ORIGINAL ARTICLE

The influence of menstrual cycle in heart rate variability and performance: A case study of a highly-trained female long-distance runner

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ABSTRACT

Introduction: Heart rate variability (HRV) is a non-invasive marker of the autonomic nervous system (ANS) that provides insights into physiological responses to training. This study investigates the relationship between HRV and athletic performance with and without the menstrual cycle (MC) in a highly-trained female long-distance runner. Methods: A 24-year-old elite female long-distance runner participated in this quantitative case study. HRV was recorded daily using a Polar H10 chest strap over three months, both with and without the MC. Athletic performance was assessed through mean power output (MPO) during 3-minute time trials (TT) using a Stryd inertial sensor. Four evaluations were conducted: two without MC and two with MC. Results: A nearly perfect correlation was found between HRV (rolling RMSSD) and MPO during the first TT without MC (r = 0.969, $p \leq .001$). However, no significant correlations were observed during the second TT with MC, the third TT without MC, or the fourth TT with MC. These findings suggest that HRV is a reliable marker for predicting athletic performance in the absence of MC but is influenced by hormonal fluctuations during the MC. Conclusion: HRV monitoring is a valuable tool for assessing internal load and predicting performance in female athletes. However, its reliability can be affected by the menstrual cycle and by accumulated fatigue. Future research should explore larger sample sizes and the impact of contraceptives on HRV and performance.
Keywords: Performance analysis, Athletic performance, Autonomic nervous system, Menstrual cycle, Inertial sensor.

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INTRODUCTION

Heart rate variability (HRV) is defined as the variation in time between each heartbeat (RR interval) and is calculated by analysing the distance in milliseconds between each RR interval of the QRS complex of a normal electrocardiogram that occurs when the ventricles depolarize (Hunt & Saengsuwan, 2018; Poehling & Llewellyn, 2019). HRV is the result of interactions between the autonomic nervous system (ANS) and the cardiovascular system. Therefore, its analysis provides a non-invasive method for studying ANS activity, which is particularly valuable in sports medicine (Campos et al., 2021; Kiss et al., 2016). The ANS functions to ensure that the physiological integrity of cells, tissues and organs throughout the body is maintained (homeostasis) and to execute adaptive responses to changes in the external and internal environment (Plews et al., 2017; Tsuji et al., 1996). The ANS is made up of two subsystems: the sympathetic nervous system (SNS), which allows the body to respond to survival challenges (fight or flight), states of anxiety, stress and physical exercise, while the second is the parasympathetic nervous system (PNS), known for its participation in energy conservation and restoration processes by causing a reduction in heart rate and blood pressure, facilitating the digestion and absorption of nutrients and the elimination of waste (Carrasco-Poyatos et al., 2020; Hunt & Saengsuwan., 2018).

Among the ANS stressors is sports training: the systematic process of exercising (stimuli) for the development of physical qualities or sports skills (Buchheit et al., 2010; Campos et al., 2021). When the stimulus are appropriate, an adaptive physiological and psychological response is generated that is unique to each individual (Campos et al., 2021; Düking et al., 2020). In endurance sports, this adaptive response to sports training can be quantified using external load methods such as real-time speed and mean power output (MPO) measurement with inertial sensors (e.g., potentiometers such as "*Stryd*") (Ruiz-Alias et al., 2023). While subjective methods such as the widely used rating of perceived exertion (RPE), retrospective questionnaires, direct observation diaries, and internal load methods such as monitoring of physiological parameters based on the measurement of oxygen consumption, blood lactate concentration and HRV can also be used (Abbiss & Laursen., 2008; Coyle et al., 1991). The HRV monitoring has gained relevance in the last decade to control stress and training adaptations, as well as detecting overtraining (Imbach et al., 2020; Perez-Gaido et al., 2021). A systematic review on HRV-guided training in long-distance runners found significant improvements in physical performance in HRV-guided groups compared to those following a conventional training plan (da Silva et al., 2019). However, the benefits of HRV-guided training for athletes' physical performance according to their biological sex, particularly for females during the menstrual cycle (MC), need further study.

