Journal of Physical Education and Sport ® (JPES), 17 Supplement issue 4, Art 219, pp. 2135 - 2141, 2017
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Autonomic cardiac activity and psychometric data analysis during different training preparation periods before the World Championship in an elite fin-swimmer: a case study

ZUZANA SVOZILOVÁ, MICHAL BOTEK, ZBYNĚK SVOZIL, JAKUB KREJČÍ
Faculty of Physical Culture, Palacky University Olomouc, Olomouc, CZECH REPUBLIC

Published online: Octomber 31, 2017
(Accepted for publication Octomber 03, 2017
DOI:10.7752/jpes.2017.s4219

Abstract:
Background: Training preparation, including taper and/or fast transition across multiple time zones, elicits specific body stress that influences heart rate variability (HRV) as a non-invasive index of autonomic nervous system (ANS) activity.
Objective: The study aimed to determine the response in both ANS and psychometric data during different training periodization periods and after transition across several time zones.
Methods: A fin-swimmer aged 24 years, BMI = 21.5 kg.m-2, and VO2max = 51.9 ml.kg-1.min-1 volunteered to participate in this study. The athlete underwent 59 ANS activity measurements during three different training blocks and after a fast transition across six time zones westwards to Colombia. The morning ANS activity was assessed during time-modified orthoclinostatic manoeuvre using HRV spectral analysis. Spectral variables, high-frequency (HF) (0.15-0.50 Hz) and low-frequency (LF) (0.05–0.15 Hz) power, and time domain variable – root mean square of successive differences (rMSSD) were calculated and transformed by natural logarithm (Ln). Training logs, fatigue and Borg scale were also calculated.
Results: Standing HR (109 ± 7 beats.min-1) was significantly ($p<0.05$) higher during the stay in Colombia compared with previous training blocks. Similarly, there was a reduction ($p<0.05$) in standing rMSSD (2.6 ± 0.4 ms) in Colombia compared with all previous training periods. However, there were no significant differences in any supine HRV variables between the monitored training periods. According to subjective assessment, morning fatigue was significantly lower during the 3rd period compared with the 2nd training period.
Conclusions:
Based on the results, cumulative stress, including standard training doses together with a fast transition over six westward time zones and the competition in Colombia caused a significant decline in standing vagal activity accompanied with HR acceleration, while supine HRV variables did not show any significant changes in the elite fin-swimmer. From this point of view, the standing position seems to be a more relevant diagnostic position to assess ANS activity in response to training and travel stress compared with the supine position, particularly in this elite fin-swimmer.
Keywords: heart rate variability, fin-swimming, vagal activity, fatigue, training load, sports performance

Introduction

To date, there are only few articles (Gautier, 2004; Oshita et al., 2009; Oshita et al, 2013) on the issue of fin-swimming. The current problems of sports training include optimization of training load and searching for solutions for making the training process more efficient in terms of physiological recovery and load exerted on the body in order to increase performance. A similar issue is also suggested by Pupišová, Pupiš, & Pivovarniček (2015), who confirm the possibility of evaluating physiological and biochemical parameters after load enables collection of more objective information about the impact of the observed stimulus and of the regenerative capabilities of the body. Pichot et al. (2002) claims that the functional state of ANS is significantly affected by the cumulative effect of body fatigue caused by increased training load. The spectral analysis (SA) of heart rate variability (HRV), and beat-to-beat fluctuation of heart rate (HR), are commonly accepted as a non-invasive method of determining ANS activity (Akselrod et al., 1981). Assessment of the autonomic nervous system (ANS) activity is according to some authors an appropriate tool for monitoring the effect of training load on the organism, or can serve as prevention of cumulative fatigue and overtraining (Leatherwood & Dragoo, 2013). HRV is utilized as an objective physiological marker to assist in training management, especially to optimize adaptation and performance in athletes (Botek, McKune, Krejčí, Stejskal & Gába, 2014; Chalencon et al., 2012; Koenig et al., 2014; Flatt & Esco, 2014; Chalencon et al., 2012).

