100.71 (14.55)	0.503
Hip circumference, (cm)	104.00 (96.50-106.00)	96.00 (92.00-121.50)	0.022
Mid-upper arm circumference, (cm)	27.00 (25.00-29.00)	28.00 (25.00-31.50)	0.073
Neck circumference, (cm)	40.00 (38.00-43.25)	37.00 (35.00-39.00)	0.001
Systolic blood pressure, (mmHg)	130.00 (120.00-150.00)	130.00 (120.00-147.50)	0.956
Diastolic blood pressure, (mmHg)	80.00 (70.00-90.00)	85.00 (70.00-90.00)	0.577
Pulse, (beats per minute)	72.00 (64.00-80.00)	72.00 (64.00-80.00)	0.989

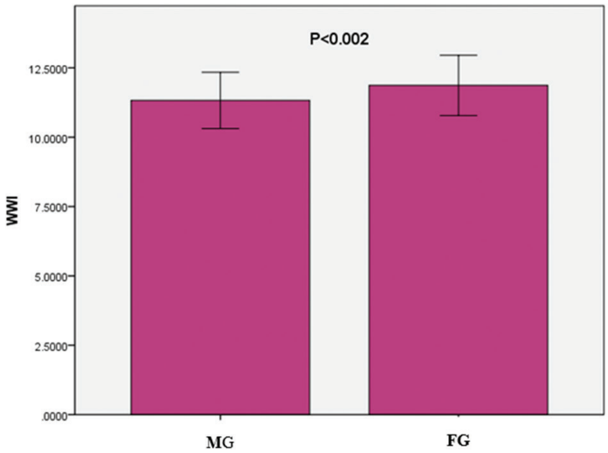

Figure 1. Mean WWI in elderly participants. Results are shown as mean ± standard deviation (X̄±SD); MG: male gender (n=66); FG: female gender (n=85); *p*: probability.

DISCUSSION

Since its introduction, WWI has been studied as a novel anthropometric measure with implications for various diseases such as cardiometabolic diseases, diabetes, bone diseases, and neurological conditions. It has shown utility in predicting mortality risk across different age groups.[6,13] With the increasing prevalence of obesity and its association with numerous risk factors, WWI, which incorporates waist circumference, is considered a valuable anthropometric measure. WWI is particularly relevant for assessing older adults due to changes in body composition and the presence of multiple risk factors during this stage of life.[6,14]

Our study results revealed a statistically significant difference in WWI values between males and females aged 65 years and older. In males, the mean WWI was 11.32±1.01, whereas in females it was 11.87±1.09. This indicates that older females have a significantly higher WWI compared to older males. This finding aligns with a study by Kim et al.[15], which explored the significance of WWI in assessing fat tissue, muscle tissue, bone health in adults, reporting mean WWI values of 10.5±0.6 for males and 11.0±0.8 for females, showing a statistically significant difference. These results are consistent with our findings. Another study investigating the efficiency of anthropometric measures for screening sarcopenic obesity in older adults reported mean WWI values of 11.0±0.6 for males and 11.5±0.7 for females[16], further confirming the significant difference in WWI between genders as observed in our study.

In a prospective cohort study conducted in China by Ding et al.[17], examining the association between WWI and mortality from various causes including cardiovascular diseases, elevated WWI values were more prevalent among individuals with hypertension, history of stroke, and those using antihypertensive medications. The study reported a significant association between WWI and mortality risk, with older females more commonly exhibiting elevated WWI values. These findings are supported by research by Wang et al.[13], investigating the association between WWI and hypertension prevalence among US residents aged over 60 years, where participants with the highest WWI values had a significantly higher risk of hypertension compared to those with lower WWI values.

In a cross-sectional study conducted by Ye et al.[18], which investigated the association between WWI and stroke, results showed that participants with the highest WWI values were predominantly females, elderly individuals, those with lower education levels, and cigarette smokers. Additionally, these participants had been diagnosed with diabetes mellitus, hypertension, coronary heart disease, and stroke. The findings of these studies are consistent with a study conducted by Qin et al.[19], which indicated that elevated WWI values are associated with an increased risk of albuminuria.

In a population-based study by Ding et al.[20] investigating the association between WWI and the risk of hyperuricemia in adults, the results indicated that higher WWI values were associated with an increased risk of hyperuricemia. Participants with the highest WWI values were predominantly elderly, with lower education levels and diagnosed hypertension. The study also concluded that with increasing age and elevated serum creatinine levels, WWI also increased.

