

HEART RATE VARIABILITY IN MALE ARTISTIC GYMNASTICS – A CASE STUDY**DOI: <http://doi.org/10.26758/10.1.17>**

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Abstract

Objectives. The aim of this paper was to emphasize the importance of HRV measured at rest, as a valuable cue for objectifying the training status of a young gymnast. Thus the coach can further integrate the data into the individualized sports training strategy.

Material and methods. The HRV research methodology was applied in this ascertaining study focused on 13 years old male junior athlete practicing artistic gymnastics. This subject was chosen by the coach to be investigated because of his results and potential for performance. The gymnast has an experience of 8 years in sports, being awarded several times the National champion title in children and junior competitions. The HRV measurements were taken by means of BioHarness BT3 units from Zephyr Technologies©. The snapshot-type assessment took place during the competitive stage, early in the morning, before the training session. The analysis of HRV parameters included the 10 minute monitoring during rest in supine position.

Results. HRV analysis demonstrates that at rest the gymnast generally fits into the normal values of other athletes emphasized in various studies. Basically the indexes calculated for the time domain, frequency domain and nonlinear analysis prove that measuring HRV during rest is a good indicator for the capability of the subject to address the autonomous nervous system.

Conclusions. These results marked the good balance between sympathetic and parasympathetic pathways. This kind of research should incorporate long term periods of monitoring so that data bases for each athlete should be available and subject for analysis and further adjustments of the training contents.

Keywords: autonomous nervous system, junior, performance.

Introduction

Derived from the cardiovascular physiology, heart rate variability (HRV) is a non-invasive tool which enables the analysis of the intrinsic regulation mechanisms through the inference of the sympathetic and parasympathetic pathways, namely the RR intervals between consecutive heart beats. The sympathetic regulation refers to cardio acceleration through activating sinoatrial node, enhanced myocardial contractility (Ehrman, Karrigan and Keteian,

2018, p. 78), raising blood pressure and peripheral vasodilatation, as well as increased mental activation (Kenney, Wilmore and Costill, 2015, p. 86). In contrast, the parasympathetic activation via the vagus nerve carries impulses to sinoatrial and atrioventricular nodes responsible for decreases in heart rate, myocardium contractility, constriction of the coronary vessels, and increasing mental focus (Kenney, Wilmore and Costill, 2015, p. 86). Given this frame, specialists acknowledge that HRV acts like a relevant marker of the balance between sympathetic and parasympathetic mechanisms.

This is possible by means of the HRV three analyzing models, namely time domain, frequency domain and nonlinear methods (Vanderlei et al., 2009). Most of the studies focus on measuring HRV indexes during supine rest (Young and Leicht, 2011), in multiple recording sessions, in order to create HRV profiles for each athlete. This will serve as a baseline for identifying different training adaptations and states such as peak performance, fatigue/burn-out, risk of injuries, recovery status.

Bucheitt (2014) connected RMSSD parameter with the endurance capabilities. LnRMSSD is linked with the adaptation to training in submaximal efforts (Thorpe et al., 2016).

Authors like Dong et al. (2018) argued that the frequency domain data indicate mental stress, acting like a stress resilience marker in competition settings.

Additionally, non-linear methods include the Poincare plot representing the RR intervals' dispersion, mathematically objectified through three indexes SD1, SD2 and S1/SD2 ratio (Task Force, 1996).

The six apparatus routines performed in men's artistic gymnastics exhibit acute and long-term effects upon the junior and senior athletes, in terms of fitness components and neuromuscular control. Along with the strength, power, and flexibility, cardio-respiratory stress is associated with high anaerobic demands especially in the floor routines, pommel horse, rings, horizontal bar and parallel bars performances, hierarchically (Papadopoulos et al., 2014). Obviously, male artistic gymnastics is a highly stressful sport due to the technical complex apparatus routines, with a maximum duration of 70 seconds (floor) and a minimum duration of 4 to 6 seconds (vault) (Jemni et al., 1998). The intensity of the effort brings the maximal heart rates up to 186 ± 11 b/min. and blood lactate from 6 to 11 mmol/l (Mkaouer et al., 2018).

In order for a gymnast to learn the technical content, to physically and mentally prepare and to deliver the best possible performance, it takes an average of 30 hours per week, with considerable variations depending on age, level of competition or national strategy in gymnastics (Malina et al., 2013). Most of the gymnasts trained two sessions daily, six days per week including warm up, stretching routines, strength training, repetition of technical elements, with energy costs varying from 3.0 to 5.0 MET (MET - metabolic equivalent of tasks) (Ridley, Ainsworth and Olds, 2008).