A very important part of training preparation not only of swimmers but all athletes is the period just before major competitions called tapering. Therefore, another goal in sports training is to optimize performance during the taper period. The taper period is the final period of training before important competitions, during

Corresponding Author ZUZANA SVOZILOVÁ, E-mail: zuzana.svozilova01@upol.cz

which the training load, intensity and volume is reduced (Mujika and Padilla 2003; Spilbury et al., 2015). The aim is to maximize physiological adaptation, whilst eliminating accumulated fatigue or further enhancing performance (Luden, 2010). Vagal activity, expressed by high frequency (HF) spectral power, was considered to be useful to determine an individual's optimal training load during the taper period (Chalencon, 2012; Garet et al., 2004) as well as intensive training (Hautala et al., 2009). As confirmed by previous studies (Atlaoui et al. (2007), Garet et al. (2004) and Chalencon et al. (2012)) there is a significant relationship between vagal activity and swimming performance with higher HRV, and increased performance. However, Iellamo et al. (2002) states that increased performance might also be caused by a decrease in HRV as a result of vagal decrease and relative sympathetic dominance.

Elite athletes take part in major competitions such as World Cups, Olympic Games or World Championships. These competitions are often held in remote countries and require travel over long distances (Leatherwood & Dragoo, 2013; Reilly, 2009). Fast flying across time zones is associated with desynchronization of circadian rhythms, possibly resulting in sleep disorders (Leatherwood & Dragoo, 2013), overall fatigue, but also mood changes (Reilly et al., 2007), which constitute HRV reducing factors (reference). Therefore, another alternative use of ANS activity assessment is in the area of fast travel across time zones (Botek et al, 2009, Weingarten & Collop, 2014, Lagarde et al, 2000) in order to assess the speed of acclimatization to new space-time conditions. Botek et al. (2009) demonstrated that in terms of changes in ANS activity, athletes showed inter-individual sensitivity to fast transitions across the meridians; in some athletes more resistant to space-time conditions, ANS changes took place only after verticalization.

There are only few relevant studies dealing with the assessment of ANS activity by means of HRV in elite athletes, including subjective assessment performed in various training periods and during competitions after flying over time zones.

Therefore, the main aim of the present study was to evaluate the response of ANS activity using HRV to regular training phases, tapering period and acclimatization after rapid air travel across time zones in both supine and standing positions. The secondary aim was to evaluate psychometric variables in the context of training periodization.

Material & Methods

Participant

A 24-year-old fin-swimmer volunteered to participate in this study. She was monitored during a period of six-month training preparation before the World Games in Colombia. The basic anthropometrical a physiological variables are shown in Table 1.

TABLE 1. Basic anthropometrical and physiological variables

Parameter (unit)	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Fat (%)	VO2max (ml/kg/min)	HRmax (BPM)	ANP (BPM)
Athlete	24	160	55	21.5	18	54.2	201	185

Legend: VO2max – maximum oxygen consumption, BMI – body mass index, HRmax – maximum heart rate, ANP – anaerobic threshold; % – percent.

Training and competition programme

The assessment of ANS activity and morning fatigue was divided into three training periods followed by a period of acclimatization after flying over time zones to the venue of the swimming competition. The swimming training sessions took place 5 times a week. During the measurement, the values of ANS activity were not disclosed to the coach or the swimmer in order to avoid any negative impacts on her mental condition prior to the most significant competition of the season in case of poor HRV results. The training load was arranged according to the long-term experience of the coach and subjective feelings of the swimmer.

During the first two periods the training sessions took place three times in the afternoon in a 20m pool and twice in the morning in a 50m pool.

The first period (15 February - 17 March 2013) focused mainly on the development of endurance (especially bifins LI) and gradual adaptation to greater load (monofin and LI and HI). During this period the World Cup Competition took place as a nomination race for the World Championship. The swimmer underwent training sessions in 20m and 50m pool and also 'dry training' outside the pool.

During the second period (22 April - 1 June 2013) the training structure was identical to the first period. The second period was planned as the most important for the development of the athlete's form and included simulation of competition distances with a higher proportion of monofin HI.

