Monitoring training response with heart rate variability in elite adolescent athletes: is there a difference between judoka and swimmers?

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: Previous studies in adults and endurance athletes have evaluated whether heart rate variability (HRV) can be used to monitor training load. We aimed to answer to question: whether HRV monitoring is useful in elite adolescent athletes practicing a sport with a major anaerobic component, i.e. judo.

Material & Methods: Eleven young swimmers (age 15.5 ±0.9 years) were compared to eleven young judoka (age 15.0 ±0.9) before and after two weeks of a similar increase in training load. Autonomic nervous system (ANS) activity was evaluated by HRV analysis during an active tilt-test (8 min supine followed by 8 min standing).

Results: In both sports, increase in parasympathetic indices (especially the proportion of adjacent RR intervals that differ by >50ms (pNN50) and the square root of the mean of the squares of successive RR differences (rMSSD) was associated with increase in training load). The association was higher in judoka than in swimmers, and higher in standing than in supine.

Conclusions: In elite adolescent athletes, we successfully monitored ANS response to training using HRV analysis, independently of the sport practiced. Moreover, pNN50 and rMSSD, both indicators of parasympathetic activity, appear to be the most pertinent indices to monitor ANS response in elite adolescent athletes. Our results also indicate that dynamic evaluation (dynamic change from supine to standing) with an active tilt-test is preferable to resting evaluation (supine rest only).

Key words: autonomic nervous system • exercise training • martial arts • tilt-test • training load

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Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (...) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '*workload volume*'. (...) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of *training load* defined as the amount of workload. It is useful in analyses with a high level of generality. (...)In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [35, p. 238].

The method for workload measurement (during the safe falling exercises and exercises involving frequent direct contact as in judo) – is based on the assumption that the only tool used in measurement process is a stopwatch and the results are noted in a special protocol. The method is applicable in almost every conditions, especially while registering HR with the use of sport-testers is impossible [35].

Basic indexes of training load (universal for swimming, judo, etc.) – the duration of particular measures i.e. given exercises or sets of exercises (T_E), rest between exercises (T_R), the duration of entire training (T), the intensity of the exercises (I_E),), the intensity of the rest (I_R), the intensity of the entire training (I); the *content of exercises* (described in words or symbols), the *scope of exercise* recorded as e.g. the number of repetitions, mistakes or any other relevant information [35]

Introduction

In high-level sports, the evaluation of training load and the athlete's physiological adaptations feature among the key issues for coaches and athletes [1]. However, a recent systematic review revealed that few studies have explored the effect of training on the autonomic nervous system (ANS) in healthy children and adolescents [2]. It is well recognized that young athletes yield significant benefits from practicing sports (higher self-esteem, peer socialization, fitness). However, competitive success requires a substantial training load (TL) and engenders psychological pressure due to the high level standard [3]. Thus, high-level adolescent athletes are exposed to training risks as much as adult athletes, and failure to recover adequately from training stress can compromise their adaptation to the training load, and may also cause impaired psychological and physiological states [4, 5].

In order to monitor autonomic imbalance, evaluation of heart rate variability (HRV) has been proposed as a pertinent method in adult athletes [6-8]. HRV and heart rate recovery (HRR) fluctuate according to TL [9, 10] and these heart rate evaluations have been highlighted as a potential tool for the evaluation of the athlete's adaptation to training [5, 8]. A recent study showed that in young adolescent soccer players, a decrease in submaximal heart rate, a faster return of heart rate after exercise and an increase in vagal indices of HRV were associated with positive adaptations to training [11].

However, to date, the relationships between HR or HRV and adaptation to TL have mainly been studied in adults, and in endurance athletes, like swimmers [12] or runners [13]. Monitoring of ANS response to training by HRV has rarely been applied in adolescents, or in sports with major strength and speed components, such as judo [14]. Therefore, the aim of this study was to answer to question: whether HRV monitoring is useful in elite adolescent athletes practicing a sport with a major anaerobic component, i.e. judo.

