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Dynamics of biological rhythms of the cardiovascular system during diurnal fasting in women while sitting // Dynamik des biologischen Rhythmus des Herz-Kreislauf-Systems bei fastenden Frauen

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Dynamics of biological rhythms of the cardiovascular system during diurnal fasting in women while sitting

V. Kozhukhova

Abstract. This paper describes changes in the parameters of the cardiovascular system during diurnal fasting in women. The results were recorded during the day, eight times from 8 a.m.–10 p.m. with a two-hour interval (8 a.m., 10 a.m., 12 noon, 2 p.m., 4 p.m., 6 p.m., 8 p.m. and 10 p.m.). Increases in cardiovascular system indices during fasting compared with the initial period were detected. Our work revealed a significant increase in all indicators of the cardiovascular system during fasting compared to the baseline period. This fact is probably consistent with the presence of the first phase of the general adaptation syndrome, a large release of catecholamines. The presence of two maximum values during the day was found for systolic blood pressure (SBP) and diastolic blood pressure (DBP). Acrophases of SBP and DBP were registered at 8 a.m. and 6 p.m. (or 8 p.m., 10 p.m.), which is associated with the release of adrenaline into the blood at this time of day. During fasting, a significant increase in SBP and DBP was found in all eight time periods relative to the baseline period.

Key words: cardiovascular system, women, sitting, diurnal fasting.

Kurzfassung: Dynamik des biologischen Rhythmus des Herz-Kreislauf-Systems bei fastenden Frauen. Diese Arbeit beschreibt Veränderungen der Parameter des Herz-Kreislauf-Systems während des täglichen Fastens bei Frauen. Die Ergebnisse wurden tagsüber 8× von 8–22 Uhr im Abstand von zwei Stunden (8, 10, 12, 14, 16, 18, 20 und 22 Uhr) aufgezeichnet. Anstiege der Herz-Kreislauf-Indizes während des Fastens im Vergleich zur Anfangsphase wurden festgestellt. Unsere Arbeit zeigte einen signifikanten Anstieg aller Indikatoren des Herz-Kreislauf-Systems während des Fastens im Vergleich zur Baseline-Periode. Diese Tatsache steht wahrscheinlich im Einklang mit dem Vorhandensein der ersten Phase des allgemeinen Anpassungssyndroms, einer großen Freisetzung von Katecholaminen. Das Vorhandensein von zwei Maximalwerten während des Tages wurde für den systolischen Blutdruck (SBP) und den diastolischen Blutdruck (DBP) gefunden. Akrophasen von SBP und DBP wurden um 8 und 18 (oder 20, 22) Uhr registriert, was mit der Freisetzung von Adrenalin in das Blut zu dieser Tageszeit verbunden ist. Während des Fastens wurde ein signifikanter Anstieg von SBP und DBP in allen acht Zeitabschnitten relativ zum Basislinienzeitraum festgestellt. **Z Gefäßmed 2022; 19 (2): 14–20.**

Schlüsselwörter: Herz-Kreislauf-System, Frau, Sitzung, tägliches Fasten

Abbreviations

BP	blood pressure (mmHg)
CEBC	coefficient of economization of blood circulation
DBP	diastolic blood pressure (mmHg)
DP	double product
HR	heart rate
MAP	mean arterial pressure
MBV	minute blood volume
PP	pulse pressure
SBP	systolic blood pressure (mmHg)
SBV	systolic blood volume
SVR	systemic vascular resistance

Introduction

During fasting, the work of many body systems, including the cardiovascular system, changes. All studies were conducted with the participation of clinically healthy middle-aged women (40–49 years old), 160–169 cm tall and weighing about 60 kg, leading an active lifestyle [1–6]. The work on collecting the material was carried out in laboratory conditions at an air temperature of + 22–24 °C. The organization of the study included the registration of parameters of the circulatory system during a one-day fast. Registration of changes in the indicators of SBP, DBP and heart rate (HR) during one day was carried out at intervals of two hours, from 8 a.m. to 8 p.m. (8 a.m., 10 a.m., 12 noon, 2 p.m., 4 p.m., 6 p.m., 8 p.m. and 10 p.m.) [7–12].

To register SBP, DBP and HR, a semi-automatic blood pressure measuring device MT-30 (10016, New York, USA) was used, which consisted of the following parts: a display showing the value of SBP DBP and HR; a special cuff connected to the display that helps to register the parameters of central hemodynamics; an air blower built into the cuff [13, 14]. To obtain objective indicators , the following conditions were met:

1. The sleeve of the garment should not squeeze the shoulder.
2. For 30 minutes before measuring the pressure and pulse rate, the subjects did not perform physical activity.
3. For five to eight minutes before the pressure measurement, the position of the body did not change.
4. During the registration of parameters, the brachial artery of the arm on which the measurement was carried out was at the level of the heart.
5. A 14 cm wide cuff was applied to the bare shoulder without squeezing it.
6. During repeated measurements, the arm rested for at least ten minutes between parameter registrations (with the cuff removed from the arm).
7. The blood pressure (BP) of the test subjects must be measured on the same arm.
8. The cuff was applied to the left humerus, located at an angle of 45 to the horizontal surface.