The third period (8 July - 17 July 2013) was the shortest one and focused on tuning the swimmer's form (taper period) with a higher proportion of swimming with the racing fin (monofin LI + monofin HI). Logically, the proportion of relaxation swimming increased (without fins – VLI). This period is crucial to achieving and maintaining the swimmer's form. Any overload and accumulated fatigue could result in failure in the race.

The period after the westward flight over 6 time zones to Colombia was from 19 July to 29 July 2013. The flight took place on 18 July and the swimmer arrived on 18 July 2013 at night. The first measurement took place right after awakening on 19 July 2013. In Colombia, until the competition day the training took place once a day and lasted 60-90 min. The training consisted of an introductory part, warm-up swimming in short fins, followed by warm-up swimming in monofin and a series of swimming in monofin aimed at practicing the race distance – 400m.

The training units in all training sessions were divided into several parts according to the intensity and training equipment (TABLE 2).

TABLE 2. Description of training equipment and load intensity

Description of equipment and intensity	Training specification
Without fins – VLI	Swimming without fins, very low intensity (introductory and final part of TU, relaxation swimming after load)
Bifins – LI	Swimming in training (short) fins. Low intensity
Bifins – HI	Swimming in training (short) fins. High intensity
Monofin – LI	Swimming in the racing fin. Low intensity
Monofin – HI	Swimming in the racing fin. High intensity

Legend: bifins – two training fins, monofin – one bigger fin used for competition, km – kilometres, VLI - very low intensity, LI – low intensity, HI – high intensity.

Heart rate variability and subjective fatigue assessment

The ANS activity measurement was performed using the VarCor PF 7 diagnostic system (DIMEA group, Olomouc, Czech Republic). The monitoring of autonomic cardiac activity and fatigue was performed between 5:00 A.M and 9:00 A.M immediately after awakening at home; the ambient temperature ranged from 22 to 24°C. The ANS activity was assessed by the swimmer herself, but she was not allowed to check the results within the study. Before the study, the athlete was fully familiarized with each step of ANS measurement. ANS activity was measured during the time-modified orthoclinostatics manoeuvre (supine-standing-supine) according to a study by Botek et al. (2013). The ECG record was examined and all premature ventricular contractions, missing beats and any artefacts were manually filtered. A set of 300 artefact-free subsequent RR intervals were obtained in the standing and supine positions. SA HRV was used to assess the autonomic cardiac activity and the power spectral density curve of the collected signals was estimated using the Fast Fourier Transform method with a partly modified Coarse-Graining Spectral Analyses algorithm (Yamamoto and Hughson, 1991). HF oscillations in R-R intervals (Akselrod et al., 1981) were suggested to reflect the cardiac vagal outflow, while reciprocal changes between vagal and sympathetic activity were assessed throughout an analysis of low frequency power - LF (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996) and LF/HF (Ori, Monir, Weiss, Sayhouni, & Singer, 1992), respectively. ANS activity was expressed by the following spectral HRV variables (Salinger et.al., 1998): LF (0.50-0.15 Hz) and HF (0.15 -0.5 Hz). HF and LF were transformed by a natural logarithm (Ln). A time domain variable – root mean square of successive difference of RR intervals (RMSSD) was also used. RMSSD is regarded an index of vagal activity (Buchheit, 2014) that is thought to be resistant to the effects of breathing frequency (Penttilä et al., 2001). Subjectively perceived fatigue was assessed on a 1-4 scale, where 1 indicated no fatigue and 4 indicated maximum fatigue. The rate of perceived exertion (RPE) was scored immediately after finishing each training unit on a 6-20 Borg scale (Borg, 1998).

