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Original Article

GERMAN VOLUME TRAINING AND MENSTRUAL CYCLE PHASES: THE EFFECT ON THE SYMPATHOVAGAL BALANCE OF YOUNG WOMEN

GERMAN VOLUME TRAINING E CICLO MENSTRUAL: O EFEITO NO BALANÇO SIMPATOVAGAL DE MULHERES JOVENS

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RESUMO
O presente estudo teve como objetivo avaliar o efeito do *German Volume Training* (GVT) na variabilidade da frequência cardíaca (VFC) nas diferentes fases do ciclo menstrual (CM) em mulheres jovens com experiencia em treinamento resistido. **Métodos:** Nove mulheres (idade: 25,88±3,13 anos), realizaram dez series (*German Volume Training* – carga 80% 1RM) até a falha concêntrica com 1 minuto de intervalo no *Leg Press* 45°. As fases do CM foram determinadas utilizando: aplicativo Flo flem®, concentração sanguínea estrogênio e progesterona, e *Clearblue* Digital (ovulação). A VFC foi coletada antes do GVT, imediatamente após, 24 e 48 horas após. A VFC foi analisada nos domínios do tempo (FC; SDNN; RMSSD e PNN50) e frequência (LF; HF e LF:HF). **Resultados:** As concentrações de progesterona foram maiores (p = 0,0001) na fase lútea. A carga do teste 1RM foi maior na fase lútea quando comparado com a fase folicular: 174,67±53,89 kg e 167,67±48,74 kg, respectivamente (p = 0,0065). A VFC não demonstrou diferença estatística entre as fases do CM (p > 0,05) e não foi observado diferença estática analisando 24 e 48 horas após (p > 0,05). **Conclusão:** Não houve diferença na performance e na VFC entre as fases do CM.
Palavras-chave: Treinamento resistido, Fase folicular, Variabilidade da frequência cardíaca, Fase lútea.

ABSTRACT
The present study aims to evaluate the effect of German Volume Training (GVT) on heart rate variability (HRV) at different stages of the menstrual cycle (MC) in young women with resistance training experience. **Methods:** Nine women (age: 25.88 ±3.13 years) performed ten sets (German Volume Training - load 80% 1RM) until concentric failure with 1 minute of rest on Leg Press 45°. The MC phases were determined using the mobile application Flo flem®, estrogen and progesterone blood concentration, and Clearblue Digital (ovulation). The HRV was collected before GVT, immediately after, 24 and 48 hours after. Time (HR, SDNN, RMSSD, and PNN50) and frequency (LF; HF and LF: HF) domains were analyzed. **Results:** Progesterone concentration was higher (p = 0.0001) in the luteal phase. The load in the 1RM test was higher in the luteal phase compared to the follicular phase: 174.67 (53.89) kg and 167.67 (48.74) kg, respectively (p = 0.0065) and HRV did not demonstrate a statistical difference between the MC phases (p>0.05). No statistical difference was observed analyzing the 24 and 48 Hours (p>0.05). **Conclusion:** Heart rate variability did not differ between MC phases.
Keywords: Resistance training, Follicular Phase, Heart rate variability, Luteal phase.

Introduction

The menstrual cycle in fertile women involves two main phases: the follicular phase (FP) and the luteal phase (LP)[1]. During FP, which begins with menstrual flow, there is a significant rise in levels of Follicle-Stimulating Hormone (FSH), estrogen (E2), and Luteinizing Hormone (LH), persisting for approximately two weeks[1]. Conversely, LP starts around the 14th day after the menstrual cycle begins and extends until the next cycle begins, characterized by elevated progesterone (P4) levels[1].

Estrogen and progesterone play pivotal roles in physiological processes, including those related to the cardiovascular[2–4]. Estrogen can influence blood pressure, heart rate, and blood flow, promoting endothelium-dependent vasodilation[2] and affecting cardiac excitability, possibly by antagonizing calcium or inhibiting the angiotensin-converting enzyme[2]. Both hormones stimulate the renin-angiotensin system, which may lead to fluid retention towards the end of the menstrual cycle[3]. However, the high progesterone phase of the menstrual cycle (luteal phase) may adversely affect performance during prolonged physical exercise, especially in warm environments, by increasing body temperature and cardiovascular strain, thereby reducing time to fatigue[4,5].

The interaction between the menstrual cycle and physical training has drawn interest from the scientific community due to its potential influence on women's cardiovascular capacity[6,7] and muscle strength[8]. In this context, German Volume Training (GVT) is an advanced method to increase muscle mass and strength[5]. It involves ten sets of 10 repetitions in a single exercise, performed at intensities ranging from 60 to 80% of 1-RM with 60-second rest intervals between sets [5].

