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Influence of BMI on Cardiovascular Circadian Rhythms of Young Adults

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Abstract

Aim. Excess body weight, obesity, and hypertension increase the risk of non-communicable diseases. The purpose of this study was to examine how body mass index (BMI) correlates with various indicators of circadian hemodynamics in young men and women.
Subjects and Methods. ABPM at 30-min intervals for 2 to 7 days was carried out in 56 of 91 Kazakh university students, aged 21.1 ± 2.9 years. Data were analyzed chronobiologically to estimate the circadian rhythm characteristics of blood pressure (BP) and heart rate (HR). The latter were linearly regressed as a function of BMI, overall and for men and women separately.
Results. There were 22.0 % students who were overweight or obese, and 15.4% were underweight. In clinically healthy Kazakh students, BMI correlated with the MESOR (rhythm-adjusted mean) of systolic (S) and diastolic (D) BP and HR, and with the daily average of the pulse-pressure product in young men. Such correlations were not found for young women.
Conclusion. The weaker influence of BMI on BP and HR in women as compared to men may be accounted for by the action of estrogens, thought to offer cardio-protection.

Introduction

According to the World Health Organization (WHO), the main types of non-communicable diseases (NCDs) are cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes. In particular, cardiovascular diseases play a special role. In 1990, the proportion of cardiovascular deaths occurring below the age of 70 years was 26.5% in developed countries, compared to 46.7% in developing countries [1, 2]. According to WHO statistics [3], proportional mortality from cardiovascular diseases in Kazakhstan is 54.0% (% of total deaths, all ages, both genders). Statistics from the Ministry of Health of Kazakhstan indicate that 1,890,398 people were diagnosed with cardiovascular

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disease in 2011, and that 2,103,129 people with cardiovascular disease sought treatment in Kazakh medical centers in 2012 [4]. Cardiovascular diseases are leading causes of death for men and women, and the most important factor that triggers cardiovascular-related death is hypertension [5]. According to WHO, hypertension occurs in 15-25% of the adult population; its frequency increases with age; more than 50% of people over 65 years of age are hypertensive. Hypertension can be present for a long time without obvious clinical symptoms, but soon enough it can cause acute cerebrovascular events (transient ischemic attack, ischemic or hemorrhagic stroke) and the development of myocardial hypertrophy. In addition, hypertension is a risk factor for atherosclerosis and myocardial infarction [6].

Modifiable behaviors, such as smoking cessation, physical activity, a healthy diet, and refraining from alcohol abuse, can all decrease the risk of NCDs [7]. 80% of premature heart disease and stroke is preventable [8]. The middle- to long-term effectiveness of such lifestyle changes was associated with reduced body weight, body mass index, waist circumference, blood pressure, blood lipids and blood glucose in overweight and obese people, with favorable effects maintained for up to three years [9].

Most studies rely on single or a few repeated BP measurements to diagnose the presence of hypertension or to examine the influence of various factors, such as the body mass index (BMI). By contrast, the present study is based on around-the-clock measurements of BP for several days to obtain reliable estimates of the average BP and, in addition, of its circadian characteristics in a group of clinically healthy young adults of both genders in order to examine how they may be differentially influenced by the BMI, the purpose of this study.

Subjects and Methods

The study was conducted after clearance from the local ethics committee of the Al-Farabi Kazakh National University (No. IRB-A017). Consent was obtained from all study participants, who were clinically healthy undergraduate and graduate students from the faculty of biology and biotechnology and from the medical school. They had to be between 16 and 32 years of age. Study participants did not smoke and did not consume alcohol. Their physical activity was average. The level of physical activity was not an exclusion criterion.

Weight and height were assessed in 91 clinically healthy volunteer students of both sexes (34M and 57F), with an average age of 21.2 ± 3.1 years, most (92.3%) of whom were of Kazakh ethnicity (Asians). BMI was determined by the standard formula BMI = body weight/height^2 (kg/m^2) [10]. 29 subjects were between 17 and 19, 33 between 20 and 22, 21 between 23 and 25, and 8 between 26 and 31 years of age.