Statistical methods

A Kolmogorov-Smirnov test revealed skewed distribution of raw HRV variables; therefore, a natural logarithm (Ln) transformation was applied. HR, HRV variables, TU distance, fatigue, and Borg scale were expressed as an arithmetic mean ± standard deviation calculated from each period. The statistical significance of the changes between the periods was evaluated using one-way ANOVA and Fisher's post-hoc tests. Relative occurrences (percentages) of TU and two-phase TU between the periods were compared by means of the chi-square test. The level of statistical significance was set at $p < 0.05$. Statistical analyses were performed using the STATISTICA 12.0 programme (StatSoft, Tulsa, OK, USA).

Results

Training and competition programme

Table 3 shows that during the third period swimming in monofin prevailed over swimming in bifins at higher intensities. As shown in Table 3, the number of kilometres swum during a training unit and training day increased significantly during the third period compared with other monitored periods. Moreover, in this period the proportion of two-phased training session significantly increase compared with other periods.

TABLE 3. Percentage of training unit content in various periods

	Period 1	Period 2	Period 3	Colombia
Length:	67km	74.2km	35km	17.1km
Number of TUs:	19	21	11	9
Without fins – VLI	17.6%	15.5%	20.3%	20.4%
Bifins – LI	52.8%	47%	43.15%	36.8%
Bifins – HI	4.6%	10%	0%	0%
Monofin – LI	11.3%	9.7%	19.40%	14%
Monofin – HI	13.7%	17.8%	17.15%	28.8%

Legend: TU – training unit; bifins – two training fins, monofin – one bigger fin used for competition, km – kilometres , VLI - very low intensity, LI – low intensity, HI – high intensity.

TABLE 4 Summary of units swum in various periods

Variable	Period 1	Period 2	Period 3	Colombia	*p*
Number of days in the period	31	42	10	10	
Number of HRV examinations	20	20	7	10	
Number of days with 1 training	22	30	5	6	
Number of days with 2 trainings	2	0	3	1	
Total number of training days	24	30	8	7	
Kilometres swum total	67.0	79.7	35.0	17.1	
Percentage of training days	77	71	80	70	0.895
Percentage of days with 2 trainings	8	0	38	14	0.009
Km per 1 training day	2.8 ± 0.9‡	2.7 ± 0.7‡	4.4 ± 2.4*†§	2.4 ± 0.4‡	0.001
Km per 1 training	2.6 ± 0.9‡	2.7 ± 0.7	3.2 ± 0.7*§	2.1 ± 0.4‡	0.034

Legend: HRV – heart rate variability; km – kilometres; *p* – level of statistical significance ($p \leq 0.05$); ‡ – significant vs. Period 3; * – significant vs. Period 1; † – significant vs. Period 2; § – significant vs. Columbia.

Heart rate and heart rate variability

As shown in TABLE 5, standing HR (109 ± 7 beats.min-1) was significantly elevated during the stay in Colombia compared with the 1st, 2nd, and 3rd training period (97 ± 11; 98 ± 9, and 100 ± 10 beats.min-1). In terms of HRV variables, there was a significant reduction in standing LnrMSSD (2.6 ± 0.4 ms) in Colombia compared with the 1st, 2nd, and 3rd (2.9 ± 0.4; 3.0 ± 0.3; and 3.0 ± 0.3 ms) training period. Supine LnHF (7.9 ± 0.3 ms2) and LnrMSSD (4.7 ± 0.1 ms) tended to be higher in the 3rd training period compared with Colombia (LnHF = 7.5 ± 0.4 ms2, and LnrMSSD 4.5 ± 0.2 ms). Nevertheless, the differences between the periods did not reach significant values (p =0.081, and p =0.085, respectively).

TABLE 5 Statistical analysis of differences in HRV parameters and subjective assessment between monitored periods