Materials and Methods

The difference between SBP and DBP, that is, the amplitude of pressure fluctuations, is called pulse pressure and is calculated by the formula [2, 14]:

$$PP = SBP–DBP \quad (1)$$

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where PP = pulse blood pressure (mmHg), SBP = systolic blood pressure (mmHg), DBP = diastolic blood pressure. PP, other things being equal, is proportional to the amount of blood ejected by the heart at each systole. Normally, the value of PP is 40–70 mmHg and increases with an increase in SBP or a decrease in DBP [10]. Pulse pressure decreases in small arteries and, consequently, the difference between systolic and diastolic pressure decreases. There are no pulse waves of arterial pressure in capillaries [15, 16] and conditions are created for diffuse exchange of gases in these vessels. Thus, fluctuations in blood pressure are caused by the pulsating nature of blood flow, high extensibility and elasticity of the vascular wall [5, 7].

The mean arterial pressure (MAP) was determined by the following equation [2]:

$$MAP = DBP + ⅓\ PP \quad (2)$$

BPa is the average value at which, in the absence of pulse waves, the same hemodynamic effect is observed, that is, the average arterial pressure is the resultant of all changes in pressure in the vessels. According to [17], BPa is closer to the indicators of diastolic pressure, since the duration of the decrease in pressure during diastole is longer than the increase during ventricular systole.

The double product (DP) was calculated according to the formula proposed by [15]:

$$DP = BPa \times HR \quad (3)$$

where BPa = average blood pressure (mmHg); HR = heart rate (beats/min). It is assumed, that there is a linear relationship between DP and the amount of oxygen uptake by the myocardium [15]. DP can be used to judge the aerobic capacity of the heart. Under the same conditions, both at rest and after physical exertion, the higher the level of functional state, the lower the DP [18].

The state of normal function of the cardiovascular system can be indirectly judged by the coefficient of economization of blood circulation (CEBC), which reflects the release of blood in 1 minute. It is calculated by the formula [4]:

$$CEBC = (SBP - DBP) \times HR \quad (4)$$

Systolic blood volume (SBV, ml) was calculated using the Starr formula [6]:

$$SBV = 90.97 + 0.51\ PP + 0.57\ DBP - 0.61\ A \quad (5)$$

where PP = pulse blood pressure (mmHg); DBP = diastolic blood pressure (mmHg). The minute blood volume (MBV) was obtained as follows [6]:

$$MBV = SBV \times HR \quad (6)$$

where MBV = minute blood volume (l/min); SBV = systolic blood volume (ml); HR = heart rate (beats/min); MBV = the amount of blood ejected by the left ventricle into the aorta in 1 minute depends on: the amount of blood flowing to the right atrium; the pumping function of the heart, determined mainly by the contractility of the myocardium, SVR.

The systemic vascular resistance (SVR) can be obtained by calculation [3]:

$$SVR = PBa \times 60 \times 1333 / MBV\ din \times s \times cm^{-5} \quad (7)$$

where MAP = average arterial pressure (mmHg); MBV = minute blood volume (in l/min).

An increase in the SVR leads to a significant increase in systolic and especially diastolic pressure and a decrease in pulse pressure [19].

All the obtained material was processed statistically with the determination of the mean square deviation, the average values and the error of the average value (Q, M, m). Testing of the statistical hypothesis showed that in most cases the sample size allowed the distribution of values as normal, so the reliability of the differences was determined by the Student's t-test. Statistical analysis of the results was carried out on an electronic calculator Sadar (SL-v 88 [number: 9230499130]), manufactured in China, as well as on a computer.

Results and Discussion

Before fasting, two acrophases of SBP were detected in the sitting position, namely: at 8 a.m. and 6 p.m. (Tab. 1). The morning acrophase of SBP was found to be significantly higher than the evening one by 3.92% ($p < 0.05$). Relative to 8 a.m., there was a decrease in SBP during the day (Tab. 1). During fasting, two acrophases, SBP, were detected, namely: at 8 a.m. and 6 p.m. The morning SBP acrophase was significantly more pronounced compared to the evening acrophase (+ 2.65%, $p < 0.05$). During fasting, in a sitting position, a decrease in

Table 1. Changes in systolic blood pressure before and during fasting, while sitting (M ± m), n = 14

Time of day	Systolic blood pressure (SBP), mm Hg	
	Before fasting	**During fasting**
1. 8 a.m. A	**100.35 ± 1.88**	**102.35 ± 1.09**
2. 10 a.m. B	96.14 ± 1.41	100.42 ± 1.48
3. 12 noon C	95.57 ± 1.17	99.50 ± 1.33
4. 2 p.m. D	96.35 ± 1.80	96.92 ± 1.48
5. 4 p.m. E	93.64 ± 1.09	98.00 ± 1.64
6. 6 p.m. F	**96.42 ± 0.86**	**99.64 ± 0.70**
7. 8 p.m. G	95.21 ± 1.64	98.57 ± 0.86
8. 10 p.m. H	96.21 ± 1.33	99.14 ± 1.25
1	AB (–4.2%, $p < 0.05$)	AD (–5.31%, $p < 0.01$)
2	AC (–4.77%, $p < 0.02$)	AE (–4.26%, $p < 0.02$)
3	AE (–6.69%, $p < 0.001$)	AF (–2.65%, $p < 0.05$)
4	AF (–3.92%, $p < 0.05$)	AG (–3.70%, $p < 0.01$)
5	AG (–5.15%, $p < 0.05$)	AH (–3.14%, $p < 0.05$)
6	AH (–4.13%, $p < 0.05$)	
7	EF (+2.96%, $p < 0.05$)	

Note: Acrophases (maximum values) are highlighted in **bold**. In order to show a more complete and clearer picture of the reliability of the change in the results, letter designations were given to the time segments.

