GENDER-ASSOCIATED DIFFERENCES IN THE PREVALENCE OF CENTRAL OBESITY USING WAIST CIRCUMFERENCE AND WAIST-TO-HEIGHT RATIO, AND THAT OF GENERAL OBESITY, IN SLOVAK ADULTS

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SUMMARY

Objectives: Central obesity represents an increased risk to develop cardiovascular diseases. Guidelines of international societies suggest estimating central obesity by measuring waist circumference (WC). Robust statistical data in literature provide evidence on the superiority of waist-to-height ratio (WHtR) over WC and body mass index (BMI) for detecting cardiometabolic risk in both genders. Based on measurements of weight, height and waist circumference we compared the prevalence of central obesity using both the above mentioned criteria in the apparently healthy Slovak adults, and compared the prevalence of central obesity to that of general obesity (BMI).

Methods: Data collected from 5,184 individuals (45% males) aged ≥18 years in four cross-sectional studies carried out between the years 2009–2012 were subjected to secondary analysis.

Results: Waist circumference underestimated central obesity in males and overestimated in females: 37.3% of males and 41.8% of females presented central obesity according to WC, 54.2% males and 34.9% females according to WHtR. 17.3% of males centrally obese according to WC present WHtR < 0.5; while 7.8% of females centrally obese according to their WHtR do not display increased WC. The frequency of central obesity increased with age. According to BMI, the prevalence of overweight was 39% in males and 22% in females; that of obesity was 17% and 15%, respectively.

Conclusion: The prevalence of central obesity estimated using WC vs. WHtR differs significantly in Slovak adults. WHtR is considered superior for detection of the risk of future development of cardiovascular afflictions. Thus, further studies addressing the gender-associated discordance of central obesity measures are required to determine whether our results are consistent across geographical regions and ethnic groups.

Key words: central obesity, waist circumference, waist-to-height ratio, BMI, gender

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INTRODUCTION

Obesity, an excessive accumulation of body fat and increased body weight, is associated with negative health effects and reduced life expectancy. Rather than increased body weight per se, accumulation of visceral fat is associated with high blood pressure, atherogenic dyslipidemia, insulin resistance, type 2 diabetes, cardiovascular diseases, and certain cancers (1–3).

To identify people at increased health risk in general practice and epidemiological studies, visceral obesity is approximated by estimation of central obesity (CO). Guidelines of international societies suggest estimating CO by measuring of waist circumference (WC) employing gender- and ethnicity-specific cut-points (4, 5). The WC may over- and under-estimate CO in tall and short individuals with similar WC, respectively. Thus, the waist-to-height ratio (WHtR) ≥0.5 has been proposed as a proxy for CO (6, 7). Systemic reviews and meta-analyses of studies involving several ethnic groups provide robust statistical evidence on the superiority of WHtR over WC and body mass index (BMI) for detecting cardiometabolic risk factors in both genders (2, 3). Individuals supposed to be at risk of manifestation of cardiometabolic risk factors by their WC or WHtR are missed by BMI screening (8, 9). However, concordance or discrepancy in evaluation of CO using WC vs. WHtR is seldom tackled.

Information on the prevalence of overweight and obesity in Slovak adults comes from anthropometric measurements con-

ducted in the years 2003 to 2005 (10, 11), and from self-reported data on weight and height collected in 2009 (12). Neither of these studies employed WHtR as a measure of adiposity.

To this point we analyzed the association of estimates of CO evaluated according to WC and WHtR, and their relationship to BMI, in pooled data from 4 cross-sectional studies comprising 5,184 individuals aged ≥18 years (13–16). We hypothesized that WC and WHtR match the best in individuals with average height, and that a mismatch increases evenly with increments or decrements of the standard deviation of heights.

