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Artigo Original

# Autonomic correlates of Yo-Yo performance in soccer referees

Daniel A. Boullosa [1]
Fábio Yuzo Nakamura [2]
Luiz Augusto Perandini [2]
Anthony Scott Leicht [3]

[1] *Programa de Pós-Graduação Stricto Sensu em Educação Física, Universidade Católica de Brasília, Brasília, DF, Brasil*
[2] *Departamento de Educação Física, Universidade Estadual de Londrina, PR, Brasil*
[3] *Institute of Sport and Exercise Science, James Cook University, Townsville, Australia*

**Abstract:** We tested the hypothesis that: basal cardiac autonomic modulation (i.e. heart rate variability, HRV) was associated with the parasympathetic withdrawal during, and overall Yo-Yo IR1 performance; and therefore HRV could be used as a simple tool for specific fitness assessment. Nine sub-elite soccer referees performed the Yo-Yo IR1 until exhaustion with simultaneous recording of heart rate with the autonomic response during exercise calculated as the area under the curve (AUC). In the same week but with at least 48 hrs between days, a night-time HR recording was obtained from participants for determination of basal HRV. Correlation analysis demonstrated strong (r>0.83) relationships among Yo-Yo IR1 performance, AUC and basal HRV. These results indicate that both nocturnal HRV and AUC can be utilised as simple and valid monitoring tools of soccer referees´ fitness.
**Keywords:** vagal modulation; Yo-Yo IR1; performance monitoring.

*Correlatos autonômicos do desempenho no Yo-Yo em árbitros de futebol*

**Resumo:** Nós testamos a hipótese de: que a modulação autonômica cardíaca (i.e. variabilidade da freqüência cardíaca, VFC) está associada com a retirada parassimpática durante a execução do Yo-Yo IR1; e que, portanto, a VFC poderia ser usada como uma ferramenta simples para a avaliação do desempenho físico específico. Nove árbitros sub-elite de futebol executaram o Yo-Yo IR1 até a exaustão com registro simultâneo da freqüência cardíaca e VFC para o cálculo da área sob a curva (ASC). Na mesma semana, mas com mínimo de 48 horas entre dias, obteve-se um registro noturno da FC dos participantes para a determinação da VFC basal. As análises de correlação demonstraram elevados coeficientes (r>0,83) entre o desempenho no Yo-Yo IR1, a ASC e a VFC basal. Estes resultados indicam que a VFC noturna e a ASC podem ser empregadas como ferramentas simples e válidas para o monitoramento do desempenho de árbitros de futebol.
**Palavras-chave:** modulação vagal; Yo-Yo IR1; monitoramento do desempenho.

## Introdução

Unlike most professional players within elite and semi-elite sport, referees are typically engaged as amateurs or semi-professionals with limited time for training. Subsequently, this results in a limited number of sessions per week for physical conditioning (e.g. two-three sessions), with even fewer sessions available if referees are fatigued from exhaustive physical testing. Therefore, it is important that simple, appropriate and time-efficient methods of monitoring training be utilized to assist referees and other similar populations.

Previously, several studies have analysed the appropriateness of field-based maximal tests for soccer referees such as the 12 min running test (CASAJUS & CASTAGNA, 2007), the 50 m sprint, the 200 m sprint (CASTAGNA et al., 2002) and, more recently, the 6 × 40 m sprints and the 150 m intervals running test (MALLO et al., 2009). While these tests have been recommended by International Federation of Football Associations (FIFA) for the evaluation of referees fitness, other tests like the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) have been demonstrated to be valid and easy to apply in this population (CASTAGNA et al., 2005). Further, the Yo-Yo IR1 has been extensively studied in team sports for the evaluation of high-intensity running capacity confirming the appropriateness of this test for soccer refereeing (KRUSTRUP et al., 2003; CASTAGNA et al., 2007). While the Yo-Yo IR1 provides important information for referees, it does though require the completion of exhaustive exercise that will limit referees' weekly training. Other tests or methods may therefore provide alternate means to monitor referees progress without significantly affecting training load.

