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Effect of consecutive matches on heart rate variability in elite volleyball players

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EFFECT OF CONSECUTIVE MATCHES ON HEART RATE VARIABILITY IN ELITE VOLLEYBALL PLAYERS

KEYWORDS: Sympathetic- parasympathetic- performance- sport- recovery.

ABSTRACT: The objective of this study was to observe and determine changes in HRV parameters in volleyball players during the Mexican national professional volleyball league. Heart rate was monitored in 12 athletes (age 22.60 ± 3.4) for four months during weekends (Saturdays and Sundays). Three measures were taken during each match-day: the first at rest (REST), the second in the afternoon after the matches of the first day (R2), and the third after the matches of the second day (R4). Data were analyzed with ANOVA and the Bonferroni method. We found a difference between REST and R2 and R4 in SDNN (98.66 ± 62.50 vs. 50.35 ± 26.33 ms, $p < .001$; 59.24 ± 22.11, $p < .001$ for R2 and R4 respectively), rMSSD (43.49 ± 34.60 vs. 24.33 ± 18.89, $p < .05$; 28.44 ± 16.70, $p < .05$ for R2 and R4, respectively), pNN50 (30.37 ± 21.47% vs. 12.09 ± 16.56, $p < .001$; 13.30 ± 13.64, $p < .001$ for R2 and R4 respectively), SD1 (45.84 ± 30.17 ms vs. 22.83 ± 17.30, $p < .001$; 28.01 ± 14.94, $p <.01$ for R2 and R4, respectively) and SD2 (123.18 ± 53.67 ms vs. 65.58 ± 32.42, $p < .001$; 79.06 ± 28.33, $p < .001$ for R2 and R4, respectively). There were no significant differences between R2 and R4. These results show that heart rate variability helps determine changes after several matches in sympathetic and parasympathetic modulation in volleyball players, and that this provides information on athletes' physical performance.

Successful training programs for elite athletes typically involve relatively long periods of high training loads (TLs) where the stress/re-generation balance is challenged (Plews, Laursen, Kilding and Buchheit, 2014). The autonomic nervous system (ANS) is an important regulator of homeostasis (Plews, Laursen, Kilding and Buchheit, 2012; Sánchez, Romero and Ortís, 2013) during periods of TLs, the ANS as measured via heart rate variability (HRV).

HRV is the variation of cardiac inter-beat intervals over time which includes both periodic and aperiodic components. HRV results largely from the modulation of the heart rhythm by parasympathetic innervation to the cardiac sinoatrial node (Golosheykin, Grant, Novak, Heath, and Anokhin, in press; Reyes del Paso, Langewitz, Mulder, van Roon and Duschek, 2013). Vagal cardiac tone has been repeatedly linked to attentional and emotional control (Ramírez, Ortega and Reyes, 2015). HRV may index the ability to regulate emotion, with higher HRV reflecting greater flexibility and ability to adapt to environmental changes (Sevenster, Hamm, Beckers and Kindt, 2015; Thayer, Ahs, Fredrikson, Sollers III and Wager, 2012).

Athletes, coaches and sport scientists have a keen interest in measuring body adaptations produced by training. For this reason, methods that provide reliable information on athlete´s performance during competition or training are needed (Plews, Laursen, Kilding and Buchheit, 2013), since athletes are frequently subjected to high volume and intensity training to achieve desirable metabolic, cardiovascular and neuromuscular adaptations to increase their physical capacity (Hughson and Shoemaker, 2015; Stanley, Peake and Buchheit, 2013). During exercise, the increase in intensity produces a higher heart rate (HR) and lower heart rate variability (HRV), which may be due to an increment in sympathetic nervous activity and a decrease of vagal modulation of the heart (Ramos-Campo et al., 2016). Intensity, duration, and type of exercise are the variables that condition the effects on the body and its recovery (Seiler, Haugen and Kuffel, 2007). A failure in recovering between training sessions would cause a progressive elevation of physiological stress, which affects physical performance and increases the risk of lesions (Bahnert, Norton and Lock, 2013). If the TL is great and the recovery period is insufficient, symptoms of fatigue could appear, acutely affecting performance (Ament and Verkerke, 2009; Lamberts, Swart, Noakes and Lambert, 2009; Thomson, Bellenger, Howe, Karavirta and Buckley, 2014).