Table 2. Changes in diastolic blood pressure before and during fasting, sitting. (M ± m), n = 14

Time of day	Systolic blood pressure (SBP), mm Hg	
	Before fasting	**During fasting**
1. 8 a.m. A	67.42 ± 0.78	71.57 ± 0.78
2. 10 a.m. B	64.57 ± 1.25	68.92 ± 0.86
3. 12 noon C	63.92 ± 1.33	67.57 ± 1.09
4. 2 p.m. D	62.85 ± 1.17	67.04 ± 0.78
5. 4 p.m. E	63.07 ± 1.01	67.00 ± 1.09
6. 6 p.m. F	62.14 ± 0.86	68.28 ± 1.09
7. 8. p.m. G	65.50 ± 1.48	67.35 ± 0.94
8. 10 p.m. H	63.21 ± 1.41	68.64 ± 0.86
1.	AB (–4.2%), p < 0.05	AB (–3.71%), p < 0.02
2.	AC (–5.2%), p < 0.02	AC (–5.59%), p < 0.001
3.	AD (–6.78%), p < 0.001	AE (–6.69%), p < 0.001
4.	AE (–6.46%), p <0.001	AF (–4.6%), p < 0.02
5.	AH (–6.25%), p <0.05	AG (–5.9%), p < 0.001
6.	BF (–6.46%), p < 0.02	AH (–4.1%), P < 0.02
7.	FG (–5.40%), p <0.05	

Note: The symbols are the same like Table 1.

SBP was obtained during the day relative to 8 hours. Two acrophases of DBP were detected in the state of the body before fasting: the first at 8 a.m. and the second at 8 p.m. (Tab. 2). Relative to 8 a.m., a decrease in DBP was obtained during the day. The maximum significant decrease in DBP relative to 8 hours was recorded at 14 hours (–6.78%, p < 0.001). During fasting, two maximum values of DBP were obtained during the day, in a sitting position, namely: at 8 a.m. and 10 p.m. Morning acrophase was detected significantly more than in the evening by 4.1% (p < 0.02). During the day, a decrease in DBP was recorded relative to 8 a.m. The maximum decrease in DBP was detected at 4 p.m. (–6.39%, p < 0.001). The 16-hour acrophase was more pronounced compared to the 14-hour one.

Based on Table 3, a change in heart rate was obtained before and during fasting. Two acrophases were detected before fasting, namely: at 2 p.m. and 4 p.m. From 8 a.m. to 4 p.m. inclusive, an increase in heart rate was recorded. The maximum significant increase was detected at 4 p.m. relative to 8 a.m. (+14.83 %, p < 0.001). The minimum significant increase in

Table 3. Changes in heart rate before and during fasting, sitting. (M ± m), n =14

Time of day	Heart rate (HR), beats/min	
	Before fasting	**During fasting**
1. 8 a.m.A	54.92 ± 1.56	58.57 ± 1.41
2. 10 a.m. B	55.28 ± 1.25	58.00 ± 0.93
3. 12 noon C	59.50 ± 1.33	56.35 ± 1.09
4. 2 p.m. D	61.92 ± 1.25	58.50 ± 1.41
5. 4. p.m. E	63.07 ± 1.80	59.71 ± 1.01
6. 6 p.m. F	58.14 ± 1.17	60.71 ± 1.01
7. 8 p.m. G	58.85 ± 1.01	61.42 ± 1.25
8. 10 p.m. H	56.42 ± 1.48	60.78 ± 1.48
	AC (+8.33%, p < 0.02)	BF (+4.67%, p < 0.05)
	AD (+12.74%, p < 0.001)	BG (+5.89%, p < 0.02)
	AE (+14.83%, p < 0.001)	CE (+5.89%, p < 0.02)
	AG (+7.15%, p < 0.05)	CF (+7.73%, p < 0.01)
	BC (+7.63%, p < 0.02)	CG (+8.99%, p < 0.001)
	BD (+12.01%, p < 0.001)	CH (+7.86%, p < 0.02)
7	BE (+14 .09%, p < 0.001)	
8	BG (+6.45%, p < 0.05)	
9	DF (–6.11%, p < 0.02)	
	DG (–4.96%, p < 0.05)	
	DH (–8.89%, p < 0.01)	
	EF (–7.82%, p < 0.02)	
	EG (–6.70%, p < 0.05)	
	EH (–10.55%, p < 0.01)	

Note: The symbols are the same as in Table 1.

heart rate was obtained at 8 a.m. relative to 8 p.m. (+7.15 %, p < 0.05). From 6 p.m. to 10 p.m., a decrease in heart rate was recorded relative to 4 p.m.

The maximum reliable decrease in heart rate was obtained at 10 p.m. relative to 4 p.m. (–10.55%; p < 0,01). The maximum heart rate during the day was detected at 4 p.m. Before fasting, 14 significant changes in HR were detected. During fasting, two acrophases were registered in the sitting position, namely: at 8 a.m. and 8 p.m.