One possible method of interest is the oscillation in resting heart rate, termed heart rate variability (HRV). This non-invasive indicator of autonomic nervous system has been studied with a range of athletes and was significantly correlated with individuals' fitness levels, specifically $VO_{2max}$ (HAUTALA et al., 2009). Further, running training guided by resting HRV has been shown to be more effective than standard training regimes without HRV monitoring (KIVINIEMI et al., 2007). The intensity-dependent nature of HRV after high-intensity intermittent efforts may explain the effectiveness of HRV guided training on cardiorespiratory fitness (BUCHHEIT et al., 2009; Al Haddad et al., 2009). Therefore, HRV and in particular night-time HRV, may provide a simple and effective tool to monitor training without significantly impacting on training load, a key element for soccer referees with limited training opportunities. From a methodological point of view, HRV can also be examined during exercise with the "area under the HRV indices curve" method (AUC) (PERANDINI et al., 2009). The AUC is obtained by fitting a mono-exponential decay curve to time-domain HRV indices and has been reported to be highly related to the maximum velocity achieved in the 30-15 Intermittent Fitness Test (PERANDINI et al., 2009) and reflective of parasympathetic withdrawal during incremental exercise. Importantly, the AUC could be useful for referees and athletes monitoring as it only requires recording and analysis of HRV during sub-maximal stages of the Yo-Yo IR1 (i.e. up to 85% of HRmax, LEWIS et al., 2007; PERANDINI et al., 2009). In this manner, the AUC may provide a simple means to assess HRV and parasympathetic withdrawal during submaximal exercise typically experienced by referees and athletes during weekly training. Consequently, night-time HRV and/or AUC may provide important information to monitor referee's training without the need for exhaustive exercise assessment and/or reduction of weekly training load.

Therefore, the aim of this study was to examine the relationship between HRV (night-time resting HRV and AUC) and high-intensity intermittent performance of soccer referees. It was hypothesized that night-time HRV and the AUC index would be valid indicators of referees' performance as reflected on distance covered or exercise time during Yo-Yo IR1, therefore providing simple tools to monitor training adaptations for referees.

## Methods

### *Participants*

Nine Spanish male soccer referees (24.1 ± 3.3 years; 75.4 ± 4.2 kg; 179 ± 3 cm) of national/regional (semi-elite) level and with a minimum of 3 years of experience, volunteered for this study. All of them were informed of the procedures and provided informed written consent. The estimated sample size required to undertake this study was 9 athletes (Medcalc® v 9.2.1.0) based on a power of 0.80 and α of 0.05. This study received the approval of the local ethics committee (La Directiva del Colegio Oficial de Árbitros de Fútbol de Vigo en sesión extraordinaria celebrada con fecha 24/01/2008).

### *Field testing session*

Participants were instructed not to undertake intense exercise on the day before testing with all testing sessions performed during the afternoon (i.e. 17:00-19:00) within thermoneutral climatic conditions. After 10 min of a running warm-up on a soccer field of natural grass at an intensity of 60% of the maximum estimated HR (TANAKA et al., 2001), participants performed the Yo-Yo IR1 (KRUSTRUP et al., 2003) with concurrent recording of R-R intervals (RS800, Polar Electro OY, Kempele, Finland) until volitional exhaustion. The Yo-Yo IR1 consists of repeated 20 m exercise bouts with changes of direction and performed at progressively increasing speeds, interspersed with 10-s active rest periods, and performed until the subject achieves exhaustion. Previously, top-class soccer referees exhibited a Yo-Yo IR1 result of 1,874 (431) m, while low level referees exhibited a mean performance of 1,271 (215) m (CASTAGNA et al., 2005). Immediately following the Yo-Yo IR1, a blood lactate sample was obtained from the fingertip and analysed with a portable device (Lactate Scout, Senslab, Germany) for the determination of maximal lactate (LA). The AUC method was applied as previously described (PERANDINI et al., 2009), calculating the root mean square of successive differences between normal sinus RR intervals (RMSSD), and the standard deviation of instantaneous HRV (SD1) from Poincaré plots during each minute of the Yo-

Yo IR1. Subsequently, these parameters were fitted with a first-order exponential decay curve (see below) and AUC estimated through an integrate function (Microcal Origin 6.0, Northampson, USA).

$$y = y_0 + Ae^{-x/t}$$

where, y = RMSSD or SD1 (ms); A = amplitude (ms); x = time (s); τ = time constant (s).

