Anthropological Review • Vol. 82(2), 139–154 (2019)

sciendo

ANTHROPOLOGICAL REVIEW
Available online at: https://doi.org/10.2478/anre-2019-0010

# High normal blood pressure and hypertension among Polish students: prevalence and risk factors

*Dominika Szafraniec, Wojciech Czarny*

Department of Human Sciences, Faculty of Physical Education, University of Rzeszów, Poland

Abstract**:** The purpose of this work was twofold: to determine prevalence of hypertension and high normal blood pressure in university students, and to assess impact of body weight status, field of study and selected lifestyle factors on the arterial blood pressure (BP) values. The research was conducted in a group of 731 male and female full-time academic students who volunteered as participants in the study. The thickness of skinfolds was measured in three standard places. The percentage of fat was determined using the body composition analyzer. Body height and mass, waist circumference, hips and the largest right thigh circumference were measured and anthropometric indices calculated. The blood pressure values were measured according to the Korotkov method. Data were analyzed using quantitative and qualitative methods, one-way analysis of variance (ANOVA) and linear regression analysis. The chi-square test of independence and linear regression analysis were used to assess impact of selected factors on BP values. High normal BP was found in 19% of women and 23% of men, and hypertension in 10% of women and 32% of men. Factors having a very high effect on BP values in both women and men were the somatic structure and fat content in the body. A positive correlation was found between subscapularis muscle fatty infiltration and BP values in both women and men. Majority of lifestyle factors were not associated with BP values but smoking and alcohol consumption. The field of study and level of physical activity were directly associated with high normal BP and hypertension. In conclusion it should be stated that high blood pressure is a growing problem in young adult people with men being more likely to be exposed to this condition than women.

Key words: cardiovascular disease, young adults, body fat, lifestyle factors, body weight status

Abbreviations used in this paper: BMI – Body Mass Index; WHR – Waist-To-Hip Ratio; WHtR – Waist-To-Heigh Ratio; NATPOL – Studies on the prevalence of hypertension in Poland; ESH – European Society of Hypertension; Pol-MONICA – Multinational Monitoring of Trends and Determinants in Cardiovascular Diseases in Poland; WOBASZ – Multicenter Study of Population Health in Poland.

## Introduction

Blood pressure is the degree of pressure that blood exerts on the walls of blood vessels. The magnitude of this pressure depends on two factors: the strength with which the heart pumps blood into the bloodstream, and the elasticity and

Original Research Article Received: February 19, 2019; Revised: May 13, 2019; Accepted: May 15, 2019
DOI: 10.2478/anre-2019-0010

size of the blood vessel cross-section. The marginal value of pressure that indicates hypertension is 140/90 mmHg for all age groups (Middeke et al. 2006). Hypertension is one of the most prevalent diseases because it affects over 20% of the world's population. In 2000, about 1 billion people suffered from it, and it is predicted that in 2025 this number will increase to 1.5 billion. In 2011, the results of the NATPOL (Studies on the prevalence of hypertension in Poland) 2011 research program were presented, which once again evaluated the epidemiology of hypertension in Poland. It was shown that hypertension is present in 32% of adult Poles (<80 years of age) (Januszewicz and Prejbisz 2012). At median height, the age-specific differences in the 90th BP percentiles compared with German oscillometric reference ranged in boys from 3 to 2 mmHg and from 5 to 1 mmHg and in girls from 0 to 3 mmHg and from 5 to 1 mmHg for systolic (SBP) and diastolic (DBP) blood pressure, respectively (Kułaga et al. 2012).

There is growing evidence that heart and circulatory system diseases, including hypertension, are associated not only with genetic determination but also with modifiable risk factors such as: overweight and obesity, lack of exercise, increased intake of table salt, smoking, excessive alcohol consumption, stressors (Malinowski and Janiszewska 2010, Middeke et al. 2006). Hypertension is also related to age and genders indicating that up to 55 years of age men are more exposed than women. Studies show that postmenopausal women are more prone to hypertension than their male counterparts (Middeke et al. 2006).

Untreated hypertension can lead to serious consequences including: cardiac hypertrophy, myocardial infarction, heart failure, arrhythmia, atherosclerosis, renal failure, glomerular damage (Malinowski and Janiszewska 2010).

In the mid-1980s American researchers introduced a new concept to the classification of blood pressure: *high normal blood pressure*. In 2003, the recommendations of the 7th report of the Joint National Committee proposed introduction of the category: *prehypertension*, that is preceding the development of hypertension. Since 2007 this term has not been used (Chonanian et al. 2003). Adult high normal blood pressure varies within the range of systolic blood (SBP) 130–139 mmHg, and diastolic blood pressure (DBP) 85–89 mmHg.

Results of research conducted as part of the Framingham Heart Study confirmed the association of high normal blood pressure with an increased risk of cardiovascular disease (Vasan et al. 2001). This study revealed that people with high normal pressure were more likely at risk of future persistent hypertension and experience of cardiovascular events than those whose pressure values were lower. At present, it is recommended that all people who are in this group should change their lifestyle. High-risk groups may benefit from pharmacological treatment, although the criteria for selecting patients for whom the benefits of pharmacotherapy would be higher than the costs are difficult to define. People with high normal pressure constitute a significant part of the population in different countries. In Poland 30% of the adult population and 7.4%/5.4% of adolescent females and males aged 10–18 years have this condition (Czarnecka and Bilo 2005; Krzyżaniak et al. 2019).

Having in mind the above-mentioned facts, the purpose of this work was twofold: to determine prevalence of hyper-

tension and high normal blood pressure in young and generally healthy academic students, and to assess impact of body weight status, body fatness, field of study and selected lifestyle factors on the arterial blood pressure (BP) values.