The evening heart rate acrophase was found to be more pronounced in comparison with the morning one. From 10 a.m. to 12 noon inclusive, a decrease in heart rate was obtained relative to 8 a.m From 2 p.m.to 8 p.m. inclusive, an increase in HR was detected. Relative to 10 a.m., 2 significant increases were obtained, namely, at 6 p.m. and 8 p.m.. Relative to 12 noon, 4 significant changes were detected, namely: at 4 p.m., 6 p.m., 8 p.m. and 10 p.m. During fasting, 6 significant changes in heart rate were recorded.

Table 4. Changes in pulse blood pressure (PP) before and during fasting, sitting. (M ± m), n = 14

Time of day	Pulse blood pressure (PP), mmHg	
	Before fasting	**During fasting**
1. 8 a.m. A	32.92 ± 1.48	30.07 ± 1.09
2. 10 a.m. B	31.50 ± 1.56	31.57 ± 1.01
3. 12 noon C	31.64 ± 1.01	31.21 ± 0.86
4. 2 p.m. D	33.50 ± 1.88	29.92 ± 1.17
5. 4 p.m. E	30.57 ± 0.78	31.07 ± 1.48
6. 6 p.m. F	34.28 ± 1.41	31.35 ± 1.25
7. 8 p.m. G	29.71 ± 1.17	31.21 ± 1.09
8. 10 p.m. H	33.00 ± 0.86	30.50 ± 1.41
1	EF (+12.13%, p < 0.02)	
2	EH (+7.94%, p < 0.05)	
3	FG (–13.34%, p < 0.02)	
4	GH (+11.07%, p <0.02)	

Note: The symbols are the same as in Table 1.

Changes in pulse blood pressure (PP) were recorded during the day (Tab. 4). In the state of the body before fasting, 2 acrophases of PP were obtained, namely: at 2 p.m. and 6 p.m. The second acrophase was found to be more pronounced than the first. The maximum significant increase in PP was recorded at 10 p.m. relative to 8 p.m. (+11.07 %, p < 0.02). Table 5 shows the change in mean arterial pressure before and during fasting. Before fasting, 2 acrophases were detected, namely: at 8 a.m. and 8 p.m.

Morning acrophase of MAP was significantly greater than the evening acrophase by 3.85% (p < 0.05). From 8 a.m. to 6 p.m.

Table 5. Changes in mean arterial pressure before and during fasting, sitting. (M± m), n = 14

Time of day	Mean arterial pressure (MAP), mm Hg.	
	Before fasting	**During fasting**
1. 8 a.m. A	78.37 ± 0.99	81.55 ± 0.57
2. 10 a.m. B	75.03 ± 1.01	79.41 ± 1.07
3. 12 noon C	74.45 ± 1.14	77.01 ± 1.15
4. 2 p.m. D	74.00 ± 0.88	76.65 ± 1.01
5. 4 p.m. E	73.23 ± 0.99	77.33 ± 1.01
6. 6 p.m. F	73.53 ± 0.91	78.71 ± 0.84
7. 8 p.m. G	75.36 ± 1.33	77.59 ± 0.86
8. 10 p.m. H	67.40 ± 1.38	78.85 ± 0.72
1	AB (–4.27%, p < 0.02)	AB (–2.63%, p < 0.05)
2	AC (–5.01%, p < 0.02)	AC (–5.57%, p < 0.001)
3	AD (–5.58%, p < 0.001)	AE (–5.18%, p < 0.001)
4	AE (-6.56%, p < 0.001)	AF (–3.49%, p < 0.01)
5	AF (–6.18%, p < 0.001)	AH (–3.32%, p < 0.01)
6	AH (–3.85%, p < 0.05)	BD (–3.48%, p < 0.05)
7	CH (–9.47%, p < 0.001)	DH (+2.87%, p < 0.05)
8	EH (–7.97%, p < 0.001)	
9	FH (–8.34%, p < 0.001)	

Note: The symbols are the same as in Table 1.

Table 6. Change in systolic blood volume before and during fasting, sitting (M ± m), n = 14

Time of day	Systolic blood volume (SBV), ml.	
	Before fasting	**During fasting**
1. 8 a.m. A	117.90 ± 1.03	118.67 ± 0.51
2. 10 a.m. B	115.50 ± 0.81	117.97 ± 0.83
3. 12 noon C	115.21 ± 0.69	117.03 ± 0.75
4. 2 p.m. D	115.60 ± 0.97	116.01 ± 0.81
5. 4 p.m. E	114.14 ± 0.61	116.63 ± 0.86
6. 6 p.m. F	115.62 ± 0.49	117.52 ± 0.36
7. 8 p.m. G	115.07 ± 0.92	116.91 ± 0.48
8. 10 p.m. H	115.54 ± 0.75	117.25 ± 0.47
1	AB (–3.40%, p < 0.05)	AC (–1.39%, p < 0.05)
2	AC (–2.29%, p < 0.02)	AD (–2.25%, p < 0.01)
3	AE (–3.19%, p < 0.001)	AF (–0.97%, p < 0.05)
4	AF (–1.94%, p < 0.05)	AG (–1.49%, p < 0.02)
5	AG (–2.41%, p < 0.05)	AH (–1.20%, p <0.05)
6	AH (–2.01%, p < 0.05)	
7	EF (+1.29%, p < 0.05)	

Note: The symbols are the same as in Table 1.

inclusive, a decrease in MAP was recorded. The maximum decrease in MAP was detected at 4 p.m. relative to 8 a-m. (–6.56%, p < 0.001), and the minimum – at 10 a.m. – relative to 8 a.m. (–4.27%, p < 0.02). At 10 p.m., the minimum MAP value was obtained (67.40 ± 1.38 mmHg). This value was found to be significantly lower compared to 12 noon, 4 p.m. and 6 p. m. During fasting, 2 acrophases were detected, namely: at 8 a.m. and 10 p.m. Evening acrophase was less pronounced compared to morning (–3.32%, p < 0.01). From 8 a.m. to 8 p.m. inclusive, a decrease in MAP was detected. The maximum significant decrease in MAP relative to 8 a.m. was detected at 4 p.m. (–5.18%, p < 0.001), and the minimum – at 10 a.m. relative to 8 a.m. (–2.63%, p < 0.05).

