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Analysis of Knowledge Production about Overtraining Associated with Heart Rate Variability

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ABSTRACT

Leite GS, Sampaio LMM, Serra AJ, Miranda MLJ, Brandão MRF, Wichi RB. Analysis of Knowledge Production about Overtraining Associated with Heart Rate Variability. **JEPonline** *2*012;15(2):20-29. The purpose of this paper was to analyze scientific studies on overtraining. The survey included online documentary analysis of the publications in the Pubmed database, which included articles that emphasized the key-word "overtraining" and, more specifically, articles that discussed and/or analyzed heart rate variability. The paper reached two conclusions. First, longitudinal studies seem to be more suitable to monitoring the athlete's heart rate variability. Second, heart rate variability seems to be an excellent indicator, along with other markers, to understand the overtraining syndrome.

Key Words: Overtraining, Heart Rate Variability, Athlete, Exercise Physiology

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INTRODUCTION

Interest in sports practice and training steadily increases, especially in the realm of competitive practice, which has received much media attention lately. Sports performance has been the target of numerous investigations in recent years, with emphasis on the training process and its assessment (7,32). When properly structured, training supports a positive adaptive response to doing well in competition (20).

However, it has become increasingly obvious that athletes at all levels have been withdrawn from competitions due to poor performance. An inappropriately structured training plan can lead athletes to a phenomenon known as overtraining (15,20). It is considered a syndrome due to its multifactorial causes. Often, overtraining is described as a chronic imbalance between training and recovery with fatigue and various other physiological and psychological symptoms. Eventually, over a period of weeks or months, the symptoms that associate with overtraining result in a decrease in athletic performance (21).

Traditionally, the symptoms presented in the diagnostic literature indicate that overtraining have been described as marker groups (14) that are classified as performance (4,10), psychological (15,20,24), biochemical (21,28), immunological (22,33), and physiological (9,25). Urhausen and Kindermann (36) indicate that the athletes' performance assessment is the main marker for overtraining, given that athletes often suffer considerable decrease in performance quality that can last for weeks or even months. This would ideally be the primary marker for diagnosis, but the authors highlight the difficulty in maintaining regular tests in most sports to diagnose overtraining.

One alternative to the battery of tests is to work with other markers, such as the psychological marker group. It has been used to help understand responses to training, as in the use of effort-perceptions scales (6), training-recovery scales (20), or the athletes' mood states. Bosquet, Léger and Legros (10) presented a study on changes in the athletes' effort perceptions when maintaining the same intensity of exercise during overtraining. Hedelin et al. (17) revealed a change in athletes' mood states during the training process, showing that such protocol is sensitive to changes of the training load, and can be used as an overtraining preventive marker. As a parameter that depends on the subjective perception of the athlete, it can show a low validity when responses to scales/questions are consciously or unconsciously manipulated by the athletes.

As to the biochemical markers, there are the enzyme indicators such as creatine kinase (CK) and lactate dehydrogenase (LDH), hormonals (testosterone (T), and cortisol (C) as the most common

markers used to diagnose overtraining in athletes (26). Some researchers have demonstrated an increase in CK in the blood of athletes in whom overtraining was diagnosed (28), highlighting a limit-value of 500 U/L to demonstrate muscular injury in athletes (23). Testosterone (anabolic hormone) and cortisol (catabolic) have also been used to demonstrate hormonal adjustments to heavy training loads, given that a difference greater than 30% in the ratio between the hormones (T/C) indicates that the athlete is in overtraining (31). However, a weakness in the biochemical method is the need to secure large blood samples that can overstress the athlete.

An immune marker has had great prominence in the international literature (33). Some researchers have shown suppression of the immune system in response to the use of heavy training loads, especially in the case of immunoglobulin A, interleukins 6 and 10 (IL-6; IL-10), and in total leucocytes and leucocyte fractions (22). Consequently, individuals engaged in the training process with large training loads are probably more likely to experience inflammation and severe infection due to the decrease in immune system activity provoked by exercise. The need of blood samples is the main weakness of this diagnostic method.

The assessment of physiological parameters has been the primary method used to identify athletes who are overtrained (e.g., using the change in blood lactate to exercise or the determination of heart rate (HR) at rest and/or during sub-maximum exercise) (12). Bosque et al. (10) demonstrated change in the response of blood lactate in athletes on overtraining relating the change to the increase of training load. Borresen and Lambert (8), on the other hand, indicated that an increase in the at-rest HR and HR during submaximal exercise established HR sensitivity as a diagnostic indication of overtraining.