## Materials and Methods

Material consists of male and female students (volunteers) of full-time undergraduate and graduate studies representing two faculties, Biology and Agriculture (374 participants) and Physical Education (357 participants, intensive and regular physical activity resulting both from sports activities and sports camps as part of their studies and their own individual interests in sports) of the University of Rzeszów students. The exclusion criteria were extreme obesity, pregnancy, and cardiac pacemaker. The total number of the participants was 731, including 428 women and 303 men. The surveyed people were mostly residents of rural areas and small towns (72%), the rest were residents of medium and large cities.

The research project was approved by the Bioethics Committee of the University of Rzeszów. Non-invasive testing for BP values and their correlates did not expose study participants to loss of health. All participating individuals gave their informed consent to participate in the tests. Research was carried out in the University of Rzeszów premises.

The study consisted of anthropometric characteristics and body composition. Body height was measured with an accuracy of 1 mm using an anthropometer; waist circumference was measured by the torso narrowing in the waist; hip circumference was measured at the maximum glute convexity; the largest thigh circumference was measured just below the buttocks in the natural groove seen from the back . All circumferences were measured with an anthropometric tape with an accuracy of 1mm.

Body skinfold thickness (triceps, subscapular, supra-illac, and abdominal) was measured with a harpenden skinfold caliper, with a constant jaw pressure of 10 g/mm$^2$ with an accuracy of 0.01 cm on the right side of the body.

Subscapular was measured horizontally below the lower blade angle, triceps was measured vertically on the back surface of the arm, just above the triceps, supra-iliac abdominal was measured diagonally in a quarter of the distance between the navel and the anterior superior iliac spine.

The percentage of fat in the body and body weight with an accuracy of 0.1 kg was determined using the TANITA TBF 300 analyzer (specifications: tetrapolar bioelectrical impedance analysis, measurement frequency 50kHz, measurement current electrode 500$\mu$A, material: pressure contact stainless steel foot pads).

Bioelectrical Impedance Analysis (BIA) is a reliable, non-invasive, safe and effective method of determining body composition, BIA is about measuring the overall electrical resistance of the body, which is related to both passive and active resistance (reactance) using a set of surface electrodes connected to a computer analyzer and by means of known intensity and frequency of electrical current (Lewitt et al. 2007). In order to determine the subjects' degree of body fatness and the fat distribution in the body the following anthropometric indicators were calculated as recommended in Malinowski and Bożiłow (1997): BMI (Body Mass Index) weight and height index (body mass in kg by body height in me-

ters squared), Rohrer index (body weight by body height in cubic meters multiplied by 100), Oeder index (real body mass by theoretical body mass in kg multiplied by 100), Skerlj index (thigh circumference in cm by body height in cm multiplied by 100), WHR (waist to hip ratio) index (waist circumference in cm by hip circumference in cm), WHtR index (waist to height ratio) (body height in cm by waist circumference in cm).

Using the author questionnaire the following information about students was collected: the year and field of study, elements of lifestyle related to frequency of cigarette smoking, passive smoking, frequency of alcohol drinking, time devoted to physical activity, number of stressful events.

The systolic and diastolic blood pressure values were measured on the left arm in a sitting position using the traditional shoulder sphygmomanometer according to the Korotkov method (Kabat 2001). Classification of blood pressure was performed in accordance with the guidelines of the European Society of Hypertension – ESH 2013 (Tykarski et al. 2015):

- normal blood pressure: 120–129 mmHg systolic and 80–84 mmHg diastolic,
- high normal blood pressure: 130–139 mmHg systolic and 85–89 mmHg diastolic,
- mild hypertension: 140–159 mmHg systolic and 90–99 mmHg diastolic,
- moderate hypertension: 160–179 mmHg systolic and 100–109 mmHg diastolic.

### Statistical Analysis

Descriptive statistics, one-way analysis of variance (ANOVA) and linear regression were performed using STATISTICA 9.0 (StatSoft Polska). The Chi-square independence test was used to test qualitative data and F test for quantitative data.

Four regression models were used, separately for systolic and diastolic pressure, and separately for women and men. Set of independent variables consisted of (1) dichotomous variables: field of study, place of residence, alcohol consumption, cigarette smoking, occurrence of stress and physical activity; (2) indicators of body composition: skinfold thickness (mm) under the shoulder blade, on the shoulder, on the abdomen; percentage of body fat (%), BMI index (kg/m$^2$), Rohrer index (kg/m$^3$), Škerlj index (ratio of greatest thigh circumference to height in cm), waist to hip ratio index (WHR), waist to height ratio index (WHtR), Oeder index (ratio of body mass to theoretical body mass in kg multiplied by 100).

The optimal model of factors associated with high normal blood pressure and hypertension was chosen using the procedure of backward selection stepwise regression

## Results

Prevalence of blood pressure categories is shown in Table 1.

The systolic blood pressure remained normal for majority of study participants (65.1%). A relatively great number of study participants had high normal blood pressure and mild hypertension (22.6% and 10.3%). Moderate hypertension and hypotension were recorded in some individuals. The diastolic blood pressure was most frequently within the norm (78.4%). The high normal pressure had 7.1% study participants and mild hypertension 11.6%.

It was found statistically significant gender differences in hypertension prev-

Table 1. Distribution of systolic and diastolic blood pressure categories in academic students in Poland

| Category of blood pressure | SBP (mmHg) | | DBP (mmHg) | |
|---|---|---|---|---|
| | n | % | n | % |
| Hypotension | 11 | 1.5 | 8 | 1.1 |
| Normal | 476 | 65.1 | 573 | 78.4 |
| High normal | 165 | 22.6 | 52 | 7.1 |
| Mild hypertension | 75 | 10.3 | 85 | 11.6 |
| Moderate hypertension | 4 | 0.5 | 13 | 1.8 |

Abbreviations: SBP – systolic blood pressure; DBP – diastolic blood pressure.

alence with every tenth woman and every third man having this condition (Table 2).

Similar differences were found in prevalence of high normal pressure with 19% of women and 23% of men affected with this condition.

