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A Study on the Influence of Pulse Wave Shape and Pulse Rate Variation on the Menstrual Cycle and Dysmenorrhea

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Abstract: Background: Pulse wave, as a carrier of human hemodynamic parameters, can reflect the hemodynamic state of the menstrual cycle. Objective: To explore the influence of pulse wave shape and pulse rate variation on menstrual cycle and dysmenorrhea. Methods: The pulse waveform data of 20 women during the whole menstrual cycle were collected and monitored, and the waveform characteristics and pulse rate variation characteristics were calculated. Results: The characteristic parameters of waveform and pulse rate variation increased first and then decreased with the development of the menstrual cycle. Characteristics were associated with dysmenorrhea at different stages of the menstrual cycle. Conclusions: The findings of this study highlight the physiological significance of pulse wave characteristics and heart rate variability parameters in relation to the menstrual cycle and dysmenorrhea. These results provide new insights into the physiological mechanisms underlying pulse wave changes during the menstrual cycle and offer potential guidance for the diagnosis and treatment of dysmenorrhea.

1. Introduction

Menstruation refers to periodic bleeding from the endometrium that occurs at approximately monthly intervals and stops naturally within a defined number of days [1-2]. Dysmenorrhea refers to the periodic lower abdominal pain that occurs during or around the time of a woman's menstrual period.

As a carrier of human hemodynamic parameters, pulse wave can reflect the hemodynamic state of the menstrual cycle. The pulse rate variability of pulse wave means that there will be small differences between two adjacent pulse cycles [3-4]. The pulse rate variability index can quantify the autonomic nerve activity into a numerical value [5-6], which can well reflect the changes of hemodynamic state in the whole menstrual cycle.

This study will explore the difference of pulse wave sign parameters in the whole menstrual cycle of women from two aspects of pulse wave shape characteristics and pulse rate variation characteristics, so as to deeply understand the pulse wave related changes in the process of female menstrual cycle and screen pulse wave signs with application value.

2. Materials and methods

2.1. Subjects and specimens

This study divided the menstrual cycle into three stages: premenstrual (secretory period, 21-28), menstrual period (0-7), and postmenstrual period (proliferative period, 7-14). The subjects of this study were female students studying in Beijing University of Technology from 2021 to 2023, and their pulse wave data were collected during the above menstrual cycle. Each subject was collected for 5 minutes, and a total of 20 cases were collected.

As shown in Table 1, two types of pulse wave characteristic parameters were extracted in this study: pulse wave shape characteristic parameter and pulse wave rate variability characteristic parameter.

Table 1. Pulse wave sign parameters of the menstrual cycle.

Type	Characteristic parameters of menstrual cycle
Pulse wave characteristics	Main wave abscissa (a), dicrotic trough abscissa (c), dicrotic wave ordinate (d)
Characteristics of pulse rate variability	Time domain: pNN50, SDNN, RMSSD, $\overline{PP}$

Notes: a, the abscissa of the main wave peak; c, dicrotic trough abscissa; d, longitudinal coordinates of dicrotic wave peak; PNN50, the proportion of the number of adjacent PP intervals with a difference greater than 50ms in the total number of adjacent PP intervals; SDNN, standard deviation of PP interval sequence; , is the mean pulse interval.

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2.2. Analysis of pulse wave parameters in the whole menstrual cycle

From the subjects' pulse wave signal recordings, data were extracted for 5 minutes.

Visual analysis of pulse wave shape development in the whole menstrual cycle.

Subjects were divided into three groups: premenstrual, menstrual and postmenstrual. The waveform development of each stage was visualized and compared. As shown in Figure 1, c and d showed a trend of first increasing and then decreasing with the development of premenstrual, middle and late periods.