Another physiological assessment is the determination of variability of heart rate (HRV), which is established using a set of registers of the R-R intervals of the heart beats over a determined period (1). Hedelin and colleagues (18) indicate that a disorder of the autonomous nervous system explains some overtraining symptoms in athletes. In a non-invasive way, heart rate variability (HRV) allows for assessing changes in the autonomic nervous system (40).

Such methods of assessment were clinically widespread in 1996, when the *European Society of Cardiology* and the *American Society of Electrophysiology* published their recommendations (34) regarding measurement, interpretation, and use of HRV. After 1996, authors such as Uusitalo et al. (37) initiated the use of HRV to monitor athletes for overtraining in an attempt to explore an untapped field, and to determine what could serve as a diagnostic tool to detect overtraining.

In regards to the importance of identifying trends in scientific studies related to the diagnosis of overtraining, this study investigated the scientific literature about a possible association between heart rate variability and overtraining.

METHODS

Regardless of the year of publication, the Pubmed database was used to determine the number of published papers regarding overtraining. The data collection method was systematically carried out by the end of November 2011. The articles were analyzed on the basis of their occurrence in the Pubmed database, which is believed to be the most relevant access to scientific papers in the health field.

The parameters analyzed within the prospective study contained the following key-words: “overtraining” and “heart rate variability,” both alone and in association. Articles that addressed the

use of heart rate variability as a tool to detect overtraining in athletes were identified for further review. In addition, the articles had to be original and written in English. All works that did not meet these criteria were excluded from the analysis.

Two forms of data analysis were then used. The first consisted of the development of a summary presented in tables and figures, giving a general description of the articles found. The second procedure concerned itself with the documentary analysis of the articles found.

RESULTS AND DISCUSSION

This paper identifies the scientific trends about overtraining regarding to heart rate variability. A total of 14,665 articles were found with 4.17% relating to the key-words "overtraining" and 95.83% related to "heart rate variability." Of these articles, 13,653 (93.10%) were original articles and 1,012 (6.90%) were classified as literature reviews. Free access allowed for analysis of 18.73% of the articles (or 2,747 articles).

The association of the key-words decreases the overall analysis considerably, especially since it represents just 0.13% of the total articles found for the key-words without association. It is interesting to highlight that with association the number of review articles increased to 21.05%, and the number of original articles decreased to 78.95%. The criterion of free access also decreased the volume of papers to 10.53%. Table 1 presents the numbers related to the key-words and their association.

Table 1. Number of Articles by Key-Word and Classification.

Key Word	Type		Total	Free Access
	Original	Review		
Overtraining (OT)	461	151	612	93
Heart Rate Variability (HRV)	13192	861	14053	2654
OT + HRV	15	4	19	2

After establishing the field of analysis, further analysis was necessary regarding to the specificity of the works found. Given the inclusion criteria adopted, 100% of the selected studies had athletes as subject of their research. Four review articles were excluded because they were written in languages other than English (German, Polish, and Hungarian). Two original articles were excluded; one dealt with horses and the other did not assess athletes in overtraining. Figure 1 presents the original studies selected using the association of key-words, population, energetic metabolism used, and epidemiological characteristic.

The first article found with the established criteria was published in 1998. By November 2011, there was an article/year in the Pubmed database that met association of key-words. The incidence of the articles found in the Pubmed database is shown in Figure 1. Clearly, it is not possible to outline any trend in the production of original articles involving overtraining and heart rate variability.