The field of study appeared to be a significant risk factor of abnormal blood pressure. Students of physical education were less likely than their counterparts studying natural sciences to have hypertension in both genders (8.7% vs 11% in females and 25.1% vs 51.2% in males).

Table 3 shows results of one-way ANOVA. Average values of somatic (anthropometric) characteristics stratified by blood pressure categories confirmed differential effect of body weight status (ponderal indices such as BMI, Rohrer index, and Škerlj index) and body fat percentage on blood pressure status with the highest values of these indices associated with hypertension. Subcutaneous fat (with the exception of subscapular skinfold) was not associated with blood pressure status. Alike subcutaneous fat, central body fat distribution (WHR) was not associated with blood pressure status either.

Results of stepwise multivariate regression analysis with backward elimination showed slightly different pattern of factors associated with blood pressure status in female and male study participants (Table 4 and 5)

In the optimal model of regression for systolic blood pressure, 5 variables

Table 2. Percentage distribution of systolic and/or diastolic blood pressure categories in study participants by sex, field of study and smoking habit

| Variable | | Blood pressure category | | |
|---|---|---|---|---|
| | | Normal n (%) | High normal n (%) | Hypertension n (%) |
| Sex[1] | | | | |
| Females | | 305 (71.3) | 79 (18.5) | 44 (10.3) |
| Males | | 135 (44.6) | 70 (23.1) | 98 (32.3) |
| Field of study | | | | |
| Physical education | F[2] | 113 (81.9) | 13 (9.4) | 12 (8.7) |
| | M[3] | 112 (51.1) | 52 (23.7) | 55 (25.1) |
| Natural sciences | F[2] | 192 (66.2) | 66 (22.8) | 32 (11.0) |
| | M[3] | 23 (27.4) | 18 (21.4) | 43 (51.2) |
| Smoking habit[4]* | | | | |
| Daily | | 18 (40.0) | 35 (48.6) | 82 (44.1) |
| Occasionally | | 4 (8.9) | 18 (25.0) | 48 (25.8) |
| Never | | 23 (51.1) | 19 (26.4) | 56 (30.1) |

Abbreviations: F – females; M – males; *Sex combined; [1]$p<0.001$; [2]$p=0.0017$; [3]$p<0.001$; [4]$p=0.02$; *Note – mild and moderate hypertensions were combined into hypertension.

Table 3. Average values of anthropometric characteristics stratified by blood pressure status in female and male study participants (results of one-way ANOVA)

| Anthropometric characteristic | Females | | | | Males | | | |
|---|---|---|---|---|---|---|---|---|
| | Normal | HN | HPN | *p* | Normal | HN | HPN | *p* |
| BMI (kg/m$^2$) | 21.2 | 22.9 | 22.2 | *** | 23.2 | 24.5 | 25.0 | *** |
| Rohrer index (kg/m$^3$) | 1.29 | 1.40 | 1.34 | *** | 1.30 | 1.37 | 1.41 | *** |
| Škerlj index | 31.8 | 33.0 | 32.5 | *** | 31.0 | 32.2 | 32.4 | *** |
| WHR | 0.72 | 0.72 | 0.71 | NS | 0.82 | 0.82 | 0.83 | NS |
| WHtR | 0.40 | 0.41 | 0.40 | *** | 0.43 | 0.44 | 0.45 | *** |
| Skinfold thickness (mm) | | | | | | | | |
| Subscapular | 11.6 | 12.8 | 12.2 | * | 12.1 | 12.7 | 13.7 | * |
| Triceps | 17.6 | 19.4 | 18.2 | NS | 14.5 | 14.9 | 15.9 | NS |
| Abdominal | 20.8 | 21.4 | 20.3 | NS | 17.3 | 18.5 | 19.5 | NS |
| Body fat mass (%) | 21.5 | 23.6 | 23.6 | ** | 11.5 | 12.6 | 14.1 | *** |

Abbreviations: HN – high normal; HPN – hypertension; WHR – waist to hip ratio; WHtR – waist to height ratio; statistically significant at *$p$<0.05, **$p$<0.01, ***$p$<0.001, NS stands for not statistically significant.

were found in women, which are listed in Table 4. The adjusted determination coefficient ($R^2$) for this model was 27.3% ($F$ = 37.6, $p$<0.0001). It means that almost one third of the total variance in blood pressure status was accounted by variables in question. In the set of adjusted variables, BMI and field of study affected blood pressure values, both at $p$<0.001. Systolic pressure increased with BMI and was higher in students of the natural sciences.

The optimal regression model for diastolic pressure in women includes 3 statistically significant variables, which are listed in Table 4. The adjusted determination coefficient ($R^2$) was 10.0% ($F$ = 11.0, $p$<0.0001). That is the accuracy of estimating diastolic pressure for women using the regression model is

Table 4. Results of stepwise multivariate regression analysis with backward elimination for females

| Independent variables | *B* | *β* | *p*-value |
|---|---|---|---|
| | | Systolic blood pressure (mmHg) | |
| Abdominal skinfold (mm) | −0.035 | −0.025 | 0.644 |
| BMI (kg/m$^2$) | 2.582 | 0.572 | 0.0004 |
| Rohrer index (kg/m$^3$) | −19.901 | −0.256 | 0.109 |
| Waist to hip ratio (WHR) | 6.700 | 0.023 | 0.687 |
| Field of study (NS vs PE) | 10.515 | 0.397 | <0.001 |
| | $R^2$ = 27.3%, $F$ = 37.6, $p$<0.0001 | | |
| | | Diastolic blood pressure (mmHg) | |
| BMI (kg/m$^2$) | 1.113 | 0.331 | 0.050 |
| Rohrer index (kg/m$^3$) | −1.456 | −0.025 | 0.881 |
| Alcohol consumption (yes vs no) | 1.738 | 0.085 | 0.125 |
| | $R^2$ = 10.0%, $F$ = 11.0, $p$<0.0001 | | |

Abbreviations: $R^2$ – determination coefficient; F – test statistics with the statistical significance assessment (p) of the whole model; B – coefficient in the regression model; p – assessment of the significance of individual factors; *β* – standardized regression coefficient; NS – natural sciences; PE – physical education.

