PREDICTION OF BASELINE HEART RATE OF INDIVIDUALS WITH DIFFERENT LEVELS OF HABITUAL PHYSICAL ACTIVITY

EXERCISE AND SPORTS MEDICINE CLINIC

ORIGINAL ARTICLE

André de Assis Lauria[1]
Tony Meireles dos Santos[2]
Paulo Roberto dos Santos Amorim[1]
Fábio Antonio Damasceno Marques[1]
Jorge Roberto Perrout de Lima[1]

1. *Stricto Sensu* Graduate Program in Physical Education of the Federal University of Viçosa, Federal University of Juiz de Fora (UFV/UFJF) – Viçosa, MG and Juiz de Fora, MG.
2. *Stricto Sensu* Graduate Program in Physical Education of the Gama Filho University (UGF) – Rio de Janeiro, RJ.

Mailing address:
Rua Oscavo Gonzaga Prata, 235
ap. 501 – Jardim Laranjeiras
36033-220 – Juiz de Fora, MG – Brasil.
E-mail: lauria_aa@hotmail.com

ABSTRACT

Introduction: Baseline heart rate (HR_{bas}) is measured minutes upon waking up, since it has rhythmic changes throughout the day. Objective - Considering the difficulty in achieving the standard conditions for its measurement, the objective was to propose an equation for predicting HR_{Bas}. Therefore, at first, it was necessary to describe the pattern of rhythmicity of HR and study the influence of habitual physical activity level (PAL) on this rhythmicity. Method: 90 subjects (54 men and 36 women) filled out the Baecke Questionnaire, median was used to form the PAL A and PAL B groups. The subjects self-assessed HR_{res} at 6, 9, 12, 15, 18, 21 and 24 h using a cardio frequency meter. To describe the rhythmicity and identify the PAL influence, ANOVA followed by Tukey test (p> 0.05) were applied for absolute and normalized values of HR_{res}. The normalized values were adjusted by second-order polynomial to construct the prediction equation, whose validity was tested by Pearson correlation (p> 0.05) and standard error of the estimate (SEE). Results: HR_{res} in bpm, of the PAL A group was lower than in the PAL B group at all moments tested: 60 ± 7.5, 64 ± 9.3, 63 ± 8.1, 66 ± 8.7, 66 ± 7.7, 64 and 60 ± 8.1 ± 8.2 compared to: 66 ± 9.6, 11.4 ± 71, 72 ± 11.6, 73 ± 10.8, 10.7 ± 74, 69 ± 9.4 and 10.7 ± 68. Concerning normalized values, no significant differences were found between the two groups and both showed rhythmicity similar to a parabola. The prediction equation showed r 0.70 to 0.83 and SEE from 4.8 to 6.2 bpm. Conclusion: HR_{res} presents lower values in more active individuals, but with the same pattern of rhythmicity. This equation enables prediction of HR_{bas} from the measurement of HR_{res} taken at different times of the day.

Keywords: circadian rhythm, heart rate, physical activity.

INTRODUCTION

Measurement of baseline heart rate (HR_{Bas}) is used in physical evaluation for being an indicator of the health status of the individual. High values are related to increased risk of mortality[1-6], with association with obesity and diabetes[7] as well as overtraining[8]. Increase in HR_{Bas} is determined, among other factors, by alterations in the autonomic balance, mainly caused by reduction of the cardiac vagal tonus[3,9-11]. On the other hand, practice of moderate to intense physical activity, may result in bradycardia at rest, which occurs, among other factors, by improvement in autonomic balance, especially by the increase of the vagal activity on the heart [12-14]. The benefits derived from physical activity practice depend on the volume, intensity and type of activity performed[15,16], besides sex and age of the practitioner[17].

