Pre-competitive overload period impairs autonomic modulation in athletes: A Systematic Review and Meta-analysis

Palavras-Chave: Autonomic Nervous System, Stress and Athletes

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Abstract

The aim was meta-analyze the effect of different type of overloads on root-mean-square difference of successive normal RR intervals (RMSSD, i.e. parasympathetic modulation) of athletes. The analysis of the 14 studies selected (20 subgroups within studies), compared RMSSD of the same athletes before and after an overload period. RMSSD of athletes were lower at pre-competition compared to baseline (SMD=-0.50 [-0.83; -0.18], p=0.002), while volume, volume/intensity and post-competition showed similar RMSSD than their respective normal load periods. Thus, pre-competition overload period impairs parasympathetic modulation while the other subgroups of overload period from higher training volume/intensity, volume, or post-competition did not alter RMSSD.

Introduction

It is not new that athletes overtraining and loss in performance have been associated to excessive increase in internal load (BUDGETT, 1998). More recently, autonomic nervous system function has been assessed to characterize the individual internal load in the context of sports training by heart rate variability (HRV) analysis (DJAOUI *et al.*, 2017; NAKAMURA *et al.*, 2015). Among the HRV indexes, the root-mean-square difference of successive normal RR intervals (RMSSD) represents the parasympathetic modulation and has becoming widely used in the sports context because of your extraction needed short data acquisition periods, to its analysis by simpler software and to its potential as a monitoring tool to detect changes on general internal load variations, such as fatigue when correctly interpretated (BUCHHEIT, 2014). Periods of high volume, intensity, and competition stress are potential overload stimuli to reduce RMSSD (BARRERO *et al.*, 2019; BAUMERT *et al.*, 2006; BELLENGER *et al.*, 2016; FAZACKERLEY; FELL; KITIC, 2019; FIGUEIREDO *et al.*, 2019; FLATT *et al.*, 2017; FLATT; HORNIKEL; ESCO, 2017; MIRANDA-MENDOZA *et al.*, 2020; MORALES *et al.*, 2014), while pre-competition overload might be from anticipatory anxiety or a psychological type of stress; training load and post-competition overload might be associated to a physical type of stress and those differences might lead to different RMSSD variations. Thus, the aim of the present study was to compare the effect of different types of overloads on athletes resting RMSSD by meta-analysis of previous study of the literature.

Methods

The protocol review was registered on PROSPERO (International prospective register of systematic reviews) under the number CRD42020181966. Study selection and data collection were performed by two independent reviewers and the conflicts were discussed by both.

Search strategy. A highly sensitive search was performed in PubMed, Web of Science, Scopus, and Cochrane on November 4, 2020. PubMed syntax was used as a model to the equivalent syntax in other databases, combining the synonyms for "heart rate variability", "fatigue", "stress", and "Athletes".

SD considering the equation $(\sqrt{(n)} * (UL - LL)/(2 * T.INV\ (0.05; n-1))$, where n is the sample size, UL is the upper limit, LL is the lower limit and T.INV is the function that calculates the left-tailed inverse of the Student`s T distribution. Median and interquartile range (IQR) were replaced, respectively, by mean and SD according to the equation SD = (IQR/1.35).