Table 5. Results of stepwise multivariate regression analysis with backward elimination for males

| Independent variables | *B* | *β* | *p*-value |
|---|---|---|---|
| | | Systolic blood pressure (mmHg) | |
| BMI (kg/m²) | 1.539 | 0.341 | <0.001 |
| Field of study (NS vs PE) | 9.574 | 0.362 | <0.001 |
| Alcohol consumption (yes vs no) | 3.730 | 0.135 | 0.006 |
| | $R^2$ = 28.5%, $F$ = 39.7, $p$<0.0001 | | |
| | | Diastolic blood pressure (mmHg) | |
| Škerlj index | 0.777 | 0.227 | 0.014 |
| Waist to height ratio (WHtR) | −62.898 | −0.239 | 0.009 |
| Oeder index | 0.222 | 0.309 | 0.003 |
| Field of study (NS vs PE) | 3.629 | 0.184 | 0.001 |
| Alcohol consumption (yes vs no) | 2.167 | 0.105 | 0.053 |
| | $R^2$ = 15.1%, $F$ = 10.6, $p$<0.0001 | | |

Abbreviations: $R^2$ – determination coefficient, F – test statistics with the statistical significance assessment (p) of the whole model, B – coefficient in the regression model, p – assessment of the significance of individual factors, *β* – standardized regression coefficient; NS – natural sciences; PE – physical education.

rather low. Diastolic pressure increased with the BMI level (by 1.1 mm / Hg for BMI higher by 1), it was higher in alcohol drinkers (by 1.7). It decreased as the Rohrer index increased. Values of standardized regression coefficient *β*, indicated that the BMI and Rohrer index had the greatest influence on the diastolic pressure values (Table 4).

In the optimal regression model for systolic blood pressure, 3 statistically significant variables were found in men, which are listed in Table 5. The adjusted determination coefficient ($R^2$) was 28.5% ($F$ = 39.7, $p$<0.0001). The systolic pressure increased along with BMI levels (by 1.5 mmHg for BMI higher by 1), it was higher in students of the natural sciences (by 9.6) and people drinking alcohol (by 3.7). Values of standardized regression coefficients *β* indicated that alike in women, systolic blood pressure values were mostly affected by BMI and field of study.

In the optimal regression model for diastolic pressure, 5 variables were found in men, which are listed in Table 5. The adjusted determination coefficient was ($R^2$) was 15.1%. Diastolic pressure increased with Škerlj index and Oeder nutrition index. It was also higher in students of the natural science and alcohol drinkers. Values of standardized regression coefficient *β* indicated that the Oeder index had the greatest influence on the diastolic pressure values whereas alcohol consumption had null effect.

## Discussion

Hypertension in young adults is a problem highly underestimated by both experts and national health recommendations, and in practice this fact makes it difficult to diagnose it and treat (Gorczyca-Michta et al. 2014). Our study showed that the prevalence of hypertension in the young people group was high accounting for systolic blood pressure 11% and for diastolic pressure 14%. Majority of study participants had mild hypertension. High normal blood pressure, which is sometimes referred to as so-called pre-hypertensive state, was accounted for 23%

(systolic blood pressure) and 7% (diastolic pressure). It is very annoying tendency for quick transformation to hypertension.

Particularly worrying is the fact that systolic pressure was above the norm in 34% of young people compared to the diastolic pressure, which exceeded the normal range in 21% of the total sample. For many years it had been thought that it was the diastolic pressure that was the main prognostic indicator of organ complications in the hypertensive status, however, the results of the Framingham Heart Study showed that the systolic pressure is an independent and stronger indicator of cardiovascular risk, because it contributes to increased heart and vessel load that can result in, for example, heart failure, heart attack, cerebrovascular complications. It was shown that systolic hypertension doubled the overall mortality, increases the cardiac death rate three-fold and the probability of stroke four-fold, especially in women. It should also be emphasized that even when the systolic pressure takes values corresponding to mild hypertension, it already significantly increases the risk of cardiovascular complications and mortality (Witkowska 2004). The age seems to play an important role in this case, because it has been proven that in people under 50, the diastolic blood pressure within the high normal range more likely led to hypertension than the systolic blood pressure. In addition, it has been demonstrated that in patients under 50, diastolic pressure with normal values compared to systolic blood pressure showed a greater tendency towards high normal blood pressure with further hypertension (Kanegae et al. 2017). In our study, the diastolic blood pressure had values corresponding to the high normal blood pressure in 52 people, which was 7.1% of all subjects with an increased risk of developing hypertension.

In Poland, several epidemiological studies were carried out aiming at assessing prevalence of hypertension in relation to gender, such as: Pol-MONICA (Multinational Monitoring of Trends and Determinants in Cardiovascular Diseases in Poland), WOBASZ (Multicenter Study of Population Health in Poland) or NATPOL research series. The results revealed that until the age of 60, the prevalence of hypertension is higher in men than in women. According to the WOBASZ study, hypertension occurs in 2% of women and in 15% of men aged 20–34. These results are much lower than in our own research (Kawecka et al. 2012). The incidence of hypertension in students of the Medical University of Katowice was studied by Krzych et al. (2006). These studies showed that the prevalence of hypertension in young women is almost the same as in our own studies and is less than 10%, while in young men, compared to Rzeszów students, it is less frequently at the level of over 20%. The situation is the opposite in the case of high normal pressure, i.e. its prevalence in students is similar to that in our research and amounts to almost 25% (our research – over 23%), while its frequency in the Katowice students is lower than in female students from Rzeszów, i.e. 14%, and local students over 18%. Gorczyca-Michta et al. (2014) determined the prevalence of hypertension among the Kielce students. It showed in as many as 1/4 of the subjects.