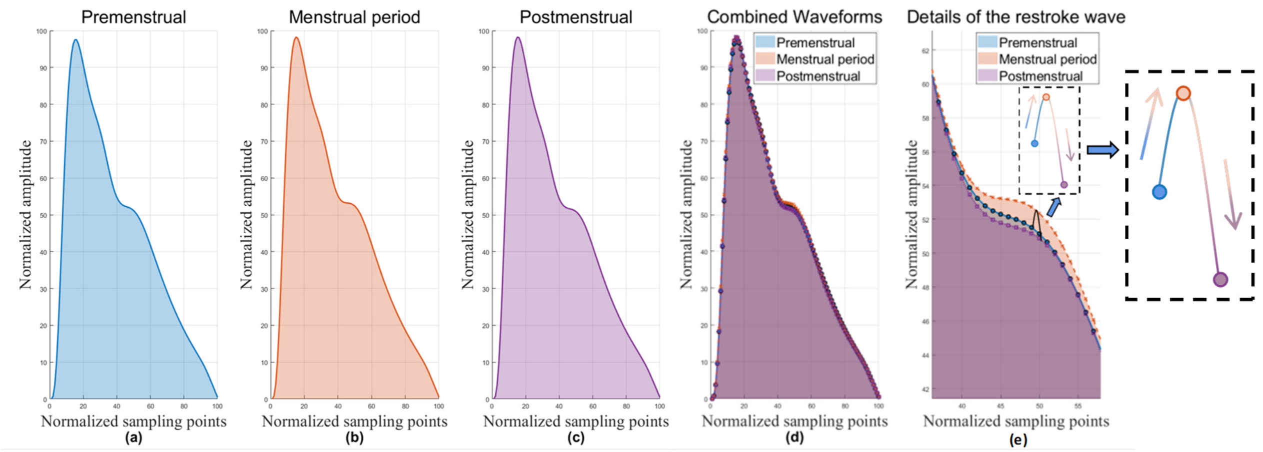

Fig. 1. Subjects' premenstrual, midmenstrual, late menstrual, and three periods of composite waveform (from left to right). (a) shows the premenstrual waveform of the menstrual cycle; (b) is the waveform of menstrual phase in the menstrual cycle; (c) is the waveform of the late menstrual phase of the menstrual cycle; (d) is the comprehensive waveform of premenstrual, middle and late menstrual cycle; (e) Detail map of dicrotic waves in the early, middle and late stages of the menstrual cycle.

The subjects were classified according to the visual analogue scale (VAS), and the score of 4-10 was defined as dysmenorrhea group. A score of 3 or less was considered as the control group. As shown in Table 2, the Mann-Whitney U test in non-parametric tests was used within the same menstrual cycle phase. Characteristics a and d were significantly different between dysmenorrhea group and control group in three periods. There was a significant difference in feature c between the mid-and late-menstrual periods.

Table 2. Non-parametric rank sum test of pulse wave shape between control group and dysmenorrhea group.

Period	Characteristic	Dysmenorrhea group	Control group	Z	P
	a	17.00(16.00,20.75)	15.00(15.00,17.00)	3.02	0.003**
Premenstrual period	c	44.00(43.00,52.75)	43.00(41.00,46.00)	1.67	0.95
	d	50.29(47.81,56.60)	42.24(35.89,49.37)	3.15	0.002**
	a	16.50(16.00,19.00)	15.00(14.00,16.00)	3.49	0.000**
Menstrual period	c	44.00(41.75,50.75)	42.00(39.00,44.00)	2.61	0.009**
	d	41.43(37.29,48.81)	54.42(48.99,58.23)	4.05	0.000**
	a	17.00(16.00,18.50)	15.00(14.00,16.00)	3.44	0.001**
Postmenstrual period	c	43.50(41.75,49.00)	42.00(40.00,44.00)	2.29	0.022*
	d	43.50(39.75,50.04)	52.40(47.48,59.05)	3.27	0.001**

Note: *, $P<0.05$; **, $P<0.01$; Z, Standardized test statistics; P, progressive significance; a, abscissa of main wave peak; c, dicrotic trough abscissa; d, longitudinal coordinates of dicrotic wave peak.

Analysis of the variation characteristics of pulse rate in the whole menstrual cycle.

As shown in Figure 2, with the development of the menstrual cycle from premenstrual to postmenstrual, the time domain characteristics of pulse rate variability all increased first and then decreased.

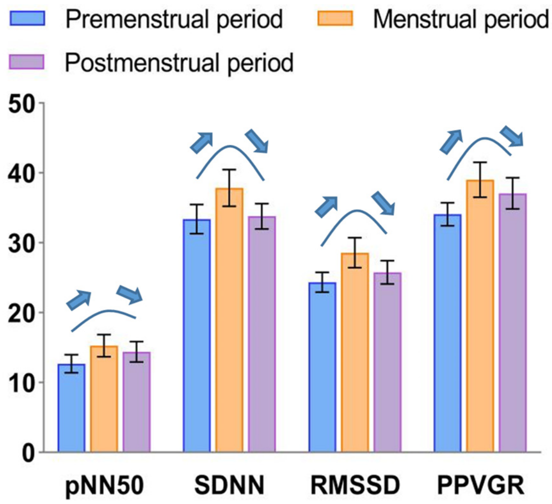

Fig. 2. A trend chart of the time domain characteristics of menstrual cycle pulse rate variation.