The lowest MAP value during fasting was obtained at 2 p.m. (76.65 ± 1.01 mmHg). This value of MAP was significantly lower than the values of the same indicator at 2 p.m. and 10 p.m.

Table 6 shows the changes in SBV before and during fasting. Before fasting, 2 acrophases were detected, namely: at 8 a.m. and 8 p.m. Evening acrophase was found to be significantly less pronounced relative to morning acrophase (–1.94%, p < 0.05). From 8 a.m. to 10 p.m., a decrease in SBV was recorded relative to 8 a.m. The maximum significant decrease in SBV relative to 8 a.m. was obtained at 10 a.m. (–3.40%, p < 0.05). The minimum significant decrease in SBV relative to 8 a.m. was detected at 6 p.m. (–1.94%, p < 0.05). During fasting, 2 acrophases were detected, namely: at 8 a.m. and 6 p.m. The morning acrophase of the SBV was significantly greater compared to the evening acrophase (–0.97%, p < 0.05). During the day, a decrease in SBV was recorded relative to 8 a.m. The maximum significant decrease in SBV relative to 8 a.m. was obtained at 2 p.m. (–2.25%, p < 0.01). The minimum value of SBV during diurnal fasting was obtained at 2 p.m. and amounted to 116.01 ± 0.81 ml. Before fasting, 2 MBV acrophases were detected, namely: at 2 p.m. and 4 p.m. (Tab. 7). From 8 a.m. to 2 p.m., an increase in the MBV was registered. From 8 a.m. to 4 p.m. inclusive, an increase in the MBV was registered relative to 8 a.m. The maximum significant increase in the MBV was recorded at 4 p.m. relative to 8 a.m. (+11.30 %; p < 0.01). From 18 a.m. to 10 p.m., a decrease in the MBV was obtained. The maximum significant decrease in the MBV relative to 4 p.m. was detected at 10 p.m. (–9.46%, p < 0.01). Of the 28 probable reliable changes in the MBV, 13 were obtained in our work, namely: 2 – relative to 8 a.m., 5 – relative to 10 o'clock, 3 – relative to 2 p.m. and 3 – relative to 4 p.m. During fasting, sitting (Tab. 7), 2 MBV acrophases were detected, namely: at 8 a.m. and 8 p.m. The evening was registered more pronounced compared to the morning. At 12 noon, the minimum value of the MBV was

Table 7. Change in the minute volume of blood before and during fasting, sitting. (M ± m), n = 14

Time of day	Minute blood volume (MBV), ml.	
	Before fasting	**During fasting**
1. 8 a.m. A	6.46 ± 0.18	6.91 ± 0.17
2. 10 a.m. B	6.37 ± 0.13	6.80 ± 0.17
3. 12 noon C	6.84 ± 0.16	6.55 ± 0.15
4. 2 p.m. D	7.15 ± 0.18	6.74 ± 0.14
5. 4 p.m. E	7.19 ± 0.21	6.91 ± 0.10
6. 6 p.m. F	6.71 ± 0.11	7.10 ± 0.10
7. 8 p.m. G	6.75 ± 0.12	7.15 ± 0.12
8. 10 p.m. H	6.51 ± 0.15	7.10 ± 0.1 0
1	AD (+10.68%, p < 0.01)	CE (+5.49%, p < 0.05)
2	AE (+11.30%, p < 0.01)	CF (+8.39%, p < 0.001)
3	BC (+7.37%, p < 0.02)	CG (+9.16%, p < 0.001)
4	BD (+12.24%, p < 0.001)	CH (+8.39%, p < 0.02)
5	BE (+12.87%, p < 0.001)	DF (+5.34%, p < 0.05)
6	BF (+5.33%, p < 0.05)	DG (+6.08%, p < 0.02)
7	BG (+5.96%, p < 0.02)	
8	DF (–6.16%, p < 0.05)	
9	DG (–5.60%, p < 0.05)	
10	DH (–8.96%, p < 0.01)	
11	EF (–6.68%, p < 0. 05)	
12	EG (–6.12%, p < 0.05)	
13	EH (–9.46%, p < 0.01)	

Note: The symbols are the same as in Table 1.