According to the American Heart Association[18], the HR_{Bas} should be measured in the morning, after a night of sleep and before getting up, so that the lowest reached values can be recorded at wake status. HR measured at other times is named rest HR (HR_{re}) and presents rhythmic alterations according to the time of the day, demonstrating a circadian rhythm. It is consistently lower at night, with difference concerning the ones obtained during the day from 5 to 10 bpm or 5 to 15% in the 24 h period, depending on the extension of the influence of external factors such as sleep, posture, physical activity practice and diet[19] and internal factors which combined cause variations in central temperature and plasma adrenaline, resulting in HR and BP increase[20]. Although the benefits of physical activity on HR_{Bas}[15-17] are known, its influence on the HR_{re} rhythmicity is not. However, it can be hypothesized that the individual who practices physical activity would present less remarkable HR_{re} oscillations during the day due to increase of vagal activity.

Considering these facts, there is a clear need to identify the HR_{Bas}. Although it is simple to be determined, the need to register it at the waking time, creates an operational difficulty for its accurate measurement identification, making its monitoring impossible even to an experienced technician. As alternatives, we can suggest the HR_{Bas} self-determination or its prediction by regression equation. Lauria *et al.*[21] demonstrated that there is validation in HR_{re} self-determination with the use of HR monitors. However, according to our knowledge, there are no studies which have proposed HR_{Bas} prediction equation. Thus, the aim of this study was to test the hypothesis that HR_{Bas} may be predicted by regression equation from the HR_{re} measurement at different times of the day, as long as the rhythmicity patterns of the HR_{re} aoscillations during the day are known. Therefore, the rhythmicity of the HR_{re} oscillations during the day as well as the influence of the physical activity level on this rhythmicity was investigated. In order to have this goal met, the study was established in three stages: 1) identification of the rhythmicity pattern of the HR_{re} along the day; 2) observation of the influence of the habitual physicla activity practice on the rhythmicity pattern; and 3) proposition of HR_{Bas} prediction equation.

METHOD

Subjects

90 individuals (59 men (27.6 ± 7.6 years) and 31 women (27.7 ± 7.8 years), with anthropometric and aerobic fitness patterns at suitable levels to health (table 1) have been recruited. The subjects signed the Free and Clarified Consent Form (according to resolution 196/96 of the Brazilian National Health Committee), presented negative PAR-Q and did not make use of any medication which could alter the HR behavior. The study was approved by the Ethics in Research with Humans Committee of the Federal University of Juiz de Fora (legal opinion # 171/2008). The participants were told not to perform physical activities and keep their eating routine in the 24 h prior the evaluations, except for the restriction to food and drinks containing caffeine in the 12 h prior the evaluations.

Table 1. Sample characterization by the physical activity level (PAL) High (H) and low (L).

Variable	H PAL (n=54)	L PAL (n=36)	Total (n=90)
Age (years)	28 ± 8	27 ± 8	27 ± 8
Body mass (kg)	73 ± 10	69 ± 14	71 ± 12
Stature (m)	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1
BMI ($kg\text{-}m^{-2}$)	24 ± 3	24 ± 3	24 ± 3
Fat (%)	15 ± 6	21 ± 7*	16.7 ± 7.3
$VO_{2máx}$ ($ml\text{-}kg^{-1}\text{-}min^{-1}$)	48 ± 7	40 ± 6*	45 ± 9
Work HPAL	2.7 ± 0.4	2.7 ± 0.4	2.7 ± 0.4
Sport HPAL	3.5 ± 0.5	2.4 ± 0.4*	3 ± 0.4
Leisure HPAL	2.8 ± 0.7	2.6 ± 0.6*	2.7 ± 0.7
Total score HPAL Escore Total	9.0 ± 1	7.6 ± 1.1*	8.5 ± 1.3

* Intergroup significant difference ($p < 0.05$).

Procedures

The individuals were characterized through measurement of body mass, stature and skinfolds of thorax, abdomen and thigh for men and triceps, suprailiac and thigh for women. For body fat percentage (%F), regression equations were applied. The volume, intensity and kind of physical activity performed were determined through a questionnaire about the haitual physical activity level (PAL) proposed by Baecke *et al.*[22], which considers the following categories: work activity (Work), systematized sport activities (Sport) and leisure and locomotion activity (Leisure). The Bruce test on treadmill was performed for estimation of VO_{2max}[23]. The median of the score Sport of the Baecke Questionnaire was calculated[22] and the subjects were divided in two groups for delimitation of the level of habitual physical activity. The subjects with the score Sport ≥ 3 were part of the higher PAL group and this group received the H PAL abbreviation, while the subjects in which the same score was < 3, composed the lower PAL group with the abbreviation L PAL (table 1).