In a cross-sectional study by Shen et al.[21], which explored the relationship between WWI and liver steatosis and fibrosis, significant correlations were found between WWI and the risk of liver steatosis and fibrosis. Partici-

Table 2. Correlation between WWI and other anthropometric measures

Variables	WWI	
	Men	**Women**
BMI, (kg/m^2)	*rho*=0.085; *p*=0.496	*rho*=0.323; *p*=0.003
Waist circumference, (cm)	*rho*=0.692; *p*<0.001	*rho*=0.741; *p*<0.001
Hip circumference, (cm)	*rho*=0.426; *p*<0.001	*rho*=0.297; *p*<0.006
Neck circumference, (cm)	*rho*=0.596; *p*<0.001	*rho*=0.348; *p*<0.001
Mid-upper arm circumference, (cm)	*rho*=0.443; *p*<0.001	*rho*=0.292; *p*=0.007

rho: Spearman correlation coefficient

pants with higher WWI values had higher degrees of steatosis. In this study, participants with the highest WWI values were predominantly elderly males, heavy alcohol consumers, and those with lower education levels. Additionally, they had elevated serum levels of cholesterol, LDL, AST, ALT, and urate.

A study conducted in China, which analyzed the relationship between WWI and the risk of mortality from various causes in individuals over 60 years old, was carried out by Cai et al.[22] over a 10-year period. The results indicated that increasing WWI values were associated with an increased risk of mortality. However, this association between WWI and mortality risk disappeared in participants older than 75 years. The researchers suggested that this might be due to the different distribution of adipose tissue in younger versus older individuals, the presence of more risk factors for mortality in the elderly, and statistically insufficient data in this study.

Our research findings demonstrated that in elderly males, there is a statistically significant positive correlation between WWI and waist circumference, hip circumference, neck circumference, and mid-upper arm circumference, while no significant correlation was found between WWI and BMI in this group. The possible reason for the lack of correlation between WWI and BMI in males is that the majority of participants (65.15%) had a BMI within the normal range. In elderly females, there was a statistically significant correlation between WWI and BMI, waist circumference, hip circumference, neck circumference, and mid-upper arm circumference.

Park et al.[6] conducted a study in which they proposed WWI as a new anthropometric measure and examined its practicality as a predictor of mortality from cardiometabolic diseases. The study results demonstrated a significant correlation between BMI and waist circumference, as well as the waist circumference-to-height ratio. There was a weak correlation between WWI and BMI. WWI showed a significant correlation with waist circumference and the waist circumference-to-height ratio. In this study, height did not correlate with BMI. It was concluded that WWI is the most significant anthropometric measure for predicting mortality from cardiovascular diseases.

Kim et al.[23] conducted a cross-sectional study involving elderly participants to evaluate the effectiveness of WWI in assessing muscle mass and fat tissue proportion compared to BMI and waist circumference. The study results show a positive, statistically significant correlation between WWI, waist circumference, and BMI. These results are partly consistent with our research findings. Furthermore, in the mentioned study, a positive correlation between WWI, waist circumference, and BMI with the proportion of fat tissue was found. There was a negative correlation between WWI and muscle mass proportion. Therefore, a high WWI value is associated with a high likelihood of increased fat tissue proportion and reduced muscle mass proportion. Similarly, Park et al.[24] found that WWI negatively correlates with muscle mass loss, unlike other anthropometric measures such as waist circumference, waist-to-height ratio, and waist-to-hip ratio.

A cross-sectional study investigating the relationship between WWI and dementia in the Chinese population with hypertension, conducted by Zhou et al.[25], reported a statistically significant positive correlation between WWI, BMI, and waist circumference. In other words, participants with higher WWI had higher BMI and waist circumference values.

In a study by Kim et al.[16], the effectiveness of various anthropometric measures in screening for sarcopenic obesity in elderly individuals aged 70 to 84 was analyzed, comparing WWI, BMI, waist circumference, and the waist circumference-to-height ratio. The study results indicate that WWI is the most significant anthropometric measure for assessing sarcopenic obesity in men, with a positive correlation found only between WWI and sarcopenic obesity in men. No anthropometric measure was significant for assessing sarcopenic obesity in women. In this study, all anthropometric measures positively correlated with the proportion of fat tissue in both men and women. In men, waist circumference showed the strongest correlation with fat tissue proportion, followed by the waist circumference-to-height ratio, BMI, and WWI. In women, BMI showed the strongest correlation with fat tissue proportion, followed by waist circumference, the waist circumference-to-height ratio, and WWI.

