PŮVODNÍ PRÁCE

# CONFIRMATION OF SIGNIFICANT CORRELATIONS BETWEEN NECK CIRCUMFERENCE AND ANTHROPOMETRIC INDICATORS OF CARDIOMETABOLIC HEALTH IN THE GROUP OF UNIVERSITY STUDENTS FROM EASTERN SLOVAKIA

# Potvrdenie signifikantných korelácií medzi obvodom krku a antropometrickými indikátormi kardiometabolického zdravia v skupine univerzitných študentov z východného Slovenska

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**Abstract**

Neck circumference is a relatively new and promising anthropological marker with the potential to predict individual health status and future complications. In this context, the aim of our study was to analyze the neck circumferences of 115 eastern Slovakian university students and correlate them with basic individual characteristics, measurements, and indices that can inform about cardiometabolic health. Data on age, gender, body height, body weight, neck circumference, waist circumference, hip circumference, blood pressure, and heart rate were obtained using standard procedures. The indices BMI, WHR, WHtR, and BAI were calculated from the obtained data. All data were processed for descriptive statistics, a Student t-test, and Pearson correlations. Almost all of the analyzed parameters and indices revealed statistically significant differences between sexes. The male and female mean neck circumferences were 37,68 ± 2,90 cm and 31,23 ± 2,12 cm, respectively. Almost 50% of males had values of neck circumference higher than optimal, according to the WHO criterion. Some, particularly positive correlations, were statistically significant. Strong positive correlations were found between the neck circumference and variables like weight, waist circumference, hip circumference, and BMI in the whole research group and in the subgroups of males and females. Except for females' systolic blood pressure ($r = 0,44$; $p = 0,0006$), no statistically significant correlation between neck circumference and blood pressure was found. Our findings provide preliminary information about neck circumference variability and correlations with cardiometabolic indicators in a group of eastern Slovakian students, and they suggest that these findings could be used in the context of assessing cardiometabolic complications in young adults after validation in larger research groups.

***Key words:*** *anthropometry, adiposity, risk factors, young adults*

**Introduction**

Neck circumference (NC) estimation is a noninvasive, easy, quick, and reliable method. Neck circumference data may be a source of interesting information about an individual's health status. Neck circumference showed significant interindividual, intersexual, and interpopulation variability, as with other anthropology measurements (Moradi et al., 2019). This anthropological parameter has been linked to a variety of pathological entities or risk factors, including obesity and metabolic syndrome (Kim, Moon, & Yun, 2021), nonalcoholic fatty liver disease (Jian et al., 2020), insulin resistance in women with polycystic ovary syndrome (Chen et al., 2021), and mortality in hospitalized COVID-19 patients (Di Bella et al., 2021). There were confirmed associations between neck circumference and indices, which are the gold standard in risk assessment of the individual's adiposity and cardiometabolic status: body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR), but also with new promising indices of general or central obesity or increased cardiometabolic risk (Kamarli Altun & Suna, 2022; Özkaya & Tunçkale, 2016; Ramoshaba et al., 2022; Tantawy et al. 2020; Zhang et al., 2020). According to this data, it is an interesting indicator and predictor and can have an important informative value.

**Aim**

Based on the mentioned facts, we decided to analyze the NC values in a group of university students from eastern Slovakia and estimate their correlation with basic individual characteristics, measurements, and indices that can inform about cardiometabolic health and risk factors.

**Methodology**

In order to determine the relation between NC and anthropometric indicators of cardiometabolic health, we invited Eastern Slovakia university students (Prešov) to participate in our research activities, which were in accordance with the Declaration of Helsinki and institutional ethics standards (no. ECUP-022023PO). All 115 research participants confirmed informed consent and anonymously provided data about gender, age, body height (cm), body weight (kg), neck circumference (NC; cm), waist circumference (WC; cm), hip circumference (HC; cm), blood pressure (BP; mmHg) and heart rate (HR; bpm). All anthropometric data were collected using standard procedures and equipment in accordance with anthropological guideline (Fetter, 1967). A digital blood pressure monitor, Sencor SBP 690, was used to measure physiological indicators - systolic and diastolic blood pressure (sBP and dBP), and heart rate (HR). All conditions for accurate and comfortable blood pressure and heart rate measurements were established (quiet room with optimal temperature, comfortable chair, privacy, triple measurement, etc.). After measurements