After the tests performance, the subjects were trained in the use of the cardio frequency meter (Polar S-801i). The HR_{bas} measurements were taken at 6 h while the HR_{re} at the times: 9,12,15,18, 21 and 24 h. All HR recordings were performed by the subjects themselves who recorded the the HR_{re} within their routines when they were at sitting position for 10 minutes[21].

Statistical treatment

Normal data distribution was verified by the Shapiro-Wilk test. Descriptive statistics was used for sample characterization. In order to discriminate the groups concerning the PAL (H PAL and L PAL), the median of the score Sport of the questionnaire by Baecke was calculated. The influence of the physical activity level on the absolute values of HR_{re} of the two groups was tested at the different times of the day, using two-way variance analysis (group x time), followed by Tukey *post hoc* test. The effect of the physical activity level on the HR_{re} rhythmicity was tested using normalization of the values of the different times giving the 100 value to the values obtained at the 6 h time. The HR_{re} values normalized by group and time were also submitted to variance analysis with two factors (group x time) followed by the Tukey *post hoc* test. When it was observed that the Pal did not influence on the rhythmicity, normalized data of the two groups were collected in a single group and adjusted by a second degree polynomial. The equation obtained by this adjustment was used in the prediction of the HR_{Bas} values of 6 h. Subsequently, the HR_{Bas} estimations were tested from each time of the day, with the use of Pearson correlation and calculation of standard error estimation (SEE). The analyses were performed by the *Statistica software* (version 8.0) with significance level of $p < 0.05$.

RESULTS

Figure 1 shows that the group of individuals with H PAL presented H Rr_e significantly lower than the group with L PAL in all the times studied.

Whe the HR_{re} values are presented in normalized units (percentage variation) to demonstrate its rhythmicity (figure 2), no significant difference was observed between groups at any of the times. Considering the intragroup variation, it was observed that the values normalized at the times 9, 12, 15, 18 and 21h of the two groups were significantly higher than at 6 h. At 24h, the values are not significantly different from the values at 6h, demonstrating that the HR_{re} absolute values in the H PAL group are lower; however, they keep the same rhythmicity of the L PAL group.

Moreover, it can be noted in figures 1 and 2 that the HR_{re} which increases with time passage during the day, tends to decrease after 18h and returns to the baseline values at 24h. Therefore, it has behavior similar to a parabola, suggesting that the normalized values present as better adjustment a second degree polynomial function

Since there was no difference between groups, the normalized values and HR_{re} were collected in a single set and adjusted by 2nd degree polynomial, as presented in figure 3.

From the adjustment equation, which presented r^2 of 0.92, the percentage value of the HR can be estimated at the moment of measurement and mathematically predict the HR_{Bas} absolute value using the following equations:

