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ORIGINAL ARTICLE

Effect of sleep duration on blood pressure in women over 55 years of age – Poznan Cohort study

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Abstract

INTRODUCTION: Hypertension is considered to be the most common pathology of the circulatory system and the most common cause of death or cardiovascular diseases' development. There are many commonly known risk factors of this condition, such as overweight, obesity, a high-fat diet, family history of ischemic heart disease, lipid disorders, and atherosclerosis. In order to reduce the effect of high blood pressure, patients should modify their lifestyle, including sleeping patterns. We wanted to investigate if, in a group of women over 55 years of age compared to the general population from Poznan cohort, sleep duration is related to hypertension.

MATERIALS AND METHODS: All subjects were divided into three research groups depending on the time of sleep. The first group included people who have been sleeping less than 6 hours a day. The second group included people who have been sleeping from 6 to 9 hours a day. The third group was characterized by people with sleep time over 9 hours a day. Due to their age, participants were divided into two groups, below and over 55 years of age.

RESULTS: There is a weak positive correlation between long sleep duration (>9h) and a higher prevalence of unregulated blood pressure ($r = 0.3$, $p = 0.017$) in the group of women over 55 years of age.

CONCLUSION: Unregulated increased blood pressure may occur more frequently in postmenopausal women whose sleep duration exceeds 9 hours a day.

INTRODUCTION

Hypertension is considered to be the most common pathology of the circulatory system and the most common cause of death or cardiovascular diseases' development (Szyndler *et al.* 2004). In Poland, according to the data from 2005 almost 30% of the population suffered from arterial hypertension (Zdrojewski *et al.* 2005) and in a later study from 2018 (Niklas *et al.* 2018) prevalence increased to about 42%. There are various symptoms of hypertension, which develop after years of its duration, including headaches, dyspnoea, worse vision, signs and symptoms of stroke, or coronary heart disease and heart failure – because of them patient reports to the doctor (Rywik 2003).

There are many commonly known risk factors of arterial hypertension, such as overweight, obesity, a high-fat diet, family history of ischemic heart disease, lipid disorders, and atherosclerosis. In order to reduce the effect of high blood pressure, patients' lifestyle and dietary habits such as limitation of salt and alcohol consumption should be modified to reduce blood pressure and delay the use of pharmacotherapy (Liakos *et al.* 2015. Additionally, sleeping patterns may also be considered as a risk factor.

In a few epidemiological studies, there was a strong suggestion that chronic sleep disorders can lead to various negative clinical effects such as obesity, type 2 diabetes, metabolic syndrome, and coronary disease (Patel and Hu 2008; Yaggi *et al.* 2006; Ferrie *et al.* 2007; Cappuccio *et al.* 2011; Kim *et al.* 2015). Guo *et al.* observed that the association between hypertension and sleep time is differed by gender, location, and definitions of short or long sleep duration (Guo *et al.* 2013). It has been reported that in the pathophysiology of incident hypertension, quality of sleep plays a notable role (Buysse *et al.* 1989). Association between poor sleep quality and higher prevalence of hypertension has also been reported in previous studies (Kara and Tenekeci 2017; Liu *et al.* 2016). Irregular sleeping patterns can lead to insomnia characterized by nocturnal awakenings. Even if this condition is compensated by sleeping more during the day, it has been found that chronic insomnia is associated with higher nighttime systolic blood pressure and blunted day-to-night systolic blood pressure dipping (Lanfranchi *et al.* 2009).

Increase of sympathetic nervous activity may mediate the association between sleep deprivation and hypertension (Spiegel *et al.* 1999). Activation of the suprachiasmatic nucleus magnify the synthesis of catecholamines, which leads to vessel constriction, succeeding increases in blood pressure and unfavorable vascular remodeling (Folkow 1990). It is also worth mentioning that short sleep duration and insomnia are associated with increased mortality and morbidity (Sforza *et al.* 2014). Number of hours of sunlight is varied around the world. In most European countries it is greater than in many other areas. Due to this fact, Europeans work longer and go to sleep later. These factors might improve their sleep-wake cycle and other biological rhythms, and thus preclude the development of hypertension (Guo *et al.* 2013).