Indeed, De Jonge (2003) observed that responses to exercise can vary depending on the stage of the MC, i.e. follicular phase (the first day of the cycle coincides with the beginning of menstruation and marks the beginning of this phase) versus luteal phase (begins after ovulation) (Aguilar-Macías & Ruiz-Sánchez, 2018; Dokumacı & Hazır, 2019). In the follicular phase, the release of follicle-stimulating hormone and luteinizing hormone is stimulated, favouring low concentrations of progesterone (PG) and the production of oestrogen (EG) (De Jonge et al., 2003). In the luteal phase, the concentrations of EG and PG tend to increase, thus one of the effects of PG is the increase in pulmonary ventilation, as well as the loss of water and sodium, reducing plasma volume during the post-ovulatory phase (Dokumacı & Hazır, 2019). A meta-analysis reported decreased cardiac vagal activity from the follicular to the luteal phase in females with regular MC (Dokumacı & Hazır, 2019). In agreement with this, MC phase comparisons revealed lower HRV in the mid-luteal phase (characterized by elevated PG) than in other phases (De Jonge et al., 2003). No significant main or interactive effects of EG on HRV were found (Aguilar-Macías & Ruiz-Sánchez., 2018). According to the scientific literature, the benefits of HRV in sports training are known, but its manifestation during the MC and its relationship with athletic performance in women is still unclear. Therefore, the present study aims to investigate the relationship between HRV and athletic performance in a female long-distance runner, both with and without MC. Based on the reviewed literature (Boullosa et al,. 2021; Brar et al,. 2015; Kokts-Porietis et al,. 2019), we hypothesized that HRV is directly correlated with athletic performance both with and without MC.

MATERIALS AND METHODS

Participant

A high-level female Chilean long-distance runner (age = 24 years; height = 164 cm; weight = 51.3 kg; training experience >4 years; weekly training volume = 130 ± 15 km) voluntarily agreed to participate in the present study. At the time of the measurements, she was training seven days per week and consistently completed the 10,000 meters in under 40 minutes. The participant, an elite athlete specializing in the 10,000-meter event, had achieved significant milestones, including a runner-up position in her inaugural adult competition and earning a spot on the national team. Furthermore, she held a record of titles in regional championships across multiple age groups and distances. At the start of the study, she was free of any illness or musculoskeletal injuries that could impact her athletic performance. This study was conducted in accordance with the principles stated in the Declaration of Helsinki and received approval from the Universidad de Los Lagos Ethics Committee under the code 0104-024.

Experimental procedure

The procedure was divided into three stages:

Stage 1: The athlete was informed about the study procedures and provided with an informed consent form containing all relevant details of the research. She was given a maximum of seven days to review the document and confirm her participation by signing the consent form.

Stage 2: Upon agreeing to participate, the evaluation period began. Anthropometric measurements were taken, including height, measured using a stadiometer (Seca 206; Seca Ltd, Hamburg, Germany), and body mass, assessed with a digital scale (Seca 813; Seca Ltd, Hamburg, Germany). The Rate of Perceived Exertion (RPE) was assessed using the 0-10 scale (Foster et al., 2001). Heart rate variability (HRV) was recorded daily for three months. Measurements involved placing a chest strap (Polar H10, Polar Electro Oy, Kempele, Finland) at chest level and recording data for three minutes in a supine position. HRV parameters, including the root mean square of successive differences in RR intervals over the last seven days (rollingRMSSD), heart rate (HR), and RR intervals over the last seven days (rollingRR), were recorded using the 'Elite HRV' smartphone application (Perrotta et al., 2017) each morning upon waking. The collected data were exported from the application and processed using a medium-threshold beats correction filter in Kubios software (v.3.0.0, HRV analysis, University of Eastern Finland) (Tarvainen et al., 2014). During this period, the athlete continued her usual training program without any modifications.