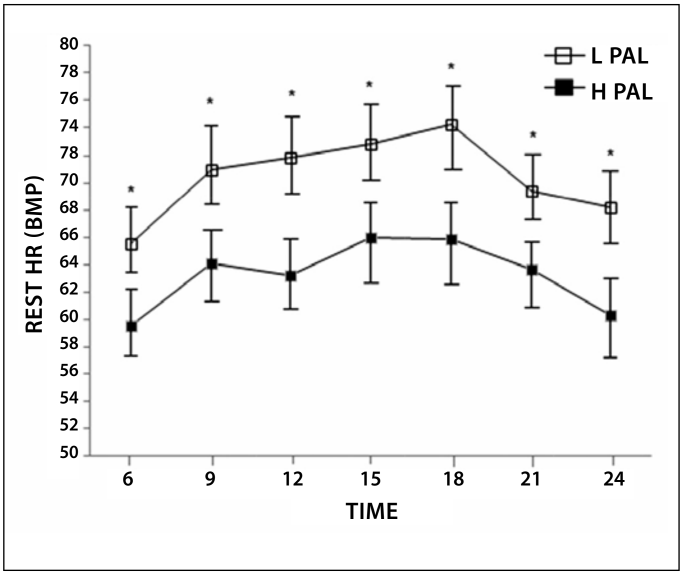

Figure 1. Rest heart rate of the H PAL and L PAL groups in absolute values, at different times of the day (mean ± confidence interval 95%).
* Significant difference between groups (p<0.05)

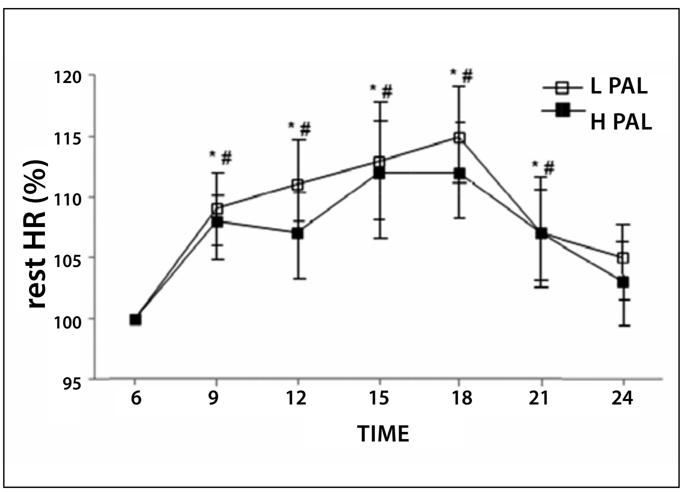

Figure 2. Rest heart rate of the H PAL and L PAL groups, in normalized units, at different times of the day (mean ± confidence interval 95%).
*Significant difference concerning 6 h in H PAL group (p<0.05).
Significant difference concerning 6 h in L PAL group (p<0.05).

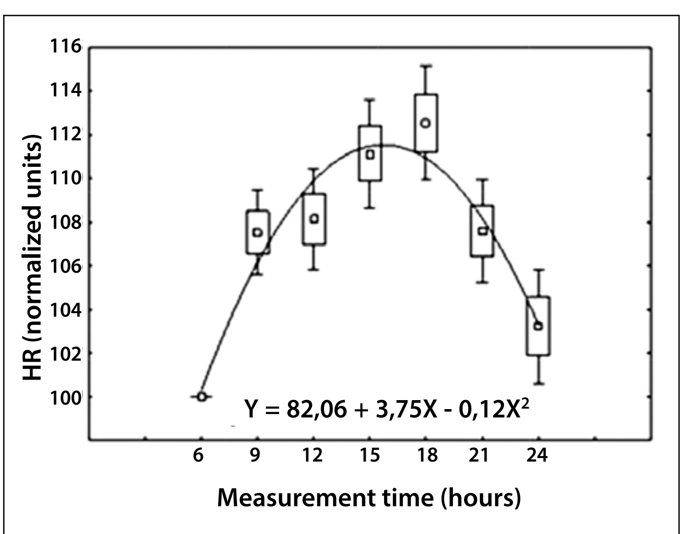

Figure 3. Rest heart rate of all individuals, in normalized units, at different times of the day (mean, standard error and confidence interval 95%), adjusted by second order polynomial.

$\% HR_{re} = 82.06 + 3.7\ t - 0.12\ t^2$
$\% HR_{re} = HR_{re\ percentage}$
t = time of measurement
$HR_{bas} = (100.\ HR_{med}) / (82.06 + 3.7\ t - 0.12\ t^2)$
where:
HR_{bas} = baseline heart rate
HR_{med} = measured heart rate
t = time of measurement

The results of the HR_{Bas} prediction obtained with the use of the proposed equation are presented in figure 4, in which the correlation values and standard error of the estimate can be observed.