Table 8. The change in the coefficient of economization of blood circulation before and during fasting. (M ± m), n = 14

Time of day	The coefficient of economization of blood circulation (CEBC), relative units	
	Before fasting	**During fasting**
1. 8 a.m. A	1790.42 ± 65.39	1762.57 ± 71.27
2. 10 a.m. B	1740.64 ± 98.48	1827.57 ± 59.04
3. 12 noon C	1893.42 ± 93.62	1765.50 ± 76.72
4. 2 p.m. D	2080.07 ± 145.13	1742.14 ± 57.39
5. 4 p.m. E	1935.42 ± 84.68	1844.50 ± 61.55
6. 6 p.m. F	1984.14 ± 74.17	1901.00 ± 81.70
7. 8 p.m. G	1741.14 ± 63.19	1913.92 ± 73.39
8. 10 p.m. H	1860.28 ± 40.85	1844.85 ± 78.56
1	AD (+16.17%, $p < 0.05$)	DG (+9.86%, $p < 0.05$)
2	AF (+10.81%, $p < 0.05$)	
3	BD (–19.5%, $p < 0.05$)	
4	BF (+13.98%, $p < 0.05$)	
5	DG (–16.3%, $p < 0.05$)	
6	EG (–10.04%, $p < 0.05$)	
7	FG (–12.25%, $p < 0.02$)	

Note: The symbols are the same as in Table 1.

Table 9. Changing the double product before and during fasting while sitting. (M ± m), n = 14

Time of day	Double product (DP), relative units	
	Before fasting	**During fasting**
1. 8 a.m. A	4303. 90 ± 126.93	4780.82 ± 130.06
2. 10 a.m. B	4139.07 ± 81.62	4604.45 ± 127.49
3. 12 noon C	4421.55 ± 118.52	4338.69 ± 83.87
4. 2 p.m. D	4583.29 ± 124.75	4477.48 ± 89.95
5. 4 p.m. E	4614.35 ± 152.82	4609.35 ± 85.64
6. 6 p.m. F	4322.47 ± 73.92	4776.43 ± 81.24
7. 8 p.m. G	4425.58 ± 104.60	4760.43 ± 74.30
8. 10 p.m. H	3823.11 ± 184.20	4791.98 ± 125.28
1	AH (–11.18%, $p < 0.02$)	AC (–9.25%, $p < 0.01$)
2	BC (+6.82%, $p < 0.05$)	AD (–6.35%, $p < 0.05$)
3	BD (+10.73%, $p < 0.01$)	CE (+6.23%, $p < 0.02$)
4	BE (+11.48%, $p< 0.01$)	CF (+10.08%, $p < 0.001$)
5	BG (+6.92%, $p < 0.02$)	CG (+9.72%, $p < 0.001$)
6	CH (–13.54%, $p < 0.01$)	CH (+10.44%, $p < 0.001$)
7	DF (–5.70%, $p < 0.05$)	DF (+6.67%, $p < 0.02$)
8	DH (–16.59%, $p < 0.001$)	DG (+6.31%, $p < 0.02$)
9	EH (–17.15%, $p < 0.001$)	DH (+7.02%, $p < 0.05$)
10	FH (–11.56%, $p < 0.02$)	
11	GH (–13.62%, $p < 0.01$)	

Note: The symbols are the same as in Table 1.

obtained (6.55 ± 0.15 beats/min). There was an increase in the MBV during fasting at 4 p.m., 6 p.m., 8 p.m. and 10 p.m. to 12 noon.

Two acrophases of CEBC were detected before fasting (Tab. 8), namely: at 2 p.m. and 6 p.m. The first one registered was bigger than the second one. The maximum significant increase in CEBC was detected at 2 p.m. relative to 8 a.m. (+ 16.17%, $p < 0.05$). From 8 a.m. to 2 p.m. inclusive, an increase in the CEBC was registered. From 4 p.m. to 10 p.m., a decrease in CEBC was detected relative to 2 p.m. In the state before fasting during the day, 2 acrophases of CEBC were obtained, namely: at 2 p.m. and 4 p.m. A slight difference was registered between them.

From 10 a.m. to 4 p.m. inclusive, an increase in DP was detected relative to 8 a.m. From 6 p.m. to 10 p.m., a decrease in DP was detected relative to 4 p.m. The maximum number of significant changes was recorded at 10 p.m. relative to 8 a.m., 12 noon, 2 p.m., 4 p.m., 6 p.m. and 8 p.m. During fasting (Tab. 9), 2 acrophases of DP were recorded, namely: at 8 a.m. and 10 p.m. The evening increase was bigger than the morning. From 10 a.m. to 2 p.m. inclusive, an increase in DP was detected relative to 8 a.m. [20].

Two acrophases of SVR were obtained before fasting, sitting (Tab. 10), namely: at 8 a.m. and 8 p.m. The morning acrophase was significantly greater than the evening acrophase (+ 8.37%, $p < 0.05$). During the day, relative to 8 a.m., a decrease in SVR was registered. The maximum significant decrease in the SVR relative to 8 hours was obtained at 12 noon (–10.26%, $p < 0.001$). Relative to 10 a.m., significant changes in the SVR were also obtained during the day, namely: at 12 noon, 2 p.m., 4 p.m. and 10 p.m., relative to 12 noon – at 4 p.m. and 10 p.m., and relative to 2 p.m. – at 4 p.m. and 8 p.m., relative to 4 p.m. at 6 p.m. and 20 p.m. and relative to 6 p.m. and 8 p.m. – at 10 p.m. During fasting, 2 acrophases of SVR were detected, namely: at 8 a.m. and 4 p.m. Morning acrophase was significantly more pronounced compared to daytime acrophase (+5.58%, $p < 0.05$). There was a decrease in SVR relative to 8 a.m., starting from 10 a.m. As can be seen from Table 11, the maximum number of reliable changes in the results was recorded at 10 a.m. (7), then at 2 p.m. (6). In the remaining hours, namely: at 12 noon, 6 p.m., 8 p.m. and 10 p.m. (5). The