According to the National Sleep Foundation, 7–9 h of sleep are needed by most adults daily for optimal health maintenance (Nationalsleepfoundation.org. 2019).

In regard to the importance of sleep pattern to overall health and hypertension, in particular, the aim of this study was to investigate if, in a group of women over 55 years of age from Poznan cohort – which assuming by age should all be postmenopausal – sleep duration was correlated with the regulation of hypertension.

We hypothesize that in this specific group, correlation of sleep duration, and regulation of blood pressure will be stronger, compared to the general population and other groups detailed below.

MATERIAL AND METHODS

Groups description

The study was designed as an observational cohort comparative study. The STROBE guidelines were implemented.

The study included patients of the Clinic of Hypertension and Metabolic Disorders of the Transfiguration Hospital of the Medical University of Karol Marcinkowski in Poznan. The project was carried out from July 2014 to May 2015. During this time, we examined our patients and collected the data. The study was conducted among 696 people. The inclusion criteria were: informed consent in writing, blood pressure >140/90 mmHg measured during the visit as described below, male or female over 18 years old. The exclusion criteria were: systemic chronic diseases (beside hypertension), diabetes, chronic diseases of the liver, pancreas, and kidneys, clinically overt atherosclerosis, chronic or acute inflammation, cancer. The study included 677 people aged between 19 and 92 (54.96 ± SD 14.20) – 19 people were excluded from the study due to irregularities in the data on blood tests results. All subjects were divided into three research groups depending on the time of sleep. The first group included 196 people (28.95%) sleeping less than 6 hours a day. 133 women and 63 men were in the first group. The second group included 408 people (60.27%), including 286 women and 122 men. In this group, people were sleeping from 6 to 9 hours a day. The third group was characterized by people with sleep time over 9 hours a day. 73 people (10.78%) were included in this group, including 51 women and 22 men. Within individual groups, we additionally divided them according to the age – below and above 55 years of age.

Tab. 1. Groups description

Group	Female [n=470]		Male [n=207]	
	N	%	N	%
Normotensive	286	60.85%	112	54.11%
Unregulated blood pressure	101	21.49%	60	28.99%
Unregulated blood pressure+Atherosclerosis	4	0.85%	1	0.48%
Unregulated blood pressure+Hypercholesterolemia	66	14.04%	25	12.08%
Unregulated blood pressure+Hypercholesterolemia + Atherosclerosis	13	2.77%	9	4.35%

Normotensive= Blood Pressure <140/90 mmHg
Unregulated blood pressure= Blood Pressure >140/90 mmHg
Hypercholesterolemia= Total cholesterol >190mg/dl
Atherosclerosis= Thickness of inner and middle membrane of the carotid artery in ultrasound examination above 1.5mm

Examination

As part of the qualification stage, patients underwent subjective examinations and blood pressure measurements. Recruitment of patients to the project was carried out as part of one visit.

The visit included a subject study in the form of a single survey, in which sleep duration was elicited by the question „How many hours of sleep do you have on an average weeknight?" Response categories were: less than 6 hours, 6–9 hours, and more than 9 hours. A similar survey was used in the previous study (Grandner *et al.* 2018). During self-report, patients can under- or overestimate sleep (Gangwisch *et al.* 2013). Basing on latest meta-analysis by Han *et al.* (2019), cut-off points of sleep duration varied in different studies, but it can be assumed that people sleeping less than 6h are short sleepers and more than 9h are long sleepers. The traditional measurement of arterial blood pressure was carried out using mercury sphygmomanometer, model PyMah (PyMah Corporation, Flemington, NJ) which is recommended by ESH (O'Brien *et al.* 2001), in accordance with ESH / ESC recommendations (Mancia *et al.* 2013).