To do this, we compared ANS response to training between elite adolescent swimmers and judoka, during a comparable training cycle. Based on the scientific literature, we hypothesized that the link observed between training load and HRV would be similar adolescent to that observed in adults, whatever the sport practiced.

Material and methods

Experimental approach to the problem

In order to monitor ANS response in adolescents, a training period of two weeks between early- and mid-January was selected. This period corresponded to an increase in TL to allow athletes to get back to an adequate level of fitness after the Christmas holidays. Adolescents were evaluated before (T1) and at the end (T2) of the two weeks of training. The session-rating of perceived exertion (session-RPE) method was used to evaluate training load in swimmers (SW) and judoka (JU) [15, 16].

Athletes were asked to rate their perceived session exertion (RPE) using a modified version of the Borg CR-10 scale. This score, given in arbitrary units (AU), represents the subjective training load, and allows comparison of the training load between swimmers and judoka, even when they different training. It is also a non-invasive method which has been used to quantify training load in SW [17] and JU [18]. We chose to evaluate ANS response to training load using an active tilt test [6, 7] in order to eliminate potential bias. Indeed, contrary to SW, JU usually practice on the floor, and are therefore likely to have greater abilities in performing vertical exercise tests like the 5'-5' proposed by Buchheit et al., which requires the athlete to run at a submaximal aerobic speed for 5' followed by 5' of rest sitting on a chair [8]. As swimmers rarely perform exercise such as running in their training process, contrary to judoka, who usually run during warm-up and to develop aerobic power, swimmers would likely be at a disadvantage in this type of test.

Participants

Eleven adolescent swimmers (SW; age 15.5 ± 0.9 years) were compared to 11 adolescent judoka (JU; age 15.0 ± 0.9 years). They were all attending specialized training center for high-level youth athletes accredited by the French Ministry of Sports, Youth, popular education and community life. All had been practicing their respective sport for more than 3 years and were ranked at national to international level. Before participation, we obtained permission from the sporting authorities. Parental and child consent were also obtained after full information. Finally, medical supervision of the participating athletes was supervised by their training center.

Procedures

Investigations were performed in the respective training area of each athlete, between 16:30 and 17:30 on Fridays, before the last training session of the week, and after 15 min of rest to stabilize cardiorespiratory indicators.

The day before the investigations, athletes performed a training session in the morning as part of their usual training. However, no training sessions were allowed on the afternoon of the day prior to the investigations. Friday, only one training session was performed in the morning.

All tests were performed under the supervision of the same investigator. Athletes were requested to refrain from ingesting beverages containing caffeine and alcohol during the 24h preceding all test sessions. The order of the test was the same for all participants. HRV recording began with 8 min in the supine position in a quiet, dimly lit room (20°C), followed by 8 min standing. Heart rate was continuously recorded using a Suunto t6 Memory Belt (Suunto Vantaa, Finland) [7].

Beat by beat intervals were determined as the interval between two successive R-spikes. We selected segments of 256 s in both supine and standing postures. Each file was visually inspected. Artifacts were manually removed and occasional ectopic beats were automatically replaced with the interpolated adjacent R–R interval values. Based on the literature [6, 8, 19] we calculated (1) in the time domain: Mean RR, the root mean square of successive differences of successive R-R intervals (rMSSD), and the proportion of the number of interval differences of successive R-R intervals greater than 50 ms (pNN50) (2) in the frequency domain with a Fast Fourier transform: the low (LF; 0.04-0.15 Hz) to high (HF; 0.15-0.40 Hz) frequency ratio (LF/HF) and the HF values in normalized units (nu) (i.e., HFnu = HF/(LF+HF), and (3) instantaneous beat-to-beat variability (SD1) derived from the nonlinear Poincare method [6].

For all indices, we calculated the change between T1 to T2 as follow $\Delta_{\%}$=(T1-T2)/T1. All R-R series data were extracted by Suunto Training Manager 2.3.0 and analyzed with Kubios HRV (version 2.0), developed by Biosignal Analysis and Medical Imaging Group (BSAMIG), Department of Physics, University of Kuopio, Finland [20].