These SD1 and RMSSD were examined as these parameters were not influenced by breathing frequency or the non-stationarity of RR interval data typical of progressive exercise (PENTTILÃ et al., 2001; TULPPO et al., 1996).

*Night-time HRV*

Night R-R recordings of a rested day were obtained in the same week of the field testing session with a minimum of 48 hrs between the night-time and Yo-Yo IR1 recordings. Participants were advised to go to bed before 00:00 with a minimum of 2 hours after the last meal. HR recordings were manually filtered (Polar Pro Trainer, v. 5.35.161, Finland) and exported for HRV analysis using custom designed software (Kubios HRV v2.0, University of Kuopio, Finland). The HRV parameters calculated were the RMSSD and the SD1 from the 00:00-05:00 interval (WENNERBLOM et al., 2001).

*Statistical analysis*

Descriptive data are shown as mean (SD). A Kolmogorov-Smirnov test was performed to verify the normal distribution of variables. Pearson product moment correlation coefficients (r) were employed for detection of significant ($p$<0.05) relationships between selected parameters.

## Results

Mean Yo-Yo IR1 performance was 1,122 (299) m which is equivalent to ~ 9:24 (min:sec), with a LA of 11.1 (2.7) $mM \cdot L^{-1}$. Due to excessive artefacts during the Yo-Yo IR1, one participant was excluded from the AUC analyses. AUC values of 3541 (1016) ms·s for RMSSD and 3119 (817) ms·s for SD1 were obtained during the Yo-Yo IR1. Mean night-time RMSSD and SD1 were 49.8 (23.4) ms, and 35.6 (16.5) ms, respectively.

Significant correlations were observed between night-time HRV parameters with Yo-Yo IR1 performance (m) (r=0.835 and r=0.833; $p$=0.005; for SD1 and RMSSD, respectively) and final time (see Figure 1). The AUC for SD1 and RMSSD until exhaustion were significantly and highly correlated with Yo-Yo IR1 final time (see Figure 2). Moreover, night-time HRV parameters (RMSSD and SD1) and AUC indices were significantly correlated among each other (r=0.934 for SD1, r=0.938 for RMSSD; $p$<0.05).

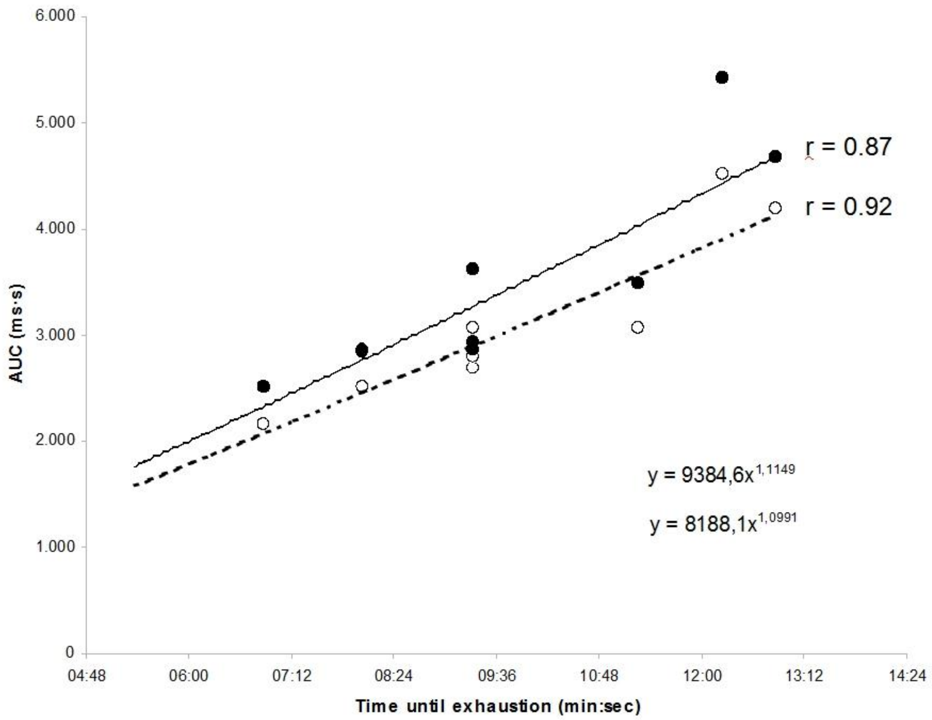


**Figure 1.** Exponential regression (n = 9) of basal SD1 (dotted line; white circles) and RMSSD (thick line; black circles) with exhaustion time in Yo-Yo intermittent recovery test level 1; r = Pearson product correlation coefficients.