MATERIALS AND METHODS

This is a secondary analysis of data obtained in 4 cross-sectional studies conducted during the years 2007–2012 on apparently healthy volunteers or general population. Studies were performed in accordance with the principles of the Declaration of Helsinki. Study protocols were approved by the Ethics Committee of the Slovak Medical University (13–15), or that of Bratislava Self-governing Region (16). All subjects signed an informed consent to participate.

Study Population

Caucasians of Middle-European descent aged 18 to 83 years (mean age: 33.1 ± 12.1 years in males and 33.9 ± 11.6 years in females) residing, working or studying in Bratislava and surroundings were recruited in 3 studies (14–16), and those from 7 Slovak cities in another study (13). Recruitment was performed via general practitioners, using advertisements posted in frequented public locations, or via provided information on the possibility to participate at companies and secondary schools. In all studies exclusion criteria were any acute or serious chronic illnesses, unstable physical condition, and in women pregnancy and lactation.

Procedures

In all studies anthropometric measurements were performed by trained medical staff. Electronic scales (Omron BF510, Kyoto, Japan), extendable stadiometers (wall-mounted Harpenden stadiometer, Holtain Ltd., Crymych, UK; or portable stadiometers model 214 Rod, Seca Corp., Hamburg, Germany), and flexible inelastic belt-type tapes were used to determine body weight, height, and WC, respectively.

Data on age, gender, body weight, height, and WC of individuals aged ≥18 years were extracted from pertinent databases. After exclusion of the subjects with incomplete data (n = 54), 5,184 individuals (45.3% males) were included into analyses. BMI and WHtR were calculated. CO was classified as WC ≥94 cm in males and ≥80 cm in females (17); and as WHtR ≥0.5 (8). Subjects were categorized into 4 groups: 1) lean subjects: WC < cut-point and WHtR <0.5 (Lean, WC-WHtR-); centrally obese by 2) both indicators (WC+WHtR+), or according to a single indicator: 3) WC+WHtR-, and 4) WC-WHtR+. Heights in which both methods showed 100% agreement were identified. To reveal trends in the differences of the two proxies, individuals shorter or taller than the height interval in which the two indicators matched were sorted into groups by 5 cm of height, except for the shortest and the tallest subjects. E.g., in males, merged marginal groups of height (e.g. ≤167 cm and ≥195 cm) were created since there were only 14 males shorter than 162 cm, and only 6 with height of ≥199 cm. Similar reasons led us to group the shortest and the tallest females. Additionally, the subjects were categorized ac-

Table 1. *Cohort characteristics*

	n	Age (years)	Height (cm)	Weight (kg)	WC (cm)	WHtR	Body mass index (kg/m²)
Males	2,349	33.1 ± 12.1 (18–83)	178.8 ± 6.9 (140–204)	83.4 ± 15.5 (48–163)	90.8 ± 13.0 (60–150)	0.51 ± 0.07 (0.33–0.83)	26.1 ± 4.5 (16.0–53.2)
Females	2,835	33.9 ± 11.6 (18–83)	165.5 ± 6.3 (143–189)	67.3 ± 15.5 (40–170)	79.9 ± 13.3 (53–148)	0.48 ± 0.08 (0.39–0.95)	24.5 ± 5.4 (15.2–58.8)

WC – waist circumference, WHtR – waist-to-height ratio, BMI – body mass index; data are given as mean ± SD and range (in brackets)

Table 2. *Prevalence of body mass categories and central obesity*

	Males	Females	p-value
Underweight (BMI < 18.5 kg/m²)	47 (2.0%)	155 (5.5%)	<0.001
Normal weight (BMI: 18.5–24.9 kg/m²)	977 (41.6%)	1,657 (58.4%)	<0.001
Overweight (BMI: 25.0–29.9 kg/m²)	926 (39.4%)	613 (21.6%)	<0.001
Obesity			
Stage I (BMI: 30.0–34.9 kg/m²)	301 (12.8%)	265 (9.3%)	<0.001
Stage II (BMI: 35.0–39.9 kg/m²)	76 (3.2%)	94 (3.3%)	0.872
Stage III (BMI > 40.0 kg/m²)	22 (0.9%)	51 (1.8%)	0.009
Central obesity			
WC (≥94 cm males; ≥80 cm females)	875 (37.2%)	1,185 (41.8%)	<0.001
WHtR (≥0.5)	1,272 (54.2%)	991 (35.0%)	<0.001