Statistical analyses

Data are presented as mean ± standard deviation (SD); or mean and 90% confidence limits (CL) when specified. When data were skewed or heteroscedastic, they were transformed by taking the natural logarithm. Since the magnitude of an effect is of more practical interest than statistical significance *per se* [21], all comparisons were also expressed as standardized mean differences (Cohen effect size, ES), calculated using the pooled standard deviations for the two testing sessions being compared. Thresholds were defined as >0.2 for small, >0.5 for moderate and >0.8 for large ES.

To identify possible within- and between-group differences for TL, and for supine and standing HRV indices, a two-way ANOVA for repeated measures ((judoka/swimmers) x times: T1-T2) was used and ANOVA post-hoc testing was performed using the LSD test. Possible differences between the $\Delta_{\%}$ of SW and JU were controlled by a t-test (p<.05). Then, relationships between HRV indices and TL were established using Pearson's product–moment correlation. The following criteria were adopted to interpret the magnitude of the correlation (*r*) between test measures: <0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; and 0.9–1.0, almost perfect. Statistical significance was accepted at p<0.05. Also, 90% CL for the correlations were calculated using a spread-sheet designed for this purpose and downloaded from http://www.sportsci.org. If the 90% CL overlapped small positive and negative values, the magnitude was deemed unclear; otherwise that magnitude was deemed to be the observed magnitude [20, 21].

Results

Training load largely increased between T1 and T2 for both SW (from 1178 ± 237 to 2056 ± 320; *p* <0.001; ES = 3.12) and JU (from 1251 ± 390 to 2250 ± 328; *p*<0.001; ES = 2.78), without significant difference between the two sports (*p* = 0.53; ES = 0.08).

For SW, in both the supine and standing positions, no significant changes were observed between T1 and T2 in the different HRV indices (Table 1). Also, no clear association was found at T1 and T2 between TL and HRV indices (p values from 0.11 to 0.99 and r values from –0.13 to 0.35). As regards the relationships

Table 1. Heart Rate Variability indices for swimmers (SW) *vs.* Judoka (JU) at the beginning (T1) and end (T2) of the training in both supine and standing postures.

		Swimmers (n = 11)					Judokas (n = 11)			
		unit	**T1**	**T2**	**P**	**ES**	**T1**	**T2**	**P**	**ES**
Supine posture	Mean RR	m·s–1	1082 ±128	1084 ±151	.98	.003	967 ± 147	992 ±152	.33	.17
	rMSSD	m·s–1	76 ±43	79 ±42	.95	.02	98 ± 72	92 ±46	.82	.07
	pNN50	%	42 ±22	47 ±25	.50	.17	44 ± 25	49 ±17	.43	.35
	HF	nu	58 ±20	61 ±24	.87	.04	57 ± 17	66 ±15	.20	.53
	LF/HF	ratio	0.9 ±0.8	1.1 ±1.3	.59	.15	0.9 ± 0.7	0.6 ±0.5	.21	.51
	SD1	m·s–1	54 ±30	56 ±30	.95	.02	70 ± 51	66 ±33	.82	.07
Standing posture	Mean RR	m·s–1	738 ±99	777 ±116	.27	.35	678 ± 113	728 ±109	.11	.47
	rMSSD	m·s–1	47 ±33	41 ±37	.36	.32	**27 ± 23**	**39 ±22**	**.04**	**.78**
	pNN50	%	15 ±14	18 ±20	.52	.10	9 ± 15	13 ±15	.11	.62
	HF	nu	27 ±21	25 ±21	.62	.18	16 ± 10	20 ±12	.41	.43
	LF/HF	ratio	5 ±3	6.2 ±6	.66	.15	7 ± 4	5 ±3	.47	.42
	SD1	m·s–1	33 ±24	29 ±26	.36	.32	**19 ± 17**	**28 ±16**	**.04**	**.78**

Note: Values are mean ± SD. Mean RR, mean of R-R intervals; rMSSD, root-mean-square of successive differences between normal sinus R-R intervals; pNN50, proportion of adjacent RR interval showing a difference of more than 50ms; HFnu, HF in normalized units; LF/HF, ratio of low-frequency on high-frequency power; SD1, standard deviation of short-term R-R interval variability. *P* represents the level of significance between T1 and T2, and ES represents Cohen's effect size between T1 and T2.

between the change between T1 and T2 ($\Delta_{\%}$), moderate and positive associations were found in the supine position between TL and rMSSD (Figure 1). In the standing posture, a moderate and positive association was found between TL and pNN50 (Figure 1).