the neck circumferences were assessed in terms of the optimal values recommended by the WHO (males NC < 37 cm and females NC < 34 cm) (WHO, 1995). Standard formulas were used for anthropology indices and ratios of adiposity calculations: BMI (Body mass index), WHR (waist – hip ratio), WHtR (waist – height ratio) and BAI (Body adiposity index) (Lam et al., 2015). Obtained data were processed by MS Excel 365, and basic descriptive statistics, a Student´s t-test, and Pearson´s correlations were calculated by Excel data analysis tools. The correlations were calculated between NC and all variables obtained from research participants (sex, age, height, weight, WC, HC, sBP, dBP, HR, and the indices BMI, WHR, WHtR, and BAI). The strength of the correlation between NC and variables was expressed according to Evans recommendations (1996). For comparing correlation coefficients of male and female subgroups, Fisher's r-z transformation was used (by online *Medcalc* calculator; *https://www.medcalc.org/calc/comparison_of_correlations.php*). Statistical significance was assigned to all results with $p \leq 0,05$.

**Results**

Our analyses of basic anthropometry parameters based on measurement of the body height, body weight, neck, waist, and hip circumferences supplemented by measurement of the blood pressure and heart rate were realized in the group of 115 university students (57 males and 58 females) with the mean age of 19,73 ± 1,09 years (Table 1). Our data confirmed statistically significant differences between males and females almost in all analyzed parameters and indices except for age, sBP, and BAI. The mean values of blood pressure were higher than optimal values (120/80 mmHg) in both sexes, probably due to emotional stress. Compared to females, the mean values of most of the parameters listed in Table 1 were significantly higher in males (69,23% of parameters). Females, on the other hand, had higher mean values of blood pressure, heart rate, and the adiposity index BAI (Table 1). The mean values of NC were 37,68 ± 2,90 cm in the males and 31,23 ± 2,12 cm in females. After analysis of the cutoff values for NC, the results showed that 27,83% of participants had higher than optimal values, namely, 49,12% of males, and 6,9 % of females.

*Table 1. General characteristics of our research group of university students*

| VARIABLE | MEAN N=115 | SD | $MEAN_M$ N=57 | $SD_M$ | $MEAN_F$ N=58 | $SD_F$ | t-TEST | p-VALUE |
|---|---|---|---|---|---|---|---|---|
| **AGE (years)** | 19,73 | 1,09 | 19,81 | 1,32 | 19,66 | 0,81 | 0,75 | ns |
| **HEIGHT (cm)** | 172,72 | 9,06 | 179,20 | 6,74 | 166,35 | 6,03 | 10,78 | *** |
| **WEIGHT (kg)** | 70,62 | 16,78 | 80,50 | 15,72 | 60,91 | 11,27 | 7,69 | *** |
| **WC (cm)** | 78,59 | 12,02 | 85,32 | 10,07 | 71,97 | 9,98 | 7,14 | *** |
| **HC (cm)** | 99,49 | 10,22 | 103,73 | 9,12 | 95,32 | 9,57 | 4,82 | *** |
| **NC (cm)** | 34,43 | 4,11 | 37,68 | 2,90 | 31,23 | 2,12 | 13,63 | *** |
| **sBP (mmHg)** | 131,80 | 12,56 | 130,51 | 13,22 | 133,07 | 11,85 | -1,09 | ns |
| **dBP (mmHg)** | 80,84 | 9,12 | 78,42 | 10,15 | 83,22 | 7,33 | 2,91 | ** |
| **HR (bpm)** | 84,97 | 13,61 | 81,47 | 14,52 | 88,40 | 11,79 | -2,81 | ** |
| **BMI (kg/m²)** | 23,53 | 4,59 | 25,05 | 4,62 | 22,04 | 4,08 | 3,70 | *** |
| **WHR** | 0,79 | 0,06 | 0,82 | 0,05 | 0,75 | 0,04 | 8,01 | *** |
| **WHtR** | 45,47 | 6,42 | 47,67 | 5,93 | 43,31 | 6,19 | 3,86 | *** |
| **BAI (%)** | 25,92 | 4,56 | 25,32 | 4,18 | 26,51 | 4,87 | -1,40 | ns |

