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Original scientific paper

BODY ROUNDNESS INDEX AMONG ADULTS WITH TYPE 2 DIABETES MELLITUS IN BANJA LUKA

Maja Šibarević[1*], Smiljana Paraš[1], Jelena Malinović Pančić[2,3], Rajko Roljić[1], Elvira Hadžiahmetović Jurida[4]

[1]*University of Banja Luka, Faculty of Natural Sciences and Mathematics, Mladena Stojanovića 2, 78000 Banja Luka, Republic of Srpska, Bosnia and Herzegovina*
[2]*Univeristy Clinical Centre of Republic of Srpska, Dvanaest beba bb, Banja Luka, Republic of Srpska, Bosnia and Herzegovina*
[3]*University of Banja Luka, Faculty of Medicine, Save Mrkalja 14, 78000 Banja Luka, Republic of Srpska, Bosnia and Herzegovina*
[4] *University of Tuzla, Faculty of Natural Science and Mathematics, Urfeta Vejzagića 4, 75000 Tuzla, Federation of Bosnia and Herzegovina, Bosnia and Herzegovina*
***Corresponding author**: maja.sibarevic@pmf.unibl.org

Abstract

The body roundness index is a novel anthropometric indicator used to assess body composition and predict the risk of various metabolic diseases, including type 2 diabetes mellitus. Diabetes, as a chronic metabolic condition, poses significant health risks, and both traditional and novel anthropometric indices are essential for evaluating its risk and progression. The aim of this study was to analyze body roundness index values among adults with type 2 diabetes mellitus in Banja Luka and to examine sex differences. The results showed significant sex-based differences in body roundness index, with women having significantly higher values (6.03 ± 1.66) compared to men (5.26 ± 1.45; $p = 0.002$). Quartile analysis indicated a broader interquartile range for women (4.76–7.11) than for men (4.34–5.81), suggesting greater variability in body roundness index values among women. Additionally, a progressive increase in body roundness index was observed across body mass index categories, with significantly higher values among individuals with higher levels of obesity ($p < 0.05$). This study provides the first preliminary data on body roundness index among adults with type 2 diabetes mellitus in this region, highlighting its potential utility in assessing body composition and metabolic risk in diverse populations.

Key words: body roundness index, type 2 diabetes mellitus, sex differences

INTRODUCTION

Diabetes is a chronic metabolic disease characterized by elevated blood glucose levels, which over time can lead to serious damage to the heart, blood vessels, eyes, kidneys, and nerves (WHO, 2024). The prevalence of diabetes, particularly type 2, has risen dramatically over the past three decades, with low- and middle-income countries being the most affected. In addition to traditional anthropometric measures such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-stature ratio (WSR), commonly used to assess the risk of diabetes and other metabolic conditions, recent studies have introduced advanced anthropometric indices (Khader *et al*., 2019). For instance, a body shape index (ABSI), body roundness index (BRI), and visceral adiposity index (VAI) have shown promising capabilities in predicting type 2 diabetes (Sadeghi *et al.*, 2024). These newer measures incorporate additional aspects of body composition and fat distribution, providing valuable tools for early identification of individuals at high risk.

The body roundness index (BRI) was first introduced by Thomas *et al.* (2013) as a geometric measure that integrates height, waist circumference, and hip circumference to quantify body shape independently of height. According to the literature, the BRI values range from 1 to 16, and rounder individuals tend to have larger values. Motamed et al. (2016), in their study, identified cut-off values for the BRI. They reported that the optimal BRI cut-off value was approximately 4 for men and 5 for women, highlighting its potential as a reliable indicator for metabolic health assessments.

Compared to the traditional body mass index, BRI has been shown to be a better predictor of visceral fat, offering improved understanding of body composition and contributing significantly to public health and preventive medicine (Qiu *et al*., 2024).

The BRI, a novel anthropometric measure, has been widely applied in various studies, including meta-studies and cross-sectional studies, investigating its association with hypertension, metabolic syndrome, cardiovascular disease, cancer and other related conditions (Calderón-García *et al*., 2021; Chen *et al*., 2024; Fahami *et al*., 2004; Yang et al., 2024; Zhang *et al*., 2024). A cohort study in the United States demonstrated an association between BRI and all-cause mortality, revealing that individuals with low (<3.4) or high BRI (≥6.9) had a significantly higher risk of mortality compared to those with medium values (4.5–5.5) (Zhang *et al*., 2024).

A retrospective longitudinal study in Japan explored the relationship between baseline BRI values and the risk of developing type 2 diabetes mellitus (T2DM). The findings indicated that baseline BRI values were significantly higher in individuals who developed T2DM. Moreover, the study identified a non-linear relationship between BRI and T2DM risk in both genders, establishing risk thresholds at 4.14 for women and 3.15 for men (Wu *et al*., 2022).