For JU, in the supine position, no significant change was observed between T1 and T2 (Table 1). No association was found between TL and HRV indices at T1 and T2 (p values from 0.41 to 0.76 and r values from 0.07 to 0.18). In the standing posture, we observed a moderate increase in rMSSD and SD1 between T1 and T2 (Table 1). TL was moderately and positively associated with rMSSD [r = 0.41 (0.06; 0.67)] and SD1 [r = 0.41(0.06; 0.67)] at both T1 and T2. No other association was found in this posture. As regards the changes between T1 and T2 ($\Delta_{\%}$), we found a large and positive association between TL and pNN50, and a large, negative association between TL and LF/HF in the supine posture (Figure 2). During standing, TL was very largely and positively associated with Mean RR and pNN50, largely and positively associated with rMSSD and SD1, and moderately and positively associated with HFnu (Figure 2). In contrast, a moderate and negative association with LF/HF was also found with TL (Figure 2).

The comparison of ANS responses between SW and JU showed that in the supine position, HRV indices were not statistically different between JU and SW at either T1 or T2. Regarding the changes between T1 and T2 ($\Delta_{\%}$), we did not find any significant difference. During standing, we observed large differences between JU and SW for rMSSD (p = 0.031, ES = 0.92) and SD1 (p = 0.031, ES = 0.94) at T1, with systematically higher values in swimmers. No difference was found between JU and SW at T2. Regarding the changes between T1 and T2 ($\Delta_{\%}$), we observed small differences, with higher values among judoka than in swimmers for rMSSD (p = 0.03, ES = 0.22) and SD1 (p = 0.03, ES = 0.23).

Discussion

Our results show that two indices (rMSSD and pNN50) were particularly associated with TL in elite adolescent athletes, whatever their sport specificities (Figures 1 and 2). Both are indices of the response of the sinus node to parasympathetic activity [22]. They are also considered as pertinent

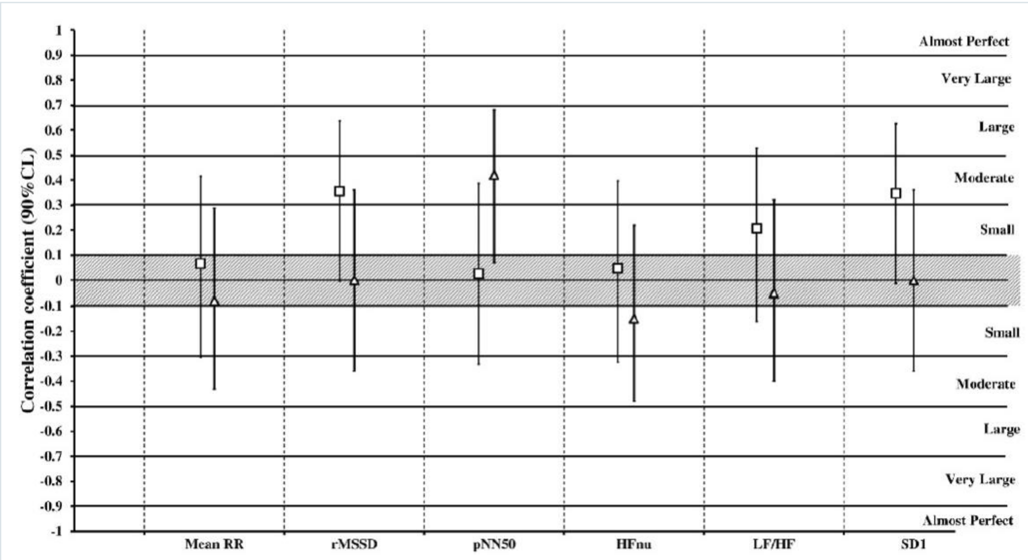

Figure 1. Correlation coefficient (90% confidence limits, CL) between changes in training load (TL) and in ANS indices for SW, considering variation between T1 to T2 in supine (□) posture and in standing (Δ) posture.