Stage 3: Performance metrics were recorded using an inertial sensor (Stryd Summit Power Meter, Boulder, CO, USA) attached to the laces of the athlete's right shoe. The sensor captured metrics such as mean power output (MPO), speed, and distance travelled. A standardized warm-up was performed before the time trial (TT), consisting of 10 minutes of low to moderate-intensity jogging on a treadmill, followed by three 30-second accelerations to maximum speed based on the athlete's level. After completing the warm-up, the athlete performed a 3-minute maximal effort time trial under identical environmental and temperature conditions (Sousa et al., 2022). This test was repeated four times.

The first and third evaluations were conducted during the non-menstrual phase (without MC), while the second and fourth evaluations took place during the follicular phase of the MC (with MC). A 4-day interval separated the first and second assessments, followed by a one-month interval between the second and third assessments, and another 4-day interval between the third and fourth assessments (Düking et al., 2020). The 'Flo' menstrual calendar smartphone application (Grieger et al., 2020) was used to monitor the MC and identify the follicular phase. Following the fourth 3-minute assessment, the collected data were analysed.

Statistical analysis

The Shapiro-Wilk test was used to confirm the normal distribution of the data ($p > .05$). The relationship between HRV (rolling RMSSD) and athletic performance (TT/with and without MC) was assessed using the Pearson correlation coefficient (r) and the standard error of estimate (SEE) obtained from linear regression analysis. The strength of the r coefficient was interpreted as: trivial (0.00-0.09), small (0.10-0.29), moderate (0.30-0.49), large (0.50-0.69), very large (0.70-0.89), nearly perfect (0.90-0.99), and perfect (1.00) (Hopkins et al., 2009). A rolling RMSSD and TT/With and Without MC relationship was considered acceptable if the following criteria were met: nearly perfect r (>0.90), low SEE (absolute ≤ 0.65; relative ≤ 0.02), and statistical significance of $p \leq .05$. Statistical analyses were performed using the SPSS software package (IBM SPSS version 25.0, Chicago, IL, USA).

Table 1. Descriptive statistics for 3-minute time trial (TT) performance and heart rate variability (HRV) metrics.

	1 TT/Without MC	2 TT/With MC	3 TT/ Without MC	4 TT/ With MC
Heart rate (bpm)	46	49	61	62
RR (ms)	1312.2	1234	1110.23	1211.89
Rolling RR (ms)	1315.25 ± 21	1278.83 ± 12.3	1346.34 ± 69.8	1270.29 ± 15.1
RMSSD (ms)	62.04	71.98	88.08	97.22
Rolling RMSSD (ms)	69.15 ± 6.66	62.79 ± 1.68	124.77 ± 22.6	120.36 ± 5.75
Distance (m)	761	755	708	767
Rhythm (km/h)	14.61 ± 0.47	14.46 ± 0.47	13.54 ± 0.86	14.70 ± 0.86
Relative power (W/kg)	4.24 ± 0.11	4.21 ± 0.12	3.95 ± 0.23	4.30 ± 0.22
Absolute MPO (W)	220.6 ± 5.82	218.77 ± 6.15	205.6 ± 12.14	223.11 ± 11.64
Relative MPO (W/kg)	4.24 ± 0.11	4.21 ± 0.12	3.95 ± 0.23	4.30 ± 0.22

Note. MC: Menstrual cycle; MPO: Mean power output; RMSSD: Root mean square of the RR intervals; Rolling: average accumulation of data (RR or RMSSD) of the last 7 days; bpm: beats per minute; TT: time trial (3-min).

RESULTS

A strong positive correlation was observed between the first evaluation of TT/without MC and the rolling RMSSD in absolute and relative values of MPO (r ≥ 0.969 and 0.962; $p \leq .001$ and .002; SEE ≤ 0.62 and 0.01 Table 2). For the TT/without MC and the rolling RR of this first evaluation the relationship criteria were not met (Table 2).