Thus, heart rate variability (HRV) is a variable that may be influenced by the acute effects of physical exercise during different menstrual cycle phases[6,7]. HRV reflects cardiovascular autonomic regulation and is a sensitive indicator of physiological adaptation and cardiovascular health[6], providing quantitative insights into sympathetic and parasympathetic modulation[6]. It has been demonstrated that cardiac vagal activity is reduced during the follicular phase compared to the luteal phase, indicating potentially distinct autonomic responses to exercise across menstrual cycle phases[7]. Moreover, monitoring HRV before and after training can facilitate prescribing training loads[9].

Despite the growing interest in the interaction between the menstrual cycle, physical training, and HRV, there still needs to be a significant gap in the literature regarding the effects of GVT on HRV across different menstrual cycle phases. Understanding the physiological repercussions of GVT application in these phases is crucial for optimizing training load prescriptions for women. Therefore, the main purpose of this study is to evaluate the effect of GVT on HRV responses during different menstrual cycle phases in young women experienced in strength training, with the potential to provide valuable insights that could significantly benefit research and practice in exercise physiology, sports science, and women's health.

Methods

Sample

Participants were recruited via social media and personal invitations and selected using convenience sampling. Nine physically active women (age 25.88±3.13 years; height: 1.65±0.05 meters; body mass in late follicular phase: 65.29±16.97 kg; and mid-luteal phase: 65.46±17.12 kg) participated in the study. All participants had at least one year of experience in strength training, attended sessions at least three times a week, and were not using birth control medication. The average menstrual cycle length was 28.78±0.83 days.

The exclusion criteria were women who had any orthopedic issues, who used some medication or beverage that could influence their physical performance or heart rate, women who did not ovulate and women with progesterone increase. The participants were instructed not to perform physical activity 48 hours before the experimental procedure. They were informed about the benefits and risks of the study before signing a free and informed consent form. The study was approved by the Ethics and Research Committee of the Federal University of Espírito Santo (nº 14250719.0.0000.5542) and adhered to the ethical principles outlined in the Declaration of Helsinki.

Procedures

Determining Follicular and Luteal Phase

Blood samples were collected after at least 8 hours of fasting to identify the concentration of estrogen and progesterone during the late follicular and mid-luteal phases. The first day of the cycle (the beginning of menstruation) was used to establish the experimental period. The participants were instructed to track their MC using the mobile application Flo flem®, as described in our previous study[10]. All participants started the tests after identifying the first day of the MC and the increase in luteinizing hormone (LH), which is the primary marker of ovulation and the phase change of the cycle.

Determining estrogen and progesterone concentration and ovulation tests

Serum analysis of estrogen and progesterone in late follicular and mid-luteal phases was conducted using collected blood samples and subsequent analysis. The samples collected contained blood from antecubital veins and were placed in tubes from Vacuette with separator gel (manufactured by Greiner Bio-One, Brazil-Americana). The samples consisted of 5 ml and were centrifuged at 3.500 rpm for 15 minutes at 8°C[10].

Besides hormonal analysis, an ovulation test was also done using Clearblue Digital (a brand belonging to Swiss Precision Diagnostics GmbH). This device can detect increases in the luteinizing hormone (LH) in urine. This test began as soon as a participant observed an increase in vaginal discharge and through updates on the mobile app Flo flem®. This procedure would be monitored for at least four days. During this monitoring process, participants were advised to adopt the following procedures: taking the test right after waking up using urine flow directly and having the device's absorbent end pointing down into the urine flow for 5 to 7 seconds. When the device displayed positive detection for ovulation, the previous experimental procedures would be adjusted[10].

Evaluation of Heart Rate Variability

The participants were instructed to rest in the dorsal decubitus position for 10 minutes. After this period, samples were collected before the exercise, immediately after, 24 and 48 hours after; the collection of samples took 5 minutes. The device Polar (model H10, Kempele, Finland; sampling frequency of 1000hz) obtained the analysis to record and monitor R-R intervals in milliseconds. The application Elite HRV®, version 5.5.4, was used to register the HRV data. After the registry, the data was extracted in txt format and analyzed with the software Kubios® (HRV Standard, Kuopio, Finland, version 3.5.0.).

In the time domain were selected: SDNN (standard deviation of NN intervals in a period, expressed in ms), RMSSD (root mean square of the successive differences in normal adjacent NN intervals in a period, expressed in ms), and PNN50 (percentage of adjacent NN intervals that differ by more than 50 ms)[11].