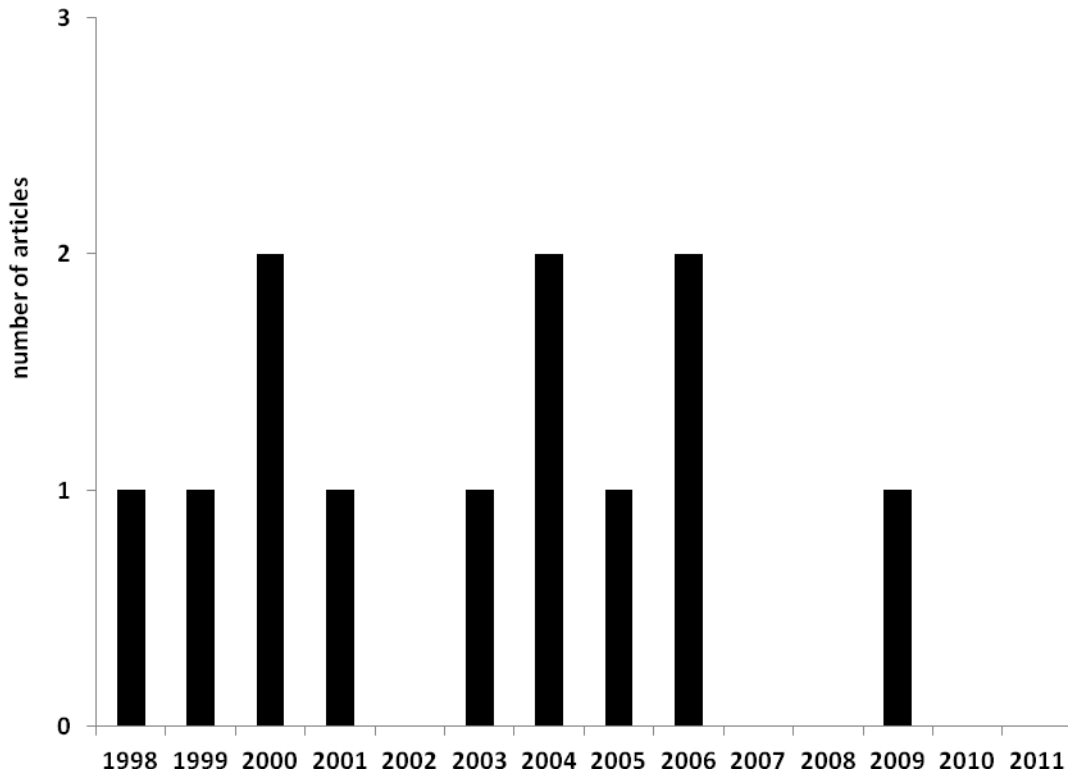

Figure 1. Incidence of Publications Involving Overtraining and Heart Rate Variability.

These articles demonstrate the use of runners (53.84%) as subjects. Only 23.07% of the articles presented experimental models that used exercises with anaerobic characteristics, and none of them presented an intermittent characteristic (aerobic and anaerobic); a pattern that normally is predominant in team sports. In regards to epidemiological characteristics, 76.93% of the articles were longitudinal and only 23.07% were transverse.

The studies with transverse characteristic observed factor and effect at the same historical moment (5,35), which can limit the diagnosis and the actual determination of overtraining syndrome. The reason is that the causes can occur in different moments, lasting weeks or even months (21,24). Therefore, it is not the best method to use when the objective is to diagnose or prevent overtraining, because it would not be indicated in the transverse cut.

Wilmore, Costill, and Kenney (41) concluded that many athletes presented symptoms related to overtraining when the syndrome has not yet been acquired, because the symptoms can be confused with responses to a period of intensified training or even with the symptoms of overreaching. In this period, a brief decrease in performance occurs that can be extended for a couple of days or weeks followed by an increase in the physiological function and improvement of the performance after the taper period.

Exhibit 1. Characteristics of the Selected Original Articles.

Study	Population	Energetic Metabolism Used	Epidemiological Characteristic
Blásquez et al. (3)	Master Swimmers	Anaerobic	Longitudinal
Baumert et al. (2)	Triathletes	Aerobic	Longitudinal
Hynynen et al. (19)	Athletes of Different Sports	Aerobic/Anaerobic	Longitudinal
Vinet et al. (39)	Young Swimmers	Anaerobic	Transverse
Buchheit et al. (13)	Runners/Sedentary Individuals	Aerobic	Transverse
Mourot et al. (25)	Athletes of Different Sports	Aerobic	Transverse
Bosquet et al. (11)	Runners/Triathletes	Aerobic	Longitudinal
Portier et al. (29)	Male Runners	Aerobic	Longitudinal
Hedelin et al. (18)	Paddlers	Aerobic	Longitudinal
Hedelin et al. (17)	Cross-Country Skiers	Aerobic	Longitudinal
Uusitalo et al. (38)	Athletes of Different Sports	Aerobic	Longitudinal
Uusitalo et al. (37)	Female Runners	Aerobic	Longitudinal

A point stressed by Halson and Jeukendrup (16) is that most studies describe overtraining incorrectly, and that what they actually found was overreaching. They pointed out that overreaching can be reversed within a two-week period, but many studies have confused the momentary effects of the athlete training with overtraining. The subjectivity of the diagnosis, the variability of the results in the studies and especially the lack of well-controlled studies are key issues in this discussion.

To better understand this point, it is reasonable that future researchers should pay attention to the classifications presented by Nederhof et al. (27): (a) functional overreaching; (b) non-functional overreaching; and (c) overtraining. The first has a short recovery of days to weeks. The second classification consists of moderate symptoms and a recovery period of weeks to months. The third is more severe with symptoms that last months to years.