All predictions presented significant correlation with r values of 0.70 to 0.83 and SEE of 4.8 to 6.2 bpm, which correspond to percentage values of 7.7 to 9.6%, respectively. Finally, increase in relative SEE was observed at the times more distant from 6 h.

DISCUSSION

The present study had the aim to test the hypothesis that HR_{Bas} could be predicted by regression equation from the measurement of HR_{re} taken at different times of the day. In order to have this goal reached, the study was divided in three stages: 1) identification of the rhythmicity pattern of the HR_{re} along the day; 2) observation of the influence of the habitual practice of physical activity on the rhythmicity pattern; and 3) proposition of the HR_{Bas} prediction equation. The findings of the study suggest that HR_{Re} presents rhythmicity pattern similar to a parabola: the values increase during the day, tend to decrease after 18 h and return to baseline values at 24 hours, in a way they can be adjusted by a second degree polynomial equation; individuals of the H PAL group presented lower HR_{re} values along the entire day; however, with the same rhythmicity pattern of the individuals in the L PAL. Although the physical activity practice causes bradycardia, no alteration in the rhythmicity pattern of HR_{re} was observed along the day; and the HR_{Bas} values may be estimated by second degree polynomial equation.

Rhythmicity of the heart rate

In the present study, lower HR value at 6 h (HR_{Bas}), significant increase from 9 h until 21 h and return to baseline values at 24h were found. In the period between 9 h and 21 h, the oscillations did not present significant differences, indicating HR_{re} stabilization. The rhythmicity pattern of the HR_{re} found in this study followed the same tendency of other studies which reported HR_{re} increase from Wake up time until reaching the highest values between 14 and 18 h, with subsequent decrease of this variable until reaching the lowest values between 2 and 4 h; that is to say, during early morning[19,24-26]. In the present study, the sleep hours were not followed, the record was limited to the awake period. Therefore, it was not possible to observe the typical lower values in the dark periods of the day. However, it was possible to observe reduction in HR_{re} in the beginning of the dark period. At 24 h, values similar to the ones at 6 h were already recorded. The amplitude verified in the present study between the times was of 7 to 14%, being according to the ones presented in the literature with difference between day and night from 5 to 15% in the 24 h period[19].