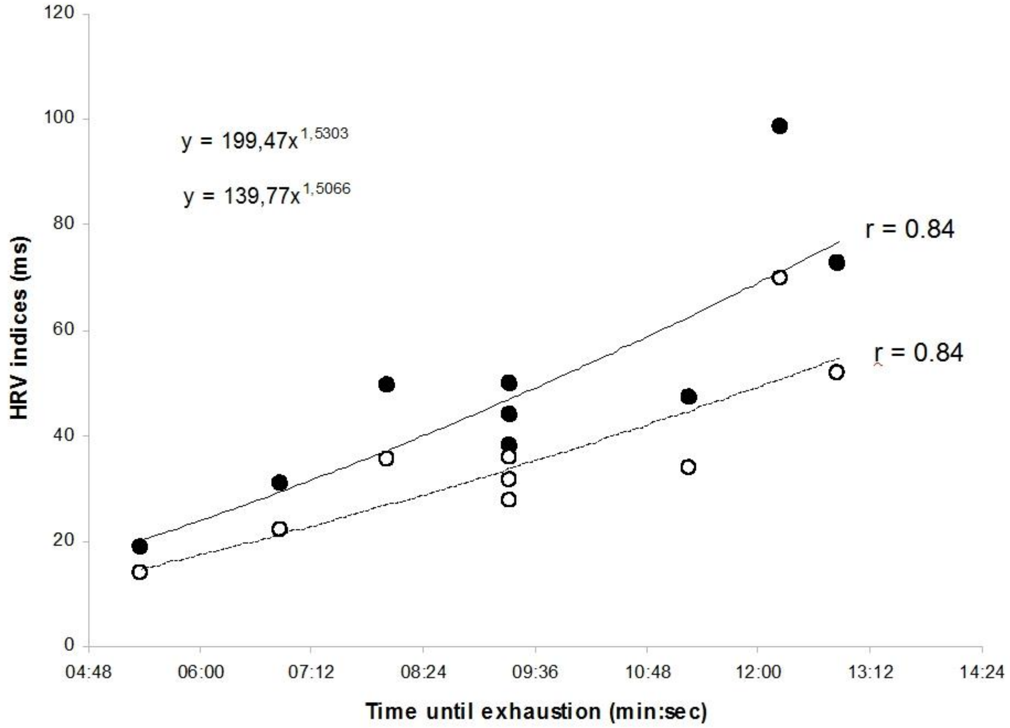


**Figure 2.** Exponential regression (n = 8) of AUC for SD1 (dotted line; white circles) and RMSSD (thick line; black circles) with exhaustion time in Yo-Yo intermittent recovery test level 1; r = Pearson product correlation coefficients.

## Discussion

As hypothesized, a significant and high correlation was observed between night-time HRV and Yo-Yo performance. Further, the AUC was also highly correlated with basal HRV and the incremental test indicating that referees with greater parasympathetic modulation and slower parasympathetic withdrawal (i.e. greater SD1 and RMSSD) per each stage of the Yo-Yo IR1, exhibited better exercise performance. Therefore, greater resting autonomic control appears to be a simple and valid indicator of greater Yo-Yo IR1 performance and lesser parasympathetic withdrawal through this test.