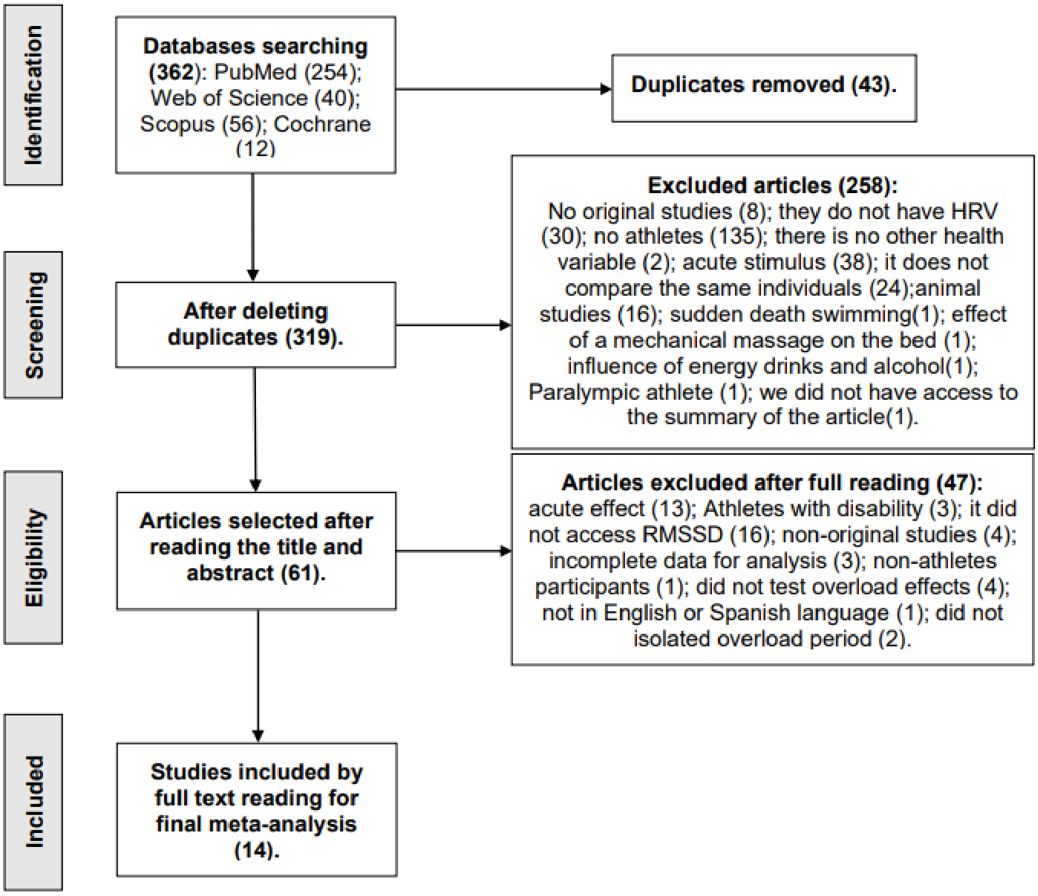

Figure 1. Selection of the studies. **Legend:** HRV: heart rate variability; (N): number of studies; RMSSD: root-mean-square difference of successive normal RR intervals.

Study selection. Were included athletes from any modality; undergoing any type of overload stimuli; observations of the same athletes during overload and normal load period; resting HRV assessed by square RMSSD (ms, percentage or logarithm). Exclusion criteria were non-original studies athletes with disability, HRV assessed immediately after overload without an overnight resting preparation, and HRV assessed during sleep.

Data collection. The RMSSD central tendency, dispersion measurements after overload periods and normal load periods, as well as the sample size were extracted from each study. Mean, standard deviation (SD) and sample size (n) were preferred for main analysis. Standard error (SE) was converted to SD by the equation $SD = SE \times (\sqrt{n})$, if SD was not provided in the original study. The 95% confidence intervals were converted to SD considering the equation (see above).

Statistical analysis. The meta-analysis was performed using the *Comprehensive Meta-Analysis software* (CMA) 3.3.070. Since the studies presented RMSSD in different unit measurement the meta-analysis of RMSSD standardized mean difference (SMD) between the overload and normal load period within the same athletes. Subgroup analysis were performed to compare the effects of different types of overloads (pre-competition, post competition, volume and volume/intensity) and p≤0.05 was considered significant. When inconsistency between studies (I^2) was >50%, random effects were applied, and when it was <40%, fixed effects were applied.

Results and Discussion

We included 14 studies (Figure 1) and a total of 20 analysis subgroups were part of this study. Among them four were classified with post-competition overload (BARRERO *et al.*, 2019; FAZACKERLEY; FELL; KITIC, 2019; FLATT; HOWELLS; WILLIAMS, 2019; MIRANDA-MENDOZA *et al.*, 2020), three with pre-competition overload (BARRERO *et al.*, 2019; FLATT; HOWELLS; WILLIAMS, 2019; MIRANDA-MENDOZA *et al.*, 2020), two presented an increase in volume (FLATT *et al.*, 2017; MORALES *et al.*, 2014) and eight presented an increase in volume/intensity (ATLAOUI *et al.*, 2007; BAUMERT *et al.*, 2006; BELLENGER *et al.*, 2016; BOURDILLON *et al.*, 2018; FIGUEIREDO *et al.*, 2019; FLATT; HORNIKEL; ESCO, 2017; LE MEUR *et al.*, 2013; UUSITALO; UUSITALO; RUSKO, 1998). The population studied was quite heterogeneous, containing national, regional, international, and recreational athletes. These groups composed by men and women, just men or just women. The majority of the HRV recordings were collected in supine position, while just two studies showed only data in sitting position. The time of HRV analyzes ranged from one to 15 minutes.

