

# Blood pressure load in adults with treated hypertension

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## Abstract

**Background and aim:** To assess blood pressure (BP) load in a population of treated hypertensive patients.

**Methods:** The study group consisted of 137 hypertensive adults, including 75 (54.75%) men and 62 (45.25%) women, with either formerly or newly diagnosed hypertension based on office BP measurements. The median age in the whole study group was 52 years (47 and 56 years among men and women, respectively). The mean body mass index (BMI) was  $27 \pm 4$  kg/m<sup>2</sup>, and median duration of hypertension was 3 years. We divided the study group into subgroups depending on age, gender, BMI, and duration of hypertension. All patients underwent single 24-h ambulatory BP monitoring. We calculated 24-h, daytime and nighttime BP loads separately for systolic and diastolic BP. Statistical analysis was carried out using the SPSS 15.0 environment.

**Results:** Men were significantly younger than women (48.17 vs. 55.48 years,  $p < 0.02$ ). Mean BMI was higher in men than women ( $28$  vs.  $26$  kg/m<sup>2</sup>,  $p < 0.044$ ). There were no differences in the mean values of BP load depending on gender, BMI and duration of hypertension ( $p = \text{NS}$ ). Twenty-four hour and daytime diastolic BP load was higher in patients aged 41–65 years than in patients above 65 years (32.4 vs. 20.8%,  $p < 0.04$ ; and 29.6 vs. 17.5%,  $p < 0.03$ ). A negative correlation was found between daytime diastolic BP load and age ( $r = -0.19$ ,  $p < 0.026$ ) and a positive correlation was found between nighttime systolic BP load and age ( $r = 0.24$ ,  $p < 0.005$ ).

**Conclusions:** There was no relationship between BP load and gender, BMI, and duration of hypertension. Diastolic BP load was age-related. Middle-aged patients were characterised by significantly higher values of 24-h and daytime diastolic BP load than the elderly patients.

**Key words:** blood pressure load, ambulatory blood pressure monitoring, ABPM, hypertension

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## INTRODUCTION

In the 2009 European Society of Hypertension (ESH) guidelines and the 2011 Polish Society of Hypertension guidelines, office blood pressure (BP) measurements were recommended as the major method to diagnose hypertension (HTN). However, a major role of ambulatory blood pressure monitoring (ABPM) was also highlighted as essential to confirm the diagnosis of HTN in selected patient groups (e.g. resistant HTN, pregnant women, patients with autonomic nervous system disorders), and showing advantage over conventional BP measurements for the prediction of cardiovascular outcomes [1, 2]. In the current 2011 British National Institute for Health and Clinical Excellence (NICE)

guidelines, the role of ABPM in the diagnosis of HTN is even higher, as this method has been recommended to confirm the diagnosis in all cases [3].

One of the basic ABPM parameters is blood pressure load (BPL), calculated for 24 h and separately for daytime and nighttime. It is defined as the proportion of abnormal values to all values obtained in a given measurement period. The BPL threshold was defined as 30% of abnormal BP values. BPL was shown to be useful for the diagnosis of HTN and prediction of target organ damage, such as left ventricular hypertrophy [4, 5]. It is also helpful in the evaluation of circadian BP variability, particularly in patients with labile HTN, and as a measure of the effectiveness of antihypertensive drugs [6–8].

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**Table 1.** Demographic characteristics of the study group according to gender

Group	Median age [years]	Standard deviation for the median [years]	Mean age [years]	Standard deviation for the mean [years]	Age range [years]
Overall	52	13	51.48	13.77	20–85
Men	47	14	48.17	14.03	20–84
Women	56	12	55.48	12.42	22–85

The aim of the present study was to evaluate BPL in adult patients with treated HTN.

## METHODS

### Study group

We studied 137 consecutive patients with HTN diagnosed based on office BP measurements. In patients with previously diagnosed HTN, duration of HTN was defined as duration of antihypertensive treatment. Patients with newly diagnosed HTN included patients who underwent outpatient BP measurements in primary care or a cardiology clinic, or during hospitalisation in a tertiary care cardiology unit in 2011–2012.