In a larger context, monitoring of each gymnast is an important prerequisite for having complementary information regarding the training status and the competition readiness prior to the major sport events.

The aim of this paper was to emphasize the importance of HRV measured at rest, as a valuable cue for objectifying the training status of a young gymnast. Thus the coach can further integrate the data into the individualized sports training strategy.

Methodology

The HRV measurements were taken by means of BioHarness BT3 units from Zephyr Technologies©. Data were collected in June 2018, before the National Artistic Gymnastics Championship. The snapshot-type assessment took place during the competitive stage, early in the morning, before the training session. The analysis of HRV parameters included a 10 minute monitoring during rest, in supine position. All raw data were extracted from the BioHarness BT3 units and analyzed with Kubios HRV software (version 2.0; Department of Physics, University of Kuopio, Kuopio, Finland) by DC. Data were analyzed following the Tasks Force Recommendations (1996).

Case presentation

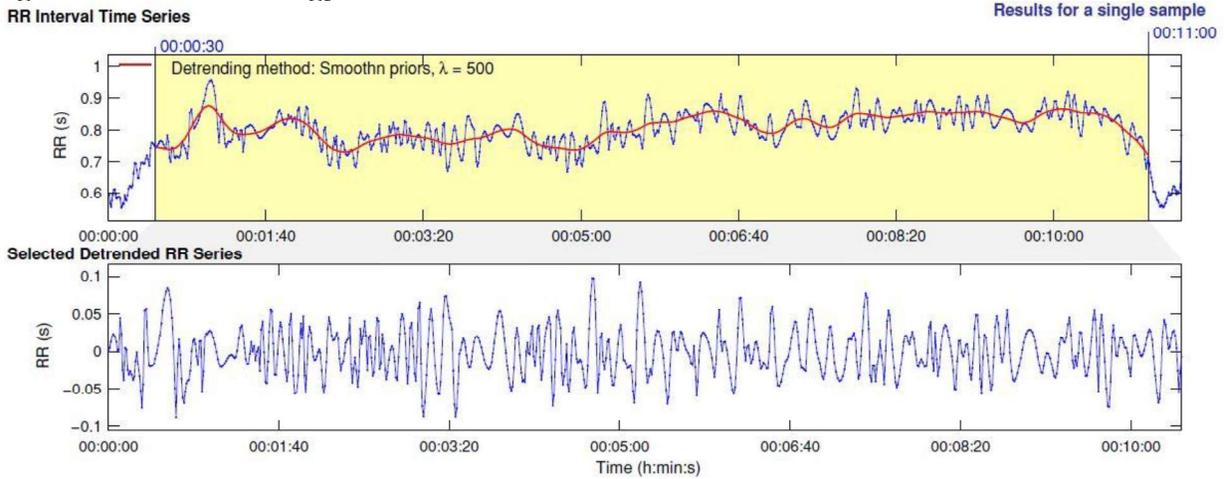
The HRV research methodology was applied in this ascertaining study, focused on a 13 years old male junior athlete practicing artistic gymnastics. This subject was chosen by the coach to be investigated because of his results and potential for performance. The gymnast has an experience of 8 years in sports, being awarded several times the National champion title in children and junior competitions. The gymnast competes for Dinamo School Sports Club from Bucharest, since the beginning of his sports career. The subject trains 5 hours per day, 5 days a week, being coordinated by coach MM.

The subject voluntarily enrolled for this study, being genuinely interested about the topics and the possible use of the information for optimizing his preparation. The subject was clinically healthy with no exercise restrictions whatsoever. The research protocol of this study was approved by the UNEFS Research Ethics Commissions which validated it in conformity with the Declaration of Helsinki.

Heart Rate Variability analysis

Figure 1 presents the RR intervals time series of the gymnast during the selected 10 minute monitoring. The first graph reveals genuine fluctuations of the RR intervals including the presence of ectopic beats which makes difficult the extraction of statistical information. The second graph shows the same curve after the trend removal and the filtering of the ectopic beats. (Thuraisingham, 2006). This pre-processing HRV data is a mandatory phase for obtaining relevant statistical inferences.