*Abbreviations: BAI – Body adiposity index, BMI – Body mass index, dBP – diastolic blood pressure, F – female, HC – hip circumference, HR – heart rate, M – male, NC – neck circumference, ns – not significant, sBP – systolic blood pressure, SD – standard deviation, WC – waist circumference, WHR – Waist to hip ratio, WHtR – waist to height ratio, * – p ≤ 0,05, ** – p ≤ 0,01, *** – p ≤ 0,001*

The results of our correlation analysis of NC with variables obtained from participants showed some statistically significant correlations in the whole research group but also in subgroups divided according to gender (Table 2). Predominantly positive correlations were detected. In the whole research group, there were confirmed statistically significant positive correlations with all anthropology measurements and calculated indices. In the case of BP, only a trivial but not significant correlation was confirmed. Between NC and HR a significant negative correlation was confirmed (r = -0,24; p = 0,0098). A strong negative correlation was calculated in the case of NC and sex (r = -0,79; p < 0,0000). In the whole research group, the highest values of correlation coefficients were confirmed between NC and weight (r = 0,86; p < 0,0000). Strong positive correlations were also found between NC and WC, HC and BMI. Of all calculated anthropometric indices, the weakest correlation was between NC and BAI (r = 0,26; p = 0,0060).

Table 2 also shows similar results from the correlation analysis for males and females. The highest value of Pearson correlation coefficients was calculated between NC and weight (r = 0,77; p < 0,0000 in males, and r = 0,83; p < 0,0000 in females). The strong positive correlations were calculated in males between NC and WC, HC, and BMI. Similar results were obtained for the females. In the subgroup of females, the values of almost all correlation coefficients were higher than in males.

In both sexes, NC and BP correlated positively, but there were no confirmed statistically significant results, except for the NC-to-sBP correlation in females (r = 0,44; p = 0,0006). All calculated correlation coefficients in males and females were compared, and the results showed an existing statistically significant difference only in the case of the coefficients expressing a relationship between NC and systolic blood pressure (p = 0,013).

*Table 2. Results of correlation analysis between NC and variables obtained from study participants*

| | ALL N = 115 | | MALES N = 57 | | FEMALES N = 58 | | r-z TRANSFORMATION | |
|---|---|---|---|---|---|---|---|---|
| | r | p-value | r | p-value | r | p-value | z | p- value |
| **SEX** | -0,79 | *** | - | - | - | - | - | - |
| **AGE (years)** | 0,22 | * | 0,30 | * | 0,20 | ns | 0,56 | ns |
| **HEIGHT (cm)** | 0,61 | *** | 0,14 | ns | 0,06 | ns | 0,42 | ns |
| **WEIGHT (kg)** | 0,86 | *** | 0,77 | *** | 0,83 | *** | -0,88 | ns |
| **WC (cm)** | 0,79 | *** | 0,70 | *** | 0,71 | *** | -0,10 | ns |
| **HC (cm)** | 0,72 | *** | 0,72 | *** | 0,73 | *** | -0,11 | ns |
| **sTK (mmHg)** | 0,04 | ns | 0,04 | ns | 0,44 | *** | -2,26 | * |
| **dTK (mmHg)** | -0,10 | ns | 0,15 | ns | 0,22 | ns | -0,33 | ns |
| **TF (bpm)** | -0,24 | ** | -0,15 | ns | 0,07 | ns | -1,11 | ns |
| **BMI (kg/m²)** | 0,71 | *** | 0,76 | *** | 0,80 | *** | -0,47 | ns |
| **WHR** | 0,65 | *** | 0,30 | * | 0,44 | *** | -0,83 | ns |
| **WHtR** | 0,64 | *** | 0,62 | *** | 0,67 | *** | -0,40 | ns |
| **BAI (%)** | 0,26 | ** | 0,57 | *** | 0,64 | *** | -0,56 | ns |