The inclusion criteria were: age  $\geq$  18 years and treated HTN diagnosed based on office BP measurements.

The exclusion criteria included pregnancy and known factors interfering with oscillometric BP measurements (cardiac arrhythmia and conduction disturbances: atrial fibrillation, atrioventricular block, frequent supraventricular and ventricular ectopy; arm circumference precluding the use of a standard cuff).

The study group included 75 men and 62 women (54.7% and 45.3% of all study subjects, respectively). Median age in the whole study group was 52 years, including 47 years among men and 56 years among women. Mean body mass index (BMI) was  $27 \pm 4$  kg/m<sup>2</sup> in the overall study group (range 19–40 kg/m<sup>2</sup>),  $28 \pm 3$  kg/m<sup>2</sup> in men and  $26 \pm 4$  kg/m<sup>2</sup> in women. Median duration of HTN was 3 years in the overall study group, 1 year in men, and 4 years in women. Demographic characteristics of the study group, including both genders separately, are shown in Table 1.

The patients were divided into groups according to gender, age, BMI, and duration of HTN treatment. Regarding age, Group 1 included patients aged  $\leq$  40 years ( $n = 29$ , 23 men and 6 women), Group 2 included patients aged 41–65 years ( $n = 86$ , 43 men and 43 women), and Group 3 included patients aged  $>$  65 years ( $n = 22$ , 9 men and 13 women). Regarding BMI, Group 1 included patients with BMI  $\leq$  24.9 kg/m<sup>2</sup> ( $n = 40$ , 16 men and 24 women), Group 2 included patients with BMI 25.0–29.9 kg/m<sup>2</sup> ( $n = 70$ , 45 men and 25 women), and Group 3 included patients with BMI  $\geq$  30.0 kg/m<sup>2</sup> ( $n = 27$ , 14 men and 13 women). Regarding duration of HTN treatment, Group 1 included patients treated for  $\leq$  12 months ( $n = 43$ , 29 men and 14 women),

Group 2 included patients treated for 13 months to 10 years ( $n = 60$ , 28 men and 32 women), and Group 3 included patients treated for more than 10 years ( $n = 34$ , 18 men and 16 women).

### 24-hour ambulatory blood pressure measurement

Patients underwent single 24-h ambulatory blood pressure measurement using an oscillometric 2430 TM blood pressure monitor (A&D). This device has been validated using the Association for the Advancement of Medical Instrumentation and British Hypertension Society criteria [9, 10]. Monitoring was initiated at 7–9 AM at working days. During monitoring, patients remained in their usual environment and undertook usual daily activities. Measurement intervals were set at 15 min from 7 AM to 10 PM and 30 min during the night (patients were advised to go to sleep between 10 and 11 PM and wake up between 6 and 7 AM). The patients were instructed to indicate the beginning and the end of daytime and nighttime periods in a diary. ABPM recordings were analysed using the device manufacturer software only if at least 70% of measurements fulfilled the quality criteria.

BPL was defined as the proportions of BP values  $\geq$  130–135/80 mm Hg during 24 h,  $\geq$  140/90 mm Hg during daytime and  $>$  120/80 mm Hg during nighttime.

### Statistical analysis

Data were analysed using the SPSS 15.0 statistical package. Normal distribution of the variables was evaluated using the Shapiro-Wilk test. Significance of differences between mean values of normally distributed variables was evaluated using the Student t test for unpaired samples, and between mean values of non-normally distributed variables using the Mann-Whitney U test. Comparisons between normally distributed variables for a larger number of groups were performed using univariate analysis of variance (ANOVA) with *post-hoc* analysis using the Tukey test. Additionally, we used the Pearson correlation coefficient to analyse relations between continuous normally distributed variables. For all analyses,  $p < 0.05$  was considered statistically significant.