The second evaluation did not meet the relationship criteria between TT/with MC and the rollingRMSSD in absolute and relative values of MPO.

The third evaluation showed no relationship between TT/without MC and the rollingRMSSD as well as the rollingRR in absolute and relative values of MPO (Table 2).

The fourth assessment showed no relationship between TT/ with MC and rollingRMSSD as well as rollingRR in absolute and relative values of MPO (Table 2).

Table 2. Relationship between HRV and sports performance (MPO).

	VFC	Power	Pearson *r*	*p*-value	R^2	SEE
1 TT/Without CM	Rolling RR (ms)	Absolute MPO (W)	0.92**	.009*	.847(+)	0.98
		Relative MPO (W/kg)	0.93**	.007*	.864(+)	0.01
	Rolling RMSSD (m/s)	Absolute MPO (W)	0.969**	.001*	.939(+)	0.62
		Relative MPO (W/kg)	0.962**	.002*	.926(+)	0.01
2 TT/With CM	Rolling RR (ms)	Absolute MPO (W)	0.093	.881	.009	-0.32
		Relative MPO (W/kg)	0.093	.881	.009	0.01
	Rolling RMSSD (m/s)	Absolute MPO (W)	0.598	.287	.357	0.77
		Relative MPO (W/kg)	0.598	.287	.357	0.01
3 TT/Without CM	Rolling RR (ms)	Absolute MPO (W)	-0.629	.001*	.396	2.7
		Relative MPO (W/kg)	-0.624	.01*	.389	0.05
	Rolling RMSSD (m/s)	Absolute MPO (W)	0.446	.029*	.162	0.05
		Relative MPO (W/kg)	0.458	.024*	.21	0.05
4 TT/with CM	Rolling RR (ms)	Absolute MPO (W)	-0.649	.236	.421	0.96
		Relative MPO (W/kg)	-0.649	.236	.421	0.01
	Rolling RMSSD (m/s)	Absolute MPO (W)	-0.237	.701	.056	1.22
		Relative MPO (W/kg)	-0.237	.701	.056	0.02

*Note. HRV: Heart Rate Variability; MC: Menstrual Cycle; R^2: Coefficient of determination; RMSSD: Root Mean Square of Successive Differences of RR intervals; SEE: Standard error of the estimate; TT: Time Trial; (+): Strong predictive power; **: Near-perfect correlation; *: Significance level of .01.*

DISCUSSION

This study aimed to explore the relationship between HRV and athletic performance (i.e.TT) in a highly-trained female long-distance runner, both with and without the influence of the MC. The findings revealed a positive correlation between HRV and athletic performance without the MC, represented by the 3-minute TT, through the MPO (r > 0.9), while this relationship is modified when the 3-minute TT is with the MC because the relationship shown is not significant (r < 0.90; *p* > .05). Additionally, HRV was found to be influenced by hormonal fluctuations during the MC and by cumulative training loads, expressed as kilometres run.

The first evaluation ("*1 TT/without MC*") demonstrated an almost perfect positive correlation between rollingRMSSD and both absolute and relative MPO values (r = 0.969 and 0.962; *p* = .001 and .002; SEE = 0.62 and 0.01). This suggests that increased HRV corresponds to improved athletic performance in the 3-minute TT. Similar findings were reported by D'Ascenzi et al. (2014), who examined elite female volleyball players and identified a relationship between HRV parameters and performance indicators for technical skills influenced by pre-competitive stress, such as serving and receiving. They concluded that autonomic nervous system activity plays a critical role in sport-specific performance, with heightened sympathetic activity being associated with fewer successful receptions. Consistently, higher rollingRMSSD values before competition were linked to improved performance.