This is the first time that a significant correlation among HRV parameters and Yo-Yo IR1 performance has been reported. Previously, Lewis et al. (2007) showed that the HRV decay constants for each power spectral component were linearly related to maximal work rate ($r>0.71$; $p<0.001$) during an incremental test in cycle ergometer. More recently, Perandini et al. (2009) reported moderate-to-strong correlations ($r=0.64$-$0.80$; $p<0.05$) among the AUC indices and the final velocity achieved in the 30-15 Intermittent Fitness Test (30-15 $_{IFT}$) in professional handball players. Interestingly, they also reported moderate-to-high correlations between seated HRV and the AUC indices, but not between seated HRV and the final velocity in the field test (PERANDINI et al., 2009). In contrast, we found substantial correlations ($r=0.83$-$0.93$) among nocturnal HRV, the AUC and performance during the Yo-Yo IR1 indicating for the first time that cardiac autonomic control assessed during rest and/or intermittent exercise can be used to estimate exercise performance of soccer referees. The finding that basal HRV predicts performance in the Yo-Yo IR1 but not in the 30-15 $_{IFT}$ is interesting and may be due to the different physiological impact of each test that warrants further consideration. Based upon these findings, we suggest that simple, night-time HRV recordings could provide important information about referees' fitness without the need for exercise assessment and/or reduction of weekly training load. This practical training tool (i.e. resting HRV) could reflect the fitness status of an individual (i.e. Yo-Yo IR1 performance) without the employment of sophisticated laboratory instruments and/or exhaustive field tests. Additionally, as the AUC has also been reported to be related to field performance and basal HRV, it may be suggested that submaximal bouts of Yo-Yo IR1 could be performed for determining the fitness status of referees without the need for volitional exhaustion.

Previous reports of significant relationships between basal HRV and $VO_{2max}$ (HAUTALA et al., 2009), and $VO_{2max}$ improvements following HRV-guided training (KIVINIEMI et al., 2007) support the current results that enhanced parasympathetic control may lead to enhanced aerobic performance. More recently, Serpiello et al. (2010) reported an 8% improvement in Yo-Yo IR1 performance after a repeated sprint training regimen with concurrent improvements in $VO_{2peak}$, HR recovery (HRR) and acceleration capacity without changes for the lactate threshold. This indicator of greater parasympathetic reactivation (i.e. greater autonomic control) along with the current and prior (BUCHHEIT et al., 2008; BOULLOSA et al., 2009; RICARDO et al., 2010) results provides further support that central cardiac autonomic control contributes substantially to training-induced adaptations (e.g. $VO_{2max}$). Although important, it is still not clear whether the enhanced parasympathetic occurs initially as a resultant of regular exercise or as a resultant of other training-induced cardiovascular changes such as enhanced stroke volume (MIDGLEY et al., 2006). Though we suggest that it may be a secondary response with exercise training reported to significantly lower intrinsic HR (SANT´ANA et al., 2011) and resting HR without concurrent HRV changes (LEICHT et al., 2003). Importantly though, the greater HRV and lower HR during rest and exercise exhibited by trained individuals results in a greater capacity to increase HR during exercise, delay the aerobic-anaerobic transition (NAKAMURA et al., 2005) and/or increase maximal cardiac output and $VO_{2max}$ (BLOMQVIST & SALTIN, 1983).

The major limitation of this study was the examination of a small number of referees. Despite this, a great range of Yo-Yo IR1 performances was examined and allowed the identification of significant correlations among HRV and performance parameters. Additionally, we did not examine the types of training undertaken by referees and therefore do not know the influence of specific training programs on both Yo-Yo IR1 and HRV. Further longitudinal studies may elaborate upon the impact of training on the relationship between HRV and exercise performance for the development of more sensitive training tools for referees. Furthermore, as previous reports have suggested that endurance training induce a greater resting HRV and a slower parasympathetic withdrawal during incremental exercise (HAUTALA et al., 2009; NAKAMURA et al., 2005), while other studies have showed that a greater resting HRV could favor greater adaptations after a training period (VESTERINEN et al., 2011), we do not know in the current study if a greater resting HRV is a consequence of the training background of the subjects, or this could favor a greater adaptation after a training period, with further studies needed.

In summary, cardiac autonomic control indicators during night-time (HRV) and exercise (AUC) were significantly correlated with Yo-Yo IR1 performance in semi-elite soccer referees. Both basal nocturnal HRV and AUC could be employed as simple and easy tools to assess and monitor training adaptations of soccer referees. Further studies could elaborate on the significance of HRV and AUC as monitoring tools for training adaptations in athletes and referees of different levels.

## References


AL HADDAD, H.; LAURSEN, P. B.; AHMAIDI, S.; BUCHHEIT, M. Nocturnal heart rate variability following supramaximal intermittent exercise. **International Journal of Sports Physiology and Performance**, Champaign, v. 4, n. 4, p. 435-447, 2009.