*Abbreviations: BAI – Body adiposity index, BMI – Body mass index, dBP – diastolic blood pressure, F – female, HC – hip circumference, HR – heart rate, M – male, NC – neck circumference, ns – not significant, r – Pearson´s correlation coefficient, sBP – systolic blood pressure, WC – waist circumference, WHR – Waist to hip ratio, WHtR – waist to height ratio, * – p ≤ 0,05, ** – p ≤ 0,01, *** – p ≤ 0,001*

**Discussion**

According to research data, the NC may be a promising marker of an individual´s health, including cardiometabolic complications. Neck circumferences less than 37 cm in men and 34 cm in women are considered normal values of NC (WHO, 1995). However, the mean values of the NC and the defined cutoff values for NC size may vary in populations of different races and ethnicities (Moradi et al., 2019).

The mean values of NC in our research group of university students with a mean age of 19,73 ± 1,09 years were 37,68 ± 2,90 cm in males and 31,23 ± 2,12 cm in females. For comparison to our results in the Shrestha study (2018), the NC means of male and female students were found to be 36,51 ± 2,03 cm and 32,58 ± 1,81 cm, respectively. Similar mean values to our study were confirmed in the studies of Raimi, Dada & Solanke (2018) and Zaciragic et al. (2018). On the other hand, our NC mean values in the subgroups according to gender were lower than the data obtained in the group of young Spanish adults (Arias Téllez et al., 2020), in healthy young adults in the Catenaccio et al. study (2017), or in participants in the Padilha et al. study (2022). After analysis of NC values according to WHO recommendations (WHO, 1995), we found out that less than 30% of all participants had elevated values of NC, predominantly males (almost 50% of males). Similar results, which indicated risk values of the NC in male individuals, have also been confirmed by another researcher, Shrestha (2018), with the result of 47,4% of values under 37 cm in males.

In our research group, comparisons of data obtained from males and females showed statistically significant results almost in all cases, except for age, sBP, and the BAI index. All anthropometric mean values were higher in males. On the other hand, BP and HR were higher in females.

In several studies, associations between NC and other outcome variables like anthropometric indices, biochemical markers, or blood pressure were expressed by correlation coefficients (Kamarli Altun & Suna, 2022; Ramoshaba et al., 2022; Zhang et al., 2020). In our study, we correlated NC with all characteristics obtained from participants. In the whole research group, we confirmed statistically significant correlations in almost all analyzed parameters except for BP. The results in the subgroups were not fully consistent with the results in the whole research group. Almost all calculated NC-correlations were positive. Other studies have found positive correlations between NC and cardiometabolic health variables (Kamarli Altun & Suna, 2022; Özkaya & Tunçkale, 2016; Tantawy et al., 2020).

In our research groups, the NC was positively correlated with all indicators of adiposity. In the whole research group and in male and female subgroups, the strongest correlation was confirmed between NC and weight. Similarly, in another research group, from all the analyzed variables, the strongest positive correlations were calculated between NC and weight (Raimi, Dada & Solanke, 2018; Shrestha, 2018). In our study, the relation between these two variables was stronger than the confirmed relation in 198 students analyzed in another study (r = 0,57 in males and r = 0,63 in females) (Shrestha, 2018).