	Average ± SD				
Variable [units]	Period 1	Period 2	Period 3	Colombia	*p* (ANOVA)
HR standing [beats/min]	97 ± 11§	98 ± 9§	100 ± 10§	109 ± 7*†‡	0.013
LnLF_ standing [ms2]	6.4 ± 0.5	6.5 ± 0.7	6.3 ± 0.8	6.1 ± 0.8	0.417
LnHF_ standing [ms2]	4.8 ± 0.9	4.9 ± 0.8	4.6 ± 0.8	4.3 ± 1.1	0.270
LnLF/HF_ standing	1.6 ± 0.8	1.6 ± 0.7	1.7 ± 0.7	1.8 ± 0.5	0.843
LnRMSSD_ standing [ms]	2.9 ± 0.4§	3.0 ± 0.3§	3.0 ± 0.3§	2.6 ± 0.4*†‡	0.016
HR supine [beats/min]	54 ± 4	53 ± 6	51 ± 2	53 ± 6	0.786
LnLF_ supine [ms2]	6.1 ± 0.9	6.3 ± 0.8	6.4 ± 0.6	6.1 ± 1.2	0.777
LnHF_ supine [ms2]	7.7 ± 0.2	7.8 ± 0.4	7.9 ± 0.3	7.5 ± 0.4	0.081
LnLF/HF_ supine	-1.7 ± 0.9	-1.5 ± 0.8	-1.5 ± 0.7	-1.4 ± 1.2	0.904
LnRMSSD_ supine [ms]	4.6 ± 0.1	4.6 ± 0.2	4.7 ± 0.1	4.5 ± 0.2	0.085
Fatigue [points]	2.3 ± 0.9	2.3 ± 0.6	1.6 ± 0.7†	1.7 ± 0.9	0.048
Borg scale [points]	16 ± 2	16 ± 3	17 ± 1	17 ± 1	0.271

Legend: HR – heart rate; LnLF – natural logarithm of low frequency; LnHF – natural logarithm of high frequency; LnRMSSD – natural logarithm of Root mean square of successive differences; *p* – level of statistical significance ($p \leq 0.05$); ‡ – significant vs. Period 3; * – significant vs. Period 1; † – significant vs. Period 2; § – significant vs. Columbia.

As far as subjective assessment is concerned, the mean feeling of morning fatigue was significantly lower during the 3rd period (1.6 ± 0.7 point) compared with the 2nd training period (2.3 ± 0.6), while RPE level did not change significantly between the monitored training periods.

Discussion

The main objective of the study was to quantify the changes in autonomic cardiac regulation and subjective assessment during training preparation, including transition across multiple time zones in an elite fin-swimmer.

Fin-swimming is a sports discipline with a limited number of research studies that would objectively describe the training process and the changes in the context of subjective and objective assessment following changes in the amount of load. HRV is considered a highly sensitive indicator of changes in the ANS activity (Task Force, 1996), reflecting the changes in the internal environment of the organism, which may take place as a result of training and non-training activity or environmental effects such as desynchronization of the biological clock (Migliaccio et al., 2016; Leatherwood & Dragoo, 2013).

Our results showed that despite the significant increase in the number of kilometres swum per training unit in the third period relative to other periods, there have been no significant changes in autonomic cardiac regulation in the standing or supine position. It should be noted however that paradoxically, an increase in the number of km in this period together with the significantly higher frequency of two-phase training sessions compared with other periods caused an insignificant increase in the values of HRV parameters representing vagal activity, specifically LnHF and LnrMSSD. Some authors associate both parameters with an increase in sports performance (Garet et al., 2004) and good sports form (Chalencon, 2012).

However, Table 3 shows that in the third period the content of the training session compared with previous periods was more specific, which documents a percentage increase in the training load, as the athlete swam in monofin primarily at lower intensities at the expense of bifin swimming at higher intensities. This may explain the significantly lowest level of subjectively perceived morning fatigue, which was again observed in the third period. It is also possible that the lower perception of fatigue could have positively influenced vagal activity in this period.

Our research also showed that there were no significant changes in the HRV parameters in the elite athlete in the supine position, although vagal activity scored the highest values in the third period and the lowest values after arrival in Colombia. From a purely diagnostic perspective, in this specific athlete the supine position is probably insufficiently sensitive to changes in ANS induced by stress factors, especially training combined with flying over multiple meridians. It is also possible that in spite of the declared changes in the volume of training load, the athlete is so well-trained (adapted) that the changes in the amount of load do not induce a significant stress response leading to changes in autonomic cardiac regulation in the supine position.