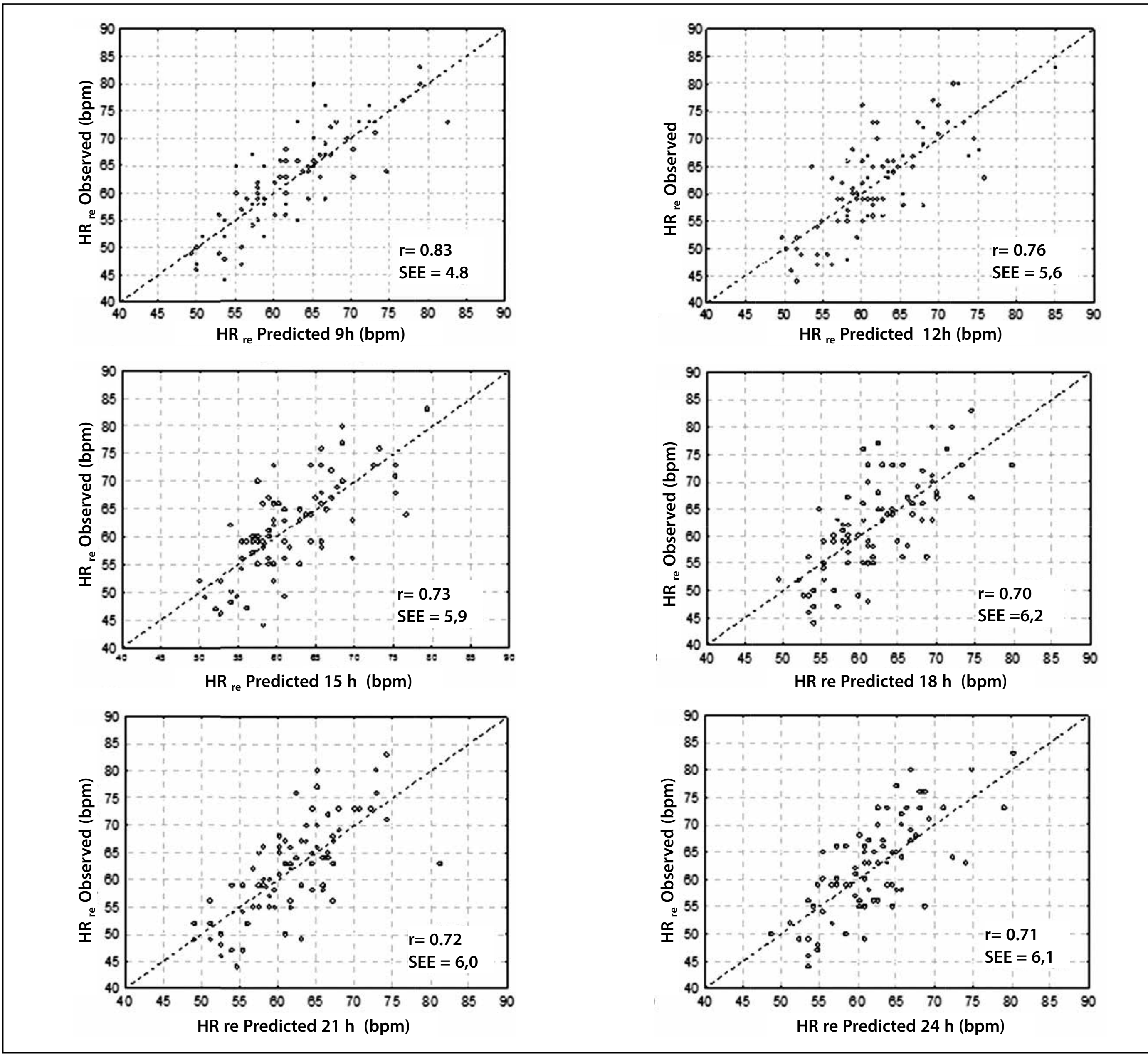

Figure 4. Correlation between measured baseline heart rate and rest heart rate at different times predicted by regression equation.

PAL influence on the rhythmicity of the heart rate

The HR_{bas} absolute values as well as of HR_{re} of the H PAL subjects were significantly lower than the L PAL subjects at all times of the day. It is possible that the response found is due to the fact that individuals with higher physical activity level present alterations in the anatomic balance[27,28], suggesting higher parasympathetic activity or lower sympathetic activity. In addition to that, some circulatory alterations such as improvement of venous return and increase of systolic volume may cause HR decrease in aerobically trained individuals[29].

When the HR_{re} values were normalized and presented in percentage of the value observed at 6h, it was observed that there were no differences between groups in any of the studied times, showing hence that the rhythmicity pattern is not altered by physical activity practice. Possibly, the adaptations concerning the autonomic control and some chronic adaptations to exercise do not have effect on the HR_{re} rhythmicity. The finding suggests that the HR_{re} rhythmicity is partly determined by the endogenous circadian rhythm given by the central command[25]. In other words, the alterations in the autonomic control which lead to bradycardia do not attenuate amplitude or modify the HR_{re} rhythmicity pattern.

Prediction of the heart rate at rest

The HR_{re} normalized values were used to demonstrate the rhythmicity pattern of the HR_{re} and test the influence of the physical activity practice. From the confirmation that the HR_{re} variations along the day were not influenced by the physical activity practice and were similar to a parabola, it was chosen to adjust the normalized values by second degree equation. It is possible to estimate the HR_{Base} percentage with the application of the equation to the absolute HR_{re} measured at a specific time of the day, knowing that the HR_{Basal} percentage which the HR_{re} measured represents, by three rule, the absolute HR_{Basal} can be estimated. Comparing the predicted values by the proposed equation with the values observed at the studied times, significant correlation and relatively low SEE were found.