BLOMQVIST, C. G.; SALTIN, B. Cardiovascular adaptations to physical training. **Annual Review of Physiology**, Palo Alto, v. 45, p. 169-189, 1983.

BOULLOSA, D. A.; TUIMIL, J. L.; LEICHT, A. S.; CRESPO-SALGADO, J. J. Parasympathetic modulation and running performance in distance runners. **Journal of Strength and Conditioning Research**, Lincoln, v. 23, n. 2, p. 626-631, 2009.

BUCHHEIT, M.; MILLET, G. P.; PARISY, A.; POURCHEZ, S.; LAURSEN, P. B.; AHMAIDI, S. Supramaximal training and postexercise parasympathetic reactivation in adolescents. **Medicine & Science in Sports & Exercise**, Madison, v. 40, n. 2, p. 362-371, 2008.

BUCHHEIT, M.; AL HADDAD, H.; MILLET, G. P.; LEPRETRE, P. M.; NEWTON, M.; AHMAIDI, S. Cardiorespiratory and cardiac autonomic responses to 30-15 intermittent fitness test in team sports players. **Journal of Strength and Conditioning Research**, Lincoln, v. 23, n. 1, p. 93-100, 2009.

CASAJUS, J. A.; CASTAGNA, C. Aerobic fitness and field test performance in elite spanish soccer referees of different ages. **Journal of Science**

**and Medicine in Sport**, Belconnen, v. 10, n. 6, p. 382-389, 2007.

CASTAGNA, C.; ABT, G.; D´OTTAVIO, S. Relation between fitness tests and match performance in elite Italian soccer referees. **Journal of Strength and Conditioning Research**, Lincoln, v. 16, n. 2, p. 231-235, 2002.

CASTAGNA, C.; ABT, G.; D´OTTAVIO, S. Competitive-level differences in yo-yo intermittent recovery and twelve minute run test performance in soccer referees. **Journal of Strength and Conditioning Research**, Lincoln, v. 19, n. 4, p. 805-809, 2005.

CASTAGNA, C.; ABT, G.; D´OTTAVIO, S. Physiological aspects of soccer refereeing performance and training. **Sports Medicine**, Auckland, v. 37, n. 7, p. 625-646, 2007.

HAUTALA, A. J.; KIVINIEMI, A. M.; TULPPO, M. P. Individual responses to aerobic exercise: the role of the autonomic nervous system. **Neuroscience Biobehavioural Reviews**, New York, v. 33, n. 2, p. 107-115, 2009.

KIVINIEMI, A. M.; HAUTALA, A. J.; KINNUNEN, H.; TULPPO, M. P. Endurance training guided individually by daily heart rate variability measurements. **European Journal of Applied Physiology**, Berlin, v. 101, n. 6, p. 743-751, 2007.

KRUSTRUP, P.; MOHR, M.; AMSTRUP, T.; RYSGAARD, T.; JOHANSEN, J.; STEENSBERG, A.; PEDERSEN, P. K.; BANGSBO, J. The yo-yo intermittent recovery test: physiological response, reliability, and validity. **Medicine & Science in Sports & Exercise**, Madison, v. 35, n. 4, p. 697-705, 2003.

LEICHT, A. S.; ALLEN, G. D.; HOEY, A. J. Influence of age and moderate-intensity exercise training on heart rate variability in young and mature adults. **Canadian Journal of Applied Physiology**, Champaign, v. 28, n. 3, p. 446-461, 2003.

LEWIS, M. J.; KINSGLEY, M.; SHORT, A. L.; SIMPSON, K. Rate of reduction of heart rate variability during exercise as an index of physical work capacity. **Scandinavian Journal of Medicine and Science in Sports**, Copenhagen, v. 17, n. 6, p. 696-702, 2007.

MALLO, J.; NAVARRO, E.; GARCÍA ARANDA, J. M.; HELSEN, W. F. Activity profile of top-class association football referees in relation to fitness-test performance and match standard. **Journal of Sports Sciences**, London, v. 27, n. 1, p. 9-17, 2009.