Table 10. Change in the systemic vascular resistance before and during fasting, sitting (M ± m), n = 14

Time of day	Systemic vascular resistance (SVR)	
	Before fasting	**During fasting.**
1. 8 a.m. A	979417.71 ± 29822.71	950603.21 ± 22230.85
2. 10 a.m. B	948006.07 ± 28129.51	942686.14 ± 30242.20
3. 12 noon C	878951.35 ± 26027.02	946067.35 ± 27441.62
4. 2 p.m. D	832267.64 ± 18699.17	914874.92 ± 24436.30
5. 4 p.m. E	823140.92 ± 22652.23	897638.92 ± 19667.22
6. 6 p.m. F	880514.64 ± 24625.51	889662.28 ± 14725.95
7. 8 p.m. G	897476.50 ± 24832.67	871349.09 ± 13144.25
8. 10 p.m. H	829.370.50 ± 5997. 61	895038.78 ± 23111.56
1.	AC (–10.26 %, $p < 0.001$)	AE (–5.58 %, $p < 0.05$)
2.	AF (–10.10 %, $p < 0.02$)	AF (–6.42 %, $p < 0.02$)
3.	AG (–8.37 %, $p < 0.05$)	AG (–8.34 %, $p < 0.001$)
4.	BC (–7.29 %, $P < 0.05$)	BG (–7.57 %, $p < 0.02$)
5.	BD (–2.21 %, $p < 0.001$)	CF (–5.97 %, $p < 0.05$)
6.	BF (–7.12 %, $p < 0.05$)	CG (–7.90 %, $p < 0.02$)
7.	BH (–12.52 %, $p < 0.001$)	DG (–4.76 %, $p < 0.001$)
8.	CE (–14.09 %, $p < 0.001$)	
9.	CH (–5.65 %, $p < 0.05$)	
10	DE (–9.27 %, $p < 0.02$)	
11.	DG (+7.83%, $p < 0.05$)	
12.	EF (+16.59 %, $p < 0.001$)	
13.	EH (+9.82%, $p < 0.001$)	
14.	FH (–5.81%, $p < 0.05$)	
15.	GH (–7.59 %, $p < 0.01$)	

Note: The symbols are the same as in Table 1.

Table 11. Statistically significant differences in indicators of the circulatory system before and during fasting, sitting. (M ± m), n = 14

No.	Time of day	Indicator	Before fasting	During fasting	% of changes.	P
1.	8 a.m.	DBP	67.42 ± 0.78	71.57 ± 0.78	+ 6.15	< 0.001
2.	8 a.m.	MAP	78.37 ± 0.99	81.55 ± 0.57	+ 4.05	< 0.01
3.	8 a.m.	MBV	6.46 ± 0.18	6.91 ± 0.17	+ 6.96	< 0.05
4.	8 a.m.	DP	4303.90 ± 126.93	4780.82 ± 130.06	+ 11.08	< 0.02
5.	10 a.m.	SBP	96.14 ± 1.41	100.42 ± 1.48	+ 4.45	< 0.05
6.	10 a.m.	DBP	64.57 ± 1.25	68.92 ± 0.86	+ 6.73	< 0.01
7.	10 a.m.	HR	55. 28 ± 1.25	58.00 ± 0.93	+ 4.92	< 0.05
8.	10 a.m.	MAP	75.03 ± 1.01	79.41 ± 1.07	+ 5.83	< 0.01
9.	10 a.m.	SBV	115.50 ± 0.81	117.97 ± 0.83	+ 2.13	< 0. 05
10.	10 a.m.	MBV	6.37 ± 0.13	6.80 ± 0.17	+ 6.75	< 0.05
11.	10 a.m.	DP	4139.07 ± 81.62	4604.45 ± 127.49	+ 11.24	< 0.001
12.	12 noon	SBP	95.57 ± 1.17	99.50 ± 1.33	+ 4.11	< 0.02
13.	12 noon	DBP	63.92 ± 1.33	67.57 ± 1.09	+ 5.71	< 0.05
14.	12 noon	HR	59.50 ± 1.33	56.35 ± 1.09	– 5.30	< 0.05
15.	12 noon	SBV	115.21 ± 0.69	117.03 ± 0.75	+ 1.57	< 0.05
16.	12 noon	SVR	878951.35 ± 26027.02	946067.35 ± 27441. 62	+ 7.63	< 0.05
17.	2 p.m.	DBP	62.85 ± 1.17	67.04 ± 0.78	+ 6.60	< 0.001
18.	2 p.m.	HR	61.92 ± 1.25	58.50 ± 1.41	– 5.53	< 0.05
19	2 p.m.	MAP	74.00 ± 0.88	76.65 ± 1.01	+ 3.58	< 0.05
20.	2 p.m.	MBV	7.15 ± 0.18	6.74 ± 0.14	– 5.74	< 0.05
21.	2 p.m.	CEBC	2080.07 ±145.13	1742.14 ± 57.39	– 16.25	< 0.02
22.	2 p.m.	SVR	832267.64 ± 18699.17	914874. 92 ± 24436.30	+ 9.92	< 0.01
23.	4 p.m.	SBP	93.64 ± 1.09	98.00 ± 1.64	+ 4.56	< 0.02
24	4 p.m.	DBP	63.07 ± 1.01	67.00 ± 1.09	+ 6.23	< 0.01
25.	4 p.m.	MAP	73.23 ± 0.99	77.33 ± 1.01	+ 5.59	< 0.01
26.	6 p.m.	SBP	96.42 ± 0.86	99.64 ± 0.70	+ 3.33	< 0.01
27.	6 p.m.	MAP	73.53 ± 0.91	78.71 ± 0.84	+ 7.04	< 0.001
28.	6 p.m.	SBV	115.62 ± 0.49	117.52 ± 0.36	+ 1.64	< 0.001
29.	6 p.m.	MBV	6.71 ± 0.11	7.10 ± 0.10	+ 5.81	< 0.01
30.	6 p.m.	DP	4322.47 ± 73.92	4776.43 ± 81.24	+ 10.50	< 0.001
31.	8 p.m.	SBP	95.21 ± 1.64	98.57 ± 0.86	+ 3.52	< 0.05
32.	8 p.m.	SBV	115.07 ± 0.92	116.91 ± 0.48	+ 1.59	< 0.05
33.	8 p.m.	MBV	6.75 ± 0.12	7.15 ± 0.12	+ 5.92	< 0.02
34.	8 p.m.	CEBC	1741.14 ± 63.19	1913.92 ± 73.39	+ 9.92	< 0.05
35.	8 p.m.	DP	4425.58 ±104.69	4760.43 ± 74.30	+ 7.56	< 0.02
36.	10 p.m.	DBP	63.21 ± 1.41	68.64 ± 0.86	+ 8.59	< 0.001
37.	10 p.m.	HR	56.42 ± 1.48	60.78 ± 1.48	+ 7.72	< 0.05
38.	10 p.m.	SBV	115.54 ± 0.75	117.25 ± 0.47	+ 1.48	< 0.05
39.	10 p.m.	MBV	6.51 ± 0.15	7.10 ± 0.17	+ 9.06	< 0.01
40.	10 p.m.	SVR	829370. 50 ± 5997.61	895038.78 ± 23111.56	+ 17.91	< 0.01

