

## Narita Target Heart Rate Equation Underestimates the Predicted Adequate Exercise Level in Sedentary Young Boys

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- A** Concept / Design
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### Abstract

**Purpose:** Optimal training intensity and the adequate exercise level for physical fitness is one of the most important interests of coaches and sports physiologists. The aim of this study was to investigate the validity of the Narita et al target heart rate equation for the adequate exercise training level in sedentary young boys.

**Methods:** Forty two sedentary young boys (19.07±1.16 years) undertook a blood lactate transition threshold maximal treadmill test to volitional exhaustion with continuous respiratory gas measurements according to the Craig method. The anaerobic threshold (AT) of the participants then was calculated using the Narita target heart rate equation.

**Results:** Hopkin's spreadsheet to obtain confidence limit and the chance of the true difference between gas measurements and Narita target heart rate equation revealed that the Narita equation most likely underestimates the measured anaerobic threshold in sedentary young boys (168.76±15 vs. 130.08±14.36) (Difference ±90% confidence limit: 38.1±18). Intraclass correlation coefficient (ICC) showed a poor agreement between the criterion method and Narita equation (ICC= 0.03).

**Conclusion:** According to the results, the Narita equation underestimates the measured AT. It seems that the Narita equation is a good predictor of aerobic not AT which can be investigated in the future studies.

**Key Words:** Anaerobic Threshold; Aerobic Threshold; Training Intensity; Heart Rate Performance Curve (HRPC)

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## INTRODUCTION

The anaerobic threshold (AT) is established as a measurement of the capacity to perform at an optimal intensity for extended periods of time and is strongly related to performance endurance<sup>[1,2]</sup>. It has been indicated that a field method of assessing the AT is available and can be done from heart rate deflection point (HRDP) in speed-heart rate relationship with accuracy either by visual method or by computer programming<sup>[3-10]</sup>. At first, Conconi et al<sup>[11]</sup> developed a field test for the noninvasive determination of the AT using the HRDP in runners<sup>[12]</sup>. However, because of the limitations of the Conconi et al technique, Cheng et al suggested a new Distance Maximum ( $D_{max}$ ) method to define the AT<sup>[13]</sup>.

Erdogan et al compared four common non-invasive indices with an invasive index for determining the AT in 22 adult male rowers. They concluded that the non-invasive indices were comparable with the invasive index and could, therefore, be used in the assessment of AT during rowing ergometer use. In addition, they showed in elite rowers that the Conconi test based on the measurement of HRDP tended to be the most adequate way of estimating AT for training regulation purposes<sup>[3]</sup>.

Fabre et al designed a study to evaluate the capacity of the  $D_{max}$  method and its modified version (Mod  $D_{max}$ ) to predict the anaerobic threshold in elite cross-country skiers. They showed that the Mod  $D_{max}$  lactate threshold measurement is extremely accurate to predict the anaerobic threshold in elite cross-country

skiers<sup>[4]</sup>.

Narita et al aimed to determine a new target heart rate formula for the adequate exercise training level. They determined the AT using cycle ergometer exercise with continuous respiratory gas measurements. The correlation of heart rate at the AT to resting heart rate, age and gender was analyzed by the multiple regression method. Based on this correlation, a new formula calculating target heart rate was established as  $74.8 + 0.76 \times (\text{resting heart rate}) - 0.27 \times (\text{age}) + 7.3 \times S$  (male: 0 or female: 1). They concluded that the resting heart rate and gender are important factors in determining the target heart rate for exercise. Therefore, they suggested that the new equation indicates the adequate exercise training level more accurately in healthy subjects<sup>[14]</sup>.

In noninvasive heart rate (HR) dependent methods for determination of AT, heart rate performance curve (HRPC) is criterion. However, it must be noted that during the incremental maximal tests, HRPC affected by the intrinsic mechanisms (i.e. sympathetic and parasympathetic nerves secretions; central nervous system commands based on active muscle afferents activation) and finally the HR-Time plot shifts from the straight line to curve<sup>[7]</sup>.

The Narita equation neglected to consider aerobic and anaerobic threshold concepts as well as important factors such as cardiorespiratory fitness, and intrinsic physiological mechanisms. The exercise-independent Narita equation just relayed on the resting heart rate (RHR), gender and age that seems cannot be able to precisely estimate the adequate exercise intensity. Current research first attempted to elucidate whether the Narita equation precisely estimates the adequate exercise intensity. Therefore, the aim of this study was to investigate the validity of Narita et al target heart rate equation for the adequate exercise level in sedentary young boys.