Figure 1. Curves of the gymnast’s RR* intervals



*RR = time between consecutive heart beats

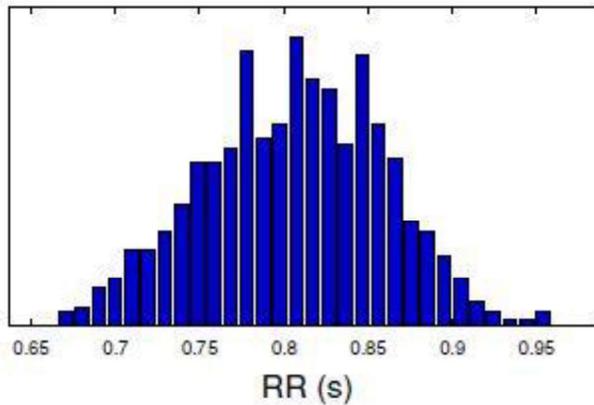
Table 1. Time domain results

Variable	Units	Value
Mean RR*	(ms)	805.7
STD RR (SDNN)	(ms)	31.7
Mean HR*	(1/min)	74.80
STD HR	(1/min)	3.65
RMSSD	(ms)	22.7
NN50	(count)	33
pNN50	(%)	4.3
RR triangular index		9.936
TINN	(ms)	155.0

These data are analyzed from the statistical standpoint and through geometric indexes (Table 1). One can notice that the average heart rate during the monitored period was 74.8 while, the mean RR was 805.7ms. Regarding the standard deviation for normal RR intervals (SDNN), the value of 31.70ms relates to both sympathetic and parasympathetic activity. The root mean square of differences between RR intervals (RMSDD), with a value of 22.7ms emphasizes the moderate activation of the parasympathetic pathway. In terms of percentage of RR intervals with a duration difference greater than 50ms (pNN50), the value of 4.3% reveals a moderate activation of the parasympathetic mechanisms.

Figure 2 shows the HRV triangular index representing the total number of heart beats divided by the number of beats with the highest peak of the histogram (Stein, 2002). It can be noticed that the RR intervals’ distribution fits into the Gaussian curve.

Figure 2. RR* intervals' distribution of the gymnast



*RR = time between consecutive heart beats

Being an oscillatory phenomenon, HRV needs to be decomposed in different frequency spectrums. Authors often debate whether they should use for analysis Fast Fourier Transformation (FFT) or Autoregressive Spectrum (AR). By means of FFT we can identify the presence of each frequency component in the HRV continuous wave. When there is a finite number of dominant frequency components, FFT is preferred over the AR spectrum which characterizes random vibration signals (Heinzel, Rudiger and Schilling, 2002). So, the data reveal that the value of LF peak is lower than the HF peak, showing reduced sympathetic activity predominance and a stronger parasympathetic activity (Table 2).

Table 2. Frequency domain analysis – Fast Fourier Transform (FFT) spectrum

Frequency band	Peak (Hz)	Power (ms ²)	Power (%)	Power (n.u)*
VLF (0-0.04 Hz)	0.0352	60	5.9	
LF (0.04-0.15 Hz)	0.1055	607	59.9	63.7
HF (0.15-0.4 Hz)	0.1719	346	34.2	36.3
Total		1014		
LF/HF		1.753		

*n.u.= normalized units

The nonlinear analysis puts the emphasis on the complexity of the cardiac regulation via the autonomous nervous system (Table 3). As the RR interval electric signals follow a nonlinear pattern, there was analyzed and quantified the approximate entropy (ApEn) and sample entropy.

The Approximate Entropy (ApEn) was developed by Pincus in order to identify the predictable regular character of HR (Pincus and Goldberger, 1994). This system models the signal in vectors of different lengths for assessing if the oscillations are recurrent. In this case study, the values for ApEn and SampEn were 1.119 and 1.161, respectively. These figures fit into the normal values accepted in literature, 1 – 1.5 (Task Force, 1996).

Table 3. Parameters from the nonlinear analysis

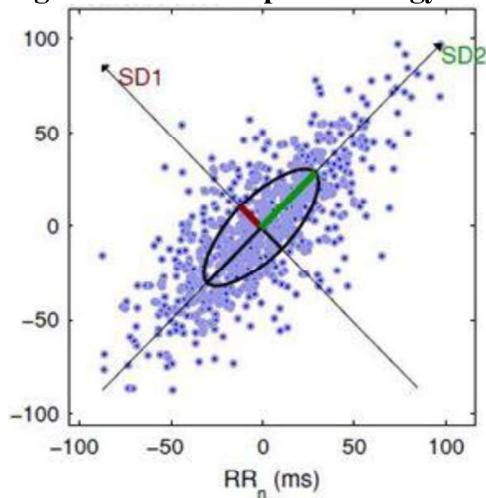
Variable	Unit	Value
Poincare plot		
SD1	(ms)	16.1
SD2	(ms)	41.8