The advantages of WWI as a new anthropometric measure include its cost-effectiveness, ease of calculation, and the simplicity of measuring height and body weight, which are inputs for the formula. This facilitates its use in both research and clinical settings. WWI encompasses the individual characteristics of each participant and allows for the prediction of morbidity and mortality from cardiometabolic and other diseases. It is a good marker for assessing obesity and changes in body composition due to increased fat tissue, especially visceral fat, which is a risk factor for cardiometabolic and other diseases. WWI is an important anthropometric measure for the elderly due to changes in body composition during this period. It has advantages over other anthropometric measures in assessing the risk of sarcopenic obesity, which is characteristic of the elderly. Recognizing and potentially preventing cognitive and other neurological changes due to obesity is crucial, and WWI offers advantages in this regard.[6,25,26]

The limitations of WWI include its inability to assess generalized obesity, focusing instead on central or visceral obesity. Additionally, the measurement of parameters used to calculate WWI can be subjective and prone to errors by the person conducting the measurement. Another limitation is that WWI does not consider the racial background of participants, socio-economic, genetic, and other characteristics, or the potential use of specific therapies, which can affect the risk of morbidity and mortality from various causes, thereby influencing the results. Sarcopenic obesity, reflecting the loss of muscle mass, can be accompanied by a loss of muscle strength and function, reducing the quality of life for the elderly. The inability to distinguish whether muscle mass loss is accompanied by a loss of muscle strength and function or is just a loss of muscle mass is another limitation of WWI.[16,24]

The strengths of our research include the focus on elderly individuals, with results showing its ability to incorporate waist circumference, which provides a more pronounced understanding of body composition and distribution of fat tissue that are critical factors in assessing health outcomes. A comprehensive literature review revealed that this is the only study examining gender differences in the elderly individuals of Bosnian descent, which is of importance since previous studies have shown that ethnicity can impact WWI values.

The limitations of this research are that it is a cross-sectional rather than a prospective study, preventing the delineation of causal relationships between the variables studied. Additionally, a relatively small number of participants from a single geriatric center were included, making it difficult to generalize the results to the entire elderly population. The presence of morbidities such as cardiometabolic diseases, vascular diseases, and CNS diseases were not assessed, suggesting future research should focus on examining morbidities and their potential associations with WWI.

CONCLUSIONS

Based on the results of our research, we believe that the calculation of WWI should be introduced not only for the elderly but also for younger populations. According to our research, WWI can be used as a possible surrogate marker of central obesity, which is an important component in assessing metabolic syndrome and cardiovascular diseases. The differences in WWI values between genders observed in the present study highlight its gender-specific implications and underline the importance of considering gender when interpreting WWI in clinical and research settings. Further research is warranted to explore additional health implications and validate its utility across diverse populations and age groups.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Гендерные различия в индексе талии с поправкой на вес среди пожилых пациентов гериатрического центра

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Резюме

Введение и цель: Индекс талии с поправкой на вес (WWI -Weight-adjusted waist index) представляет собой новый антропометрический показатель для оценки ожирения. Учитывая, что в литературе недостаточно данных о гендерных различиях в значениях WWI, целью настоящего исследования было изучение гендерных различий в значениях WWI среди пожилых людей.

Материалы и методы: Исследование проводилось в геронтологическом центре Сараево, Босния и Герцеговина. Дизайн исследования был поперечным. Оно включало 151 участник в возрасте 65 лет и старше (66 мужчин и 85 женщин). Были собраны антропометрические параметры, а также данные об артериальном давлении. WWI рассчитывался путём деления окружности талии (в cm) на квадратный корень массы тела (в kg). Различия между сравниваемыми группами анализировались с использованием t-критерия Student, Mann-Whitney U или хи-квадрат-критерия. Для оценки корреляций использовался тест Spearman.

Результаты: У пожилых женщин значения WWI были значительно выше, чем у мужчин. У пожилых мужчин-участников наблюдалась статистически значимая положительная корреляция между WWI и окружностью талии, окружностью бёдер, окружностью шеи и окружностью середины плеча, но статистически значимой корреляции с ИМТ обнаружено не было. У пожилых женщин-участников наблюдалась статистически значимая положительная корреляция между WWI и всеми протестированными антропометрическими показателями.

Заключение: Различия в значениях WWI между полами, наблюдаемые в настоящем исследовании, подчёркивают его гендерно-специфические последствия и подчёркивают важность учёта пола при интерпретации WWI в клинических и исследовательских условиях. Необходимы дальнейшие исследования для изучения дополнительных последствий для здоровья и подтверждения полезности WWI среди различных популяций и возрастных групп.

Ключевые слова

антропометрия, пожилые люди, ожирение, индекс талии с поправкой на вес