Morgan et al. (24) stressed the importance to define and break the cause (defined as the process) and the consequence (defined as result or product) to better understand the overtraining phenomenon. Longitudinal or horizontal research is an investigation in which the same participants are studied for a long period (months or years) (35) and it aims to identify the causes and the results (5). At this point, athletes of the same modality should be observed through one or more training

cycles (annual or multiannual), and the overtraining markers already outlined should be monitored as well.

CONCLUSIONS

It was found that the prevalence of experimentation included activities that were cyclic, aerobic, and pedestrianism in associated with heart rate variability and overtraining. Also, heart rate variability appeared to be an indicator, along with other markers, allowing diagnosis of overtraining syndrome. Longitudinal studies appear to be more suitable to monitoring the athlete's heart rate variability and to properly diagnose overtraining or overreaching.

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REFERENCES

1. Aubert AE, Seps B, Beckers F. Heart rate variability in athletes, ***Sports Med***. 2003;33(12):889-919.
2. Baumert M, Brechtel L, Lock J, Hermsdorf M, Wolff R, Baier V, Voss A. Heart rate variability, blood pressure variability, and baroreflex sensitivity in overtrained athletes. ***Clin J Sport Med***. 2006;16(5):412-7.
3. Blásquez JCC, Font GR, Ortís LC. Heart-rate variability and precompetitive anxiety in swimmers, ***Psicothema***, 2009;21(4):531-6..
4. Booth CK, Probert B, Forbes-Ewan C, Coad RA. Australian army recruits in training display symptoms of overtraining. ***Mil Med***. 2006;171(11):1059-64.
5. Bordalo, AA. Estudo transverse e/ou longitudinal. ***Rev Para Med****.* 2006 Dez; 20(4): 5-5.
6. Borg G. Psychophysical bases of perceived exertion. ***Med Sci Sports Exerc***. 1982;14(5):377-81.
7. Borin JP, Gomes AC, Leite GS. Preparação desportiva: aspectos do controle da carga de treinamento nos jogos coletivos. ***R. da Educação Física****.* 2007;18:97-105.
8. Borresen J, Lambert MI. Autonomic control of heart rate during and after exercise - measurements and implications for monitoring training status, ***Sports Med***. 2008;38(8):633-46.
9. Bosquet L, Merkari S, Arvisais D, Aubert AE. Is heart rate a convenient tool to monitor overreaching? A systematic review of the literature. ***Br J Sports Med*****.** 2008;42(9):709-14.

10. Bosquet L, Leger L, Legros P. Blood lactate response to overtraining in male athletes. ***Eur J Appl Physiol***. 2001;84(1-2):107-14.

11. Bosquet L, Papelier Y, Léger L, Legros P. Night heart rate variability during overtraining in male endurance athletes. ***J Sports Med Phys Fitness***. 2003;43(4):506-12.

12. Boulay MR. Physiological monitoring of elite cyclists – pratical methods. ***Sports Med***. 1995l;20(1):1-11.

13. Buchheit M, Simon C, Piquard F, Ehrhart J, Brandenberger G. 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):H2813-8.

14. Coutts AJ; Wallace LK; Slattery KM. Monitoring changes in performance, physiology, biochemistry, and psychology during overreaching and recovery in triathletes. **Int *J Sports Med***. 2007;28(2):125-34.

15. Foster C. Monitoring training in athletes with reference to overtraining syndrome. ***Med Sci Sports Exerc***. 1998;30(7):1164-8.

16. Halson SL, Jeukendrup AE. Does overtraining exist? An analysis of overreaching and overtraining research. ***Sports Med***. 2004;34(14):967-81.

17. Hedelin R, Wiklund U, Bjerle P, Henriksson-Larsén K. Cardiac autonomic imbalance in an overtrained athlete. ***Med Sci Sports Exerc***. 2000;32(9):1531-3.

18. Hedelin R, Kenttä G, Wiklund U, Bjerle P, Henriksson-Larsén K. Short-term overtraining: effects on performance, circulatory responses, and heart rate variability. ***Med Sci Sports Exerc***. 2000;32(8):1480-4.

19. Hynynen E, Uusitalo A, Kontrinen N, and Rusko H. Heart Rate Variability during Night Sleep and after Awakening in Overtained Athletes. ***Med Sci Sports Exerc***. 2006;38(2):313-7.