Variable	Unit	Value
Recurrence plot		
Mean line length (Lmean)	(beats)	8.45
Max line length (Lmax)	(beats)	159
Recurrence rate (REC)	(%)	25.79
Determinism (DET)	(%)	97.89
Shannon Entropy (ShanEn)		2.927
Other		
Approximate entropy (ApEn)		1.119
Sample entropy (SampEn)		1.161
Detrended fluctuations (DFA): α_1		1.318
Detrended fluctuations (DFA): α_2		0.369
Correlation dimension (D2)		1.292
Multiscale entropy (MSE)		0.456-1.894

Note: $RR_{n+1}(ms)$

The ratio $SD1/SD2$ as shown in the Poincare plot (figure 4) represents the dispersion of RR intervals in a time period. $SD1$ value was 16.1, while $SD2$ was 41.8. These values indicate a fast response to stimuli of the gymnast, fact argued by $SD1$ which shows a parasympathetic predominance.

Figure 4. Poincare plot of the gymnast’s RR intervals dispersion



Discussions

HRV analysis demonstrates that at rest the gymnast generally fits into the normal values of other athletes emphasized in various studies. The indexes calculated for the time domain, frequency domain and nonlinear analysis prove that measuring HRV during rest is a good indicator for the capability of the subject to address the autonomic nervous system. Concretely, these values mark the good balance between sympathetic and parasympathetic pathways.

The time domain results even in a snapshot evaluation confirmed that the values are conclusive for a good parasympathetic activity which is an asset for the gymnast's physiological status during the precompetitive stage. That means a good resilience to training stimuli and a fair readiness to compete in a short while. The combination of SDNN, RMSSD, pNN50 and triangular index should be taken into consideration on a regular basis to monitor cardiac autonomous activity (Plews, Laursen and Boucheit, 2016).

The frequency domain data also emphasize a predominance of the low frequency band as an indicative for the activation of the vagus nerve modulating the response of sinoatrial node, associated with a more variable heart rate. Articles on cardiac control acknowledge our results (Grossman, Wilhelm and Spoerle, 2004).

Generally, nonlinear HRV data are scarce in sports area. Although few of them reported that this analysis is probably connected to predicting competition results, specialists have not clearly described its role in different sports or different age groups. The longer the RR intervals, the greater the dispersion in Poincare plot; as noticed in our case study, the gymnast exhibited a high dispersion of the values at rest, signifying a good adaptation to the specific training. Different studies on this topic agree with our findings (Shaffer and Ginsberg, 2017). The low values of the entropy demonstrated that the RR intervals followed a predictable, regular pattern without ectopic beats.

Limitations of the study

Our case study refers to a snapshot HRV assessment giving insights about the training status at a certain point. The authors have not taken into account in this analysis aspects about respiration pattern, training load, or other performance-related factors.

Conclusions

Time domain, frequency domain and the non linear method are convergent in objectifying the autonomic nervous system regulation in the sport context, expressed in the prevalence of either sympathetic or parasympathetic reactions, with influences on training, recovery state and peak performance.

The data collected in this case study through a ten minute HRV measurement might be a complementary source of information for coaches, in order to have an additional standpoint for adjusting the training content.

The gymnast's results confirmed the aim of the research and the efficiency of the HRV assessment. The subject performed as his peak during the 2018 National Artistic Gymnastics Championships, winning the team competition and the second place in the individual all-around ranking. Due to his accomplishments, the gymnast was selected for the National Junior Team.

Given the above findings, one can generally state that HRV measured at rest could possibly act as a predictor for the competitive behaviour of the athlete within target competitions.

Ideally, this kind of research should incorporate long term periods of monitoring, so that data bases for each gymnast should be available and subject for analysis and baseline for further adjustments in the training contents. Repetitive assessments are recommended within each training stage or in particular sensitive situations, such as post-recovery, psychological challenges or other environmental factors.

HRV measured at rest is a topic to be developed by specialists, in interdisciplinary teams, so that the athletes should have a relevant objective feed-back for indicating their training status, in different preparation stages.

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The contribution of authors

All authors have equally contributed to this study.