Quick transition over multiple time zones results in individually variable responses of athletes in terms of higher or lower sensitivity (Botek et al., 2009), which is reflected in ANS activity changes. On the other hand, numerous studies suggest that changes in ANS be monitored after verticalization (Perini & Veicsteinas, 2003; Hedelin et al., 2001) or in a combined standing and supine position (Botek et al., 2014; Kowalewski & Urban, 2004) in order to increase sensitivity to detect discrete changes in autonomic cardiac regulation not detectable in the supine position. Similarly, in the present study the standing position proved to be more suitable as opposed to the supine position because of a significant increase in SF and reduction in vagal activity (LnrMSSD). It is apparent that the accumulation of stress factors in the form of training, competition stress, and flying over time zones induces a significant response of the regulatory system, but detectable only in the standing position.

The athlete's performance at the World Championship was beyond expectations. The swimmer improved her personal best. It turns out that a short-term decrease in HRV as a result of reduction in vagal activity before the race probably does not have a significant negative effect on sports performance. In contrast, temporary deviation of ANS activity in favour of the sympathetic activity observed in the standing position might have a positive stimulation effect. This was also observed by Iellamo et al. (2001) in elite rowers, who underwent highly intensive training and showed significant prevalence of sympathetic activity. According to the authors, this contributes to increased performance of the cardiovascular and muscular system (Grassi & Passatore, 1988) during the race. On the other hand, Iellamo et al. (2002) point out that in the long term, this autonomic imbalance is not beneficial in terms of potential health risks and hypertension. In another study, an increase in the LFnu value as a sympathetic activity indicator during the taper period in recreational marathon runners was considered a predictor of good sports performance (Manzi et al., 2009). From a practical point of view, HRV seems to be a promising training tool that could provide coaches with additional information about the athletes' functional state before important competitions.

Conclusion

The present study showed that different training doses and content induced rather marginal changes in autonomic cardiac regulation as well as in subjective feeling of morning fatigue. Nevertheless, it is clear that cumulative stress, including standard training doses together with a fast transition over six westward time zones and the competition in Colombia caused a significant decline in standing vagal activity accompanied with HR acceleration, while supine HRV variables did not show any significant changes in a well-trained fin-swimmer. From this point of view, the standing position seems to be a more relevant diagnostic position to assess ANS activity response to training and travel stress compared with the supine position, particularly in this elite fin-swimmer.

References:

Akselrod, S., Gordon, D., Madwed, J. B., Snidman, N. C., Shannon, D. C., & Cohen, R. J. (1985). Hemodynamic regulation: Investigation by spectral analysis. *American Journal of Physiology*, *249(*4*)*, 867-875.

Atlaoui, D., Pichot, V., Lacoste, L., Barale, F., Lacour, J. R., & Chatard, J. C. (2007). Heart rate variability, training variation and performance in elite swimmers. *International Journal of Sports Medicine, 28*(5), 394-400.

Becker, T., Penzel, T. & Fietze, I. (2015). First jet lag symptoms after travelling across multiple time zones. *Biological Rhythm Research, 46*(3)*,* 361.

Borg, G. (1985). *An introduction to Borg´s RPE-scale.* Ithaca, NY: Movement Publications.

Botek, M., Krejčí, J., & Weisser. R. (2014). Autonomic cardiac regulation and morpho-physiological responses to eight week training preparation in junior soccer players. *Acta Gymnica, 44*(3), 155–163. doi: 10.5507/ag.2014.016

Botek, M., McKune, A. J., Krejčí, J., Stejskal, P., & Gába, A. (2014). Change in performance in response to training load adjustment based on autonomic activity. *International Journal of Sports Medicine, 35*, 482-488.

Botek, M., Stejskal, P., & Svozil, Z. (2009). Autonomic nervous system activity during acclimatization after rapid air travel across time zones: a case study. *Acta Universitatis Palackinae Olomoucensis. Gymnica, 39,* 13-22.