Since the ANS, through the sympathetic and parasympathetic systems, offers relevant information on the balance between work and recovery, HRV has become a tool commonly used in sports. This is because HRV offers effective information on the condition of sympathetic and parasympathetic systems of ANS in response

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to exercise (Edmonds, Leicht, McKean and Burkett, 2015; Lucini et al., 2014; Naranjo, De la Cruz, Sarabia, De Hoyo and Domínguez-Cobo, 2015). HRV is a reliable non-invasive tool that allows practical and reproducible control of adaptations to training (de Rezende Barbosa et al., 2015; Hettinga, Monden, Van Meeteren and Daanen, 2014) using different variables (Bricout, DeChenaud and Favre-Juandvin, 2010; Plews, Laursen, Kilding, et al., 2013). With adequate adaptation to workloads, parasympathetic activity at rest will predominate; in contrast, poor adaptation will be reflected by a predominance of sympathetic activity (Bricout et al., 2010; Mazon et al., 2013; Plews, Laursen, Stanley, Kilding and Buchheit, 2013).

The time needed for HRV to recover after exercise can vary from 1 to 72 hours depending on its intensity and duration (Buchheit, Laursen, Al Haddad and Ahmaidi, 2009; Stanley et al., 2013). Recent research has analyzed HRV in team sports in training and competition situations (Leme et al., 2015) with soccer being the sport that has most frequently been studied. In one of these studies, researchers recorded HRV weekly in professional players during a whole season (Naranjo et al., 2015). In these studies, HRV has been a good indicator for monitoring the assimilation of TLs triggers perpetual physiological changes, giving an overview of exercise adaptation during a competition season (Podstawski, Boraczyński, Nowosielska-swadźba and Zwolińska, 2014). The accumulation of stress accompanied by insufficient regeneration is one of the main causes of overtraining (Di Fronso, Nakamura, Bortoli, Robazza and Bertollo, 2013), that can impair performance and increase the risk of injury (Barnett, 2006). On the other hand, in individual sports such as gymnastics, HRV has also been used to monitor a group of elite gymnasts during 10 weeks of training with reliable results (Sartor, Vailati, Valsecchi, Vailati and La Torre, 2013).

Mazon et al. (2013) studied volleyball players at the start and end of a competition period of 12 microcycles measuring cortisol, testosterone, catecholamines and HRV; they found no changes between the start and end of the period. Another study in volleyball compared changes in HRV during training and competition periods, finding that changes were mostly related with emotional status (Podstawski, Boraczyński, Nowosielska-swadźba and Zwolińska, 2014). Despite this, another study with volleyball players used HRV with the aim of measuring stress and anxiety three days before a playoff game, and found slight changes between measurements (D'Ascenzi et al., 2014).

Several studies in volleyball use HRV to quantify TL generated by competition, and a few of them took measurements comparing changes caused by training; but to our knowledge, all of them have a cross-sectional design; therefore, data should be acquired during an entire season, increasing the number of post-match measurements. The objective of this study was to observe and determine changes in HRV parameters in volleyball players during the Mexican national professional volleyball league.

Material and Methods

Participants

Twelve male volleyball players (The physical characteristics of the athletes are shown in Table 1.) with experience in national and international tournaments took part in the study. All subjects were informed of the study procedures and provided written informed consent. The study was previously approved by the Ethics Committee of the local University.