Blood pressure measurement was first made on both arms. In the case of a pressure difference > 10 mmHg, arm with the higher measurement was used for the next measurement. Another measurement was made after 2 minutes. In the case when the first two measurements of blood pressure were significantly different – the measurements were averaged. Blood pressure was measured after 3–5 minutes rest in a sitting position. In addition to the blood pressure measurements during the visit, the past medical history of hypertension diagnosis and its pharmacotherapy were also taken into consideration. However, from this group, we recruited only patients with blood pressure >140/90 mmHg in the assumption that if the patient is normotensive, it does not affect the sleeping pattern. Furthermore, as atherosclerosis might influence our results, we aimed to divide our participants into those with, and without atherosclerotic lesions in their carotid arteries. To investigate this issue, we performed a Doppler ultrasound examination of the carotid arteries, during which we measured the thickness of the inner and middle membranę of the vessel. The value above 1.5mm was classified as atherosclerotic plaque. Doppler ultrasound examination of the carotid and vertebral arteries was performed in the Radiology Laboratory of the Transfiguration Hospital at 84 Szamarzewskiego Street in Poznań. Measurement of the thickness of the inner and middle membrane complex of the carotid arteries was performed in the distal carotid artery by ultrasound in duplex and B-mode.

Tab. 2. Metabolic abnormalities in normotensive subjects

Group	Female [n=286]		Male [n=112]	
	N	%	N	%
Healthy patients	192	67.13%	85	75.89%
Atherosclerosis	7	2.45%	5	4.46%
Hypercholesterolemia	75	26.22%	19	16.96%
Hypercholesterolemia + Atherosclerosis	12	4.20%	3	2.68%

Healthy patients = Normotensive patients without hypercholesterolemia and atherosclerosis
Hypercholesterolemia= Total cholesterol >190mg/dl
Atherosclerosis= Thickness of inner and middle membrane of the carotid artery in ultrasound examination above 1.5mm

Tab. 3. Systolic blood pressure in examined groups

Group	Sex	Age	N	Average	Median	Min	Max	±SD
Healthy Patients	F	<55	134	115.84	116	87	138	10.68
		>55	58	123.59	125.5	98	139	9.88
	M	<55	48	123.67	124.5	100	139	9.98
		>55	37	124.11	125	100	139	9.06
Normotensive	F	<55	153	116.51	117	87	139	10.88
		>55	133	124.21	126	98	139	10.03
	M	<55	54	124.26	126	100	139	10.17
		>55	58	124.98	125	100	139	8.64
Unregulated blood pressure	F	<55	38	150.18	146.5	109	205	16.65
		>55	63	151.83	152	128	185	11.41
	M	<55	27	146.89	145	127	178	11.84
		>55	33	157,97	154	132	200	15.83
Unregulated blood pressure + atherosclerosis	F	>55	4	152.75	153.5	144	160	8.46
	M	>55	1	170.00	170	170	170	
Unregulated blood pressure + Hypercholesterolemia	F	<55	14	150.86	148.5	129	179	12.84
		>55	52	154.90	150	131	199	15.23
	M	<55	5	150.60	152	142	159	7.40
		>55	20	153.70	153.5	140	179	10.52
Unregulated blood pressure + Hypercholesterolemia + Atherosclerosis	F	<55	1	171.00	171	171	171	
		>55	12	155.58	151.5	124	180	18.50
	M	<55	1	159.00	159	159	159	
		>55	8	154.00	154.5	141	169	10.61
Normotensive + Hypercholesterolemia	F	<55	18	121.94	122	90	139	11.33
		>55	57	125.84	128	102	139	9.91
	M	<55	5	129.00	135	108	138	12.73
		>55	14	127.50	127.5	109	139	8.23
Normotensive + Hypercholesterolemia + Atherosclerosis	F	<55	1	109.00	109	109	109	
		>55	11	120.36	124	103	128	8.12
	M	>55	3	127.00	123	122	136	7.81
Normotensive + Atherosclerosis	F	>55	7	122.14	126	100	137	14.06
	M	<55	1	129.00	129	129	129	
		>55	4	122.75	120	118	133	7.09

Healthy patients = Normotensive patients without hypercholesterolemia and atherosclerosis
Hypercholesterolemia= Total cholesterol >190mg/dl
Atherosclerosis= Thickness of inner and middle membrane of the carotid artery in ultrasound examination above 1.5mm
Normotensive= Blood Pressure <140/90 mmHG
Unregulated blood pressure= Blood Pressure >140/90 mmHg
F=Female
M=Male