The goal of this study is to analyze BRI values among adults with T2DM in the context of Banja Luka and to examine sex-based differences in these values. Based on the available literature and data, such a regional analysis has not been previously conducted, offering a unique contribution to understanding sex differences in body composition among adults with T2DM in this area.

MATERIALS AND METHODS

This cross-sectional study was conducted at the University Clinical Centre of the Republic of Srpska, Banja Luka. The study involved 160 adults, with a mean age of 65.3±8.32 diagnozed with type 2 diabetes mellitus. Participants were selected as they attended endocrinology consultations at the hospital. General information about the study and inclusion criteria were provided to eligible individuals during their visits. The inclusion criteria required participants to be adults diagnosed with T2DM, while the exclusion criteria included pregnancy, lactation, or recent surgery.

Anthropometric measurements were performed by the same person, with the participants lightly dressed and without shoes. Weight, height (stature), and waist circumference (WC) were measured using standard procedures (National Center for Health Statistics, 2018). After measuring body height and weight, the BMI was calculated using the formula BMI = body weight (kg) / (body height (m))². BRI was calculated using the formula BRI = $364.2–365.5\times(1 – [WC/2\pi]^2/[0.5 \times height^2)^{½}$ (Zhao *et al.*, 2021).

Written informed consent was obtained from all participants. The study was approved by the Ethical Review Committee of the University Clinical Centre of the Republic of Srpska (No. 01-19-420-2/22).

For statistical analysis, SPSS v.22 software was used. Descriptive statistics were applied to summarize the data, including the mean (M), median (Md), mode (Mo), standard deviation (SD), skewness, standard error of skewness (SE Skewness), kurtosis, standard error of kurtosis (Se Kurtosis), and the minimum and maximum values. Quartiles (Q1, Q2, Q3) were also calculated to assess the distribution of the body roundness index by sex, categorizing participants into low risk (Q1), medium risk (Q1-Q3), and high risk (Q3) groups.

Independent samples t-test was used to assess sex differences. One-way ANOVA was used to examine differences based on BMI categories with BRI as dependent variable. Post-hoc comparisons were conducted using the Tukey test. A p-value of less than 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Table 1 presents descriptive statistics of the basic anthropometric characteristics for the entire sample of 160 participants. The average age of participants was 65.3 ± 8.34 years, indicating a relatively homogeneous group of older adults. The average BMI was 30.78 ± 4.47 kg/m², categorizing the group as obese, with moderate variability in BMI values. The average WC was 102.74 ± 11.35 cm, suggesting an increased risk of metabolic complications. Additionally, the average BRI was 5.69 ± 1.61, reflecting moderate variability in body roundness among participants.

In comparison, a Chinese study by Chang *et al.* (2015) reported lower anthropometric values in a group with diabetes, with an average BMI of 26.2 ± 3.7 kg/m², WC of 87.1 ± 9.5 cm, and BRI of 3.87 ± 1.29. Similarly, another Chinese study reported lower values, with a BRI averaging 5.02 ± 1.48, BMI of 26.19 ± 3.92 kg/m², and WC of 90.22 ± 9.71 cm (Liu *et al.*, 2021). These results are substantially lower than the corresponding values in the current study, highlighting potential differences in body composition and adiposity patterns between the populations, likely influenced by genetic, lifestyle, or cultural factors.

Table 1. Descriptive statistics of anthropometric characteristics for the entire sample (N = 160)

	M	Md	Mo	SD	Skewness	SE Skewness	Kurtosis	Se Kurtosis	Min	Max
Age	65.3	66.5	67.00	8.34	-0.630	0.192	0.626	0.381	40.00	80.00
Height (cm)	169.38	168.75	160.00	8.71	-0.028	0.192	-0.476	0.381	147.10	188.50
Weight (kg)	88.45	87.50	84.10	14.92	0.312	0.192	0.243	0.381	53.70	130.60
BMI (kg/m^2)	30.78	30.50	32.00	4.47	0.503	0.192	0.439	0.381	21.30	44.60
WC (cm)	102.74	101.85	95.40	11.35	0.144	0.192	0.229	0.381	70.20	133.60
BRI	5.69	5.49	2.27	1.61	0.539	0.192	0.008	0.381	2.27	10.05

(BMI- body mass index; WC- waist cirkumference; BMI – body mass index; BRI- body roundeness index; M – mean; Md – mode, Mo – median; SD – standard deviation)

Sex-based differences in body fat distribution are well-documented, with men typically exhibiting higher levels of visceral fat, whereas women tend to accumulate more subcutaneous fat, particularly in the gluteofemoral region (Stevens *et al.*, 2010). These physiological differences are influenced by hormonal factors, with estrogen promoting fat storage in subcutaneous depots, while testosterone favors visceral fat accumulation.