The main finding of the present study was that only pre-competition led to significant lower RMSSD (p=0.002) in a very homogeneous analyses (I^2 = 36%), while post-competition, volume/intensity and volume did lead reduced RMSSD (p >0.05) in a considerable inconsistent analysis (Figure 2). The main sources of lower pre-competition RMSSD that differs from the physical overload of the other stimuli we tested here, might be the pre-competition stress and anxiety. The pre-competition anxiety have been defined as an immediate emotional state in which feelings of apprehension and tension accelerates sympathetic activity (MARTENS; VEALEY; BURTON, 1990). Although, pre-competitive cognitive and somatic anxiety have been negative associated with post-competition RMSSD (FORTES *et al.*, 2017), here we did not find significant reduction in RMSSD in this overload subgroup, within the almost the same studies that led to reduction in RMSSD pre-competition. Higher competition anxiety might be dependent on level of training, the nature of the sport (individual competitors and team competition) and the experimental conditions (training condition or competition conditions (CERVANTES BLÁSQUEZ; RODAS FONT; CAPDEVILA ORTÍS, 2009; KIRKBY, 1999; MORALES *et al.*, 2013). Nevertheless, in our analysis, the lower pre-competition RMSSD was observed among a variety of sports, including handball university college athletes, ultra-endurance runners and regional or national female cyclists (BARRERO *et al.*, 2019; FAZACKERLEY; FELL; KITIC, 2019; MIRANDA-MENDOZA *et al.*, 2020).

Conclusion

Pre-competition overload period decrease parasympathetic modulation while in the others overload periods from higher training, volume, volume/intensity, or post-competition period did not. Whether the psychological parameters, in pre-competition period are in fact associated to RMSSD reduction still to be determined. The heterogeneity among the physical overload stimuli suggests a need for further studies to confirm these findings.

References

ATLAOUI, D *et al.* Heart rate variability, training variation and performance in elite swimmers. **International journal of sports medicine**, Germany, v. 28, n. 5, p. 394–400, 2007. https://doi.org/10.1055/s-2006-924490

BARRERO, Anna *et al.* Daily fatigue-recovery balance monitoring with heart rate variability in well-trained female cyclists on the Tour de France circuit. **PloS one**, [*s. l.*], v. 14, n. 3, p. e0213472, 2019. https://doi.org/10.1371/journal.pone.0213472

BAUMERT, Mathias *et al.* Heart rate variability, blood pressure variability, and baroreflex sensitivity in overtrained athletes. **Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine**, United States, v. 16, n. 5, p. 412–417, 2006. https://doi.org/10.1097/01.jsm.0000244610.34594.07

BELLENGER, Clint R *et al.* Contextualizing Parasympathetic Hyperactivity in Functionally Overreached Athletes With Perceptions of Training Tolerance. **International journal of sports physiology and performance**, United

States, v. 11, n. 7, p. 685–692, 2016. https://doi.org/10.1123/ijspp.2015-0495

BOURDILLON, Nicolas *et al.* Overload blunts baroreflex only in overreached athletes. **Journal of science and medicine in sport**, Australia, v. 21, n. 9, p. 941–949, 2018. https://doi.org/10.1016/j.jsams.2018.01.008

BUCHHEIT, Martin. Monitoring training status with HR measures: Do all roads lead to Rome? **Frontiers in Physiology**, [*s. l.*], v. 5 FEB, n. February, p. 1–19, 2014. https://doi.org/10.3389/fphys.2014.00073

BUDGETT, Richard. Fatigue and underperformance in athletes: The overtraining syndrome. **British Journal of Sports Medicine**, [*s. l.*], v. 32, n. 2, p. 107–110, 1998. https://doi.org/10.1136/bjsm.32.2.107