Of the 91 volunteers who enrolled in the study, 56 (21M + 35F) agreed to monitor their BP. ABPM was carried out at 30-min intervals for 2 to 7 days (235 ± 86 measurements). The 56 volunteers were 17-31 years of age (mean ± SD: 21.1 ± 2.9 years). Data were analyzed by cosinor to obtain estimates of the MESOR (rhythm-adjusted mean), 24-hour amplitude and acrophase (measures of the extent and timing of predictable change within a day). Pulse pressure (PP) was estimated as the difference between the MESOR of systolic (S) BP and the MESOR of diastolic (D) BP. The pulse-pressure product (DP) was estimated by multiplying the MESORs of SBP and heart rate (HR), divided by 100. Circadian rhythm characteristics of BP and HR were linearly regressed as a function of BMI. The TM-2430 monitor from A&D (Tokyo, Japan) was used to measure BP and HR.

Results

While most (57) students (62.6%) had an acceptable BMI, 14 (15.4%) were underweight (16.0 < BMI < 18.5), 17 (18.7%) were overweight (25 < BMI < 30), and 3 (3.3%) were obese (BMI > 30). Sex dimorphism in the distribution of BMI is most pronounced in relation to body mass deficit. Among the young men, body weight deficiency was 2.2%, while among girls it was 13.2%. On average, the young men (N = 34; 21 ± 3 years) had a body weight of 73.1 ± 14.0 kg, a height of 177.3 ± 6.5 cm, and a BMI of 23.25 ± 4.28 kg/m^2. The young women (N = 57; 21 ± 3 years) had a body weight of 56.39 ±

9.87 kg, a height of 162.96 ± 5.83 cm, and a BMI of 21.25 ± 3.65 kg/m^2, Figure 1.

Overall, the MESOR of SBP averaged (± SD) 118.7 ± 11.5 mmHg, that of DBP 70.4 ± 6.1 mmHg, and that of HR 74.9 ± 7.2 beats/min; pulse pressure (PP) averaged 48.6 ± 6.9 mmHg, and the pulse-pressure product (DP) 90.5 ± 15.1 mmHg.beats/min%.

The MESORs of SBP, DBP, HR, and DP of young women with excess body weight were found to be numerically higher than those of female students with an acceptable BMI, but the differences were not statistically significant (Table 1). The BP parameters were within the acceptable range of values for all young women with excessive body weight: on average, their 24-hour mean (± SD) values were 115.6 ± 5.5 mmHg for SBP, 70.1 ± 2.3 mmHg for DBP, and 77.5 ± 4.5 beats/min for HR.

A positive association (r > 0.50) of the MESORs of SBP, DBP and the pulse-pressure product with BMI was statistically significant overall. Pulse pressure (PP) was only weakly related to BMI. When considering male and female students separately, the correlation with BMI was statistically significant for men (SBP, DBP, HR, DP), but not for women. Results are illustrated in Figures 2-5 for DP, and the MESOR of SBP, DBP, and HR, respectively. The MESOR of SBP was higher on days of fitness and sport exercises for women. Young women with higher values of BMI (>25) have a SBP MESOR within the acceptable range.

Some of the women with a normal BMI, although they had an acceptable daily average BP, had a circadian amplitude of SBP exceeding the chronobiologic reference limits. This condition is known as CHAT, brief for Circadian Hyper-Amplitude-Tension. It has been associated with an increase in cardiovascular disease risk in several outcome studies [11]. Arrhythmia were also detected in the ECG of women with SBP CHAT in our study [12]. No correlation with BMI was found in the case of the circadian amplitude of SBP, DBP, and HR.