## RESULTS

BPL and diastolic BP during 24 h, daytime, and nighttime were normally distributed ( $p = 0.000$ ).

**Demographic characteristics of the study group according to gender.** Men outnumbered women in the overall study group (75 men, 62 women), among young subjects (age Group 1: 23 men, 6 women), overweight subjects (BMI group 2: 45 men, 25 women), and subjects only recently treated for HTN (HTN treatment duration Group 1: 29 men, 14 women). Proportions of the 2 genders were equal or relatively equal in middle-aged subjects (age Group 2: 43 men, 43 women), obese subjects (BMI Group 3: 14 men, 13 women), subjects treated for HTN for more than 12 months (HTN treatment duration Group 2: 28 men, 32 women; and Group 3: 18 men, 16 women). Women were more prevalent among elderly subjects (age Group 3: 9 men, 13 women) and subjects with normal BMI (BMI Group 1: 16 men, 24 women).

**Age and BMI differences in relation to gender.** Women were significantly older than men (mean age 55.5 vs. 48.2 years,

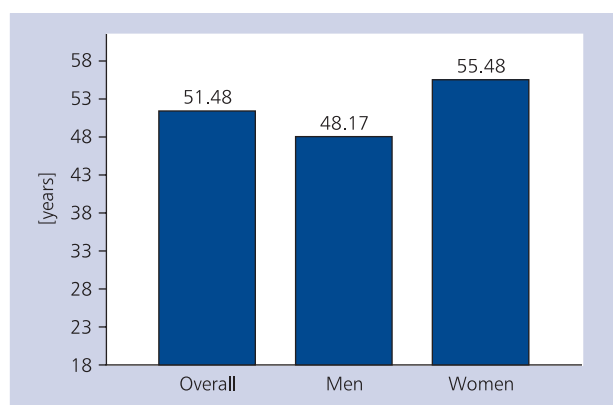


Figure 1. Comparison of mean age according to gender

$p < 0.02$ ), as shown in Figure 1. In contrast, men had higher significantly BMI than women (28 vs. 26 kg/m<sup>2</sup>,  $p < 0.044$ ).

**Differences in systolic blood pressure load during 24 h (SBPLa), daytime (SBPLd) and nighttime (SBPLn) and diastolic blood pressure load during 24 h (DBPLa), daytime (DBPLd) and nighttime (DBPLn) in relation to gender.** No significant differences ( $p = \text{NS}$ ) in mean BPL values were shown between men and women (Fig. 2).

**Differences in systolic blood pressure load during 24 h (SBPLa), daytime (SBPLd) and nighttime (SBPLn) and diastolic blood pressure load during 24 h (DBPLa), daytime (DBPLd) and nighttime (DBPLn) in relation to age.** Significant differences in mean diastolic BPL were found between age groups (overall between-group variance:  $p = 0.05$  for DBPLa,  $p = 0.037$  for DBPLd, and  $p = 0.034$  for DBPLn), which were not shown for systolic BPL (Fig. 3). In *post-hoc* Tukey analysis, DBPLa in Group 2 was significantly higher compared to Group 3 ( $p = 0.040$ ), as was DBPLd ( $p = 0.033$ ). Nonsignificant trends were noted when comparing SBPLn (Group 1 < Group 3,  $p = 0.059$ ) and DBPLn (Group 1 < Group 2,  $p = 0.067$ ).

**Differences in systolic blood pressure load during 24 h (SBPLa), daytime (SBPLd) and nighttime (SBPLn) and diastolic blood pressure load during 24 h (DBPLa), daytime (DBPLd) and nighttime (DBPLn) in relation to duration of HTN treatment.** No significant differences in mean BPL values were shown when comparing groups of different duration of HTN treatment (Fig. 4).