minimum number of significant changes in the results was detected at 8 a.m. (4) and 4 p.m. (3).

Of the 10 parameters under study, DBP significantly changed 6 times, namely, at 8 a.m., 10 a.m., 12 noon, 2 p.m., 4 p.m., and 10 p.m., and MBV also significantly changed 6 times at 8 a.m., 10 a.m., 12 noon, 2 p.m., 4 p.m., and 10 p.m. SBP – 5 times – at 10 a.m., 12 noon, 4 p.m., 6 p.m. and 8 p.m., SDV – 5 times – at 10 a.m., 12 noon, 6 p.m., 8 p.m. and 10 p.m. and MAP changed significantly 5 times – at 8 a.m., 10 a.m., 2 p.m., 4 p.m. and 6 p.m. HR changed significantly 4 times – at 10 a.m., 12 noon, 2 p.m. and 10 p.m. and DP – 4 times – at 8 a.m., 10 a.m., 6 p.m. and 8 p.m. SVR – 3 times – at 12 noon, 2 p.m. and 10 p.m. CEBC changed significantly 2 times – at 2 p.m. and 8 p.m.

It is known from the literature that fasting affects the indicators of the circulatory system, namely: blood pressure, heart rate, blood composition, and so on. Fasting is a set of human sensations associated with the body's need for food intake [8]. Fasting is associated with the cessation of eating any food [9]. Some authors [13] suggest that fasting can be considered as a typical, albeit somewhat delayed, stress reaction associated with the release of catecholamines (adrenaline and norepinephrine). As is known, the stress reaction develops in three stages, namely: tension, resistance and exhaustion. In the first stage, the body reacts to the presented load uneconomically, with excessive expenditure of energy [21].

The onset times of acrophases (maximal values) of HR in the state before - and during fasting differed sharply (Tab. 3). Statistically significant changes in heart rate were obtained during fasting compared with the initial period, namely: at 10 a.m. and 10 p.m. – an increase in HR, and at 12 noon and 2 p.m. – a decrease in HR. The remaining indicators are calculated, depending on HR, SBP and DBP. Apparently, the body reacts to

a stressful situation in this way. Heart rate is a universal indicator of human health, it should be taken into account that the refusal of food places high demands on the work of many vital body systems (heart, endocrine glands, pressure)

Conclusions

The presence of 2 acrophases, not equal in size, was recorded. There were also significant changes between the hours in the state of the body before and during fasting. Significant changes in the state of the organism during the fasting period relative to the initial period were revealed during all 8-time intervals. Our work revealed a significant increase in all indicators of the cardiovascular system during fasting compared to the baseline period. This fact is probably consistent with the presence of the first phase of the general adaptation syndrome, a large release of catecholamines. The presence of two maximal values of SBP and DBP during the day were detected. Acrophases of SBP and DBP were registered at 8 a.m. and 6 p.m. (or 8 p.m., 10 p.m.), which is associated with the release of adrenaline into the blood at this time of day. During fasting, a significant increase in SBP and DBP was found in all eight time periods relative to the baseline period. Apparently, fasting is a stressful reaction for the body. It was shown that there were two maximum heart rate values during the day, both before and during diurnal fasting.

Conflict of interest

The author confirms, that there are no conflicts of interest to disclose.

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