The results showed that the NC is independently associated with cardiovascular risk factors (Zhang et al., 2020). It is assumed that there could be a connection between the NC and the risk of hypertension or other cardiovascular complications, but data about associations between NC and BP or HR are ambiguous (Ben-Noun & Laor 2004; Ramoshaba et al., 2022; Zaciragic et al., 2019). In the study of 127 students, Pearson correlation analysis also confirmed that NC positively correlated with both the sBP and dBP (r = 0,5; p < 0,001 and r = 0,3; p < 0,001) (Ramoshaba et al., 2022). Moradi et al. (2019) reported a direct correlation of NC with BP and a positive association with the risk of prehypertension and hypertension in adults, particularly in Western populations. Only a trivial but not statistically significant correlation between NC and BP was analyzed in 111 Bosnian young adults (Zaciragic et al. 2019). In Raimi´s male subgroup, the results were not statistically significant (p > 0,05) (Raimi, Dada & Solanke 2018). These results are consistent with our observations. In the case of our research group, we confirmed a statistically significant positive correlation only between NC and sBP in the female subgroup with Pearson correlation coefficient r = 0,44, which was the same as in the group of 133 Nigerian females ($r_{sBP}$ = 0,44) (Raimi, Dada & Solanke 2018). Similar findings have been reported in other studies. Meta-analysis revealed that the relationship between the NC and BP varies depending on adjustments based on different variables, such as sex, BMI, etc. (Moradi et al. 2019).

**Conclusion**

In conclusion, we can state that NC is a promising anthropology marker with great potential to predict an individual´s health status. We could argue that the high interindividual, intersexual, and interpopulation variability in this anthropology measurement is comparable to the variability in other characteristics, including those obtained from our participants. Our findings supported the hypothesis that there are significant correlations between NC and selected characteristics and indices associated with cardiometabolic complications. Although we did not fully declare statistically significant correlations between the NC values and all variables including blood pressure and heart rate, this was only pilot study, which shows first information about NC correlations to cardiometabolic indicators, and we plan to verify our results in a larger research sample and in other age categories.

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**Súhrn**

Obvod krku je relatívne nový a sľubný antropologický marker s potenciálom predikovať individuálny zdravotný stav respektíve budúce komplikácie. V tejto súvislosti bolo cieľom našej štúdie analyzovať obvod krku v skupine 115 univerzitných študentov z východného Slovenska a determinovať korelácie medzi obvodom krku a antropometrickými ukazovateľmi kardiometabolického zdravia. Údaje o veku, pohlaví, telesnej výške, telesnej hmotnosti, obvode krku, obvode pása, obvode bokov, krvnom tlaku a srdcovej frekvencii boli získané pomocou štandardných postupov. Na základe získaných antropometrických dát boli vypočítané indexy BMI, WHR, WHtR a BAI. Deskriptívna štatistika, Studentov t-test a Pearsonove korelácie boli vypočítané na základe údajov o participantoch štúdie. Výsledky ukázali štatisticky významné rozdiely medzi mužmi a ženami takmer vo všetkých analyzovaných parametroch a indexoch. Priemerné hodnoty obvodu krku u mužov boli 37,68 ± 2,90 cm a u žien 31,23 ± 2,12 cm. Takmer 50 % mužov malo hodnoty obvodu krku vyššie ako optimálne hodnoty odporučané WHO. Korelačná analýza potvrdila niekoľko štatisticky významných korelácií. Väčšina korelácií bola vyhodnotených ako pozitívne. Silné pozitívne korelácie boli nájdené medzi obvodom krku a premennými ako telesná hmotnosť, obvod pása, obvod bokov a BMI v celej výskumnej skupine a v podskupinách mužov a žien. Medzi obvodom krku a krvným tlakom nebola zistená štatisticky významná korelácia. Výnimkou bola skupina žien, kde bola potvrdená signifikantná korelácia obvodu krku a systolického krvného tlaku (r = 0,44; p = 0,0006). Naše zistenia poskytujú predbežné informácie o variabilite obvodu krku a koreláciách tejto obvodovej miery s indikátormi kardiometabolických komplikácií v skupine univerzitných študentov z východného Slovenska. Výsledky zároveň naznačujú, že po validácii vo väčších výskumných súboroch by obvod krku mohol byť použitý pri hodnotení a predikcii kardiometabolických komplikácií u mladých dospelých.

***Kľúčové slová**: antropometria, adipozita, rizikové faktory, mladí dospelí*

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