The issue of blood pressure among students also raises the interest of scientists from around the world. For example, measurements of blood pressure values were made among students of a medical university in India. Pre-hypertension or

hypertension was found in 67% of Indian students. Interesting is the fact that in the vast majority of cases it is the antihypertensive state, which, however, can very quickly turn into hypertension. Similarly to Polish students, abnormal pressure values are more common in young men (Patnaik and Choudhury 2015). This type of research was also conducted among academic youth in Slovakia, to be precise, among the students of the University of Trnava. Overall, pre-hypertension was reported in over 22% of students, and hypertension in 18% of the subjects. These results are very similar to those obtained in our research. It was also shown that both hypertension and pre-hypertension, mainly affect men, over 30% and almost 41%, respectively. Our results corroborate with those above described in terms of hypertension but prevalence of pre-hypertension was much higher in our sample. The incidence of high normal pressure in Slovak female students is virtually identical to that of female students in Rzeszów and amounts to 18%, but in young women in Slovakia the prevalence of hypertension is clearly higher and is 16% (Hujová 2013). The young adult residents of the United States have shown an increase in health awareness and control of hypertension, but it is still a big problem in this population. For example, the incidence of high normal pressure in this group is 23.4% (irrespective of gender) (Zhang and Moran 2017) and this is a result similar to the own research – women 18.5%, men 23.1%.

Among male students, hypertension is three times more common than among women and affects up to 32% of young men. The high normal pressure also affects them slightly more often than women. This state of affairs is probably largely the result of more anti-health lifestyle of men compared to women. One of its elements is the tobacco addiction, our research showed a significant relationship (chi-square independence test) between the frequency of cigarette smoking and the occurrence of hypertension (over half of smokers have hypertension).

A similar and statistically significant dependence was demonstrated by Maniecka-Bryła et al. (2009), who examined the participants of the Early Prevention of Cardiovascular Disease Program in the Non-Public Medical Care Center in Zgierz (excluding persons who had previously been diagnosed with cardiovascular disease and/or diabetes). Pandey et al. (2013) showed the existence of a direct relationship between hypertension and the frequency of smoking and alcohol consumption based on the results of research conducted among the Indian rural population.

Our research showed the association between the frequency of cigarette smoking and the occurrence of hypertension, i.e. young men who smoked cigarettes every day were most often classified as hypertensive, while regression analyzes did not show the existence of a linear relationship between smoking frequency and blood pressure. According to these studies, every second person suffering from hypertension smoked, while in the group with optimal pressure every tenth. Jatoi et al. (2007) assessed the arterial stiffness, among others, by measuring the speed of the pulse wave and it turned out that present and former smokers had a significantly higher speed of the pulse wave and thus greater stiffness of the arteries leading to the development of hypertension in comparison with non-smokers. Arterial stiffness parameters returned to non-significant levels after a decade of quitting

smoking. The results of the studies carried out among Vietnamese men indicate that in the development of hypertension significant is not just to currently be a smoker, but the length of smoking period and the number of cigarettes smoked – the longer the period and the higher the amount of tobacco smoked, the higher the probability of hypertension (Thuy et al. 2010). Some reports also emphasize the independent effect of smoking and hypertension on increasing the risk of cardiovascular diseases (Leone 2015). Results of Japanese studies suggest that the elimination of two main factors, hypertension and smoking, reduces the risk of death from cardiovascular disease in men by 35% and in women by 22% (Hozawa et al. 2007).

Hypertension is still considered to be the main mortality factor in the world. Razvodovsky (2014) examined a 100,000 population of the Russian Federation in terms of the relationship between mortality and alcohol consumption, the results clearly showed that alcohol is an important factor contributing to high mortality due to hypertension. Regression analysis confirmed that alcohol consumption is an important factor increasing the level of blood pressure, especially in the case of systolic blood pressure in young men, which is a bad prognostic for the future of this group of subjects. The empirical relationship between heavy alcohol consumption and the occurrence of such circulatory system diseases as hypertension, cardiomyopathy, atrial arrhythmia or hemorrhagic stroke has been established. Reliable information has also appeared on the mechanisms that underlie the protective effects of light and moderate alcohol consumption in cardiovascular diseases (Klatsky 2015). The key factor seems to be not the fact of drinking or not drinking alcohol, but its frequency and, above all, the amount of alcohol consumed. Research by Briasoulis et al. (2012) showed a protective effect of light and moderate alcohol consumption only for women. Undoubtedly, all these links require further in-depth research and analysis.

The association of overweight and obesity with the occurrence of high blood pressure has been the subject of quite a number of studies and its existence does not raise any doubts at present. The key factor here is not the excess fat itself, but the relative reduction in muscle mass and increased visceral fat, this type of regularity is already observed at a very early stage of postnatal development, i.e. in children diagnosed with primary hypertension (Litwin and Niemirska 2011). Correlation between the value of blood pressure and the values of somatic indicators, the BMI index among others, WHtR index and total fat content in the body was confirmed by own research. BMI is the most frequently used indicator in this type of research, the correlation between BMI classification and hypertension in medical students in Uganda was examined and confirmed by Nyombi et al. (2016), only men were the subjects of these studies and the average age was 22 years. The authors also found that the risk of cardiovascular disease in this group was high. Choukem et al. (2017) examining students in Cameroon showed that each increase in BMI by 1 kg/m$^2$ was associated with an 11% higher probability of hypertension. Quite surprising is the lack of relationship between the blood pressure value and the WHR index in the research on Rzeszów students. Most data from the literature confirms the existence of a correlation between the WHR index and hypertension. In his work, Zhao et al. (2000)