The present study reveals a significant difference in BRI values between men and women. The mean BRI in men is 5.26 ± 1.45, while in women, it is significantly higher at 6.03 ± 1.66. Statistical analysis ($t = -3.08$, $p = 0.002$) confirms a significant difference between sexes, with a medium effect size ($\eta^2 = 0.06$). These findings indicate that women, on average, exhibit a greater degree of body roundness compared to men (Table 2). In a study conducted in Japan, the mean BRI values were significantly lower than those observed in our study, with reported averages of 2.57 ± 0.93 for women and 2.88 ± 0.84 for men (Zhao, 2021). On the other hand, Chang *et al.* (2015) reported in their study that the mean BRI values were 4.64 ± 1.88 for men and 5.16 ± 2.24 for women, which are higher than those reported in Japan. BRI has been recognized as a strong predictor of insulin resistance (IR), with notable sex-based differences. Li *et al*. (2024) demonstrated that in a Chinese population with a mean age of 57.6 years, the average BRI was 4.89, with women exhibiting significantly higher values than men (5.04 vs. 4.72). These findings are consistent with the present study, where women with T2DM demonstrated significantly higher BRI values than men.

The observed difference in BRI values between sexes may be attributed to hormonal influences and variations in fat deposition. While estrogen promotes subcutaneous fat accumulation in women, testosterone is associated with increased visceral fat storage in men. These differences become particularly relevant in metabolic disorders such as T2DM, where changes in fat distribution may influence disease progression and associated health risks (Li *et al*., 2024).

Table 2. Differences in BRI between sexes

		N (%)	M	SD	t	p	η^2
BRI	Male	68 (42.5%)	5.26	1.45	-3.08	0.002*	0.06

	Female	92 (57.5%)	6.03	1.66			

(BRI- body roundness index; M-mean; SD-standard deviation; t-test; p value <0,05 statistically significant; η^2- effect size)

Table 3 presents the quartile distribution of the BRI by sex, revealing notable differences between men and women. The median BRI for women is higher (5.73) compared to men (4.89), indicating that women, on average, have a greater degree of body roundness. Furthermore, the interquartile range (IQR), which encompasses the middle 50% of values, is broader for women (4.76–7.11) than for men (4.34–5.81), suggesting greater variability in BRI values among women. Despite these differences, the distribution of participants across risk categories (low, medium, and high) is identical for both sexes: 25% of participants fall into the low-risk category, 50% into the medium-risk category, and 25% into the high-risk category. Feng *et al.* (2019) demonstrated that the distribution of the BRI across quartiles showed a progressive increase in the risk of insulin resistance with higher quartile values, with women having significantly higher average BRI values compared to men.

Table 3. Quartile distribution of BRI by sex

Variable	Sex	N	Q1	Median Q2	Q3	Min	Max	N (%) Low risk (Q1)	N (%) Medium risk (Q1 - Q3)	N (%) High risk (Q3)
BRI	M	68	4.34	4.89	5.81	2.58	9.61	17 (25)	34 (50)	17 (25)
	F	92	4.76	5.73	7.11	2.27	10.05	23 (25)	46 (50)	23 (25)

(BRI- body roundness index; M – male, F – female; Q – quartile)

Table 4 presents the analysis of differences in BRI across various BMI categories: normal weight, overweight, obesity class I, class II, and class III. The results indicate significant differences between groups ($F = 53.21$, $p < 0.001$) with a very large effect size ($\eta^2 = 0.58$). Mean BRI values progressively increase from normal weight (3.62 ± 1.09) to higher obesity classes: overweight (4.81 ± 0.91), obesity class I (6.03 ± 1.09), obesity class II (7.59 ± 1.28), and obesity class III (8.91 ± 1.30). These findings align with the original research by Thomas *et al.* (2013), which demonstrated that BRI increases with BMI. Other studies have also demonstrated a strong positive correlation between BRI and BMI. For example, a significant correlation of $r = 0.71$ ($p < 0.01$) has been reported, highlighting the interrelationship between these measures in assessing body composition (Anto *et al.*, 2022).

Post-hoc comparisons using the Tukey test revealed significant differences in BRI among BMI categories, with progressively higher values observed from normal weight to obesity class III ($p < 0.05$). However, no statistically significant difference was found between obesity class II and class III ($p > 0.05$).