Procedure

A medical and body composition evaluation using Dual Energy X-Ray Absorptiometry (DPX-MD densitometer, GE Lunar Prodigy Advance, Madison, WI) was performed at the start of the study with the aim of ruling out any disease that could affect the purpose of the study. All subjects trained between 15 and 18 hours per week. HRV measurements were made during their participation in the Mexican professional volleyball league, which lasted four months; during this time, they played a total of 14 matches during seven weekends (Saturday and Sunday), one match per day. However, due to logistic issues, the team studied could only play four weekends during the league competition; therefore, they had to play two matches per day; i.e., two on Saturday and two on Sunday. After the preliminary round was over, 15 days later the first four qualified teams played the final round with semifinals on Saturday and the final on Sunday.

All players were measured during each and every weekend round. The first measurement was performed on Saturday morning, as soon as they got up and after a fast (REST); the second, after the second match on Saturday afternoon (R2), while the third was carried out after the fourth match on Sunday afternoon (R4). R2 and R4 recordings were made within 30 minutes after the end of the match.

HRV analysis

HRV was recorded for 15 minutes in supine position using Polar Team2 (Polar Electro, Kempele, Finland) following the guidelines of the Task Force of the European Society of Cardiology (1996). The data obtained were examined with KUBIOS software (University of Eastern Finland, Kuopio, Finland) considering the following time domain parameters:

Parameters	M	SD	Minimum	Maximum
Age (years)	22.60	3.40	20	32
Height (cm)	189.4	5.4	176.1	195.2
Weight start (kg)	84.86	6.49	76.4	100.6
Weight end (kg)	84.29	5.99	76.4	99.0
Lean mass start (%)	70.75	6.43	62.88	86.33
Lean mass end (%)	72.48	5.89	65.84	89.06
Adipose mass start (%)	17.41	4.58	10.50	27.30
Adipose mass end (%)	15.28	4.64	8.60	26.30

Table 1. Physical characteristics of the volleyball players (n = 12).

SDNN (the standard deviation of all NN intervals), rMSSD (the square root of the mean squared differences of successive NN intervals), pNN50 (the percentage of consecutive NN intervals that differ by more than 50 ms), and the SD1 and SD2 axes of the Poincare scatter plot (Naranjo et al., 2015; Podstawski, Boraczyński, Nowosielska-swadźba and Zwolińska, 2014).

Statistical analysis

A descriptive analysis with means and standard deviations was performed. The normality of variable distributions using the Kolmogorov-Smirnov test, and the equality of the variances using Levene's test were determined. Once normality and variances equality was confirmed, a contrast hypothesis among multiple distributions using one-factor ANOVA and the Bonferroni procedure for multiple ad hoc comparisons were performed. Significance was established at p value < .05. For data analysis, the statistical software SPSS 21 was used.

Results

During the first analysis, a comparison of baseline measurements (REST) of the five rounds was made with no significant difference being found. This same procedure was done with the R2 and R4 recordings obtained during the five rounds; also, no significant differences were found. Since no differences were found in the three recordings made during the five rounds, the baseline recordings and the R2 and R4 recordings of the five rounds were grouped to increase the number of measurements to be compared (Table 2).

The variables of time domain at rest, at the end of the first day (R2) and second day (R4) of competition from round one to round five, as well as mean data from all rounds are shown in Figure 1.

The variables of Poincare plot comparing the five rounds with the mean of the five rounds are presented in Figure 2.

	N	Rest		R2		R4	
		Means	SD	Means	SD	Means	SD
SDNN (ms)	55	98.66	62.50	50.35 ***	26.33	59.24 ***	22.11
rMSSD (ms)	55	43.49	34.60	24.33 *	18.89	28.44 *	16.70
pNN50 (%)	55	30.37	21.47	12.09 ***	16.56	13.30 ***	13.64
SD1 (ms)	55	45.84	30.17	22.83 ***	17.30	28.01 **	14.94
SD2 (ms)	55	123.18	53.67	65.58 ***	32.42	79.06 ***	28.33

Note: Rest corresponds to al baseline measures during the five rounds; R2 corresponds to all recordings made after the second game of the five rounds; R4 corresponds to all recordings made after the fourth game of the five rounds. There were no significant differences between R2 and R4.