**Differences in systolic blood pressure load during 24 h (SBPLa), daytime (SBPLd) and nighttime (SBPLn) and diastolic blood pressure load during 24 h (DBPLa), daytime (DBPLd) and nighttime (DBPLn) in relation to BMI.**

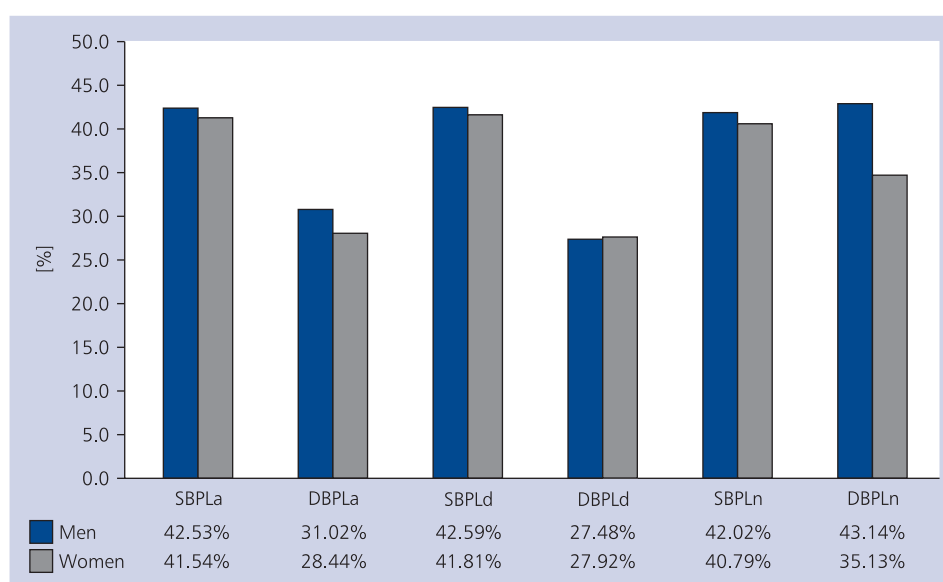


Figure 2. Comparison of mean blood pressure load values in men and women; abbreviations — see text

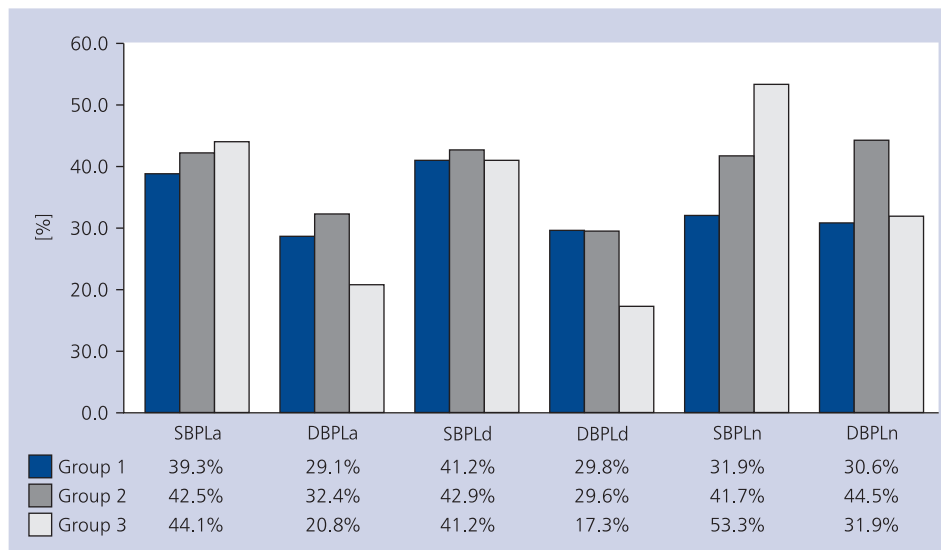


Figure 3. Comparison of mean blood pressure load values between age groups; abbreviations — see text