The thickness assessment of the complex was made on the distal wall to the head of the transducer. The patient was placed in a supine position during the examination; head slightly turned backward and directed opposite to the examined side. Depending on the anatomical conditions, the examination was performed from the anterolateral, lateral, and postero-lateral approach. Visibility of the artery and assessment of the thickness of the complex took place in several projections. Measurements were made at several points, approximately 1 cm proximal to the *sinus caroticus*. The result of the thickness measurement of

Tab. 4. Sleep duration depending on the presence of increased blood pressure, ultrasound features of atherosclerosis, and hypercholesterolemia in women

Group	N	Sleep duration					
		<6h		6-9h		>9h	
		N	%	N	%	N	%
Atherosclerosis	7	4	57.14%	2	28.57%	1	14.29%
Hypercholesterolemia	75	22	29.33%	44	58.67%	9	12.00%
Hypercholesterolemia + Atherosclerosis	12	8	66.67%	3	25.00%	1	8.33%
Unregulated blood pressure	101	20	19.80%	69	68.32%	12	11.88%
Unregulated blood pressure+ Atherosclerosis	4	1	25.00%	1	25.00%	2	50.00%
Unregulated blood pressure + Hypercholesterolemia	66	14	21.21%	45	68.18%	7	10.61%
Unregulated blood pressure + Hypercholesterolemia + Atherosclerosis	13	5	38.46%	6	46.15%	2	15.38%
Healthy patients	192	59	30.73%	116	60.42%	17	8.85%

Normotensive= Blood Pressure <140/90 mmHg
Unregulated blood pressure= Blood Pressure >140/90 mmHg
Hypercholesterolemia= Total cholesterol >190mg/dl
Atherosclerosis= Thickness of inner and middle membrane of the carotid artery in ultrasound examination above 1.5mm
Healthy patients = Normotensive patients without hypercholesterolemia and atherosclerosis

the intima-media complex was presented as the mean of measurements made for the right carotid artery and the left carotid artery. On this basis, we divided patients into two groups – with or without atherosclerosis. The measurement of cholesterol from fasted venous blood plasma was carried out in the Central Laboratory of the Heliodor Święcicki Clinical Hospital of Medical University in Poznań according to standard procedures. According to laboratory results, patients were divided into two groups – with hypercholesterolemia if cholesterol level was higher than 190mg/dl and without hypercholesterolemia if lower.

Statistical analysis

STATISTICA (version 12) by StatSoft Inc. (data analysis software system) and Microsoft Excel (version 2016) were used to analyze the data. To check the normal distribution, we used the Shapiro-Wilk test. Study of the relationship between variables was carried out by using the Spearman R test and the chi-square test. The unpaired t-test (for data with normal distribution) or the Mann–Whitney U test was used to carry out comparisons between groups. The Pearson correlation test (for data with normal distribution) or Spearman's rank analysis was performed to calculate correlation coefficients. A p value of less than .05 was regarded as significant. The correlation degree has been divided on very weak, weak, moderate and strong. Multivariate analysis by linear regression analyses has been performed. It has been calculated that a sample size of at least 70 subjects in each group would yield at least 75% power of detecting statistically significant results at the 0.05 α level.

Consent

The study design obtained the consent of the Bioethical Commission at the Karol Marcinkowski Medical University in Poznań, Poland – Resolution No. 606/12 and 453/13 and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. We obtained informed consent from every participant, to examine them and use the results in this study.

RESULTS

The general characteristics of the group, with respect to the presence of increased blood pressure, ultrasound features of atherosclerosis, and hypercholesterolemia are presented in Table 1 – the differences between women and men were statistically insignificant.

The presence of metabolic abnormalities in normotensive subjects are presented in Table 2.

We demonstrated statistically significant differences in the values of systolic blood pressure (p <0.001)

Tab. 5. Age and blood pressure correlation. Spearman test.