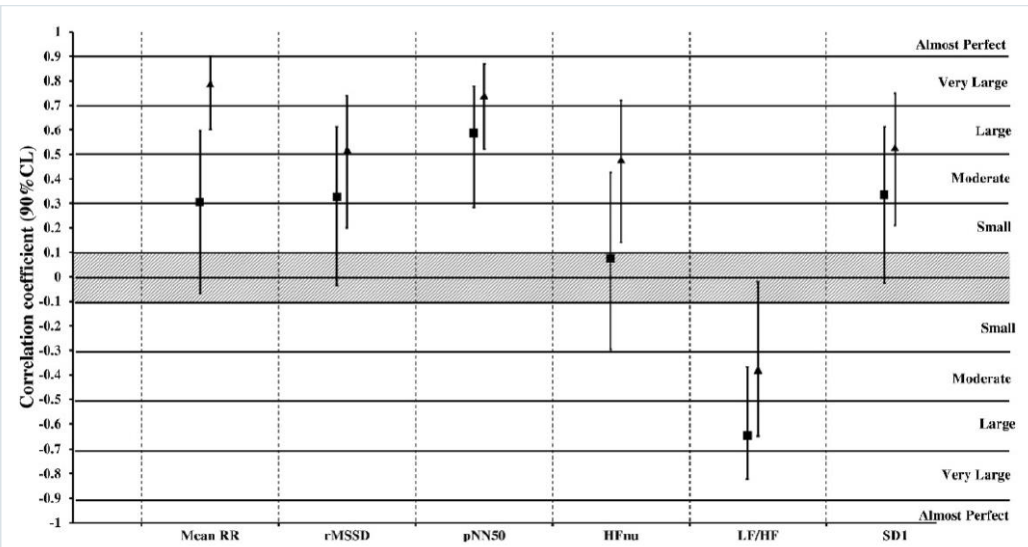

Figure 2. Correlation coefficient (90% confidence limits, CL) between changes in training load (TL) and in ANS indices for JU, considering variation between T1 to T2 in supine (■) posture and in standing (▲) posture.

and easy tools for monitoring ANS response to TL [8, 23]. This is especially true in the present study with pNN50, which was associated with TL for both sports during ST (Figures 1 and 2).

During this study, the increase in TL was not statistically different between JU and SW. However, we observed higher ANS changes with training for JU than for SW (Table 1). For JU, the increase in TL was positively associated with the increase of several parasympathetic indices (pNN50 during SU and Mean RR, rMSSD, pNN50, HFnu and SD1 during ST; Figure 2). We also observed a negative association between the increase in TL and an index that could be considered as an indicator of sympathetic over parasympathetic balance [24, 25]; even if this interpretation should be viewed with caution [26]), i.e. LF/HF during both SU and ST (Figure 2).

These results are in accordance with previous studies with strength/speed component sports [23, 27]. Thus, we can conclude that using HRV to monitor the ANS response to an increase in TL is possible among adolescent judoka. On the other hand, for SW, the increase in TL was associated with an increase in parasympathetic indices (Figure 1, especially rMSSD during SU and pNN50 during ST). Such positive correlations between TL and vagal indices have been shown in adult elite rowers during their preparation for the London Olympic Games [28].

The higher ANS changes observed with training for JU as compared to SW can likely be explained by the fact that SW had greater parasympathetic activity than JU at the beginning of the training period, as assessed by rMSSD and SD1 during the standing posture at T1 (Table 1). More interestingly, the ANS difference between JU and SW disappeared after the training period (Table 1) suggesting larger ANS adaptation for the adolescents practicing judo. We can consider that the initial level of fitness of SW and JU adolescents was different. Indeed, previous studies investigating ANS response to training reported that the training history of athletes influences their ANS responses to training load [19].