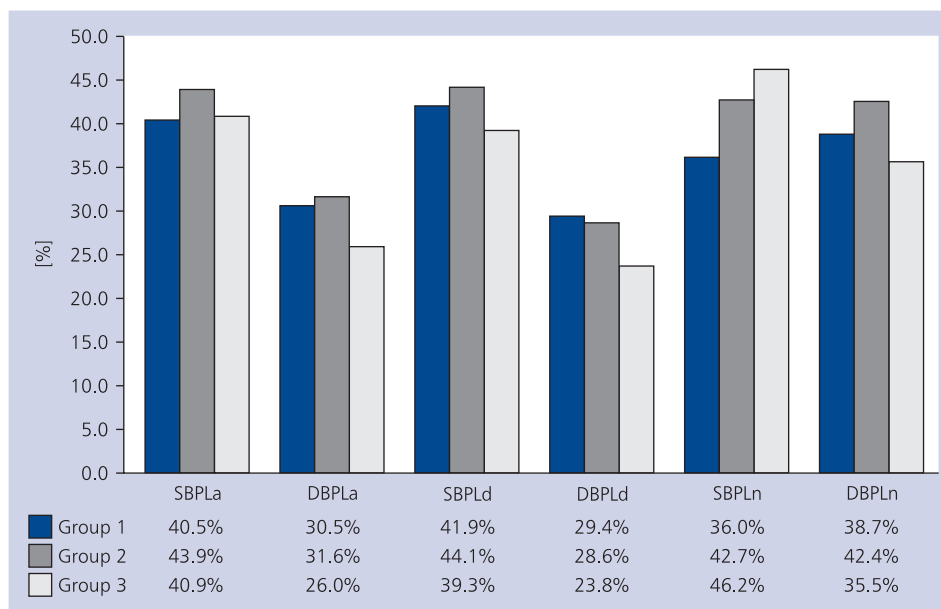


Figure 4. Comparison of mean blood pressure load values between groups of varying duration of treatment for hypertension; abbreviations — see text

No significant differences in mean BPL values were shown when comparing patients in different BMI categories (Fig. 5).

**Systolic blood pressure load during 24 h (SBPLa), daytime (SBPLd) and nighttime (SBPLn) and diastolic blood pressure load during 24 h (DBPLa), daytime (DBPLd) and nighttime (DBPLn) in relation to age, BMI, and duration of HTN treatment.** Mean BPL values were found to be significantly related only to age, with a negative correlation for DBPLd ( $r = -0.19$ ,  $p = 0.026$ ), and a positive correlation for SBPLn ( $r = 0.24$ ,  $p = 0.005$ ). These correlations were shown in Figures 6 and 7, respectively.

### DISCUSSION

Although importance of BPL for prediction of target organ damage in HTN has been well documented [11–13], we were unable to find any published analysis of this parameter in relation to age, duration of HTN treatment and gender in a general population of hypertensive patients. BPL may be expected to change in time depending on duration of HTN, its treatment, and concomitant cardiovascular diseases. Korean studies in children with increased BMI showed that both systolic and diastolic BPL was significantly higher in overweight and obese children. In addition, BPL was shown to be superior to the