Group	Pair of Variables	Sleep duration <6h				Sleep duration 6-9h				Sleep duration >9h			
		N	R	t(N-2)	p	N	R	t(N-2)	p	N	R	t(N-2)	p
Whole population	Age & SBP	196	0.30609	4.47829	0.000013	408	0.357417	7.71112	<0.0001	73	0.358402	3.234845	0.00185
	Age & DBP	196	0.0457	0.63719	0.524753	408	0.010534	0.21226	0.83201	73	0.038726	0.326559	0.74496
Women	Age & SBP	133	0.37915	4.68968	0.000007	286	0.429653	8.01849	<0.0001	51	0.441108	3.440573	0.0012
	Age & DBP	133	0.0078	0.08928	0.928993	286	0.073929	1.2493	0.21259	51	0.103766	0.730302	0.46868
Men	Age & SBP	63	0.27964	2.27482	0.026444	122	0.140406	1.55346	0.12295	22	0.056641	0.253715	0.80231
	Age & DBP	63	0.20738	1.65564	0.102931	122	-0.15347	-1.7014	0.09146	22	-0.11625	-0.52342	0.60644

and diastolic blood pressure in the studied groups (p <0.001). The results were significant for both women (SBP: p <0.001, DBP: p <0.001) and men (SBP: p <0.001, DBP: p <0.001). In both examined age groups, differences in systolic blood pressure values were observed depending on the presence of metabolic abnormalities, especially significant differences were observed among people over 55 (p <0.001) – Table 3. For the general population, no differences were found in the length of sleep depending on the presence of increased blood pressure, ultrasound features of atherosclerosis, and hypercholesterolemia. On the other hand, there were differences in the length of sleep between a group of women and the general population, depending on the features mentioned above (p = 0.02) – Table 4. In the group of men, no such relationship was observed. There were no differences in the length of sleep among people under 55 and over 55 years of age. Among women under the age of 55, there was no relationship between the length of sleep and occurring metabolic features. There was also no such relationship for women over 55 years of age. Among men, no relationship was found between the length of sleep and the occurring metabolic features in both age categories examined. In Table 5 we present correlations in general groups, divided to categories depending on sleep duration. For

Tab. 6. Statistically significant correlations of sleep duration with other parameters. Spearman test.

Group	Correlated parameter	Valid	Spearman	t(N-2)	*p*-value
		N	R		
Whole population	Age	677	0.090053	2.34919	0.019102
	SBP	677	0.078245	2.03913	0.041826
	DBP	677	0.03514	0.91353	0.361292
Men	Age	207	0.294569	4.41341	0.000016
	SBP	207	0.033814	0.48442	0.628604
	DBP	207	-0.02349	-0.3364	0.73691
Normotensive Men	Age	112	0.322908	3.57838	0.000516
	SBP	112	-0.07732	-0.81338	0.417757
	DBP	112	-0.12863	-1.36034	0.176504
Unregulated blood pressure, Woman >55 years	Age	63	0.299728	2.45376	0.017008
	SBP	63	-0.02488	-0.19436	0.846541
	DBP	63	0.083425	0.65385	0.515668
Normotensive Woman, <55 years	Age	153	-0.16845	-2.09992	0.037399
	SBP	153	-0.01141	-0.14015	0.888727
	DBP	153	-0.08444	-1.04133	0.299386

Normotensive= Blood Pressure <140/90 mmHg; Unregulated blood pressure= Blood Pressure >140/90 mmHg