For example, it has been shown that an increase in vagal-related HRV indices occurs with training in moderately trained (4 to 6h training per week) but not in highly trained athletes (more than 18h training per week), even in the absence of competition, fatigue, or overload [29].

While in our study both the SW and JU were enrolled in high level structures, their training volume (in hours) differed on a typical week of training (~12h training per week for JU; ~20h for SW). From this perspective we could consider that the higher ANS changes with training for JU than for SW are consistent with the literature.

Methodological considerations lead us to underline the relevance of data variations (e.g. $\Delta_{\%}$) in order to monitor the ANS response to TL. Indeed, while we found few associations between TL and HRV (e.g. in standing posture for JU) using raw data, we found associations for all sports and postures when using the measure of change between T1 and T2 ($\Delta_{\%}$). Such methodological considerations are in accordance with previous studies [9, 30] highlighting that it is the variation of HRV indices that is associated with the variation of TL.

Finally, in this study, we chose to use an active tilt-test in order to eliminate potential bias due to the fact that JU usually practice on the floor and therefore, likely have greater abilities for performing dynamic vertical tests like the 5'-5'[8]. In this context, our results strengthened that together with a resting position (e.g., supine) stimulating the cardiovascular system (e.g., standing) is important to obtain a better evaluation of the ability of the ANS to respond to training. Challenging the ANS activity by an orthostatic test allow to evaluate not only how is the ANS activity, but also how it is able to react in face of a stressful condition such as the constrain of a training session or a competition. This is in line with previous studies dealing with the physiological evaluation of the ANS response to exercise [31] or training [7] in adulthood athletes, and especially with the new findings that evaluating athletes both during supine and active standing allowed to characterize different types of fatigue in high-level athletes [32].

The main limitations of this study are, firstly, the low number of athletes evaluated in each sport, and secondly, the fact that our investigations were performed on a simple T1 to T2 protocol. Nevertheless, the low number of athletes is a recurrent characteristic of studies carried out in athletes of any class level [5, 14, 28, 33, 34]. In order to compensate the simple T1 to T2 protocol and to strengthen these preliminary results, further studies with other teams, athletes and sports presenting similar characteristics (like Greco- Roman wrestling for example) are required. Finally, future studies need to pay attention to TL monitoring methods (RPE and TRIMP for example), TL characteristics (volume/intensity) and HRV recording protocols (tilt-test or 5min/5min, for example) as the most effective tools remain to be identified.

This study, specifically designed to assess whether monitoring the autonomic nervous system response to training using heart rate variability analysis in elite adolescent athletes is possible in sports with a major aerobic or strength and speed components, revealed associations between training load and parasympathetic indices among both judoka and swimmers. These results also emphasize that dynamic evaluation through an active tilt-test is preferable to resting evaluation.

Conclusions

In elite adolescent athletes, we successfully monitored ANS response to training using HRV analysis, independently of the sport practiced. Moreover, pNN50 and rMSSD, both indicators of parasympathetic activity, appear to be the most pertinent indices to monitor ANS response in elite adolescent athletes. Our results also indicate that dynamic evaluation (dynamic change from supine to standing) with an active tilt-test is preferable to resting evaluation (supine rest only).