showed that both BMI and WHR are good indicators for determining the risk of hypertension, however, it should be noted that people in medium and older age were the research group in this case. In turn, the results of studies conducted among men in India indicate that the BMI index is the best for assessing the risk of hypertension, while WHR for the assessment of the risk of type 2 diabetes (Kaur et al. 2008). Newer research carried out by Sule et al. (2015) among the patients in a hospital in Nigeria showed a correlation between BMI and WHR indices and hypertension. Cross-sectional studies among adult residents of Nigeria suggest that the best tool for diagnosis of the risk of hypertension in this group of patients is not the BMI or WHR index, but the WHtR index (Chua et al. 2017), own studies also showed the existence of a significant correlation between the value of arterial pressure in both sexes and this indicator. American studies conducted among women aged 27–44 years also clearly showed that the strongest predictor of the development of hypertension is the BMI index (Forman et al. 2009). These results confirm our own regression analyzes, which clearly indicate the dominant role of the BMI index (the exception is diastolic pressure in men) – blood pressure increased with the increase of the BMI index. The results of the research on the assessment of the usefulness of individual anthropometric indicators to determine the risk of hypertension are not conclusive. Probably the correlation of individual indicators with the fat content in the body is of great importance here, in particular the so-called internal fat, or visceral fat.

Our research showed a strong relationship between the BMI and WHtR index and the fat content in the body, and at the same time, the lack of such a relationship in the case of WHR index; and, as it is known, it is mainly the visceral fat that is responsible for the development of a number of various diseases including hypertension. This partially explains the results of own research on the existence or absence of correlation of the indicators with blood pressure values. The correlation of external fatness determined mainly by the thickness of skinfolds and blood pressure values was insignificant. The WHR index, as an index calculated only on the basis of body circumferences, reflects, in the first place, the external fatness of the body and this may be the reason for the lack of the relationship between this indicator and pressure values in Rzeszów students. An interesting exception is the positive correlation between the value of blood pressure and the thickness of the subscapular fold in the studied women and men, however this unusual relationship requires further research.

In our study, two levels of physical activity were represented by students studying physical education (high level of physical activity) and the natural sciences (mild to low level of physical activity). It was found that students of physical education were more likely to have normal blood pressure values (especially men) as compared to their peers of the natural science. The positive influence of regular physical activity on risk reduction for hypertension in both men and women regardless of the level of obesity in Finnish studies has been demonstrated by Hu et al. (2004) The beneficial effect of activity is not limited to simple translating. Increased physical activity decreases the BMI value, which, in turn, causes a decrease in blood pressure, and this impact is probably much more complex. Re-

search carried out, for example, by Diaz et al. (2017) among African-Americans suggests that BMI does not directly mediate the relationship between activity and hypertension, and of major importance may here be, for example, the mechanisms including improved endothelial function, activity of the sympathetic system or the renin-angiotensin system. Longitudinal observations and analyzes among women aged 45–50 in Australia proved that both increased BMI and reduced physical activity seem to play an important role in the development of hypertension (Jackson et al. 2014). Papathanasiou et al. (2015) on the sample of young adults of both sexes in Greece, suggest a significant relationship between BMI and blood pressure values and the lack of such relationship in the case of physical activity. Physical training has proved to be one of the basic methods of both prevention and treatment of hypertension on the physiological basis induced by alcohol consumption (Husain et al. (2014).) This explains in part higher blood pressure values in students of the natural sciences compared to those studying physical education who are characterized by a high level of physical activity, despite the fact that alcohol consumption is high among the students of both types of studies – especially in men (linear regression analysis).

Geleijnse et al. (2004) assessed the influence of various factors related to lifestyle on the development of hypertension in people seen as the population of Western countries, i.e. Finland, Italy, the Netherlands, the United Kingdom and the USA. According to them, factors such as excessive body mass and lack of physical activity have a large share in the development of hypertension, which corresponds to our own research, but according to the same studies, the influence of alcohol on the occurrence of hypertension in people from all the countries that were considered is small, which is, in turn, contrary to the results of our own research. Extensive research done in England on a sample of over one million women showed that moderate physical activity is associated with a lower risk of coronary heart disease, venous thromboembolism and cerebrovascular disease compared to physically inactive people (concerns the scheduled physical activity, e.g. exercises, jogging, etc.).

The same studies also indicate the negative effect of intense physical activity on the cardiovascular system, e.g. by increasing the risk of coronary heart disease (Armstrong et al. 2015). However, our study (linear regression analysis) showed a clearly positive effect of physical activity on blood pressure – clearly lower blood pressure values in physically active students of physical education – mainly men (exception – diastolic pressure in the group of women).

The problem of the relationship between physical activity and blood pressure seems to be much more complicated than previously thought. The ambiguous research results suggest that body weight and level of physical activity may be independent predictors of blood pressure values, which may have a mutual effect on these values, but may also act independently, and the strength and character of this compound may be influenced by biological, environmental factors and lifestyle of individuals. This problem undoubtedly requires further in-depth research and analysis.

The data found in the literature show that high blood pressure values in young adults are not a local problem but a global one. To a large extent this is due to the fact that the world has become a

global village so some of the occurring in it problems are also global. Further research is needed on young adults in terms of hypertension, with particular emphasis on longitudinal studies, with an emphasis on further search for risk factors of cardiovascular diseases. Information campaigns in schools, universities, and primary care physicians are also necessary. On the one hand, campaigns like this would place emphasis on prevention, and on the other, aim to make young people and doctors aware that problems with high blood pressure values affect not only middle-aged and elderly people, but also young people.

## Summary and conclusions

Arterial hypertension and high normal pressure are widespread among the students of south-eastern Poland. Research conducted in a group of young people with a high level of physical activity, such as students of physical education, clearly show its positive effect on reducing the occurrence of hypertension and high normal pressure. In a significant part of the examined students, systolic arterial pressure, being an independent risk factor for the development of cardiovascular diseases, exceeds the norm. There is a strong correlation between the values of BMI, WHTR, Rohrer, Škerlj and Oeder nutrition indices with the level of blood pressure. The higher their values, the higher the blood pressure, this correlation was not recorded in the WHR index. Body fatness showed that the total body fat percentage and subcutaneous fat were not statistically significant for blood pressure status.