CERVANTES BLÁSQUEZ, Julio César; RODAS FONT, Gil; CAPDEVILA ORTÍS, Lluís. Heart-rate variability and precompetitive anxiety in swimmers. **Psicothema**, [*s. l.*], v. 21, n. 4, p. 531–536, 2009. http://www.ncbi.nlm.nih.gov/pubmed/19861094

DJAOUI, Léo *et al.* Monitoring training load and fatigue in soccer players with physiological markers. **Physiology and Behavior**, [*s. l.*], v. 181, n. September, p. 86–94, 2017. https://doi.org/10.1016/j.physbeh.2017.09.004

FAZACKERLEY, Lewis A; FELL, James W; KITIC, Cecilia M. The effect of an ultra-endurance running race on heart rate variability. **European journal of applied physiology**, Germany, v. 119, n. 9, p. 2001–2009, 2019. https://doi.org/10.1007/s00421-019-04187-6

FIGUEIREDO, Diego H *et al.* Effect of Overload and Tapering on Individual Heart Rate Variability, Stress Tolerance, and Intermittent Running Performance in Soccer Players During a Preseason. **Journal of strength and conditioning research**, United States, v. 33, n. 5, p. 1222–1231, 2019. https://doi.org/10.1519/JSC.0000000000003127

FLATT, Andrew A *et al.* Interpreting daily heart rate variability changes in collegiate female soccer players. **The Journal of sports medicine and physical fitness**, Italy, v. 57, n. 6, p. 907–915, 2017. https://doi.org/10.23736/S0022-4707.16.06322-2

FLATT, Andrew A; HORNIKEL, Bjoern; ESCO, Michael R. Heart rate variability and psychometric responses to overload and tapering in collegiate sprint-swimmers. **Journal of science and medicine in sport**, Australia, v. 20, n. 6, p. 606–610, 2017. https://doi.org/10.1016/j.jsams.2016.10.017

FLATT, Andrew A; HOWELLS, Daniel; WILLIAMS, Sean. Effects of consecutive domestic and international tournaments on heart rate variability in an elite rugby sevens team. **Journal of science and medicine in sport**, Australia, v. 22, n. 5, p. 616–621, 2019. https://doi.org/10.1016/j.jsams.2018.11.022

FORTES, Leonardo S. *et al.* Influence of competitive-anxiety on heart rate variability in swimmers. **Journal of Sports Science and Medicine**, [*s. l.*], v. 16, n. 4, p. 498–504, 2017.

KIRKBY, ROBERT J. Precompetition Anxiety in Chinese Athletes. **Perceptual and Motor Skills**, [*s. l.*], v. 88, n. 1, p. 297, 1999. https://doi.org/10.2466/pms.88.1.297-303

LE MEUR, Y *et al.* Evidence of parasympathetic hyperactivity in functionally overreached athletes. **Medicine and science in sports and exercise**, [*s. l.*], v. 45, n. 11, p. 2061-2071, 2013. https://doi.org/10.1249/MSS.0b013e3182980125

MARTENS, Rainer; VEALEY, Robin S.; BURTON, Damon. **Competitive anxiety in sports**. [*S. l.*]: HUMAN KINETICS, 1990.

MIRANDA-MENDOZA, J *et al.* STRESS SCORE AND LnrMSSD AS INTERNAL LOAD PARAMETERS DURING COMPETITION. **REVISTA INTERNACIONAL DE MEDICINA Y CIENCIAS DE LA ACTIVIDAD FISICA Y DEL DEPORTE**, EDIF BRONCE, PLAZA DE MANUEL GOMEZ MORENO, S-N 2A PLANTA, MADRID, 28020, SPAIN, v. 20, n. 77, p. 21–35, 2020. https://doi.org/10.15366/rimcafd2020.77.002

MORALES, Jose *et al.* The use of heart rate variability in assessing precompetitive stress in high-standard judo athletes. **International Journal of Sports Medicine**, [*s. l.*], v. 34, n. 2, p. 144–151, 2013. https://doi.org/10.1055/s-0032-1323719

MORALES, José *et al.* Use of heart rate variability in monitoring stress and recovery in judo athletes. **Journal of strength and conditioning research**, United States, v. 28, n. 7, p. 1896–1905, 2014. https://doi.org/10.1519/JSC.0000000000000328

NAKAMURA, Fabio Y. *et al.* Ultra-short-term heart rate variability is sensitive to training effects in team sports players. **Journal of Sports Science and Medicine**, [*s. l.*], v. 14, n.