* $p < .05$ compared to baseline measure; ** $p < .01$ compared to baseline measure; *** $p < .001$ compared to baseline measure.

Table 2. Time domain and non-lineal variables analyzed.

Discussion

The main contribution of this study is the finding that, in professional volleyball players, post game HRV values decrease with the accumulation of two matches on the same day, but were not affected after two matches on consecutive days.

Since we found a lack of literature about HRV indices in team sports with anaerobic predominance, the objective of this study was to examine changes in HRV in volleyball players after several matches played within a short period of time during a national tournament. This is important because athletes need to adapt to competition induced stress and maintain an optimum level of performance (Córdova, Sureda, Tur and Pons, 2010).

We have only seen one similar model in literature, though in individual sports (Garrido, De la Cruz, Medina, Garrido and Naranjo, 2011). In this work, changes in HRV were assessed in different matches of the World Badminton Circuit, in which winners played a total of three matches in a weekend. Garrido et al. (2011) found lower post-match HRV values than at the baseline. However, no clear accumulative effect was shown since there were no significate differences in HRV parameters through the weekend. These results were in concordance with ours, where HRV values of the second day showed no significant differences with the first, suggesting no accumulated work load effect between measurements. Therefore, we can assume a near complete recovery to baseline HRV values in between game days happened. This implies that there is enough rest time from one competition day to another. We believe that a main factor playing in favor of recovery is the athletes´ level of training (Plews et al., 2013; Stanley et al., 2013).

Our results appear to differ with other studies (Edmonds, Sinclair and Leicht, 2013; Leme et al., 2015) who compared HRV values before, during and after competition, finding significant changes in HRV, with a reduction in parasympathetic activity and greater sympathetic activity up to two days after competition. The authors recommend that coaches guarantee at least two days of rest after intense training or competition if adequate recovery was to be achieved. This is because athletes experiment significant cardiovascular stress even after competition, which could affect subsequent performance. We believe that recovery implies a response of diverse body systems to return to homeostasis, and during this process the ANS plays a principal role in the autoregulation mechanisms. The reduction in HRV after exercise occurs independently of the individual´s level of training; however, for the purpose of recovery, the level of training does have an influence, as it was suggested by our results.

Athletes showed high HRV values prior to the first competition weekend, this represent ANS parasympathetic dominance and indicate that athletes are highly trained facing the first two matches (Kiviniemi et al., 2010). Nevertheless, we found a progressive drop of the pre-competition HRV values throughout the tournament. This is in line with a study by Buchheit et al. (2013) carried out in soccer, in which they made daily measurements of TL and HRV during a two-week period of training. The outcomes of the study showed that an increase in daily TL relates to a reduction in HRV at rest.

These results also coincide with the study of Bricout et al. (2010), who monitored a soccer team for five months and found reduced HRV values after matches than training sessions. This indicates that soccer matches imply higher TL that training sessions. Our results suggest that this can also be true in volleyball since reduction in HRV values after matches were significantly different from baseline values. However, our outcomes are in contrast with a study carried out in elite volleyball players (Podstawski et al., 2014) that compared a four-week training period with five months of competition using HRV and found no significant differences between the two situations. Our results also differ from Mazon et al. (2013), who did not find differences in HRV values before and after a period of training. It is important to mention that this study used isolated measurements before and after specific periods of time, so it was impossible to relate any changes to TLs.

A limitation of our study is that we did not controlled the match time of each player during the matches and other variables related to internal load. In future studies, it would be important to include another baseline measure on the second day morning to be able to control partial recovery from one day to the next.

Lastly, there are factors that influence team competition that cannot be controlled in these types of studies, such as rivals' level of competition, players' substitutions based on match strategies, or the fact that some players do not participate in all the matches.

In conclusions, the analysis of HRV in volleyball players after several matches allow us to determine the changes in the ANS through parasympathetic and sympathetic modulation in a rapid manner with non-invasive methods. This information can provide trainers and athletes with parameters that can prevent overtraining and harm to the athlete..