References

1. Buchheit, M., 2014. Monitoring training status with HR measures: do all roads lead to Rome?. *Frontiers in Physiology*, [e-journal] 5:73, doi: 10.3389/fphys.2014.00073.
2. Dong, S.Y., Lee, M., Park, H. and Youn, I., 2018. Stress Resilience Measurement With Heart-Rate Variability During Mental And Physical Stress. *Conference Proceedings - IEEE Engineering in Medicine and Biology Society*, [e-journal] 2018:5290-5293. doi: 10.1109/EMBC.2018.8513531.
3. Ehrman, J.K., Kerrigan, D.J. and Keteyian, S.J., 2018. Advanced exercise physiology. Essential concepts and applications, Human Kinetics.
4. Grossman, P., Wilhelm, F.H. and Spoerle, M., 2004. Respiratory sinus arrhythmia, cardiac vagal control, and daily activity. *American Journal of Physiology. Heart and Circulatory Physiology*, [e-journal] 287(2): H728-34. doi:10.1152/ajpheart.00825.2003.
5. Heinzl, G., Rüdiger, A. and Schilling, R., 2002. Spectrum and spectral density estimation by the Discrete Fourier transform (DFT), including a comprehensive list of window functions and some new at-top windows. [online] Available at: <https://holometer.fnal.gov/GH_FFT.pdf> [Accessed 20 May 2020].
6. Jemni, M., Friemel, F., Lechevalier, J. and Origas, M., 1998. Bioenergetics of high-level gymnastics. *Movement and Sport Science*, [e-journal] 35: 105-106.
7. Kenney, W.L., Wilmore, J.H. and Costill, D.L., 2015. Physiology of sport and exercise. Human Kinetics.
8. Malina, R.M., Baxter-Jones, A.D.G., Armstrong, N., Beunen, G.P., Caine, D., Daly, R.M., Lewis, R.D., Rogol, A.D. and Russell, K., 2013. Role of Intensive Training in the Growth and Maturation of Artistic Gymnasts. *Sports Medicine*, [e-journal] 43:783–802. doi: 10.1007/s40279-013-0058-5.
9. Mkaouer, B., Jemni, M., Chaabene, H., Amara, S., Njah, A. and Chtara, M., 2018. Effect of Two Different Types of Olympic Rotation Order on Cardiovascular and Metabolic Variables in Men's Artistic Gymnastics, *Journal of Human Kinetics*, [e-journal] 61:179-187, doi: 10.1515/hukin-2017-0120.
10. Papadopoulos, G., Kaimakamis, V., Kaimakamis, D. and Proios, M., 2014. Main characteristics of rules and competition systems in gymnastics from 1896 to 1912. *Science of Gymnastics Journal*, [e-journal] 6(2): 29-40.

11. Pincus, S.M. and Goldberger, A.L., 1994. Physiological Time-Series Analysis: What Does Regularity Quantify? *American Journal of Physiology*, [e-journal] 266(4 Pt 2):H1643-56, doi: 10.1152/ajpheart.1994.266.4.H1643.
12. Plews, D., Laursen, P. and Boucheit, M., 2016. Day-to-day Heart Rate Variability (HRV) Recordings in World Champion Rowers: Appreciating Unique Athlete Characteristics. *International Journal of sports physiology and performance*, [e-journal] 12(5):1-19, doi: 10.1123/ijsp.2016-0343.
13. Ridley, K., Ainsworth, B.E. and Olds, S., 2008. Development of a compendium of energy expenditures for youth. *International Journal Behavioral Nutrition and Physical Activity*, [e-journal] 5:45–52, doi: 10.1186/1479-5868-5-45.
14. Shaffer, F. and Ginsberg, J.P., 2017. An overview of heart rate variability, metrics and norms. *Frontiers in Public Health*, [e-journal] 5: 258, doi:10.3389/fpubh.2017.00258.
15. Stein, P., 2002. Assessing Heart Rate Variability from Real-World Holter Reports Cardiac. *Electrophysiology Review*, [e-journal] doi: 10.1023/A:1016376924850.
16. Thorpe, R.T., Strudwick, A.J., Buchheit, M., Atkinson, G., Drust, B. and Gregson, W., 2016. Tracking Morning Fatigue Status Across In-Season Training Weeks in Elite Soccer Players. *International Journal of Sports Physiology and Performance*, 11(7):947-952, doi: 10.1123/ijsp.2015-0490.
17. Thuraisingham, R.A., 2006. Preprocessing RR interval time series for heart rate variability analysis and estimates of standard deviation of RR intervals. *Computer Science, Mathematics, Medicine*, [e-journal] doi:10.1016/j.cmpb.2006.05.002.
18. Vanderlei, L.C.M., Pastre, C.M., Hoshi, R.A., Carvalho, T.D. and Godoy, M.F., 2009. Basic notions of heart rate variability and its clinical applicability. *Revista Brasileira de Cirurgia Cardiovascular*, [e-journal] 24(2): 205-217, doi: 10.1590/S0102-76382009000200018.
19. Young, F.L. and Leicht, A.S., 2011. Short-term stability of resting heart rate variability: influence of position and gender, *Applied Physiology Nutrition and Metabolism*, 36(2):210-8, doi: 10.1139/h10-103.
20. ***Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. *Circulation*; 93(5):1043-65.