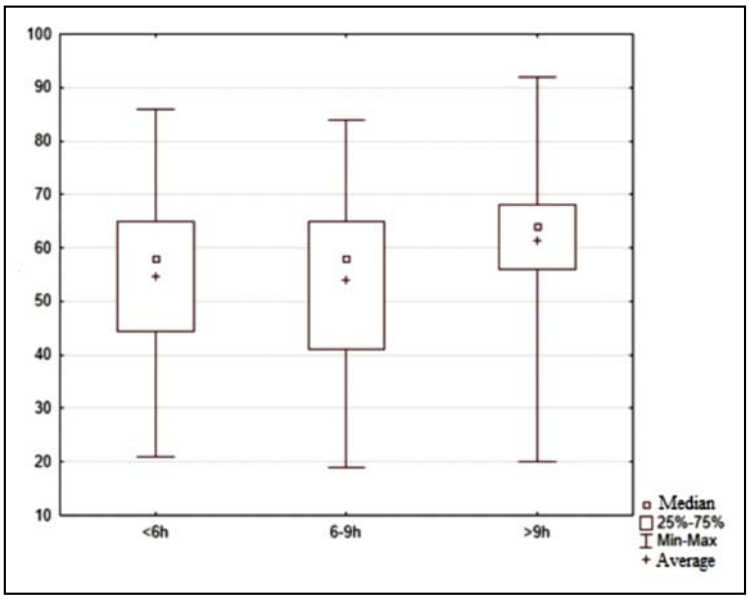

Fig. 1. Age and Sleep Duration in the general population

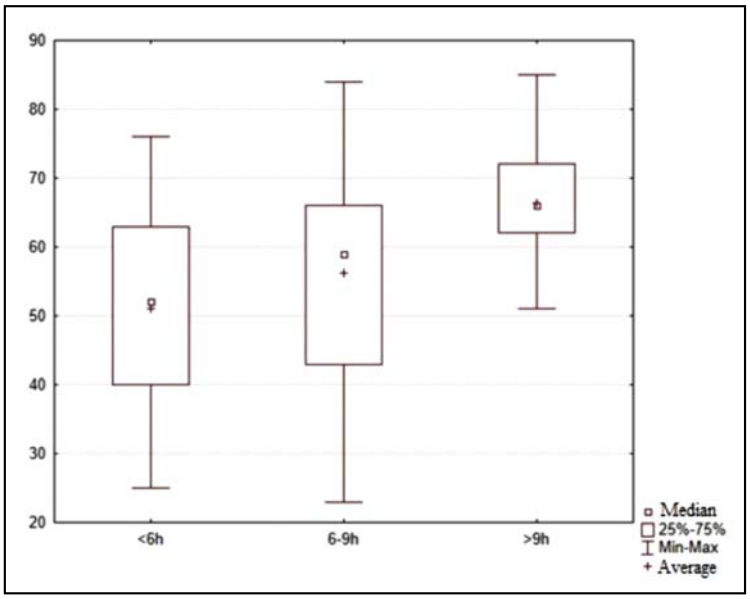

Fig. 2. Age and Sleep Duration in men

the general population, a very weak positive correlation was found between the length of sleep and age (r = 0.09, p = 0.019). Higher age was associated with a greater length of sleep – fig. 1. The above correlation also occurred in men (r = 0.29, p = 0.000016) – fig. 2. The weak positive correlation between age and sleep length among men occurred in the normotensive group (r = 0.32, p = 0.0005) – fig. 3. A similar correlation was also observed in women over 55 years of age with unregulated blood pressure (r = 0.3, p = 0.017) – fig. 4. In normotensive women under 55 years of age, an inverse relationship was observed, the correlation was very weak and negative (r = -0.17, p = 0.037) – a higher age was associated with less sleep – fig. 5. These correlations are presented in Table 6.

In order to increase the credibility and reliability of the results, the largest possible cohort of patients was included in the study, and the division into subgroups was made retrospectively on the included cohort according to earlier assumptions – hence the patients' quantity in groups is uneven. Due to the unequal groups, appropriate statistical methods have been used to compare groups with unequal numbers. The patients' quantity in each group exceeded calculated statistical power and was high enough to detect statistically significant results.