Among the studied young men there are two very important risk factors for the development of cardiovascular diseases, high blood pressure and smoking, which may interact, but are also independent predictors of the development of cardiovascular disease. More detailed statistical analysis of linear regression showed that in women the strongest relationship with the systolic blood pressure level have BMI (the lower it is the lower the blood pressure) and the type of studies (associated with the level of physical activity and its regularity – lower values of blood pressure in female students of physical education), while only the BMI index turned out to have a significant influence on the diastolic blood pressure. In the group of men, regression analyzes gave the same result as in women in the case of systolic pressure, while the factor most strongly associated with the diastolic blood pressure is the Oeder nutrition index. In summary, the etiology of systolic hypertension in the study group is associated primarily with the body weight and weight-increase index and the level of physical activity, while the diastolic hypertension is mainly associated with body weight and an indicator of nutritional status. Undoubtedly, further research in this area is necessary, such as longitudinal research, which probably would allow getting unambiguous answers to many questions.

An interesting result was found in women – the decrease in systolic blood pressure with the increase in the abdominal skinfold thickness and the increase in WHR. Both characteristics reflect the external fatness of the body (people with this phenotype are often referred to as the so-called FOTI type), which means fat outside – thin inside. This type of obesity is considered the healthiest because it is associated with a slight visceral obesity of the internal organs and low share of the so-called internal fat.

The phenomenon of high blood pressure among young adults is a common and complex problem requiring further in-depth analyzes. This requires further research that the authors intend to carry out in the near future.

### Authors' contributions

Both authors contributed equally to this paper.

### Conflict of interest

The authors declare that they have no competing interests regarding publication of this paper.

### Corresponding author

Dominika Szafraniec, Department of Human Sciences, Faculty of Physical Education, University of Rzeszów, Towarnickiego 3, 35-959 Rzeszów, Poland
e-mail:dominika.szafraniec.87@wp.pl

## References

Armstrong MEG, Green J, Reeves GK, Beral V, Cairns BJ. 2015. Frequent Physical Activity May Not Reduce Vascular Disease Risk as Much as Moderate Activity Large Prospective Study of Women in the United Kingdom. Circulation 131:721–29.

Briasoulis A, Agarwal V, Messerli FH. 2012. Alcohol Consumption and the Risk of Hypertension in Men and Women: A Systematic Review and Meta-Analysis. J Clin Hypertens 14(11):792–98.

Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, et al. 2003. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Hypertension 42:1206–52.

Choukem SP, Kenge AP, Nguefack M L, Mboue – Djieka Y, Nebongo D, et al. 2017. Four-year trends in adiposity and its association with hypertension in serial groups of young adult university students in urban Cameroon: a time – series study. BMC Public Health 217(499):1–6.

Chua EY, Zalilah MS, Haemamalar K, Norhasmah S, Geeta A. 2017. Obesity indices predict hypertension among indigenous adults in Krau Wildlife Reserve, Peninsular Malaysia. J Health Popul Nutr 36(24):1–7.

Czarnecka D, Bilo G. 2005. Pacjent z ciśnieniem wysokim prawidłowym – czy wymaga leczenia?. Choroby Serca i Naczyń 2(4):187–89.

Diaz K M, Booth III JN, Seals SR, Abdalla M, Dubbert M, Sims M et al. 2017. Physical Activity and Incident Hypertension in African Americans The Jackson Heart Study. Hypertension 69:421–27.

Forman JP, Stampfer MJ, Curhan GC. 2009. Diet and Lifestyle Risk Factors Associated With Incident Hypertension in Women. JAMA 302(4):401–11.

Geleijnse JM, Kok FJ, Grobbee DE. 2004. Impact of dietary and lifestyle factors on the prevalence of hypertension in Western populations. Eur J Public Health 14:235–39.

Gorczyca-Michta I, Kucfir J, Wożakowska-Kapłon B. 2014. Czynniki predysponujące do występowania nadciśnienia tętniczego w populacji młodych dorosłych. Folia Cardiologica 9(2):127–34.

Hozawa A, Okamura T, Murakami Y, Kadowaki T, Nakamura K, Hayakawa T et al. 2007. Joint impact of smoking and hypertension on Cardiovascular disease and all-cause mortality in Japan: NIPPON DATA 80, a 19-year follow-up. Hypertens Res 30:1169–75.

Hu G, Barengo NC, Tuomilehto J, , Lakka TA, Nissinen A, Jousilahti P. 2004. Relationship of Physical Activity and Body Mass Index to the Risk of Hypertension: A Prospective Study in Finland. Hypertension 43:25–30.

Hujová Z. 2013.The prevalence of obesity and hypertension among first-year students at Trnava University in Slovakia. Int J Med Med Sci 5(8):361–67.

Husain K, Ansari RA, Ferder L. 2014. Alcohol-induced hypertension: Mechanism and prevention. World J Cardiol 6(5):245–52.

Jackson C, Herber-Gast GC, Brown W. 2014. Joint Effects of Physical Activity and BMI on Risk of Hypertension in Women: A Longitudinal Study. Journal of Obesity ID 271532:1–7.

Januszewicz A, Prejbisz A. 2012. Nadciśnienie tętnicze – wybrane zagadnienia patogenezy, diagnostyka i leczenie. Medycyna Praktyczna: 26–27.

Januszewicz W, Sznajderman M. 2002. Wysokie prawidłowe ciśnienie tętnicze – próba nowego spojrzenia. Arterial Hypertension 6(3):143–46.

Jatoi N A, Jerrard – Dunne P, Feely J, Mahmud A. 2007. Impact of smoking and smoking cessation on arterial stiffness and aortic wave reflection in hypertension. Hypertension 49:981–85.