As shown in Table 3, by Mann-Whitney U test, there were significant differences in the time domain characteristics of pulse rate variation between the dysmenorrhea group and the control group in the premenstrual, menstrual and late menstrual phases of the menstrual cycle, respectively, indicating that dysmenorrhea or not had an impact on the time domain characteristics parameters of pulse rate variation.

Table 3. Non-parametric rank sum test of pulse wave shape between control group and dysmenorrhea group.

Period	Characteristic	Dysmenorrhea group	Control group	Z	P
Premenstrual period	pNN50	2.94(0.00,6.30)	8.00(2.58,19.18)	-2.84	0.004**
	SDNN	24.05(14.67,26.58)	29.55(20.56,40.78)	-2.97	0.003**
	RMSSD	17.98(9.38,19.83)	20.18(14.66,28.69)	-2.15	0.031*
	$\overline{PP}$	25.80(13.71,28.55)	29.12(21.93,43.61)	-2.25	0.025*
Menstrual period	pNN50	2.26(0.00,19.00)	11.03(4.22,26.83)	-3.98	0.000**
	SDNN	19.48(14.61,23.93)	32.54(24.38,47.39)	-4.69	0.000**
	RMSSD	13.98(11.39,17.02)	22.19(17.96,33.89)	-4.59	0.000**
	$\overline{PP}$	21.20(15.49,25.14)	33.45(24.63,49.34)	-4.58	0.000**
Postmenstrual period	pNN50	1.30(0.54,5.90)	12.76(2.61,26.42)	-4.16	0.000**
	SDNN	19.42(16.80,26.18)	31.51(22.45,45.97)	-4.57	0.000*
	RMSSD	14.19(11.77,18.75)	22.53(16.35,30.83)	-3.97	0.000**
	$\overline{PP}$	20.33(17.28,27.79)	33.17(24.15,48.41)	-4.14	0.000**

Note: *, P＜0.05; **, P＜0.01; Z, Standardized test statistics; P, progressive significance .

3. Results

According to Figure 1, the waveform characteristics c and d gradually changed from low to high and then back to low with the menstrual cycle. Figure 2 shows that the variation trend of the time domain characteristics of pulse rate variation (PNN50, SDNN, RMSSD and $\overline{PP}$) increased first and then decreased, which further supports the effect of menstrual cycle on pulse wave characteristics parameters.

As shown in Tables 2 and 3, the waveform characteristics of pulse wave (a,c,d) and the time domain characteristics of pulse rate variation (PNN50, SDNN, RMSSD and $\overline{PP}$) in the premenstrual, middle and late periods of the menstrual cycle were significantly different between the dysmenorrhea group and the control group, indicating that dysmenorrhea had an impact on the waveform and the time domain characteristics of pulse rate variation.

4. Discussion

Some studies have focused on the impact of the menstrual cycle on cardiovascular function [7] and the association of pulse waveform characteristics with the menstrual cycle [8]. In addition, studies have used circulatory variability analysis methods such as pulse rate variability (HRV) or blood pressure variability, To assess the effect of the menstrual cycle [9-10]. In this study, it can be observed that the waveform parameters c and d change from low to high and then back to low. With the decrease of the peripheral resistance and the improvement of the elasticity of the vessel wall, the wave velocity of the reflected wave decreases gradually, and the parameters change from low to high. With the increase of the peripheral resistance and the deterioration of the elasticity of the vessel wall, the wave velocity of the reflected wave gradually increased from high to low.

At the same time, when the menstrual event comes, the body initiates a high degree of sympathetic activity, reflected by an increase in heart rate variability. However, with the end of the menstrual event, the increase in parasympathetic activity is higher relative to sympathetic activity, making these parameters lower.

In addition, this study found that pulse wave characteristics and pulse rate characteristics have an impact on dysmenorrhea, which may be related to vascular tone, hemodynamic abnormalities, and changes in autonomic nervous function. These findings have important implications for further understanding the physiological mechanisms of pulse wave variation throughout the menstrual cycle, which can help provide more data and observations in related research fields.

5. Conclusion

The results of this study provide detailed information about pulse wave changes throughout the menstrual cycle, and provide important support for understanding the relationship between pulse waveform characteristics and menstrual cycle and its physiological mechanism. The correlation between the characteristics of pulse waveform and pulse rate variation and dysmenorrhea is found, which provides potential guidance for the diagnosis and treatment of dysmenorrhea, so as to promote the further development of women's health and cardiovascular health.

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