20. Kenttä G, Hassmén P. Overtraining and recovery - a conceptual model. ***Sports Med***. 1998;26(1):1-16.

21. Lehmann M, Gastmann U, Petersen KG, Bachl N, Seidel A, Khalaf AN, Fischer S, Keul J. Training-overtraining: performance and hormonal levels after a defined increase in training volume vs. intensity in experienced middle and long-distance runners. ***Br J Sports Med***. 1992 Dec;26(4):233-42.

22. MacKinnon LT. Special feature for the Olympics: effects of exercise on the immune system: overtraining effects on immunity and performance in athletes. ***Immunol Cell Biol***. 2000t;78(5):502-9.

23. Martínez-Amat A, Boulaiz H, Prados J, Marchal JA, Padial Puche P, Caba O, Rodríguez-Serrano F, Aránega A. Release of alpha-actin into serum after skeletal muscle damage. ***Br J Sports Med***. 2005;39(11):830-4.

24. Morgan, WP, Brown, DR, Raglin, JS, O'Connor, PJ, Ellickson, KA. Psychological monitoring of overtraining and staleness. ***Br J Sports Med***. 1987;21(3):107-14.

25. Mourot L, Bouhaddi M, Perrey S, Cappelle S, Henriet MT, Wolf JP, Rouillon JD, Regnard J. Decrease in heart rate variability with overtraining: assessment by the Poincaré plot analysis. ***Clin Physiol Funct Imaging***. 2004;24(1):10-8.

26. Mujika I, Padilla S, Pyne D, Busso T. Physiological changes associated with the pre-event taper in athletes. ***Sports Med.*** 2004;34(13):891-927.

27. Nederhof E, Lemmink KA, Visscher C, Meeusen R, Mulder T, Psychomotor speed: possibly a new marker for overtraining syndrome. ***Sports Med***. 2006;36(10):817-28.

28. Petibois C, Cazorla G, Poortmans JR, Déléris G. Biochemical aspects of overtraining in endurance sports. ***Sports Med***. 2002;32(13):867-78.

29. Portier H, Louisy F, Laude D, Berthelot M, Guezennec CY. Intense endurance training on heart rate and blood pressure variability in runners. ***Med Sci Sports Exerc***. 2001;33(7):1120-5.

30. Rohlfs ICPM, Rotta TM, Luft CDB, Andrade A, Krebs RJ, Carvalho T. A Escala de Humor de Brunel (Brums): instrumento para detecção precoce da síndrome do excesso de treinamento. ***Rev Bras Med Esporte***. 2008;14(3):176-181.

31. Simões HG, Marcon F; Oliveira F; Campbell CSG; Baldissera V; Rosa LFBPC. Resposta da razão testosterona/cortisol durante o treinamento de corredores velocistas e fundistas. ***Rev. bras. Educ. Fís. Esp.*** 2004;18(1):31-46.

32. Smith DJ. A framework for understanding the training process leading to elite performance. ***Sports Med***. 2003;33(15):1103-26.

33. Smith LL. Overtraining, excessive exercise, and altered immunity. ***Sports Med.*** 2003;33(5): 347-64.

34. Heart rate variability: Standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. ***Circulation.*** 1996;93(5):1043-65.

35. Thomas JR, Nelson, J, Silverman, S. ***Research Methods in Physical Activity***. Human Kinetics Publishers; 6th Revised Edition, 2010.

36. Urhausen A, Kindermann W. Diagnosis of overtraining: what tools do we have? ***Sports Med.*** 2002;32(2):95-102.

37. Uusitalo AL, Uusitalo AJ, Rusko HK. Exhaustive endurance training for 6-9 weeks did not induce changes in intrinsic heart rate and cardiac autonomic modulation in female athletes. ***Int J Sports Med***. 1998;19(8):532-40.

38. Uusitalo AL, Uusitalo AJ, Rusko HK. Heart rate and blood pressure variability during heavy training and overtraining in the female athlete. ***Int J Sports Med.*** 2000;21(1):45-53.

39. Vinet A, Beck L, Nottin S, Obert P. Effect of intensive training on heart rate variability in prepubertal swimmers. ***Eur J Clin Invest***. 2005;35(10):610-4.

40. Wichi RB, De Angelis K, Jones L, Irigoyen MC. A brief review of chronic exercise intervention to prevent autonomic nervous system changes during the aging process. ***Clinics (Sao Paulo)***. 2009;64(3):253-8.

41. Wilmore JH, Costill DL, Kenney WL. ***Fisiologia do exercício e do esporte.*** Manole, 4th Edition, 2010.

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