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References

1. Saboul D, Balducci P, Millet G et al. A pilot study on quantification of training load: The use of HRV in training practice. Eur J Sport Sci 2015: 1-10
2. Da Silva CC, Pereira LM, Cardoso JR et al. The effect of physical training on heart rate variability in healthy children: a systematic review with meta-analysis. Pediatr Exerc Sci 2014; 26(2): 147-58
3. Difiori JP, Benjamin HJ, Brenner J et al. Overuse Injuries and Burnout in Youth Sports: A Position Statement from the American Medical Society for Sports Medicine. Clin J Sport Med 2014; 24 (1): 3-20
4. Matos NF, Winsley RJ, Williams CA. Prevalence of nonfunctional overreaching/overtraining in young English athletes. Med Sci Sports Exerc 2011; 43(7): 1287-94
5. Meeusen R, Duclos M, Foster C et al. Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science (ECSS) and the American College of Sports Medicine (ACSM). Eur J Sport Sci 2013; 13(1): 1-24
6. Mourot L, Bouhaddi M, Perrey S et al. Decrease in heart rate variability with overtraining: assessment by the Poincare plot analysis. Clin Physiol Funct Imaging 2004; 24(1): 10-8
7. Schmitt L, Regnard J, Desmarets M et al. Fatigue Shifts and Scatters Heart Rate Variability in Elite Endurance Athletes. PLoS One 2013; 8(8): e71588
8. Buchheit M. Monitoring training status with HR measures: Do all roads lead to Rome? Front Physiol 2014; 5: 73
9. Buchheit M, Gindre C. Cardiac parasympathetic regulation: respective associations with cardiorespiratory fitness and training load. Am J Physiol Heart Circ Physiol 2006; 291: 451-8
10. Buchheit M, Chivot A, Parouty Jet al. Monitoring endurance running performance using cardiac parasympathetic function. Eur J Appl Physiol 2010; 108: 1153-67
11. Buchheit M, Simpson MB, Al Haddad H et al. Monitoring changes in physical performance with heart rate measures in young soccer players. Eur J Appl Physiol 2012; 112: 711-23
12. Koenig J, Jarczok MN, Wasner M et al. Heart rate variability and swimming. Sports Med 2014; 44(10): 1377-91
13. Plews DJ, Laursen PB, Kilding AE et al. Evaluating training adaptation with heart-rate measures: A methodological comparison. Int J Sports Physiol Perform 2013; 8: 688-91
14. Morales J, Álamo J, García-Massó X et al. The use of heart rate variability in monitoring stress and recovery in judo athletes. J Strength Cond Res 2014; 28: 1896-905
15. Foster C. Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sports Exerc 1998; 30: 1164-8
16. Foster C, Florhaug JA, Franklin Jet al. A new approach to monitoring exercise training. J strength Cond Res 2001; 15(1): 109-15
17. Wallace LK, Slattery KM, Coutts AJ. The ecological validity and application of the session-RPE method for quantifying training loads in swimming. J Strength Cond Res 2009; 23(1): 33-8
18. Santos L, González V, Iscar M et al. Retesting the validity of a specific field test for judo training. J Hum Kinet 2011; 29: 141-50
19. Achten J, Jeukendrup A. Heart rate monitoring: Applications and limitations. Sports Medicine 2003: 517-38
20. Mourot L, Fabre N, Andersson E et al. Cross-Country Skiing and Post-Exercise Heart Rate Recovery. Int J Sports Physiol Perform 2015; 10(1): 11-6
21. Hopkins WG, Marshall SW, Batterham AM et al. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 2009; 41: 3-12
22. Malik M., Bigger JT, Camm AJet al. Heart rate variability standards of measurement, physiological interpretation, and clinical use. Eur Heart J 1996; 17: 354-81
23. Makivić B, Nikić M, Willis M. Heart Rate Variability (HRV) as a Tool for Diagnostic and Monitoring Performance in Sport and Physical Activities. J Exerc Physiol 2013; 16(3): 103-131
24. Pagani M, Lombardi F, Guzzetti S et al. Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympatho-vagal interaction in man and conscious dog. Circ Res 1986; 59: 178-93
25. Malik M. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Circulation 1996; 93: 1043-65
26. Reyes del Paso GA, Langewitz W, Mulder LJ et al. The utility of low frequency heart rate variability as an index of sympathetic cardiac tone: a review with emphasis on a reanalysis of previous studies. Psychophysiology 2013; 50: 477-87
27. Buch AN, Coote JH, Townend JN. Mortality, cardiac vagal control and physical training – what's the link? Exp Physiol 2002; 87(4): 423-35
28. Plews D, Laursen P, Kilding A et al. Heart Rate Variability and Training Intensity Distribution in Elite Rowers. Int J Physiol Perform 2014; 9(6): 1026-32
29. Buchheit M, Simon C, Piquard F et al. Effects of increased training load on vagal-related indexes of heart rate variability: a novel sleep approach. Am J Physiol Heart Circ Physiol 2004; 287(6): 2813-8
30. Buchheit M, Racinais S, Bilsborough JC et al. Monitoring fitness, fatigue and running performance during a pre-season training camp in elite football players. J Sci Med Sport 2013; 16(6): 550-5
31. Mourot L, Bouhaddi M, Tordi N et al. Short- and long-term effects of a single bout of exercise on heart rate variability: comparison between constant and interval training exercises. Eur J Appl Physiol 2004; 92(4-5): 508-17
32. Schmitt L, Regnard, J, Millet GP. Monitoring Fatigue Status with HRV Measures in Elite Athletes: An Avenue Beyond RMSSD? Front Physiol 2015; 6: 343
33. Hellard P, Avalos M, Hausswirth C et al. Identifying optimal overload and taper in elite swimmers over time. J Sport Sci Med 2013; 12: 668-78
34. Chalencon S, Busso T, Lacour J-R et al. A Model for the Training Effects in Swimming Demonstrates a Strong Relationship between Parasympathetic Activity, Performance and Index of Fatigue. PLoS One 2012; 7(12): e52636
35. Kalina RM. Methodology of measurement, documentation and programming optimal workload continuous with variable intensity – applications in sports medicine, physiotherapy, geriatrics, health-related training, sport for all. Arch Budo 2012; 8(4): 235-249
36. Barczyński BJ, Graczynski M, Kalina RM. Barriers Restricting the Free Dissemination of Scientific Achievements: Own Experiences in Crossing Walls and Bridges. J Hum Kinet 2009; 22(22): 7-14
37. Iermakov SS, Arziutov GN, Jagiełło W. Quick training of students to judo techniques. Arch Budo 2016; 12: 15-24