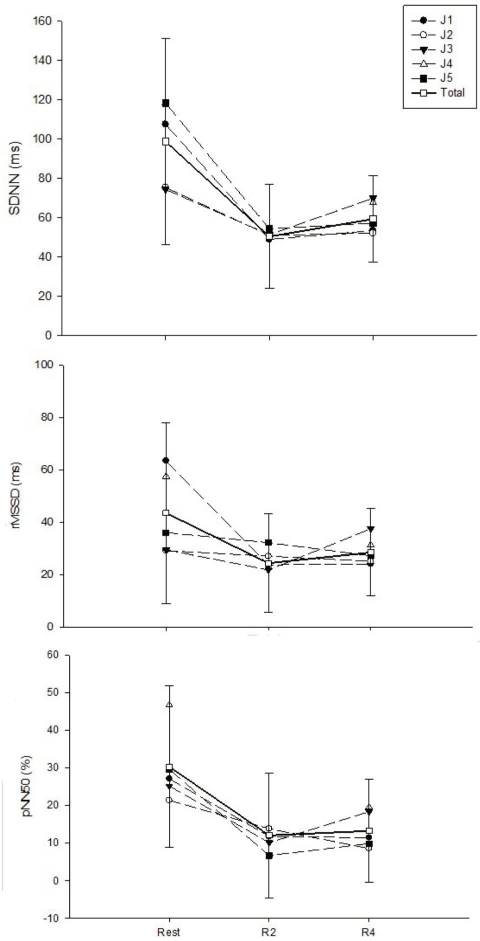

Figure 1. Comparison of changes in time domain variables of HRV in each round vs. the total mean of the rounds. SDNN, the standard deviation of all NN intervals; rMSSD, the square root of the mean squared differences of successive NN intervals; pNN50, the percentage of consecutive NN intervals that differ by more than 50 ms; Rest = baseline conditions; R2 = end of first day of competition; R4 end of second day of competition. J1 = round 1; J2 = round 2; J3 = round 3; J4 = round 4; J5 = round 5; Total = mean of the five rounds.

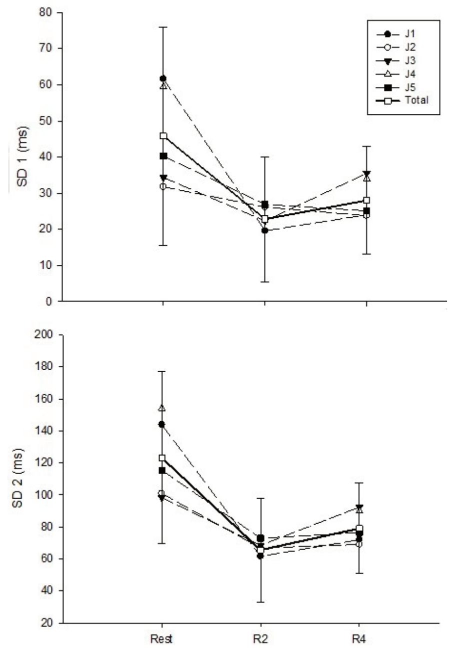

Figure 2. Comparison of the changes in cross-sectional (SD1) and longitudinal diameter (SD2) of the Poincare plot for each round vs. the total mean of the rounds. Rest = baseline conditions; R2 = end of first day of competition; R4 end of second day of competition. J1 = round 1; J2 = round 2; J3 = round 3; J4 = round 4; J5 = round 5; Total = mean of the five rounds.