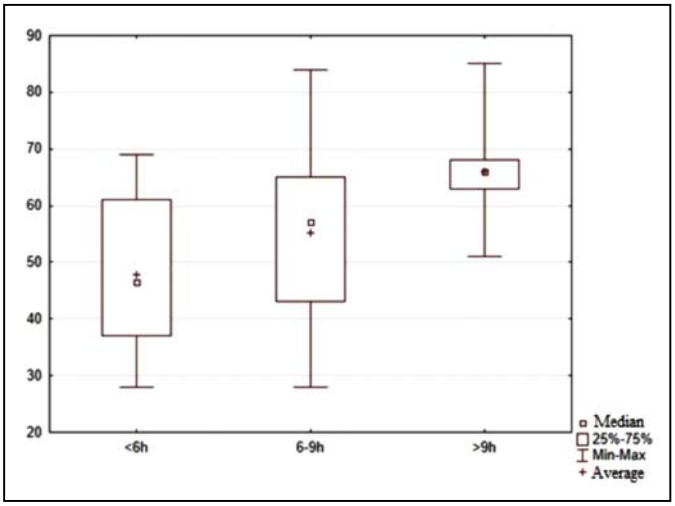

Fig. 3. Age and Sleep Duration in normotensive men

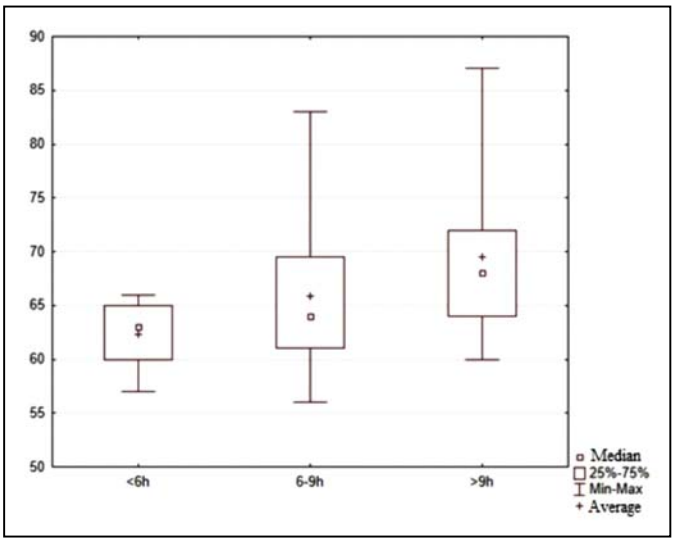

Fig. 4. Age and Sleep Duration in women over 55 years of age with unregulated pressure

DISCUSSION

In this study, we investigated relationships between the duration of sleep and values of blood pressure. As we have demonstrated, women over 55 years of age with sleep duration over 9h, have increased risk of incidence of unregulated blood pressure compared to others – what is novel finding compared to previous studies on this topic. The development of hypertension is affected by many factors, such as age, race, family history, obesity, low physical activity, nicotinism, alcohol abuse, stress, and chronic diseases, for instance renal failure, diabetes, and obstructive sleep apnea (Mayo Clinic Staff 2019). Considering the results, the number of people suffering from hypertension with other comorbidities like hypercholesterolemia, atherosclerosis or both, in summary is greater than the number of people suffering from hypertension only. However, in our study there is no statistical difference in sleep duration between groups representing different comorbidities, so we assume that sleep duration does not affect their prevalence. Our study is in opposite to actual knowledge presented by Gangwisch in his review (Gangwisch 2014), where many researchers state that a higher prevalence of hypertension is related with short sleep duration or there is no correlation at all. On the other hand, assuming that all women over 55 years of age are postmenopausal – they have estrogens deficiency and so higher risk of the incidence of cardiovascular diseases. However, the exact mechanism is still unknown (Rosano *et al.* 2006). Possible cause of hypertension in long-sleepers may be obesity, which is also related to menopause. Strong correlation was found by Jike *et al.*, between sleep time and obesity (Jike *et al.* 2018), and Legio *et al.* proposed the pathophysiological mechanisms of the obesity-hypertension relationship, associated with the production of adipokines by adipocytes – which modulate inflammatory and metabolic processes thereby affecting negatively the endothelium of the blood vessels, leading to its