The predictions were made for each studied time and presented r values between 0.70 and 0.83 and SEEs which ranged from 4.8 and 6.1 bpm (7.7 to 9.6%), depending on the measured time. The more distant from 6 h the HRre measurement is taken, the higher the error of this measurement will be. No study which had investigated the HR_{Basal} prediction was found to compare the prediction quality. As illustration, we can compare the present results with the equations which estimate the HR_{max}. The equation propsoed by Tanaka *et al.*[30] presents correlation of 0.81 and SEE of 6 bpm.

Study limitations

Individuals with different patterns of systematized practice of sport activities were studied; however, they were not athletes. It is not known if the responses found in the present study would be the same in highly trained athletes, which opens a gap in the investigation for future studies. In order to obtain more accurate results, a laboratory study would be recommended, with the aim to increase the control level of the routine of the studied subjects. On the other hand, it was chosen that the individuals remained in their routine, expressing hence their habitual rhythm with no interference of desynchronization forced by a constant routine performed in a laboratory. Such option was chosen in an attempt to increase external validity of the study, so that the prediction equation proposed could be applied to real situations.

Practical implications

As previosuly mentioned, despite its easy performance, the HR_{Basal} measurement requires complicated logistics so that it can be performed by the evaluator at really baseline conditions. Two possible solutions were recommended: self-evaluation performed by the subject or prediction by equation. In a previous study, Lauria *et al.*[21] demonstrated that it is possible that the subject alone using a cardio frequency meter could record his HR_{Basal}. In this study, it was also demonstrated that it is possible to predict the HR_{Basal} from measurements at any time of the day.

CONCLUSION

It was concluded that individuals with higher habitual physical activity level demonstrate lower HR_{re} values regardless of the time of the day when compared to active individuals, but with lower habitual physical activity level, not presenting difference in rhythmicity pattern. The HR_{Bas} can be fairly determined based on measurement taken at any time of the day.

All authors have declared there is not any potential conflict of interests concerning this article.