EFECTO DE PARTIDOS CONSECUTIVOS SOBRE LA VARIABILIDAD DE LA FRECUENCIA CARDÍACA EN JUGADORES ELITE DE VOLEIBOL

PALABRAS CLAVE: Simpático- parasimpático - rendimiento - deporte - recuperación

RESUMEN: El objetivo del estudio fue realizar observar y determinar los cambios en la variabilidad de la frecuencia cardiaca (VFC) de un equipo de voleibol masculino durante su participación en la liga profesional nacional de México. Se registró a 12 atletas (Edad 22.60 ± 3.4) por cuatro meses durante el fin de semana (sábado y domingo). En cada jornada se realizaron tres mediciones, la primera por la mañana en reposo (REST); la segunda por la tarde al finalizar los partidos del primer día (R2) y la tercera al finalizar los partido del segundo día (R4). Los datos se analizaron con el test ANOVA y el test de Bonferroni. Se encontró diferencia entre REST con respecto a la R2 y con la R4 en SDNN (98.66±62.50 ms vs. 50.35±26.33, $p < .001$; 59.24±22.11, $p < .001$ para R2 y R4 respectivamente), en la rMSSD (43.49±34.60 ms vs. 24.33±18.89, $p < .05$; 28.44±16.70, $p < .05$ para R2 y R4 respectivamente), en el pNN50 (30.37±21.47 % vs. 12.09±16.56, $p < .001$; 13.30±13.64, $p < .001$ para R2 y R4 respectivamente), en SD1 (45.84±30.17 ms vs. 22.83±17.30, $p < .001$; 28.01±14.94, $p < .01$ para R2 y R4 respectivamente) y en SD2 (123.18±53.67 ms vs. 65.58±32.42, $p < .001$; 79.06±28.33, $p < .001$ para R2 y R4 respectivamente), entre la R2 y la R4 no hay diferencias significativas. Los resultados indican que en jugadores de voleibol posterior a varios partidos permite determinar los cambios en la modulación simpática y parasimpática a través de la VFC brindando información sobre el estado de rendimiento físico de los atletas.

EFEITO DE JOGOS CONSECUTIVOS NA VARIABILIDADE DA FREQUÊNCIA CARDÍACA EM JOGADORES DE VÔLEI DE ELITE

PALAVRAS CHAVE: Simpático- parassimpático - performance - esporte - recuperação

RESUMO: O objetivo do estudo foi realizar, observar e determinar mudanças na variabilidade da frequência cardíaca (VFC) da equipe de voleibol dos homens, enquanto participavam na nacional liga profissional México. Foram registrados 12 atletas (entre 22,60 ± 3,4 anos de idade) por quatro meses durante o fim de semana (sábado e domingo). Cada dia se realizaram três medições, a primeira de manhã em repouso (REST); a segunda pela tarde no final das primeiros jogos do dia (R2) e a terceira na parte final das jogos do segundo dia (R4). Os dados foram analisados com o teste ANOVA e teste de Bonferroni. Uma diferença foi encontrada entre o REST no que diz respeito a R2 e R4 em SDNN (98,66 ± 62,50 ms vs 50,35 ± 26,33 ms, $p < 0{,}001$; 59,24 ± 22,11, $p < 0{,}001$ para R2 e R4, respectivamente), em rMSSD (43,49 ± 34,60 ms vs 24,33 ± 18,89, $p < 0{,}05$; 28,44 ± 16,70, $p < 0{,}05$, para R2 e R4, respectivamente), no pNN50 (30,37 ± 21,47% vs 12,09 ± 16,56%, $p < 0{,}001$; 13,30 ± 13,64, $p < 0{,}001$ para R2 e R4, respectivamente), SD1 (45,84 ± 30.17 ms vs. 22,83 ± 17,30, $p < 0{,}001$; 28,01 ± 14,94, $p < 0{,}01$ para R2 e R4, respectivamente) e no SD2 (123,18 ± 53,67 ms vs 65,58 ± 32,42 ms, $p < 0{,}001$; 79,06 ± 28,33, $p < 0{,}001$ para R2 e R4, respectivamente), entre R2 e R4 não há diferenças significativas. Os resultados indicam que, nos jogadores de vôlei trás várias jogos, permite determinar alterações na modulação simpático e parassimpático através do VFC fornecendo informações sobre o estado de desempenho físico dos atletas.

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