3, p. 602–605, 2015.
UUSITALO, A L; UUSITALO, A J; RUSKO, H K. Endurance training, overtraining and baroreflex sensitivity in female athletes. **Clinical physiology (Oxford, England)**, England, v. 18, n. 6, p. 510–520, 1998. https://doi.org/10.1046/j.1365-2281.1998.00121.x

First author, year (Subgrpoup)	SMD	LL	UL	p-Value	Total	Relative Weight
Miranda-Mendoza, 2020	0.440	-0.108	0.989	0.116	14	21.50
Barrero, 2019	1.499	0.596	2.403	0.001	10	18.70
Fazackerley, 2019	-0.231	-0.782	0.320	0.412	13	21.49
Flatt, 2019 (DC)	-0.727	-1.423	-0.030	0.041	10	20.41
Flatt, 2019 (IC)	-1.783	-2.780	-0.786	0.000	10	17.89
Post competition (R)	**-0.142**	**-1.002**	**0.718**	**0.746**	**57**	**100**
Miranda-Mendoza, 2020	-0.605	-1.175	-0.036	0.037	14	29.29
Barrero, 2019	-0.974	-1.727	-0.221	0.011	10	20.56
Flatt, 2019 (DC)	0.042	-0.578	0.662	0.893	10	26.51
Flatt, 2019 (IC)	-0.633	-1.312	0.046	0.068	10	23.63
Pre competition (F)	**-0.504**	**-0.826**	**-0.182**	**0.002**	**44**	**100**
Flatt, 2017	-0.280	-0.912	0.352	0.385	10	57.15
Morales, 2014	-1.397	-2.438	-0.356	0.009	7	42.85
Volume (R)	**-0.759**	**-1.842**	**0.324**	**0.170**	**17**	**100**
Baumert, 2006	-0.554	-1.220	0.111	0.103	10	10.85
Bellenger, 2016	0.140	-0.280	0.560	0.514	22	13.44
Bourdillon, 2018 (AF)	-0.003	-0.744	0.737	0.993	7	10.08
Bourdillon, 2018 (FOR)	0.020	-0.673	0.713	0.954	8	10.57
Le Meur, 2013	0.261	-0.237	0.759	0.305	16	12.63
Uusitalo, 1998	-0.212	-0.873	0.449	0.529	9	10.91
Atlaoui, 2007	0.101	-0.444	0.646	0.716	13	12.13
Figueiredo, 2019	-2.138	-3.026	-1.250	0.000	16	8.69
Flatt and Hornikel, 2017	-0.640	-1.320	0.041	0.065	10	10.70
Volume/intensity (R)	**-0.272**	**-0.659**	**0.116**	**0.170**	**111**	**100**
Overall effects (R)	**-0.386**	**-0.646**	**-0.127**	**0.004**	**229**	**100**

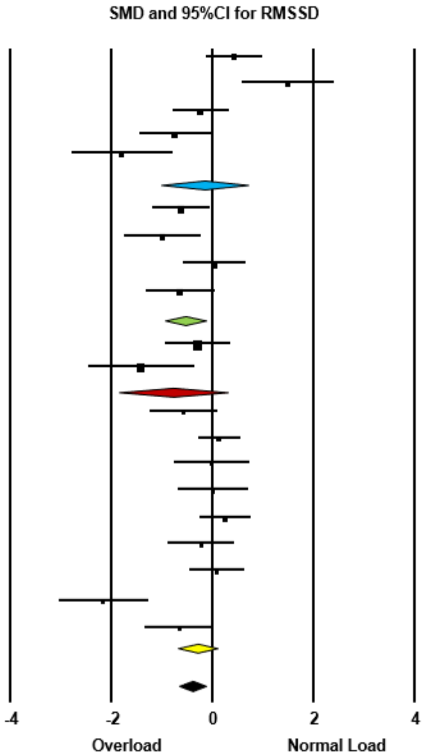

Figure 2. Forest Plot of overload effect on RMSSD; AF: acute fatigue; CI: confidence interval; DC: domestic competition; F: fixed model; FOR: functional overreaching; IC: international competition; LL: low limit; R: random model; SMD: standardized mean difference lower limit; UL: upper limit.

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