Botek, M., Krejčí, J., Neuls, F., & Novotný, J. (2013). Effect of modified method of autonomic nervous system activity assessment on results of heart rate variability analysis. Acta Gymnica, *43*(2), 39-46.

Buchheit, M. (2014). Monitoring training status with HR measures: Do all roads lead to Rome? *Frontiers in Physiology, 27,* 73.

Flatt A.A., Eco M.R. (2014). Endurance performance relates to resting heart rate and its variability: a case study of collegiate male cross-country athlete. *Journal of Australian Strength and Conditioning, 22,* 39-45.

Freitas, C. G., Aoki, M. S., Franciscon, C. A., Arruda, A.F.S., Carling, Ch., & Moreira, A. (2014). Psychophysiological responses to overloading and tapering phases in elite young soccer players. *Pediatric Exercise Science, 26,* 196-202.

Garet, M., Tournaire, N., Roche, F., Laurent, R., Lacour, J. R., Barthélémy, J. C., & Pichot, V. (2004). Individual interdependence between nocturnal ANS activity and performance in swimmers. *Medicine & Science in Sports & Exercise, 36,* 2112-2118.

Grassi, C. & Passatore, M. (1988). Action of the sympathetic system on skeletal muscle. *The Italian Journal of Neurological Sciences, 9*(1), 23-28.

Gautier, J., Laurent, B., Zanone, P. G., & Watier, B. (2004). A kinematic study of finswimming at surface. *Journal Sports Science and Medicine, 3,* 91-95.

Hedelin, R., Bjerle, P., & Henriksson-Larsén, K. (2001). Heart rate variability in athletes: Relationship with central and peripheral performance. Medicine & Science in Sports & Exercise, *33*(8), 1394–1398.

Chalencon, S., Busso, T., Lacour, J.R., Garet, M., Pichot, V., Connes, P., Gabel, C.P., Roche, F., & Barthélémy, JC. (2012). A model for the training effects in swimming demonstrates a strong relationship between parasympathetic activity, performance and index of fatigue. *PloS ONE*, *7*.

Iellamo, F., Legramente, M.F., Pigozzi, F., Spataro, A., Norbiato, G., Lucini, D., & Pagani, M. (2002). Conversion from vagal to sympathetic predominance with strenuous training in high-performance world class athletes. *Circulation, 105,* 2719-2724.

Koenig, J., Jarczok, M. N., Wasner, M., Hillecke, T. K., & Thayer, J. F. (2014). Heart rate variability and swimming. *Sports Medicine, 44*(10)*,* 1377-1391.

Kowalewski, M. A., & Urban, M. (2004). Short- and long-term reproducibility of autonomic measures in supine and standing positions. *Clinical Science*, *106*(1), 61–66. http://doi.org/10.1042/CS20030119

Lagarde, D., Chappuis, B., Billaud, P., Ramont, L., Chaufard, F., & French, J. (2000). Evaluation of pharmacological aids on physical performance after a transmedian flight. *Medicine & Science in Sport & Exercises*. 628-634.

Leatherwood, W.L., Dragoo, J.L. (2013). Effect of airline travel on performance: a review of the literature. *Br J Sports Med, 47,* 561-567.

Luden, N., Hayes, E., Galpin,A., Minchev, K., Jemiolo, B., Raue, U., … Trappe, S. (2010). Myocellular basis for tapering in competitive distance runners. *Journal of Sports Medicine, 14*(1)*,* 1501-1509.

Maglischo, E. W. (2003). *Swimming fastest*. Champaign: Human Kinetics.

Manzi, V., Castagna, C., Padua, E., Lombardo, M., D´Ottavio, S., Massaro, M…Iellamo, F. (2009). Dose-response relationship of autonomic nervous system responses to individualized training impulse in marathon runners. *American Journal of Physiology - Heart and Circulatory Physiology, 296*(6), 1733-1740. DOI: 10.1152/ajpheart.00054.2009

Migliaccio, G. M., Di Nino, A., Avaldi, F., Bazzu, A., Mullen, G. J., & Padulo, J. (2016). Effects of circadian rhythms on night-time swimming during the Olympics: The results of a pilot study in preparation for Rio 2016. *Journal Swimming Research, 24*(1)*,* 3-12.