In the frequency domain, low-frequency (LF: 0.04 to 0.15 Hz) and high-frequency (HF: 0.15 to 0.4 Hz) components were evaluated (sympathetic and parasympathetic modulation, respectively), as well as sympathovagal balance (LF/HF), which is calculated according to normalized LF and HF. Normalized units (nu) are obtained by dividing a component's potency by the total potency (from which VLF will be subtracted) and multiplying by 100[11]. For the moments pre, 24, and 48 hours post, the participants were instructed to go to the bathroom, urinate, and then rest for 10 minutes; after that, HRV collection would start[11].

Familiarization

In the first session, participants were familiarized with the Leg Press 45° machine, performing three sets of ten repetitions with one-minute intervals between each set using only the platform's weight (90 kg).

Rating of Perceived Exertion

To evaluate the Rating of Perceived Exertion Scale (RPE), the OMNI-RES scale was used to classify one's subjective perception of strain; this scale varied from 0 to 10, with 0 meaning "extremely easy" and 10 meaning "extremely hard"[12]. The classifications given for each set were noted and analyzed.

One-Repetition Maximum (1RM) Test

The participants were asked about the weight they used to perform the ten maximum repetitions on the Leg Press 45° machine. After the weight used was known, a calculus was done to estimate the corresponding load to the 1RM test[16]. The weight was determined to correspond to 50% to 80% of the maximum load estimated. Next, the angle of 90º of the knees was measured using a goniometer and marked as the reference point for a range of motion.

Following up, the participants performed a specific warm-up on the Leg Press 45° machine, consisting of 2 sets: one set of ten repetitions with 50% of the estimated weight and a 2-minute rest interval. The second set was performed with 80% of the maximum load estimated.

As the warm-up was completed, five attempts were made to establish the maximum load to execute one repetition, and a 5-minute rest interval was established between each set. Load progression, if necessary, respected the quality of the movement and the participants' feedback on their condition for doing one or more repetitions with the imposed load and RPE scale by the OMNI-Resistance Exercise Scale. A 20% load increase would occur if a participant mentioned their subjective perception as below 5 (OMNI-RES). If the rate were higher, 10% of the load would be increased[10]. During the tests, the participants were accompanied by physical education professionals and received verbal encouragement while they attempted the sets[13]. This end protocol was carried out both in the follicular and the luteal phase.

After 48 hours, a 1-RM retest was done to establish an intraclass correlation coefficient (ICC) of 0.98, which is classified as excellent. The same protocol was used, as mentioned previously. The first attempt utilized the highest load established in the 1-RM test. If necessary, the load would be increased with each attempt[14].

German Volume Training

A set of ten repetitions was performed until a 90-degree angle. The load used was 50% of 1-RM obtained in the 1-RM test. A 60-second interval was given between the warm-up and the protocol.

GVT Protocol

After a warm-up, the load was readjusted to 80% of the 1-RM, and the GVT protocol started. This protocol had ten sets and would continue until concentric failure, with 60-second intervals between each set. The participant's PSE was written down at the end of each set.

Statistical analysis

The data are presented as mean ± standard deviation. Shapiro-Wilk normality test was conducted. Since a normal distribution of data was detected, the Student's t-test was applied to the paired samples to analyze the data on estrogen and progesterone blood concentration, the data obtained in the 1-RM test, and the session's total volume. Furthermore, to analyze HRV, a two-way ANOVA with a repetition factor was used to evaluate the interaction effect of the following variants: heart rate (HR), LF (nu), HF (nu), LF: HF, SDNN, RMSSD, and PNN50. Tukey´s *post-hoc* was also adopted to identify differences between MC phases and moments (time); the latter was analyzed in the pre-moment, post-moment, 24 and 48-hour post. The intraclass correlation coefficient (ICC) was applied to establish the reproducibility of the 1 RM test. The significance level was set as $p<0.05$. The effect size (ES) used was Hedges' g to determine the magnitude difference between the variants. An effect size between 0.20 and 0.49

was considered small, a medium size of 0.50 to 0.79, and an effect size ≥0.80 was considered the highest effect magnitude. The software GraphPad Prism (8.4.3) was used for data analysis.

Results

Table 1 shows hormonal values and 1-RM test across MC phases. For hormonal concentrations, a higher progesterone concentration was observed in LF compared to FP (p=0.0001). No statistical difference was observed in estrogen concentration across phases. In the 1RM test, a significantly higher value was observed in the LP compared to FP (p=0.006).

Table 1 – Blood concentration of estrogen and progesterone hormones and 1RM test values.