BMI – body mass index, WC – waist circumference, WHtR – waist-to-height ratio, data are given as number of subjects and percentage

cording to BMI as those presenting underweight (BMI < 18.5 kg/m^2), normal weight (BMI: 18.5–24.9 kg/m^2), overweight (BMI: 25.0–29.9 kg/m^2), class I (BMI: 30.0–34.9 kg/m^2), class II (BMI: 35.0–39.9 kg/m^2), and class III (BMI > 40.0 kg/m^2) obesity.

Statistical Analysis

In males and females, the prevalence of CO according to WC or WHtR was calculated with regard to height, BMI category, or decades of age. Data are given as mean ± standard deviation, or as percentages. Categorical data were compared by chi-square test or McNemar's test (exact, 2-tailed), as appropriate. $P < 0.05$ was considered significant. Statistical analyses were performed using SPSS version 22 software (SPSS Inc., Chicago, IL, USA).

RESULTS

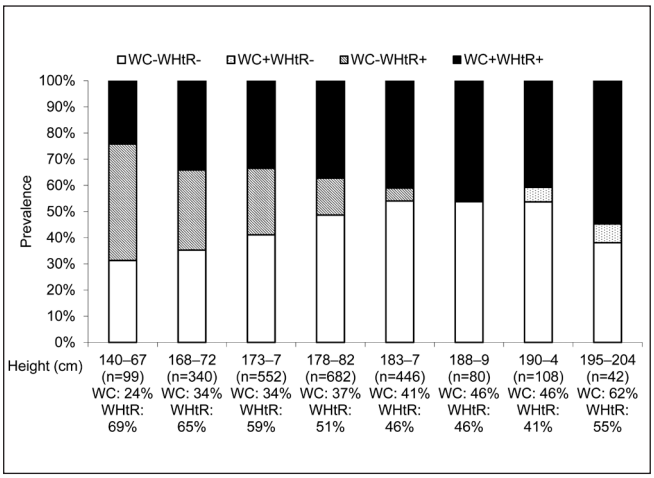
Cohort characteristics are given in Table 1. The prevalence of underweight, normal BMI, overweight, and obesity and that of CO according to WC and WHtR cut-points are summarized in Table 2.

Males

Central obesity: The prevalence of CO employing WC cut-point was significantly lower (37.2%) if compared with that evaluated according to WHtR (54.2%, McNemar $p < 0.001$) (Table 2). WHtR correlated significantly with WC ($y = 0.005x + 0.015$, $R^2 = 0.927$, $p < 0.001$). WC and WHtR classified concordantly central obesity or leanness in 82.3% (n = 1,934) of males; a mismatch between 2 proxies of CO was observed in 415 (17.7%) subjects (Table 3).

Both methods fully matched in classification of CO in 188 cm and 189 cm high males (Figure 1a). 17.3% of males were classified as CO by WHtR but not according to WC (Table 3). Since all of them were shorter than 188 cm (Fig. 1a), thus WC vs. WHtR underestimated CO in 19.2% of shorter subjects. Among all participants, 0.4% presenting WC ≥ 94 cm displayed WHtR < 0.5 (Table 3). All of them were taller than 189 cm (Fig. 1a), thus among tall men mismatch reached 6.0%.

McNemar's test indicated significant difference between classifications in all height categories bellow 188 cm ($p < 0.001$, all), and in males 190–194 cm tall ($p = 0.016$). In comparison with WHtR, WC underestimated CO in all age-decade groups (Figure 2). The lowest discordance (3.6%) was observed in 60–69 years old subjects, the highest (24.3%) in those aged 40–49 years.