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Editorial note

Apart from the standard review procedure (authors respond to the reviewers' remarks, text is improved by the authors according to reviewers' suggestions, etc.), Scientific Editors had to make two interventions in this article. We have included positions 35-37 in the references and drawn up a glossary of key terms related to training load which are crucial for the effective management of sports and health training.

This is an example showing that one of the most important missions of the journals is being accomplished – both readers of papers published in *Archives of Budo* and potential authors become closer to scientific achievements which for many years were almost exclusively available in Polish or Russian. Many of these articles were created in the period when the world was divided by the *Iron Curtain*. This situation is widely discussed in the paper of Barczyński BJ et al. [36].

However, until today the most expressive cognitive and application effect of that time is the impoverished premises to study and discuss the results of recently published articles by authors who share their knowledge regardless of the language barriers. However, the authors of the papers from English-language countries still refer to publications written in that language and by analogy to Russian, Spanish, Portuguese, Japanese, Polish, etc.

As the Editorial Office of the *Archives of Budo* is located in Poland and its experts were educated in Polish and foreign universities, we are able to efficiently overcome the language barrier. The biggest value is the possibility of complementing the knowledge of the phenomena studied with prudent expert editorial intervention.

That is the case in this article where the authors discuss the key subject of training load in too general manner. Meanwhile, the nature of combat sports consists of the fact that the same exercise performed at the same time by athletes representing extreme weight categories (but with similar motivation to exercise) results very often in different neurophysiological responses in the body. Therefore, accurate estimation of stimuli during training is a methodological necessity. Over 40 years ago, Russian scientists (Andriejev et al., 1974), followed by Polish scientists (Jaskólski et al., 1978, 1979) developed effective methods for assessment of the training load in judo (more in 35).

As far as the Editorial Board is concerned, Professor Władyslaw Jagiełło is an expert in sport science and combat sports, proficient in Russian and who has a great knowledge of scientific literature about this subject [37]. He received a grant from the Polish Government with the power of an international agreement and graduated from the National University of Physical Education and Sport of Ukraine in Kyiv. He also obtained further academic degrees there. His master's thesis and doctoral dissertation were promoted by Professor Vladimir Nikolayevich Platonov (who was for a long time the Rector of this University), world-famous theoretician of sport.