Mujika, I., & Padilla, S. (2003). Scientific bases for precompetition tapering strategies. *Medicine and Science in Sports and Exercise, 35,* 1182-1187.

Murrell, G. A. C., Sein, M. L., Walton, J., Linklater, J., Appleyard, R., Kirkbride, B., & Kuah, D. (2010). Shoulder pain in elite swimmers: primarily due to swim-volume-induced supraspinatus tendinopathy. *Br J Sports Med*, *44*, 105–113. http://doi.org/10.1136/bjsm.2008.047282

Ori, Z., Monir, G., Weiss, J., Sayhouni, X. & Singer, D.H.(1992). Heart rate variability. Frequency domain analysis. *Cardiology Clinics, 10*(3), 499-537.

Oshita, K., Ross, M., Koizumi, K., Kashimoto, S., Yano, S., Takahashi, K., & Kawakami, M. (2009). The critical velocity and 1500-m surface performances in finswimming. *International Journal of Sports Medicine, 30*(8)*,* 598-601.

Oshita, K., Ross, M., Koizumi, K., Tsuno, T., & Yano, S. (2013). Gender difference of aerobic contribution to surface performance in finswimming: Analysis using the critical velocity method. *Asian Journal of Sports Medicine, 4*(4)*,* 256-262.

Penttila, J., Helminen, A., Jartti, T., Kuusela, T., Huikuri, H.V., Tulppo, M.P…Scheinin, H. (2001). Time domain, geometrical and frequency domain analysis of cardiac vagal outflow: effects of various respiratory patterns. *Clinical Physiology and Functional Imaging, 21*(3), 365-376. DOI: 10.1046/j.1365-2281.2001.00337.x

Perini, R., & Veicsteinas, A. (2003). Heart rate variability and autonomic activity at rest and during exercise in various physiological conditions. *European Journal of Applied Physiology*, *90*(3–4), 317–325. http://doi.org/10.1007/s00421-003-0953-9

Pichot, V. et al. (2002). Autonomic adaptations to intensive and overload training periods: a laboratory study. *Medicine and Science in Sport and Exercise, 34*(10)*,* 1660-1666.

Plews D.J., Laursen P.B., Stanley, J. et al. (2013). Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. *Sports Medicine, 43,* 773-781. doi:10.1007/s40279-013-0071-8

Pupišová, Z., Pupiš, M., & Pivovarniček, P. (2015). Effects of swimming performance on a change in blood parameters. *Journal of Physical Education and Sport*, *15*(4), 844–848. http://doi.org/10.7752/jpes.2015.04130

Reilly, T., Atkinson, G., Edwards, B., Waterhouse, J., Akerstedt, T., Davenne, D., Lemmer, B., & Wirz-Justice, A. (2007). Copying with jet-lag: A Position Statement for the European College of Sport Science. *European Journal of Sport Science, 7*(1)*,* 1-7.

Reilly, T. (2009). How can travelling athletes deal with jet-lag? *Kinesiology 41*(2)*.*128-135.

Spilbury, K.L., Fudge, B.W., Ingham, S.A., Faulkner, S.H., & Nimmo, M.A. (2015). Tapering strategies in elite British endurance runners. *European Journal of Sport Science, 15*(5)*,* 367-373.

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. Special report. *Circulation, 93,* 1043-1065.

Weingarten, J.A., & Collop, N.A. (2013). Air travel. Effects of sleep deprivation and jet lag. *Chest, Postgraduate education corner*, *144*(4), 1394-1401.

Yamamoto, Y., & Hughson, R.L. (1991). Coarse-graining spectral analysis: new method for studying heart rate variability. *Journal of Applied Physiology, 71*(3), 1143-1150.

Young, F.L., Leicht, A.S. (2011). Short-term stability of resting heart rate variability: influence of position and gender. *Appl Physiol Nutr Metab, 36,* 210-218.