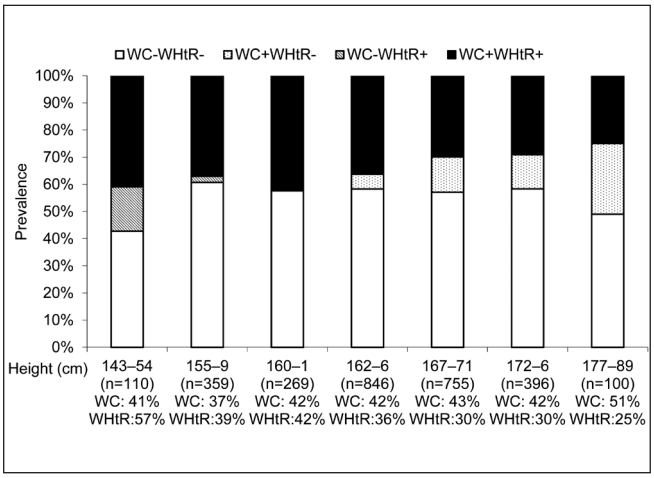


Fig. 1. *Prevalence of central obesity estimated by waist circumference and waist-to-height ratio in relation to height in males (1a) and females (1b).*

Central obesity was classified as WC ≥ 94 cm in males and ≥ 80 cm in females (17), and as WHtR ≥ 0.5 (8). Subjects were grouped by 5 cm increments/decrements from the height in which WC and WHtR matched in classification of central obesity. Four categories were used to characterize the prevalence of central obesity: WC-WHtR-: lean subjects: WC < 94 cm (males) or < 80 cm in females and WHtR < 0.5; WC+WHtR-: centrally obese only according to WC; WC-WHtR+: centrally obese only according to WHtR; WC+WHtR+: centrally obese according to both measures. Height intervals are indicated in the first row under the bars. Number of probands (n) in each height category is given in the second row. WC – prevalence of central obesity classified according to waist circumference cut-point; WHtR – prevalence of central obesity classified according to waist-to-height ratio.

Table 3. *Prevalence of central obesity according to waist circumference or waist-to-height ratio in underweight/lean (BMI ≤ 24.9 kg/m^2) and overweight/obese (BMI ≥ 25.0 kg/m^2) males and females*

	Males				Females			
	WC		WHtR		WC		WHtR	
	< 94 cm	≥ 94 cm	< 0.5	≥ 0.5	< 80 cm	≥ 80 cm	< 0.5	≥ 0.5
BMI ≤ 24.9 kg/m^2	974 (41.5%)	50 **(2.1%)**	869 (36.9%)	155 **(6.6%)**	1,522 (53.7%)	290 **(10.2%)**	1,650 (58.2%)	162 **(5.7%)**
BMI ≥ 25.0 kg/m^2	500 **(21.3%)**	825 (35.1%)	208 **(8.9%)**	1,117 (47.6%)	128 **(4.5%)**	895 (31.6%)	194 **(6.8%)**	829 (29.3%)
WHtR < 0.5	1,068 (45.4%)	9 **(0.4%)**	–	–	1,624 (57.3%)	220 **(7.8%)**	–	–
WHtR ≥ 0.5	406 **(17.3%)**	866 (36.9%)	–	–	26 **(0.9%)**	965 (34.0%)	–	–

BMI – body mass index, WC – waist circumference, WHtR – waist-to-height ratio; data are given as number of subjects and percentage, percentage given in bold indicate the discordance between 2 methods compared