In contrast to the first evaluation, the second evaluation ("*2 TT/with MC*") revealed no significant relationship between rollingRMSSD and athletic performance (i.e., MPO in the 3-minute TT). This aligns with previous studies (Pestana, 2014; Kokts-Porietis, 2019) that also found no correlation between HRV during the MC and athletic performance in women. Additionally, other research highlights increased sympathetic nervous system (SNS) activity and decreased parasympathetic nervous system (PNS) activity during the follicular and luteal phases of the MC (Dokumacı & Hazır, 2019). These findings suggest that hormonal changes associated with the MC may significantly affect athletic performance in women.

The third evaluation, conducted without the MC ("*3 TT/without MC*"), revealed significant differences when compared to the first evaluation (i.e., "*1 TT/without MC*"), with a lack of correlation between HRV and TT performance (r = 0.44; p = .02). This discrepancy may result from accumulated fatigue during the training period preceding the competition and assessment, as noted in earlier studies (Schmitt et al., 2013; Halson et al., 2014).

Similarly, the fourth evaluation ("*4 TT/with MC*") showed no relationship between rollingRMSSD and performance, consistent with the findings from the second evaluation. This could be attributed to the combined effects of fatigue accumulation and hormonal changes during the MC (Schmitt et al., 2013; Halson et al., 2014).

Finally, these findings should be interpreted within the context of the study's limitations. One limitation is the high-performance level of the participant, which may limit generalizability to other populations. Additionally, the short evaluation period (three months) restricts broader conclusions. Nevertheless, this study provides valuable insights and a foundation for future research on the influence of the menstrual cycle on HRV and athletic performance.

Practical applications and future directions

HRV-guided training allows coaches to assess training and physiological readiness of the athletes prior to the different phases of the MC and thus control and/or adapt training loads with the aim of achieving greater performance. Therefore, HRV can be considered a reliable and valuable tool for optimizing the sports performance of both novice and trained female athletes and thus reduce physiological stress, considering one of the most important female biological processes, the MC. Therefore, taking into account the aforementioned limitations, the results serve as a basis for future research.

Future investigations should aim to increase sample size and explore the association between the effects of contraceptives used by athletes and their implication on sports performance and thus determine its impact on HRV-guided and monitored athletic performance.

CONCLUSION

The quantification of HRV in the time domain provides information regarding internal load in highly trained athletes. However, individual characteristics such as the athletic level and the MC phase could influence these measures. Therefore, our results highlight the potential role of HRV as a monitoring tool for athletes and coaches to better dose training loads and improve performance across the MC.

AUTHOR CONTRIBUTIONS

Conceptualization: F.B.-M., J.A.-G., A.Ñ.-A.; methodology: F.B.-M., J.A.-G., A.Ñ.-A.; software: A.Ñ.-A.; validation: F.B.-M., J.A.-G., A.Ñ.-A.; formal analysis: F.B.-M., J.A.-G., A.Ñ.-A.; investigation: F.B.-M., J.A.-G., A.Ñ.-A., L.Ñ.-A., E.G.-C., V.C.-U., M.C.-B.; resources: F.B.-M., J.A.-G., A.Ñ.-A., L.Ñ.-A., E.G.-C., V.C.-U., M.C.-B.; data curation: F.B.-M., J.A.-G., A.Ñ.-A., L.Ñ.-A., E.G.-C., V.C.-U., M.C.-B.; writing—original draft preparation: F.B.-M., J.A.-G., A.Ñ.-A., L.Ñ.-A., E.G.-C., V.C.-U., M.C.-B.; writing—review and editing: F.B.-M., J.A.-G., A.Ñ.-A., L.Ñ.-A., E.G.-C., V.C.-U., M.C.-B.; visualization: F.B.-M., J.A.-G., A.Ñ.-A., L.Ñ.-A., E.G.-C., V.C.-U., M.C.-B.; supervision: F.B.-M., J.A.-G., A.Ñ.-A., L.Ñ.-A., E.G.-C., V.C.-U., M.C.-B. All authors have read and approved the final version of the manuscript.