Table 4. Differences in BRI across various BMI categories

		N (%)	M	SD	F	p	η^2
BRI	Normal weight	13 (8.13%)	3.62	1.09	53.21	<0.001	0.58
	Overweight	57 (35.63%)	4.81	0.91			
	Obesity class I	65 (40.63%)	6,03	1.09			
	Obesity class II	19 (11.89%)	7.59	1.28			
	Obesity class III	6 (3.75%)	8.91	1.30			

(BRI-body roundness index; N-number; M-mean; SD-standard deviation; F-value; p-value; η^2 -effect size)

While aging is often associated with increased BRI due to changes in body composition and fat redistribution, findings from this study and previous research suggest that elevated BMI is also a major determinant of BRI, regardless of age. The results from this study demonstrate a progressive increase in BRI across BMI categories, with the highest values observed in individuals with severe obesity (8.91 ± 1.30 in obesity class III). Similarly, Solak *et al*. (2018) found that younger adults with obesity (mean age 37.8 years for females and 38.8 years for males) exhibited high BRI values, despite their relatively younger age. Their study reported significantly higher BRI in women (5.62 ± 2.15) compared to men (4.69 ± 1.51, p<0.001), reinforcing the notion that BMI-driven adiposity contributes to body roundness independently of age-related factors.

These findings emphasize that high BRI values should not be solely attributed to aging but also to the degree of obesity, further supporting the relevance of BRI in assessing metabolic risk across different age groups. This is particularly important in metabolic disorders such as T2DM, where excess adiposity, regardless of age, plays a key role in disease progression and cardiovascular risk.

CONCLUSION

This study presents the first preliminary results on the BRI among adults with T2DM in Banja Luka. Significant sex differences were identified, with women exhibiting higher BRI values compared to men. Stratifying participants based on quartiles provides valuable insights for risk categorization and the potential application of the BRI. This is particularly significant, as data on the BRI in the T2DM population in this region were previously unavailable. Future research is recommended to include a control group to enable ROC analysis and determine optimal BRI cut-off values for assessing the risk of metabolic complications associated with diabetes. These preliminary findings provide a solid foundation for further exploration of the BRI and its application in clinical practice.

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INDEKS ZAOBLJENOSTI TIJELA KOD ODRASLIH S DIJABETESOM TIP 2 U BANJALUCI

Maja Šibarević[1*], Smiljana Paraš[1], Jelena Malinović Pančić[2,3], Rajko Roljić[1], Elvira Hadžiahmetović Jurida[4]

[1]*Univerzitet u Banjoj Luci, Prirodno-matematički fakultet, Mladena Stojanovića 2, 78000 Banja Luka, Republika Srpska, Bosna i Hercegovina*
[2]*Univerzitetski Klinički Centar Republike Srpske, Dvanaest beba bb, 78 000 Banja Luka, Republika Srpska, Bosna i Hercegovina*
[3] *Univerzitet u Banjoj Luci, Medicinski fakultet, Save Mrkalja 14, 78 000 Banja Luka, Republika Srpska, Bosna i Hercegovina*
[4] *Univerzitet u Tuzli, Prirodno-matematički fakultet, Urfeta Vejzagića 4, 75000 Tuzla, Federacija Bosne i Hercegovine, Bosna i Hercegovina*
***Autor za korespondenciju:** maja.sibarevic@pmf.unibl.org

Sažetak

Indeks zaobljenosti tijela je nov antropometrijski pokazatelj koji se koristi za procjenu tjelesne kompozicije i predviđanje rizika od različitih metaboličkih bolesti, uključujući dijabetes melitus tip 2. Dijabetes, kao hronično metaboličko oboljenje, predstavlja značajan zdravstveni rizik, a tradicionalni i novi antropometrijski indeksi ključni su za procjenu rizika i napredovanja bolesti. Cilj ove studije bio je da analizira vrijednosti indeksa zaobljenosti tijela kod odraslih sa dijabetesom tip 2 u Banjaluci i da ispita razlike između polova. Rezultati su pokazali značajne razlike u vrijednostima indeksa zaobljenosti tijela između polova, pri čemu su žene imale značajno više vrijednosti (6,03 ± 1,66) u poređenju sa muškarcima (5,26 ± 1,45; p = 0,002). Analiza kvartila ukazala je na širi interkvartilni opseg kod žena (4,76–7,11) nego kod muškaraca (4,34–5,81), što sugeriše veću varijabilnost vrijednosti indeksa zaobljenosti tijela kod žena. Pored toga, primjećen je progresivni porast vrijednosti indeksa zaobljenosti tijela kroz kategorije uhranjesti indeksa tjelesne mase, sa značajno višim vrijednostima kod osoba sa višim stepenom gojaznosti (p < 0,05). Ova studija pruža prve preliminarne podatke o indeksu zaobljenosti tijela kod odraslih sa dijabetesom u ovom regionu, ističući njegovu potencijalnu primjenu u procjeni tjelesne kompozicije i metaboličkog rizika u raznovrsnim populacijama.

Ključne riječi: indeks zaobljenosti tijela, dijabetes tipa 2, polne razlike

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