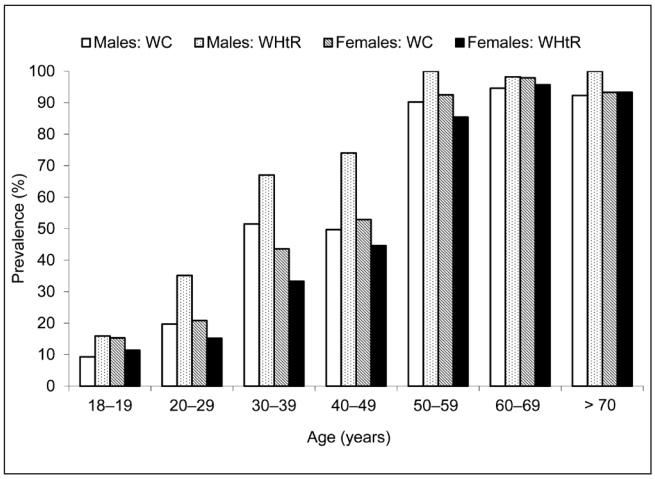


Fig. 2. *Age-dependent prevalence of central obesity classified according to waist circumference (WC) and waist-to-height ratio (WHtR) in males and females.*

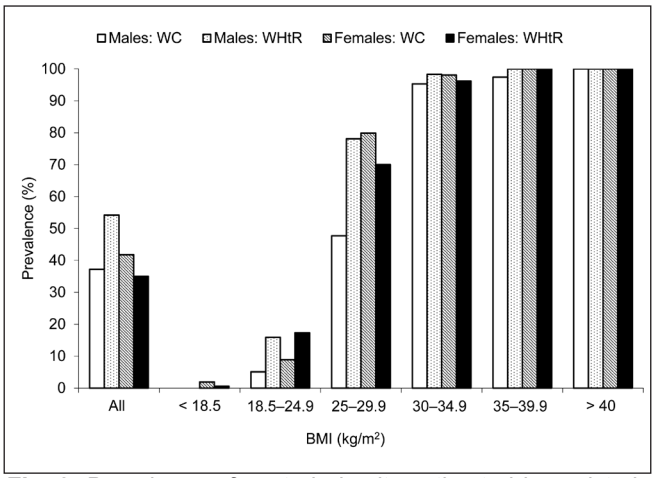


Fig. 3. *Prevalence of central obesity estimated by waist circumference (WC) and waist-to-height ratio (WHtR) according to body mass index (BMI) categories in males and females.*

Body mass index: Regardless of the method of CO estimation, none of the males with BMI < 18.5 kg/m^2 presented CO; and all class III obese males were concordantly classified as CO (Figure 3). In males with BMI ranging from normal to class II obesity, WC in comparison with WHtR underestimated CO: discordance ranged from 2.6% in class II obese males to 30.3% in subjects presenting overweight (Figure 3). The prevalence of overweight/obesity was similar to that of the CO estimated by WHtR (Table 2), but only 84.3% (n = 1,117) of overweight/obese males presented WHtR ≥ 0.5. 62.3% (n = 825) overweight/obese males were centrally obese according to WC classification. Total mismatch between BMI and central adiposity measures was higher for WC (23.4%, e.g. 21.3% plus 2.1%) than for WHtR (15.5%, e.g. 6.6% plus 8.9%) (Table 3).

Females

Central obesity: The prevalence of CO according to WC (41.8%) was significantly higher in comparison with WHtR (35.0%, McNemar p < 0.001) (Table 2). WHtR correlated with WC ($y = 0.006x + 0.007$, $R^2 = 0.947$, $p < 0.001$). WC and WHtR concordantly classified central leanness or central obesity in 91.3% of females, a mismatch was recorded in 8.7% of subjects (Table 3).

In 160 cm and 161 cm high females, WC and WHtR classified CO consistently (Figure 1b). 0.9% of females with WC < 80 cm presented CO according to their WHtR (Table 3). All of them were shorter than 160 cm (Fig. 1b), thus among these females 4.0% were classified as CO by WHtR but were missed using WC. Among females, 7.8% classified as CO by WC presented WHtR < 0.5 (Table 3). All of them were taller than 161 cm, thus among taller females (Fig. 1b) the prevalence of this mismatch reached 11.2%.