	Follicular Phase	**Luteal Phase**
Estrogen (pmol.L^{-1})	478.9±1.11	681.8±406.2
Progesterone (nmolL.L^{-1})	1.54±1.11	46.35±8.19*
1-RM test (kg)	168±49	175±54*

Notes: Values are given as mean ± SD. *Statistical difference compared to the follicular phase.
Source: Authors

For time domain (HRV), repeated-measures two-way ANOVA revealed a significant time effect on HR ($F_{(3. 48)}$ = 73.07; P<0.0001), SDNN ($F_{(2.157, 34.52)}$ = 22.96; P<0.0001), RMSSD ($F_{(2.066, 33.05)}$ = 23.72; P<0.0001) and PNN50% ($F_{(2.289, 36.62)}$ = 35,18; P<0,0001). A significant difference is observed in the moment after the exercise (post) compared to all other moments (pre, 24h, and 48h) (Table 2). However, no significant difference was displayed between pre-, 24, and 48 hours. The interaction effect between time and MC phases was not observed (P > 0.05). There was also no statistical effect between the MC phases (P>0.05).

Table 2 - Heart Rate Variability in the Time Domain

HRV	MC Phases	Pre	Post	24 h	48 h
HR (bpm)	Follicular Phase	64.22 ± 7.00	90.56 ± 7.21#	62.67 ± 9.26@	64.67 ± 9.31@
	ES		g= 3.53	g= -0.18	g= 0.05
	Luteal Phase	65.00 ± 6.86	88.89 ± 5.30#	68.78 ± 8.97@	67.56 ± 9.11@
	ES		g= 1.32	g= 0.06	g= 0.029
SDNN (ms)	Follicular Phase	66.84 ± 38.11	21.01 ± 6.43#	78.39 ± 34.83@	75.72 ± 36.78@
	ES		g= -1.60	g= 0.30	g= 0.23
	Luteal Phase	71.13 ± 36.85	19.21 ± 5.72#	67.68 ± 28.56@	74.06 ± 34.96@
	ES		g= -1.88	g= -0.10	g= 0.08
RMSSD (ms)	Follicular Phase	64.39 ± 24.19	14.03 ± 4.98#	82.87 ± 45.24@	74.44 ± 30.28@
	ES		g= -2.75	g= 0.49	g= 0.35
	Luteal Phase	73.98 ± 26.38	14.43 ± 4.89#	66.17 ± 38.19@	70.74 ± 43.24@
	ES		g= 2.99	g= 0.23	g= 0.09
PNN50 (%)	Follicular Phase	39.15 ± 14.98	0.79 ± 1.27#	42.90 ± 25.05@	39.73 ± 21.17@
	ES		g= -3.44	g= 0.17	g= 0.03
	Luteal Phase	44.46 ± 20.73	0.70 ± 0.95#	33.98 ± 22.42@	36.51 ± 24.19@
	ES		g= -2.84	g= -0.46	g= -0.34

Note: Values are given as mean ± SD. HR = Heart Rate; SDNN = standard deviation of all NN intervals recorded in a period, expressed in milliseconds (ms); RMSSD = root mean square of the successive differences in normal adjacent NN intervals in a period, expressed in ms; PNN50 = represents the percentage of adjacent NN intervals that differ by more than 50 ms. ES = effect size – (post vs. pre), (24h vs. pre), and (48h vs. pre). # Statistical difference from Post (P < 0.05).
Source: Authors.

For the frequency domain (HRV), repeated-measures two-way ANOVA revealed a significant time effect on LF ($F_{(2.179, 34.87)}$ = 4,145; P=0.0215) and HF ($F_{(2.322, 37.15)}$ = 8,692; P=0.0005), but no effect on LF:HF ($F_{(1.049, 16.79)}$ = 3,024; P=0.0990). A significant difference was observed in the post-exercise moment compared to pre (LF) and post compared to 24h and 48h (HF) (Table 3). The interaction effect between time and MC phases was not observed (P>0.05). There was also no statistical effect between the MC phases (P>0.05).