REFERENCES

1. Greenland P, Daviglus ML, Dyer AR, Liu K, Huang C, Goldberger JJ, et al. Resting heart rate is a risk factor for cardiovascular and noncardiovascular mortality: the Chicago Heart Association Detection Project in Industry. Am J Epidemiol 1999;149:853-62.
2. Palatini, P. Need for a revision of the normal limits of resting heart rate. Hypertension 1999;33:622-5.
3. Almeida MB, Araújo CGS. Efeitos do treinamento aeróbico sobre a frequência cardíaca. Rev Bras Med Esporte 2003;9:104-12.
4. Engel G, Cho S, Ghayoumi A, Yamazaki T, Chun S, Fearon WF, et al. Prognostic significance of PVCs and resting heart rate. Ann Noninvasive Electrocardiol 2007;12:121-9.
5. Thayer JF, Lane RD. The role of vagal function in the risk for cardiovascular disease and mortality. Biol Psychol 2007;74:224-42.
6. Hsia J, Larson JC, Ockene JK, Sarto GE, Allison MA, Hendrix SL, et al. Resting heart rate as a low tech predictor of coronary events in women: prospective cohort study. BMJ 2009;338:b219.
7. Shigetoh Y, Adachi H, Yamagishi S, Enomoto M, Fukami A, Otsuka M, et al. Higher heart rate may predispose to obesity and diabetes mellitus: 20-year prospective study in a general population. Am J Hypertens 2009;22:151-5.
8. Achten J, Jeukendrup AE. Heart rate monitoring: applications and limitations. Sports Med 2003;33:517-38.
9. Ribeiro AL, Moraes RS, Ribeiro JP, Ferlin EL, Torres RM, Oliveira E, et al. Parasympathetic dysautonomia precedes left ventricular systolic dysfunction in Chagas disease. Am Heart J 2001;141:260-5.
10. Bilchick KC, Fetics B, Djoukeng R, Fisher SG, Fletchar RD, Singh SN, et al. Prognostic value of heart rate variability in chronic congestive heart failure (Veterans Affairs' Survival Trial of Antiarrhythmic Therapy in Congestive Heart Failure). Am J Cardiol 2002;90:24-8.
11. Tapanainen JM, Thomsen PE, Kober L, Torp-Pedersen C, Makikallio TH, Still AM, et al. Fractal analysis of heart rate variability and mortality after an acute myocardial infarction. Am J Cardiol 2002;90:347-52.
12. Stein R, Medeiros CM, Rosito GA, Zimerman LI, Ribeiro JP. Intrinsic Sinus and atrioventricular node electrophysiologic adaptations in endurance athletes. J Am Coll Cardiol 2002;39:1033-8.
13. Pichot V, Roche F, Gaspoz JM, Enjobras F, Antoniadis A, Minini P et al. Relation between heart rate variability and training load in middle-distance runners. Med Sci Sports Exerc 2000;32:1729-36.
14. Iellamo F, Legramante JM, Pigozzi F, Spataro A, Norbiato G, Lucini D, et al. Conversion from vagal to sympathetic predominance with strenuous training in high-performance world class athletes. Circulation 2002;105:2719-24.
15. Morris JN, Clayton DG, Everitt MG, Semmence AM, Burgess EH. Exercise in leisure time: coronary attack and death rates. Br Heart J 1990;63:325-34.
16. Yu S, Yarnell JWG, Sweetnam PM, Murray L. What level of physical activity protects against premature cardiovascular death? The Caerphilly study. Heart 2003;89:502-6.
17. Acsm. ACSM's Guidelines for Exercise Testing and Prescription. Baltimore: Lippincott Williams & Wilkins. 2010
18. American Heart Association, Rest Heart Rate, disponível em http://www.americanheart.org, consultado em 11 de outubro de 2010.
19. Reilly T, Atkinson G, Waterhouse J. Chronobiology and physical performance. Philadelphia: Lippincott Williams & Wilkins; 2000.
20. Minati A, Santana MG, Mello MT. A influência dos ritmos circadianos no desempenho físico. Rev Bras Ci Mov 2006;14:75-6.
21. Lauria AA, Marins JCB, Marques FAD, Perantoni CB, Amorim PRS, Santos TM, et al. Fidedignidade intra e interdias da frequência cardíaca de repouso. Fit Perf J 2010;9:66-71.
22. Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. Am J Clin Nutr 1982;36:936-42.
23. Andrade J, Brito FS, Vilas-Boas F, Castro I, Oliveira JA, Guimarães JI, et al. Diretrizes da sociedade brasileira de cardiologia sobre teste ergométrico. Arq Bras Cardiol 2002;sup II:118-21.
24. Cohen CJ. Human circadian rhythms in heart rate response to a $_{max}$imal exercise stress. Ergonomics 1980;23:591-5.
25. Reilly T, Robinson G, Minors DS. Some circulatory responses to exercise at different times of day. Med Sci Sports Exerc 1984;16:477-82.
26. Deschenes MR, Sharma JV, Brittingham KT, Casa DJ, Armstrong LE, Maresh CM. Chronobiological effects on exercise performance and selected physiological responses. Eur J Appl Physiol Occup Physiol 1998;77:249-56.
27. Shin K, Minamitani H, Onishi S, Yamazaki H, Lee M. Assessment of training-induced autonomic adaptations in athletes with spectral analysis of cardiovascular variability signals. Jpn J Physiol 1995;45:1053-69.
28. Boutcher SH, Cotton Y, Nurhayati Y, Craig GA, McLaren PF. Autonomic nervous function at rest in aerobically trained and untrained older men. Clin Physiol 1997;17:339-46.
29. Bonaduce D, Petretta M, Cavallora V, Apicella C, Ianniciello A, Romano M, et al. Intensive training and cardiac autonomic control in high level athletes. Med Sci Sports Exerc 1998;30:691-6.
30. Tanaka H, Monahan KD, Seals DR. Age-predicted $_{max}$imal heart rate revisited. J Am Coll Cardiol 2001;37:153-6.