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No potential conflict of interest was reported by the authors.

REFERENCES

Abbiss, C. R., & Laursen, P. B. (2008). Describing and Understanding Pacing Strategies during Athletic Competition. Sports Medicine, 38(3), 239-252. https://doi.org/10.2165/00007256-200838030-00004

Buchheit, M., Chivot, A., Parouty, J., Mercier, D., Al Haddad, H., Laursen, P. B., & Ahmaidi, S. (2010). Monitoring endurance running performance using cardiac parasympathetic function. Eur J Appl Physiol, 108(6), 1153-1167. https://doi.org/10.1007/s00421-009-1317-x

Boullosa, D., Medeiros, A. R., Flatt, A. A., Esco, M. R., Nakamura, F. Y., & Foster, C. (2021). Relationships between workload, heart rate variability, and performance in a recreational endurance runner. Journal of Functional Morphology and Kinesiology, 6(1), 30. https://doi.org/10.3390/jfmk6010030

Brar, T. K., Singh, K. D., & Kumar, A. (2015). Effect of different phases of menstrual cycle on heart rate variability (HRV). Journal of clinical and diagnostic research: JCDR, 9(10), CC01. https://doi.org/10.7860/JCDR/2015/13795.6592

Campos, F. S., Borszcz, F. K., Flores, L. J. F., Barazetti, L. K., Teixeira, A. S., Hartmann Nunes, R. F., & Guglielmo, L. G. A. (2021). HIIT Models in Addition to Training Load and Heart Rate Variability Are Related With Physiological and Performance Adaptations After 10-Weeks of Training in Young Futsal Players. Front Psychol, 12, 636153. https://doi.org/10.3389/fpsyg.2021.636153

Coyle, E. F., Feltner, M. E., Kautz, S. A., Hamilton, M. T., Montain, S. J., Baylor, A. M., Abraham, L. D., & Petrek, G. W. (1991). Physiological and biomechanical factors associated with elite endurance cycling performance. Med Sci Sports Exerc, 23(1), 93-107. https://doi.org/10.1249/00005768-199101000-00015

D'Ascenzi, F., Alvino, F., Natali, B. M., Cameli, M., Palmitesta, P., Boschetti, G., ... & Mondillo, S. (2014). Precompetitive assessment of heart rate variability in elite female athletes during play offs. Clinical physiology and functional imaging, 34(3), 230-236. https://doi.org/10.1111/cpf.12088

De Jonge, X. A. J. (2003). Effects of the menstrual cycle on exercise performance. Sports medicine, 33, 833-851. https://doi.org/10.2165/00007256-200333110-00004

Da Silva, D. F., Ferraro, Z. M., Adamo, K. B., & Machado, F. A. (2019). Endurance Running Training Individually Guided by HRV in Untrained Women. J Strength Cond Res, 33(3), 736-746. https://doi.org/10.1519/JSC.0000000000002001

Dokumacı, B., & Hazır, T. (2019). Effects of the Menstrual Cycle on Running Economy: Oxygen Cost Versus Caloric Cost. Res Q Exerc Sport, 90(3), 318-326. https://doi.org/10.1080/02701367.2019.1599800

Düking, P., Zinner, C., Reed, J. L., Holmberg, H. C., & Sperlich, B. (2020). Predefined vs data-guided training prescription based on autonomic nervous system variation: A systematic review. Scand J Med Sci Sports, 30(12), 2291-2304. https://doi.org/10.1111/sms.13802

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. J Strength Cond Res, 15(1), 109-115. https://doi.org/10.1519/00124278-200102000-00019

Grieger, J. A., & Norman, R. J. (2020). Menstrual cycle length and patterns in a global cohort of women using a mobile phone app: retrospective cohort study. Journal of Medical Internet Research, 22(6), e17109. https://doi.org/10.2196/17109