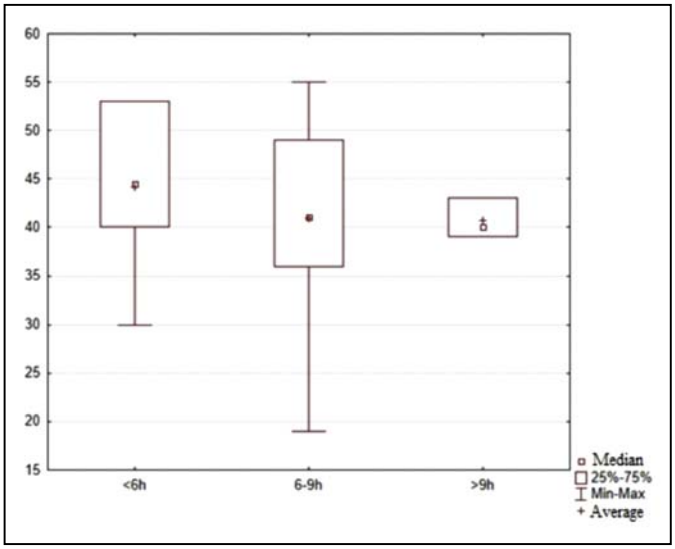

Fig. 5. Age and Sleep Duration in normotensive women under 55 years of age

dysfunction and in the further stage to increased stiffness of vessels and hypertension (Leggio *et al.* 2017). Other menopause hormonal changes besides hypoestrogenemia, are related with relative hyperandrogenemia and low SHGB levels which affects regulation of metabolism and energy balance leading to increase of body weight, redistribution of fat mass and decrease in fat-free mass (Kozakowski *et al.* 2017) composing the image of obesity. Another possible explanation could be, that hormonal changes after menopause cause modification of autonomic control of the cardiovascular system which is under the constant influence of sympathetic and parasympathetic systems, so any shift towards sympathetic hyperactivity which is related with estrogen deficiency causes a higher incidence of cardiovascular incidence in postmenopausal women (Dureja *et al.* 2017). When it comes to causes of longer sleep time, it was observed in patients with sleep apnea. This is because apnea episodes lead to numerous awakenings at night. Such a defective sleep compensates as a longer sleep or spending more time in bed (Grandner and Drummond 2007). Intermittent hypoxia associated with sleep apnea episodes increases the activity of the sympathetic nervous system and weakens the reflexes of the baroreceptors, which is associated with increased blood pressure and hypertension (Tamisier and Levy 2017). Last but not least, a possible explanation is an assumption that a long sleep duration does not have to go hand in hand with its quality. It is known that hyperactivity of the sympathetic nervous system that accompanies most sleep disorders is a confirmed risk factor for the development of hypertension (Chouchou *et al.* 2013). Finally, in the study by Grandner *et al.* (2018) the relationship between short sleep duration and hypertension existed independently of the functional state, while the relationship between hypertension and long sleep duration was stronger with functional limitations, which further confirms that long sleep is more likely a consequence of deterioration of health and not its cause. What surprised us, is a positive correlation between age and sleep duration in the general population, which is in opposition to previous studies on this subject – where typically sleep duration declines with advancing age. The possible explanation could be an overestimation of sleep duration in self-report, which is one of the limiting factors among a few others that our research has. First of all, the results obtained in a clinic population may not necessarily relate to less biased, non-clinic populations. Next important factor limiting the results is the number of patients and the period of data collection. Among the publications of other authors like Bjorvatn *et al.*, Fang *et al.* or Gangwisch *et al.*, the duration of the study was at least two years, and the number of questionnaires analyzed was much higher (Gangwisch *et al.* 2013; Bjorvatn *et al.* 2007; Fang *et al.* 2012). Although the reported sleep time is close to objective sleep length measurements, some studies suggest there is a tendency to overestimate (Choi *et al.* 2011), and the most objective tests such as polysomnography or actinography were not within our reach – the use of these methods in future studies would eliminate the problem of under- or overestimation of sleep duration, as it happens when the patient is self-reporting with questionnaire. What is more, the pressure measurements were made at different times of the day and the temporal relationship between sleep hours and high blood pressure is unknown to us – therefore, no exact causal relationship can be proven (Lusardi *et al.* 1996). Due to different test results of many authors and the fact of coexistence of many risk factors which we did not measure such as sleep quality, social jetlag or dietary habits, etc., it must be taken into consideration that the results may not be objective and highly dependent on a specific population. In the future studies on sleep and blood pressure, for more accurate data, patients could use personal blood pressure measuring

devices like Quardioarm or iHealth Track, from which data can be easily evaluated and they fulfill the criteria of European Society of Hypertension International Protocol Revision 2010 (ESH-IP2) (Mazoteras-Pardo *et al.* 2018; Mazoteras-Pardo *et al.* 2019).

CONCLUSION

In this study, we showed a positive correlation between long sleep duration (>9h) and a higher prevalence of poorly regulated blood pressure in the group of women over 55 years of age. Moreover, we have shown that the length of sleep positively correlates with age in the general population.

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