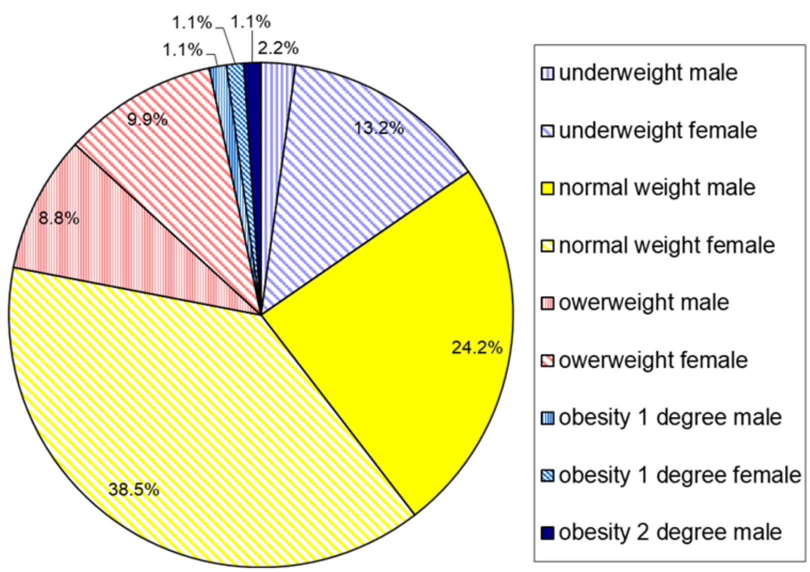

Figure 1. Body mass index of university students (N = 91; age: 17-31 years).

Table 1. Average (± SE) circadian hemodynamics of young women with acceptable (top) or excessive (bottom) body weight

BMI Range (kg/m^2)	N subjects	SBP MESOR (mmHg)	DBP MESOR (mmHg)	PP (mmHg)	DP (mmHg.beats/min%)	HR MESOR (beats/min)
17-24.9	29	112.7±8.7	68.1±4.2	44.9±5.2	86.0±9.2	75.7±5.0
25.0-34.0	6	115.6±5.5	70.1±2.3	45.5±4.6	90.7±4.4	77.5±4.5

Table 2. Correlation* results of BMI with hemodynamic parameters of young adults (17-31 years) monitored up to 7 days (235 ± 86 times)

Variable‡	Gender	r	F	P
SBP MESOR	Men (N = 21)	0.537	7.710	**0.012**
	Women (N = 35)	0.277	2.743	0.107
	All (N = 56)	0.507	18.719	**<0.001**
DBP MESOR	Men	0.566	8.946	**0.007**
	Women	0.291	3.059	0.090
	All	0.511	19.121	**<0.001**
HR MESOR	Men	0.678	16.156	**<0.001**
	Women	0.109	0.397	0.533
	All	0.325	6.366	**0.015**
PP	Men	0.284	1.672	0.211
	Women	0.228	1.805	0.188
	All	0.408	10.815	**0.002**
DP	Men	0.693	17.632	**<0.001**
	Women	0.318	3.730	0.062
	All	0.566	25.485	**<0.001**

‡ correlated with BMI; * Statistically significant (P < 0.05) associations shown in bold.

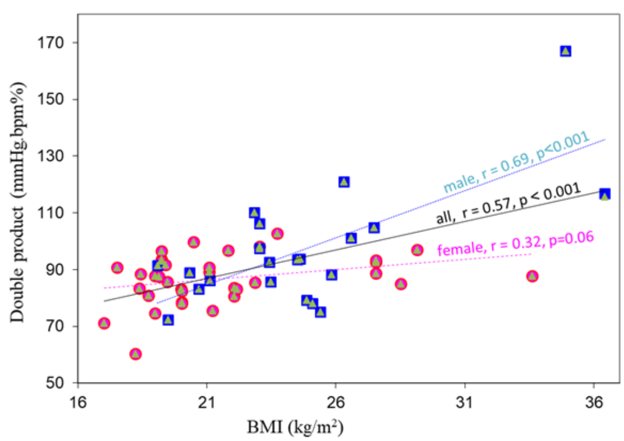

Figure 2. The positive association of DP with BMI is stronger for men (squares) than for women (circles).