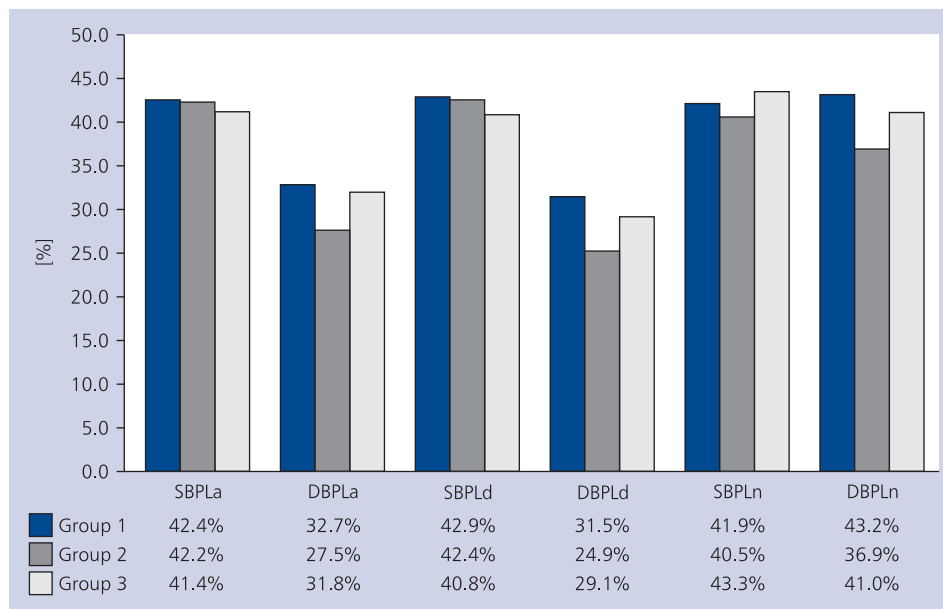


Figure 5. Comparison of mean blood pressure load values between groups of varying body mass index; abbreviations — see text

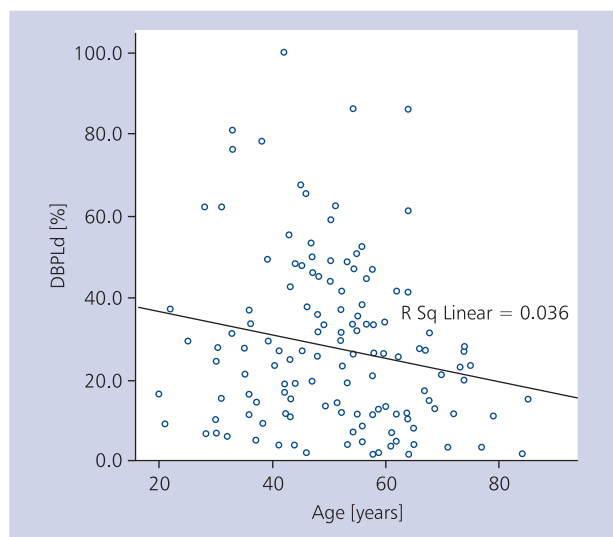


Figure 6. Correlation between daytime diastolic blood pressure load (DBPLd) and age

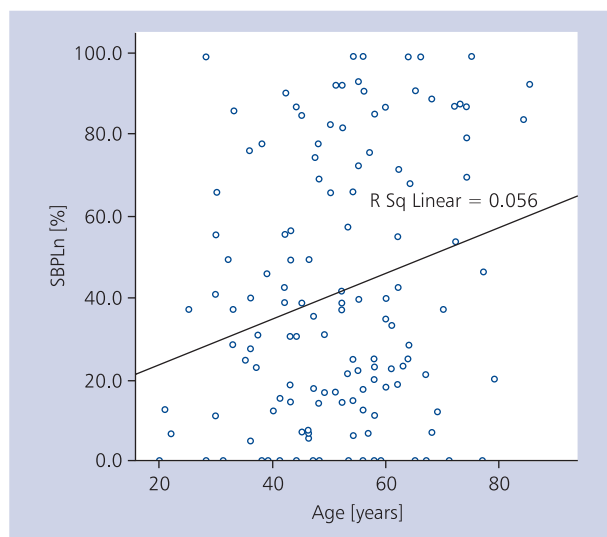


Figure 7. Correlation between mean nighttime systolic blood pressure load (SBPLn) and age

conventional evaluation of mean 24-h BP in diagnosing HTN and monitoring the effects of antihypertensive treatment [14].

The aim of the present study was to evaluate BPL in treated adult patients with HTN. This approach has many limitations, as the study group was heterogeneous in regard to the type of treatment, severity of target organ damage, and the presence of concomitant conditions. We did not include children and pregnant women to our study. In most cases, complete data related to possible presence of secondary forms of HTN were not available, and thus the study group might have also been heterogeneous in regard to the aetio-

logy of HTN. By categorisation into subgroups according to age, BMI, and duration of HTN treatment, we attempted to obtain relatively comparable groups (young vs. middle-aged vs. elderly subjects, normal weight vs. overweight vs. obese subjects, HTN treated for a short, medium or long time). The study group reflected a mixed hypertensive population at various stages of HTN severity and treatment, managed by primary care physicians or specialists in our region.