Kabat M. 2001. Metody pomiaru ciśnienia krwi – uwagi praktyczne. Przewodnik Lekarski 4(12):65–70.

Kanegae H, Oikawa T, Okawara Y, Hoshide S, Kario K. 2017. Which blood pressure measurement, systolic or diastolic, better predicts future hypertension in normotensive young adults ?. J Clin Hypertens 19:603–10.

Kaur P, Radhakrishnan E, Sankarasubbaiyan S, Rao SR, Kondalsamy-Chennakesava S, Rao T, et al. 2008. A comparison of anthropometric indices for predicting hypertension and type 2 diabetes in a male industrial population of Chennai, South India. Ethnicity & Disease 18(1):31–36.

Kawecka-Jaszcz K, Pośnik-Urbańska A, Jankowski P. 2007. Rozpowszechnienie nadciśnienia tętniczego w zależności od płci w świetle badań epidemiologicznych w Polsce. Arterial Hypertension 11(5):377–83.

Klatsky AL. 2015. Alcohol and cardiovascular diseases: where do we stand today ?. J Intern Med 278:238–50.

Krzych Ł, Kowalska M., Zejda JE. 2006. Styl życia młodych osób dorosłych z podwyższonymi wartościami ciśnienia tętniczego. Arterial Hypertension 10(6):524–31.

Krzyżaniak A, Stawińska-Witoszyńska B, Krzywińska-Wiewiorowska M, Siwińska A, Kaczmarek M. 2019. Revealing burden of elevated blood pressure among Polish adolescent participants in a population-based ADOPOLNOR study: prevalence and potent risk factors. Anthropol Rev 82(1):65–77.

Kułaga Z, Litwin M, Grajda A, Gurzkowska B, Góźdź M. 2012. Oscillometric blood pressure percentiles for Polish normal-weight school-aged children and adolescents. J Hypertens 30(10):1942–54.

Leone A.2015. Smoking and hypertension. JCCR 2(2):1–7.

Lewitt A, Mądro E, Krupienicz A. 2007. Podstawy teoretyczne i zastosowania analizy impedancji bioelektrycznej (BIA). Endokrynologia, Otyłość i Zaburzenia Przemiany Materii 3(4):79–84.

Litwin M, Niemirska A. 2011. Nadciśnienie tętnicze pierwotne i zaburzenia metaboliczne u dzieci i młodzieży. Forum Zaburzeń Metabolicznych 2(2):124–31.

Malinowski A, Bożiłow W. 1997. Podstawy antropometrii: metody, techniki, normy. Warszawa–Łódź: PWN.

Malinowski A, Janiszewska R. 2010. Biomedyczne podstawy rozwoju i zdrowia człowieka. pp 326–27.

Maniecka – Bryła I, Maciak A, Kowalska A, Bryła M. 2000. Częstość palenia tytoniu wśród uczestników Programu Profilaktyki wczesnego Wykrywania Chorób Układu Krążenia. Medycyna Pracy 60(2):109–15.

Middeke M, Pospisil E, Volker K. 2006. Nadciśnienie – eliminować czynniki ryzyka: 15.

Nyombi KV, Kizito S, Mukunya D, Nabukalu A, Bukama M, Lunyera J et al. 2016. High prevalence of hypertension and cardiovas-

cular disease risk factors among medical students at Makerere University College of Health Sciences, Kampala, Uganda. BMC Research Notes 9(110):1–6.

Papathanasiou G, Zerva E, Zacharis I, Papandreou M, Papageorgiou E, Tzima Ch. et al. 2015. Association of High Blood Pressure with Body Mass Index, Smoking and Physical Activity in Healthy Young Adults. Open Cardiovasc Med J 9:5–17

Patnaik A, Choudhury Kch. 2014. Assessment of risk factors associated with hypertension among undergraduate medical students in a medical students in Odischa. Adv Biomed Res 4(38):1–7.

Razvodovsky YE. 2014. Contribution of Alcohol to Hypertension Mortality in Russia. Journal of Addiction ID 483910:1–6.

Sule HM, Salihu D, Gyang BZ, Bot I. 2015. Anthropometric Indices of Obesity and Hypertension Among Adults in A Primary Care Setting of an Urban Tertiary Hospital in North Central Nigeria. Int J Curr Res 7(10):21789–94.

Thuy AB, Blizzard L, Schmidt MD, Luc P H, Granger R, Dwyer T. 2010. The association between smoking and hypertension in a population – based sample on Vietnamese men. J Hypertensi 28(2):245–50.

Tykarski A, Narkiewicz K, Gaciong Z, Januszewicz A, Litwin M, Kostka-Jeziorny K. 2015. 2015 Guidelines for the management of hypertension Part 1–7 Recommendations of the Polish Society of Hypertension Arterial Hypertens 19(2):53–83.

Vasan RS, Larson MG, Leip EP, Evans JC, O'Donnell CJ, Kannel WB et al. 2001. Impact of high-normal blood pressure on the risk of cardiovascular disease. N Engl J Med 345:1291–97.

Venkataraman R, Kumar SBP, Kumaraswamy S M, Singh R, Pandey M (main author), Tripathi P et al. 2013. Smoking, alcohol and hypertension. Int J Pharm Pharm Sci 5(4):28–32.

Witkowska M. 2000. Izolowane nadciśnienie skurczowe – niezależny czynnik zagrożenia powikłaniami sercowo – naczyniowymi. Arterial Hypertension 4(3):201–07.

Zhang Y, Moran AE. 2017. Trends in the Prevalence, Awareness, Treatment, and Control of Hypertension Among Young Adults in the United States, 1999 to 2014. Hypertension 70:736–42.

Zhao WH, Xu HQ, Zhang X, Wang J.I, Yin CC, Li M, Chen JS. 2000.The association of BMI and WHR on blood pressure levels and prevalence of hypertension in middle-aged and elderly people in rural China. Biomed Environ Sci 13(3):189–97.