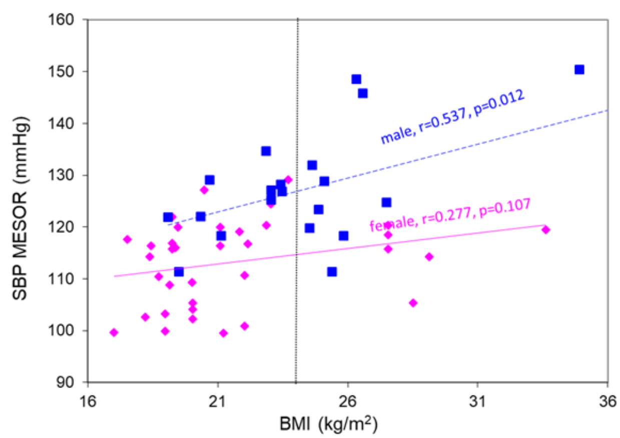

Figure 3. The positive association of the SBP MESOR with BMI is stronger for men (squares) than for women (circles).

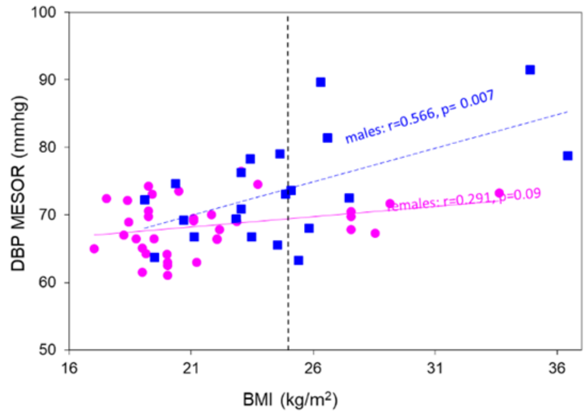

Figure 4. The positive association of the DBP MESOR with BMI is stronger for men (squares) than for women (circles) (see Table 2).

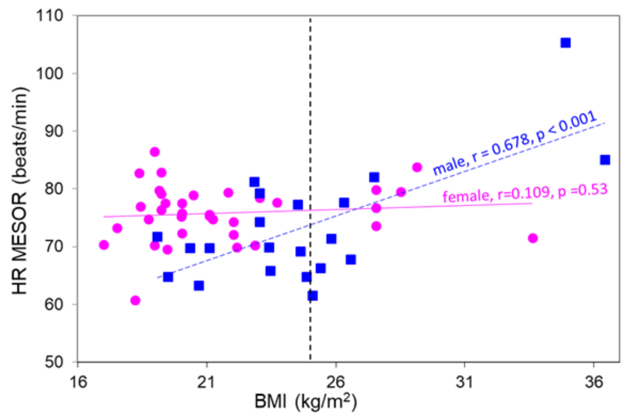

Figure 5. The positive association of the HR MESOR with BMI is statistically significant for men (squares) but not for women (circles).

Discussion

Intercountry comparable overweight and obesity estimates from 2008 show that 55.6% of the adult population (>20 years old) in Kazakhstan were overweight and 23.7% were obese. The prevalence of the overweight state was lower among men (55.2%) than women (56.0%). The proportion of men and women who were obese was 19.1% and 27.6%, respectively [13]. The Kazakh Academy of Nutrition also reported that "In 2008, every second woman (50.6%) and a slightly smaller percentage of men (45.4%) aged 25-59 years qualified as overweight (29.0% of women and 34.4% of men) or obesity (25.7% of women and 11.0% of men). These conditions were 4.5 times less common among men (10.2%) and women (11.5%) aged 15-24 years." Kazakh Academy of Nutrition studies showed in 2012 that the average prevalence of overweight was 30.6% in women and 36.8% in men; the average prevalence of obesity was 27.6% in women and 15.9% in men. This suggests that more than half of Kazakhstan's population is overweight or obese. As for children, every fifth child aged 1-14 years (21.5%) was overweight or obese, with half of them obese [14]. However, according to Fursov et al. [15], the incidence of cases of overweight and obesity in 2016 was 180.7 for every 100,000 people, and the incidence of obesity was 91.2 for every 100,000 people. The age range of the sample was not specified by the authors. These estimates are much lower than those indicated by the Kazakh Academy of Nutrition and the WHO report.