McNemar's test indicated significant difference in the frequencies of CO between the methods in all height categories ($p = 0.008$ in 155–159 cm tall, others: $p < 0.001$), except for 160–161 cm tall females in whom total concordance was observed. In comparison with WHtR, WC overestimated CO in all age-groups but > 70 years old females, in whom both methods of CO classification matched (Figure 2). The lowest mismatch (2.2%) was observed among the 60–69 years old subjects; the highest (10.3%) in females aged 30–39 years.

Body mass index: In women with BMI ≤ 34.9 kg/m^2, WC overestimated CO in comparison with WHtR in 1.3–10.0% of individuals in different BMI categories (Figure 3). The prevalence of overweight/obesity and CO estimated using WHtR was similar (Table 2). However, only 81.0% (n = 829) of overweight/obese females presented WHtR ≥ 0.5; while 87.5% (n = 895) of overweight/obese females presented CO according to their WC. Among females, discordance between classification according to BMI and WC reached 14.7% (e.g. 10.2% plus 4.5%), while in case of WHtR it represented 12.5% (5.7% plus 6.8%) (Table 3).

DISCUSSION

This first study comparing three adiposity measures in apparently healthy Slovak adults shows that the prevalence of overweight, obesity, and CO is very high. Except for CO estimated using WC cut-points, the prevalence was higher among males. Discordance between three employed adiposity measures was also more frequent in males than in females. In contrast to our hypothesis, WC vs. WHtR did not show the highest concordance in estimation of CO in individuals of average height.

General Obesity

The former Slovak studies reported 36–43% prevalence of overweight according to BMI cut-points in males and 27–29% in females; while that of obesity varied between 15% to 27% in males and 16% to 35% in females (10–12). Our data correspond to the lower ranges indicated for males, but the prevalence of both overweight and obesity was lower in our females. Considering the rising incidence of overweight and obesity worldwide, our data might look paradoxical. However, a relatively low prevalence might be, among others, due to the recruitment: our volunteers might represent subjects being interested in their health status, and thus might stand for a "healthier" part of Slovak population.

While prevalence of obesity in our study exceeded that reported from neighbouring countries for both genders (using BMI), our males presented rather low prevalence of overweight, similar to that reported from Austria. The prevalence of overweight in our

females appeared even slightly lower than that in neighbouring countries (18). Our males and females presented similar prevalence of class II obesity, while females presented 2-fold higher prevalence of class III obesity in comparison with males. Observed shift towards obesity is particularly alarming since Slovaks present high prevalence of diabetes (9.3%) (19), and one of the highest cardiovascular mortality rates from among EU-27 countries (20, 21).

In contrast to former Slovak studies (10–12), but in accordance with the data from neighbouring countries (18), in our study the prevalence of obesity was higher in males compared to females. This might reflect the general observation that in the last decade BMI and the frequency of obesity increased more steeply in males than in females (22–25). Although in Europe overweight and obesity generally show an inverse socioeconomic gradient, data from 2002 suggest that this relationship holds true only for Slovak women (18). Educational attainment was not tracked in our studies, but we estimate that majority of volunteering subjects received secondary or higher education. This might have influenced the observed higher prevalence of obesity among males.