Quantitative analysis of our study group in regard to gender, age, BMI, and duration of HTN showed heterogeneous distribution of the analysed parameters in the study popula-

tion. Men outnumbered women, and they were significantly younger than women. In addition, men were more prevalent among overweight subjects and those treated for HTN for a short time. Thus, HTN in our study group was more often a problem in men, but these patients were younger than women. Of note, median age in women was 56 years, i.e. more than half of women in our study group was older than the average age of menopause in the Polish population (as of 2000–2004) [15]. This may indicate an important effect of hormonal balance on the development of HTN in relation to gender and age. In addition, men had significantly higher BMI than women, and the mean BMI in the overall study group was above the upper limit of normal values ( $27 \pm 4 \text{ kg/m}^2$ ). Thus, men were even more prevalent among overweight subjects. Among those with normal body weight, women were more prevalent than men which may support the hypothesis that women generally care more about their body shape and appearance than men. However, these differences were not subjected to a statistical analysis.

Although duration of HTN treatment ranged from 1 month to 30 years, HTN was diagnosed and treated for not more than 3 years in 50% of patients. In our study group, patients with HTN treated for a short time comprised nearly one third, which may confirm the significance of HTN as an epidemiological problem. Among men, as many as 50% had their HTN treated for not more than 1 year (median duration of treatment in men was 1 year compared to 4 years in women). This may also indicate underestimation of HTN in men, particularly younger men, who are less likely to present to a physician and more reluctant to undergo chronic treatment.

We found that BPL is relatively independent from gender and duration of HTN treatment. Similarly, no relation between BPL and BMI was found, with an insignificant trend for higher BPL values in subjects with normal BMI (Fig. 5), in contrast to the above mentioned Korean paediatric findings [14]. In addition, a trend for higher diastolic BPL was noted in middle-aged subjects (age Group 2) compared to younger (Group 1) and older (Group 3) subjects. Taking into account generally higher systolic BPL values observed with age, the explanation may be predominant systolic HTN in the elderly. In younger subjects, a larger compliance reserve of the arterial bed likely contributes to the maintenance of relatively lower diastolic BP values.

## CONCLUSIONS

1. BPL was not related to duration of HTN treatment, gender, and BMI.
2. There could be a relationship between the diastolic BPL and age in hypertensive patients.
3. Middle-aged patients were characterised by significantly higher values of 24-h and daytime diastolic BPL than the elderly patients.

**Conflict of interest:** none declared

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# Ładunek ciśnienia tętniczego u dorosłych chorych z leczonym nadciśnieniem tętniczym

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## Streszczenie

**Wstęp i cel:** Celem pracy była ocena ładunku ciśnienia tętniczego w populacji dorosłych chorych z leczonym nadciśnieniem tętniczym (HTN).