Our sample in the age range of 17-31 years is at the juncture of two age groups listed above, with 81 out of 91 students aged up to 24 years, which is probably why the proportion of overweight and obese students of 18.7% and 3.3%, respectively, differs from that of the Kazakh Academy of Nutrition [14]. The 15.4% of young people with insufficient body weight (weight deficit) in our study (Figure 1) stands out as an unexpectedly high prevalence. It could be an ethnic feature; from large-scale twin studies it is known that genetics appear to play an increasingly important role in accounting for the variation in weight, height, and BMI from early childhood to late adolescence [16, 17]. But, some authors [15] consider malnutrition as one of the possible causes of deterioration in the health of the population of Kazakhstan. The gender distribution of 14.3% young men and 85.7% girls among individuals with insufficient weight, showing a significant bias towards women, is in agreement with similar data from England, where males accounted for 29.7%, and females for 70.3% in a sample of underweight people16 years and older [18].

The positive association between BP and HR with BMI found herein for males needs to be qualified by the presence of outliers that may have overly contributed to the correlation. Indeed, the two male students with a BMI above 34 also had higher DP, SBP, DBP, and HR values on average. The results, however, agree with previous reports. A positive correlation of BP with BMI has indeed been repeatedly reported [9, 19, 20]. Also widely examined is the dependence of BP on BMI over the age of 40 [9, 19], as well as in children and adolescents [20, 21]. In adolescents (Grade 10 students), this correlation was found only in young men, among many other indicators, while in girls there is no correlation of BP with excess weight and obesity. Correlation with BMI has been reported for both genders in the case of insulin, high-density lipoprotein cholesterol ($P < 0.001$), and highly sensitive C-reactive protein ($P < 0.001$) concentrations [21].

In addition to age and gender, the dependence of BP on BMI is influenced by ethnicity [22]. In terms of life expectancy, as one of the significant health indicators, the optimal BMI for black people has a higher upper limit (between 23 and 30) than for Caucasians (between 23 and 25) [23]. In the group of clinically healthy Kazakh students belonging to the South Siberia race, transitional between the Asian and Caucasoid large races [24], a correlation with BMI was found for the MESOR of SBP, DBP, HR, and for DP for young men, but not for young women.

Such a small influence of BMI on BP and HR in girls can be accounted for by the action of estrogens, mainly in the form of estradiol, which are believed to play an important role in cardioprotection [25]. Cardioprotection by estrogens can be attributed to effects of both gene expression and signaling cascades associated with membrane receptors of smooth muscle cells of blood vessels and other cardiovascular cells [26, 27]. The mechanisms underlying this action include, among others, the work of nerve centers located in the brain stem and controlling sympathetic activity, transducing afferent signals from arterial baroreceptors, and central and peripheral chemoreceptors responsive to changes in cardiovascular status [28-31]. Many G protein-coupled receptor-mediated processes are involved in cardiovascular function, and some exhibit clear sex divergence [32].

Conclusion

At a young adult age, BMI has a weak effect on daily hemodynamics. In the group of clinically healthy Kazakh students, a correlation with BMI was found for the MESOR of SBP, DBP, and for DP. For young men positive correlations are between BMI and average daily values of SBP, DBP, HR, DP, but there are hardly any correlations with $r>0.5$ for young women. Young women with higher values of BMI (>25) have a SBP MESOR within the acceptable range. Pulse pressure (PP) was only weakly related to BMI.

Obese or overweight young men were found to have abnormal circadian BP and/or HR patterns, known as vascular variability anomalies. No such abnormalities were found in overweight young women in this study. This fact and the absence of significant correlations between BMI and circadian rhythm characteristics of BP and HR in girls could be accounted for by the cardioprotection of estrogens, which is the highest at this age.

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