Table 3 - Heart Rate Variability in the Frequency Domain

HRV	MC Phases	Pre	Post	24 h	48 h
LF (nu)	Follicular Phase	50.20 ± 24.80#	78.29 ± 14.47	51.59 ± 17.63	57.71 ± 24.14
	ES		g= 1.32	g= 0.06	g= 0.29
	Luteal Phase	43.77 ± 24.56#	65.28 ± 20.93	52.23 ± 22.79	53.94 ± 25.82
	ES		g= 0.90	g= 0.34	g= 0.38
HF (nu)	Follicular Phase	49.77 ± 24.79#	21.68 ± 14.44	48.39 ± 17.62#	42.27 ± 24.13#
	ES		g= -1.32	g= -0.06	g= -0.29
	Luteal Phase	55.98 ± 24.40#	34.40 ± 20.93	47.17 ± 23.03#	46.05 ± 25.80#
	ES		g= -0.90	g= -0.35	g= -0.38
LF:HF	Follicular Phase	1.85 ± 2.11	7.66 ± 9.70	1.34 ± 0.94	2.41 ± 2.37
	ES		g= 0.79	g= -0.30	g= 0.24
	Luteal Phase	1.58 ± 2.40	3.29 ± 3.07	1.91 ± 2.36	1.96 ± 1.75
	ES		g= 0.59	g= 0.13	g= 0.17

Notes: Values are given as mean ± SD. LF (nu) = low-frequency component, varying between 0.04 Hz and 0.15 Hz; HF (nu) = high-frequency component, varying between 0.15 Hz and 0.4 Hz; LF/HF = ratio of low/high frequency (1.5 - 2.0). ES = effect size—(post vs. pre), (24h vs. pre), and (48h vs. pre). # Statistical difference from Post ($P < 0.05$).
Source: Authors.

Discussion

The present study evaluated the effect of GVT on HRV across different phases of the menstrual cycle in young women. The main findings suggest a significant increase in progesterone levels during the luteal phase compared to the follicular phase, superior performance in the one-repetition maximum (1-RM) test during the luteal phase, and similar effects on HRV across menstrual cycle phases following a session of German Volume Training (GVT) at pre, 24h, and 48h time points.

During the mid-follicular and mid-luteal phases, significantly higher loads were observed during the LP compared to the FP in the 1-RM test. Thus, the literature suggests that during the early menstrual phase, there is a decrease in P4 and E2 levels[15]. Conversely, during the late FP, there is an increase in E2 and a decrease in P4, potentially enhancing training performance. Estrogen, known for its role in potentiating growth hormone (GH) action, increasing myofibrillar protein synthesis, and improving muscle regeneration, may contribute to these benefits[15,16]. However, the data from the present study revealed no differences in E2 levels across the MC phases evaluated. However, higher levels of P4 were observed during the LP, which enabled the volunteers to lift more weight during the 1RM test than FP. Similar to our findings, Simão[8] observed a reduction in muscle strength using the 8RM test, specifically during the follicular phase in women who were not using oral contraceptives but only for the lower limbs. In contrast, no differences were observed in muscle strength, assessed using the 10RM test for single and multi-joint exercises across the menstrual cycle's follicular, ovulatory, and luteal phases in women using oral contraceptives[17].

Thus, despite hormonal and muscle performance variations throughout the MC, these differences did not significantly affect the autonomic heart response to GVT in trained women. Statistical analysis revealed no significant differences in time and frequency domain indices across the menstrual phases evaluated at pre-, 24-, and 48-hour intervals. However, an increase in HR was observed immediately after GVT, accompanied by vagal withdrawal in both the follicular and luteal phases. Unlike our findings, studies indicate decreased cardiac parasympathetic activity during the FP and a predominance of sympathetic activity during the LP[18–20]. Although our study did not find statistical differences, possibly due to substantial variability among subjects, a discernible trend in the data aligns with findings in the literature.

Therefore, to the best of our knowledge, no study has investigated the effect of GVT on HRV in the different phases of the MC in trained women. However, when comparing the acute effect of GVT on HRV in healthy young men, significant vagal withdrawal was observed for approximately 30 minutes post-session compared to rest[21]. Furthermore, greater sympathetic activity was observed between 20 and 30 minutes post-exercise in the GVT group than the control group, indicating that GVT can induce greater stress on the autonomic nervous system[21].

Thus, the significant increase in HR after GVT may have been influenced by the exercise's total volume and intensity. One possible explanation for the increase in HR after GVT could be attributed to the glycolytic involvement, leading to elevated blood lactate levels and vagal withdrawal[22,23], which can be observed in our results by the time and frequency domain indices representing vagal activity. In addition, previous studies have demonstrated that volume [24] and intensity [23] can influence autonomic control after an acute resistance training session.

This study has its limitations. First, the volunteers continued training throughout all phases of the MC. Second, they needed to gain experience with the 1-RM test. Third, the experimental evaluation was limited to one MC. Nevertheless, this study establishes a solid foundation for further research to examine how hormonal variations and menstrual cycle phases influence the physiological response to acute resistance training.

Conclusion

The present study demonstrated that performance and heart rate variability were not different between MC phases.

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