**Metody:** Grupa badana składała się ze 137 dorosłych chorych, w tym 75 (54,7%) mężczyzn (M) i 62 (45,3%) kobiet (K), z leczonym HTN. Mediana wieku grupy badanej wyniosła 52 lata, odpowiednio 47 i 56 lat dla mężczyzn i kobiet. Średni wskaźnik masy ciała (BMI) wynosił  $27 \pm 4$  kg/m<sup>2</sup>, a mediana czasu leczenia — 3 lata. Kryteriami włączenia do badania były: wiek  $\geq 18$ . rż. i HTN w trakcie farmakoterapii hipotensyjnej, rozpoznane za pomocą gabinetowych pomiarów ciśnienia. Kryteriami wykluczenia z badania były: ciąża i czynniki utrudniające pomiar ciśnienia tętniczego metodą oscylometryczną (zaburzenia rytmu i przewodzenia: migotanie przedsionków, bloki przewodzenia przedsionkowo-komorowego, liczne dodatkowe pobudzenia nadkomorowe i komorowe, obwody ramienia uniemożliwiające zastosowanie standardowego mankietu ciśnieniomierza). Chorych podzielono na podgrupy w zależności od płci, wieku, BMI i czasu leczenia. W zakresie wieku wyróżniono trzy grupy: grupa 1 (chorzy do ukończonego 40. rż.; łącznie 29 osób, w tym 23 M i 6 K), grupa 2 (chorzy w wieku 41–65 lat; łącznie 86 osób, rozkład płci 50%/50%) oraz grupa 3 (chorzy > 65. rż.; 22 osoby, w tym 9 M i 13 K). W zakresie BMI wyróżniono trzy grupy: grupa 1 (chorzy z BMI do 24,9 kg/m<sup>2</sup>; łącznie 40 osób, w tym 16 M i 24 K), grupa 2 (chorzy z BMI 25,0–29,9 kg/m<sup>2</sup>; łącznie 70 osób, w tym 45 M i 25 K), grupa 3 (chorzy z BMI  $\geq 30,0$  kg/m<sup>2</sup>; łącznie 27 osób, w tym 14 M i 13 K). W zakresie czasu leczenia HTN podzielono chorych na trzy grupy: grupa 1 (HTN leczone nie dłużej niż 12 miesięcy; łącznie 43 chorych, w tym 29 M i 14 K), grupa 2 (chorzy z HTN leczonym nie krócej niż 13 miesięcy, lecz nie dłużej niż 10 lat; łącznie 60 osób, w tym 28 M i 32 K) i grupa 3 (czas leczenia > 10 lat; łącznie 34 chorych, w tym 18 M i 16 K). U wszystkich pacjentów wykonano zapis ciśnienia metodą ambulatoryjnego monitorowania ciśnienia tętniczego. Uzyskano wartości dobowego, dziennego oraz nocnego ładunku skurczowego i rozkurczowego ciśnienia tętniczego. Analizę statystyczną przeprowadzono przy użyciu pakietu SPSS 15.0.

**Wyniki:** Mężczyźni byli istotnie młodsi od kobiet (48,2 vs. 55,5 roku,  $p < 0,02$ ). Średni BMI u mężczyzn był istotnie wyższy niż u kobiet (28 vs. 26 kg/m<sup>2</sup>,  $p < 0,044$ ). Nie stwierdzono różnic w średnich wartościach ładunku ciśnienia tętniczego w zależności od płci, BMI i czasu leczenia ( $p = \text{NS}$ ). Wartości dobowego i dziennego ładunku rozkurczowego ciśnienia tętniczego były wyższe u chorych w wieku 41–65 lat niż u chorych > 65. rż. (odpowiednio 32,4 vs. 20,8%,  $p < 0,04$  i 29,6 vs. 17,5%,  $p < 0,03$ ). Stwierdzono ujemną korelację między średnią wartością dziennego ładunku rozkurczowego ciśnienia tętniczego a wiekiem ( $r = -0,19$ ;  $p < 0,026$ ) oraz dodatnią korelację między średnią wartością nocnego ładunku skurczowego ciśnienia tętniczego a wiekiem ( $r = 0,24$ ;  $p < 0,005$ ).

**Wnioski:** Ładunek ciśnienia tętniczego nie jest zależny od płci, BMI i czasu leczenia nadciśnienia tętniczego. Ładunek rozkurczowego ciśnienia tętniczego może być zależny od wieku. Chorzy w wieku średnim charakteryzują się wyższymi wartościami dobowego i dziennego ładunku rozkurczowego ciśnienia tętniczego w stosunku do pacjentów w wieku starszym.

**Słowa kluczowe:** ładunek ciśnienia tętniczego, ambulatoryjny pomiar ciśnienia tętniczego, ABPM, nadciśnienie tętnicze

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