MIDGLEY, A. W.; MCNAUGHTON, L. R.; WILKINSON, M. Is there an optimal training intensity for enhancing the maximal oxygen uptake of distance runners? empirical research findings, current opinions, physiological rationale and practical recommendations. **Sports Medicine**, Auckland, v. 36, n. 2, p. 117-132, 2006.

NAKAMURA, F. Y.; AGUIAR, C. A. de; FRONCHETTI, L.; AGUIAR, A. F.; PERROUT DE LIMA, J. R. Alteração do limiar de variabilidade da freqüência cardíaca após treinamento aeróbio de curto prazo. **Motriz,** Rio Claro, v. 11, n. 1, p. 1-9, 2005. Disponível em: <http://www.periodicos.rc.biblioteca.unesp.br/index.php/motriz/article/viewFile/291/246>. Acesso em: 24 dez. 2010.

PENTTILÄ, J.; HELMINEN, A.; JARTTI, T.; KUUSELA, T.; HUIKURI, H. V.; TULPPO, M. P.; COFFENG, R.; SCHEINING, H. Time domain, geometrical and frequency domain analysis of cardiac vagal outflow: effects of various respiratory patterns. **Clinical Physiology**, Oxford, v. 21, n. 3, p. 365-376, 2001.

PERANDINI, L. A.; CHIMIN, P.; OKUNO, N. M.; PERROUT DE LIMA, J. R.; BUCHHEIT, M.; NAKAMURA, F. Y. Parasympathetic withdrawal during 30-15 intermittent fitness test correlates with its´ maximal aerobic speed in male handball players. **Journal of Exercise Physiology Online**, Duluth, v. 12, n. 2, p. 29-39, 2009. Disponível em: <http://faculty.css.edu/tboone2/asep/JEPonlinePerandiniApril2009.pdf>. Acesso em: 24 dez. 2010.

RICARDO, D. R.; SILVA, B. M.; VIANNA, L. C.; ARAÚJO, C. G. S. Cardiac vagal withdrawal and reactivation during repeated rest-exercise transitions. **European Journal of Applied Physiology**, Berlin, v. 110, n. 5, p. 933-942, 2010.

SANT´ANA, J. E.; PEREIRA, M. G.; SILVA, V. J. D. da; DAMBRÓS, C.; COSTA-NETO, C. M.; SOUZA, H. C. Effect of the duration of daily aerobic physical training on cardiac autonomic adaptations. **Autonomic Neuroscience**, New York, v. 159, n. 1-2, p. 32-37, 2011.

SERPIELLO, F. R.; MCKENNA, M. J.; STEPTO, N. K.; BISHOP, D. J.; AUGHEY, R. J. Performance and physiological responses to repeated-sprint exercise: a novel multiple-set approach. **European Journal of Applied Physiology**, Berlin, v. 111, n. 4, 669-678, 2011.

TANAKA, H.; MONAHAN, K. D.; SEALS, D. R. Age-predicted maximal heart rate revisited. **Journal of the American College of Cardiology**, New York, v. 37, n. 1, p. 153-156, 2001.

TULPPO, M. P.; MAKIKALLIO, T. H.; TAKALA, T. E.; SEPPANEN, T.; HUIKURI, H. V. Quantitative beat-to-beat analysis of heart rate dynamics during exercise. **American Journal of Physiology. Heart and Circulatory Physiology**, Bethesda, v. 271, p. H244–H252, 1996.

VESTERINEN, V.; HAKKINEN, K.; HYNYNEN, E.; MIKKOLA, J.; HOKKA, L.; NUMMELA, A. Heart rate variability in prediction of individual adaptation to endurance training in recreational endurance runners. Scandinavian Journal of Medicine and Science in Sports, Copenhagen, 2011. In press.

WENNERBLOM, B.; LURJE, L.; KARLSSON, T.; TYGESEN, H.; VAHISALO, R.; HJALMARSON, A. Circadian variation of heart rate variability and the rate of autonomic change in the morning hours in healthy subjects and angina patients. **International Journal of Cardiology**, Amsterdam, v. 79, n. 1, p. 61-69, 2001.

Endereço:

Daniel A. Boullosa
Universidade Católica de Brasília - UCB
QS 07, LT1 S/N - Sala 111 - Bloco G
Águas Claras DF Brasil
71966-700
Phone number: +55 61 3356-9489
e-mail: d_boullosa@yahoo.es

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