Halson, S. L. (2014). Monitoring training load to understand fatigue in athletes. Sports medicine, 44(Suppl 2), 139-147. https://doi.org/10.1007/s40279-014-0253-z

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc, 41(1), 3-13. https://doi.org/10.1249/MSS.0b013e31818cb278

Hunt, K. J., & Saengsuwan, J. (2018). Changes in heart rate variability with respect to exercise intensity and time during treadmill running. Biomed Eng Online, 17(1), 128. https://doi.org/10.1186/s12938-018-0561-x

Imbach, F., Candau, R., Chailan, R., & Perrey, S. (2020). Validity of the Stryd Power Meter in Measuring Running Parameters at Submaximal Speeds. Sports (Basel), 8(7). https://doi.org/10.3390/sports8070103

Kiss, O., Sydó, N., Vargha, P., Vágó, H., Czimbalmos, C., Édes, E., Zima, E., Apponyi, G., Merkely, G., Sydó, T., Becker, D., Allison, T. G., & Merkely, B. (2016). Detailed heart rate variability analysis in athletes. Clinical Autonomic Research, 26(4), 245-252. https://doi.org/10.1007/s10286-016-0360-z

Kokts-Porietis, R. L., Minichiello, N. R., & Doyle-Baker, P. K. (2019). The effect of the menstrual cycle on daily measures of heart rate variability in athletic women. Journal of Psychophysiology. https://doi.org/10.1027/0269-8803/a000237

Perez-Gaido, M., Lalanza, J. F., Parrado, E., & Capdevila, L. (2021). Can HRV Biofeedback Improve Short-Term Effort Recovery? Implications for Intermittent Load Sports. Appl Psychophysiol Biofeedback, 46(2), 215-226. https://doi.org/10.1007/s10484-020-09495-8

Pestana, E. R., Mostarda, C. T., Silva-Filho, A. C., Salvador, E. P., & de Carvalho, W. R. G. (2018). Effect of different phases of menstrual cycle in heart rate variability of physically active women. Sport Sciences for Health, 14, 297-303. https://doi.org/10.1007/s11332-018-0426-5

Perrotta, A. S., Jeklin, A. T., Hives, B. A., Meanwell, L. E., & Warburton, D. E. (2017). Validity of the elite HRV smartphone application for examining heart rate variability in a field-based setting. The Journal of Strength & Conditioning Research, 31(8), 2296-2302. https://doi.org/10.1519/JSC.0000000000001841

Plews, D. J., Laursen, P. B., & Buchheit, M. (2017). Day-to-Day Heart-Rate Variability Recordings in World-Champion Rowers: Appreciating Unique Athlete Characteristics. Int J Sports Physiol Perform, 12(5), 697-703. https://doi.org/10.1123/ijspp.2016-0343

Ruiz-Alias, S. A., Ñancupil-Andrade, A. A., Pérez-Castilla, A., & García-Pinillos, F. (2023). Running Critical Power: A Comparison Of Different Theoretical Models. Int J Sports Med, 44(13), 969-975. https://doi.org/10.1055/a-2069-2192

Schmitt, L., Regnard, J., Desmarets, M., Mauny, F., Mourot, L., Fouillot, J. P., ... & Millet, G. (2013). Fatigue shifts and scatters heart rate variability in elite endurance athletes. PloS one, 8(8), e71588. https://doi.org/10.1371/journal.pone.0071588

Tarvainen, M. P., Niskanen, J. P., Lipponen, J. A., Ranta-Aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV-heart rate variability analysis software. Computer methods and programs in biomedicine, 113(1), 210-220. https://doi.org/10.1016/j.cmpb.2013.07.024

Tsuji, H., Larson, M. G., Venditti, F. J., Jr., Manders, E. S., Evans, J. C., Feldman, C. L., & Levy, D. (1996). Impact of reduced heart rate variability on risk for cardiac events. The Framingham Heart Study. Circulation, 94(11), 2850-2855. https://doi.org/10.1161/01.CIR.94.11.2850