Central Obesity

Single former Slovak study reporting prevalence of CO according to IDF criteria estimated that 47% of males and 54% of females were centrally obese (10). In our study, the prevalence was lower. However, in both studies the prevalence was higher among females compared to males. On the other hand, WHtR used to classify CO in our study yielded, strikingly, higher prevalence of CO in males than in females. We asked whether this discrepancy might stem from the fact that the average anthropometric characteristics, particularly the height, of our participants deviated from an average reported for Slovak adults. According to the EHIS study, the average height of adult Slovak male was 177.6 cm, average weight was 82.8 kg, and that of BMI reached 26.2 kg/m^2 (12). Grasgruber et al. (26) reported the average height of 179.3 cm. An average adult female height was 165.2 cm, average weight 67.9 kg, and BMI 25.0 kg/m^2 (12). According to data from the 7th Nationwide Survey (22), average heights of 18-years old males and females correspond to those reported in the EHIS study (12). Thus, the anthropometric characteristics of our male and female cohorts acceptably reflect those of White Caucasian Slovak adults.

In males, both methods concordantly classified CO in subjects slightly taller than average plus 1 SD (e.g. in those 188–9 cm tall). In shorter males (< 188 cm tall), accounting for 90% in our cohort, WC underestimated CO if compared with WHtR; while in those taller than 189 cm (representing 6% of our males), WC overestimated CO in comparison with WHtR. This mismatch stemmed from the fact that in our males WHtR of 0.5 corresponded to WC of 89 cm (and WC of 94 cm to WHtR of 0.52). Among females, concordance was reached in those shorter from the average by 1 SD of height (e.g. those 160–1 cm tall). Thus, in females shorter than 160 cm (accounting for 16.5% of all females) WC in comparison with WHtR underestimated CO, while in those taller than 161 cm (73.0% of the cohort) WC overestimated CO if compared with the WHtR classification. In contrast with males, in females estimation of CO using WHtR underclassified CO in comparison with WC. This stems from the fact that in Slovak females WHtR of 0.5 corresponds to WC of 83 cm, and WC of 80 cm corresponded to WHtR of 0.49. Mismatch between the methods was 2-fold higher in males in comparison with females. In both genders discordance was more frequent in young and middle aged subjects, reflecting a well-known age-dependent rise in frequency of CO (9, 10).

BMI vs. WHtR misclassified 15.5% males and 12.5% females. These percentages are similar to those reported previously (8). However, while in this study approximately 75% from the mismatched subjects where those at risk by WHtR but missed by BMI screening, in our cohorts the proportion of those at risk by BMI but not at risk by WHtR was higher. Total mismatch between BMI and WC was the highest among the compared methods in both genders, pointing to overestimation of adiposity by BMI vs. WC in males and underestimation in females.

The main strengths of our study are its large size and the use of objective measures of weight, height and waist circumference. Elderly participants were not institutionalized. One possible limitation is that the gender, age and educational level structure do not closely resemble the socio-demographic distribution of the Slovak population. Our probands were not completely independent, close relatives and family members might have participated. We did not collect data on determinants of obesity, such as socioeconomic status, dietary habits, alcohol intake, or physical activity. Anthropometric data were collected according to the same protocol, scales from one manufacturer and portable stadiometers of the same provenance were used. All staff members participating in anthropometric data collection where either employees or students of the Slovak Medical University, Faculty of Medicine of Comenius University or the Public Health Authority of the Slovak Republic. Participating students were rigorously trained to perform data collection, and during measurements performance they were supervised by employees of the mentioned institutions. However, we cannot exclude bias in data collection.

CONCLUSION

The prevalence of overweight/obesity and CO among apparently healthy Slovak adults is very high and should be compellingly tackled by appropriate policies of the institutions in charge. We confirmed the accepted assumption that in comparison with WHtR, WC, a method recommended by numerous professional organizations, overestimates central obesity in taller subjects. However, in our cohort this overestimation was observed only in males presenting height by about one standard deviation above the average; while in females it was in those who were shorter than an average minus one standard deviation. Further studies addressing the discordance of CO measures are required to determine whether our results are consistent across geographical regions and ethnic groups. As WHtR seems to be a better predictor for estimation of future cardiometabolic risk, data from different populations could provide basis for decision-making policies of the institutions in charge with regard to estimation of the central obesity associated risk evaluation.

Conflict of Interests
None declared

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