## METHODS AND SUBJECTS

**Participants:** Forty two sedentary young boys [mean (SD) age 19.07 (1.15) years, height 174.91 (5.98) cm,

weight 63.79 (8.13) kg] were selected as subjects. Inclusion criteria were sedentary lifestyle (lack of any training program at least for a minimum of 9 months prior to participating in the study), normal resting heart rate, absence of cardiovascular and pulmonary signs and symptoms. Exclusion criteria included obesity (BMI [greater than or equal to] 30 kg/m<sup>2</sup>), high cardiorespiratory fitness (Vo<sub>2</sub>max  $\geq 35$  ml/kg/min), presence of musculoskeletal disorders, history of cardiovascular disease, orthopedic problems or other medical conditions that would contraindicate exercise. The information sheet and consent form have been reviewed and signed by the subjects. The research protocol has been approved by the Research Ethical Committee in the University of Mohaghegh Ardabili.

**Data collection:** Participants attended the exercise-testing lab. on two separate phases. During the first phase participants undertook body composition and physiological tests on three consecutive days. A minimum of 72 h after the initial testing session, during the second phase, the participants completed an AT maximal treadmill test to volitional exhaustion (GXT) with continuous respiratory gas measurements on five consecutive days. The time interval between AT maximal test conduction and the subject's last meal were at least five hours. All testing protocols were completed at the 17 to 20 P.M.

**Anaerobic threshold measurements:** The AT of the participants was calculated by the continuous respiratory gas measurements (Ganshorn Medizin Electronic GMBH, Germany) according to the Craig method<sup>[15]</sup> and Narita target heart rate equation<sup>[14]</sup>. In the Craig method, AT was calculated using the modified Dmax method and determined by the point on the polynomial regression curve that yielded the maximal perpendicular distance to the straight line connecting the first increase in lactate above resting level and the final lactate point<sup>[15]</sup>.

The anaerobic threshold (AT) of the participants was calculated using the Narita target heart rate equation. Based on this equation, target heart rate was considered as  $74.8 + 0.76 \times (\text{resting heart rate}) - 0.27 \times (\text{age}) + 7.3 \times S$  (male: 0 or female: 1).

**VO<sub>2</sub>max measurement:** The exercise workloads are

selected to gradually progress in increments from moderate to maximal intensity. Oxygen uptake is calculated from measures of ventilation and the O<sub>2</sub> and CO<sub>2</sub> in the expired air, and the maximal level is determined at or near test completion. The subject was considered to have reached their Vo<sub>2</sub>max if several of the following occurred: a plateau in oxygen uptake, attainment of a respiratory exchange ratio of 1.15 or greater and volitional exhaustion<sup>[7]</sup>.

**Blood sampling and lactate measurement:** Blood samples were collected from unpreferred hand mid-fingertips in five phases by a certificated lactometer. For the purpose of estimating blood lactate using a lactate analyzer (Analox P-LM55, UK) found in an Analox lactate kit supplied by Analox (UK). The analyzer had been calibrated with known lactate standards<sup>[15]</sup> (5.0 and 15.0 mM). Air temperature and relative humidity values for the track were recorded (21.34 ± 3.67, and 24.34 ± 3.48°C, respectively) using an Arco device (Model TC14P; Germany).

Mean and peak Vco<sub>2</sub>, Vo<sub>2</sub>, RER, heart rate values, time to exhaustion, phase of exhaustion were also determined from the GXT data. All testing protocols for predicting Vo<sub>2</sub>max and AT were performed on a treadmill (Sport ART, Model 6150E).

**Anthropometric and body composition variables measurements:** To estimate the percentage of body fat the three points' skinfold measurement (Chest, Abdomen, and Thigh) were taken on the right side. Measurements were taken when the skin is dry, and not overheated. To eliminate inter-observer variability only one highly trained investigator performed these procedures. The Lafayette standard caliper was used to measure the skin-fold thickness in millimeters. Body density was then determined using the equation of

Jackson and Pollock as follows: Body Density = 1.10938 - (0.0008267 x sum of chest, abdomen and thigh skinfolds in mm) + (0.000016 x square of the sum of chest, abdomen and thigh) - (0.0002574 x age). Relative body fat was then calculated using the Siri equation as % Body Fat = (495 / Body Density) - 450. All anthropometric and body composition variables measured after 14 hours of last training session. We used Pollock and Wilmore methods for measuring anthropometric values. The body mass index (BMI) was calculated from the height (m) and weight (kg) [weight/height<sup>2</sup>]<sup>[16]</sup>.

**Statistics:** Data is presented as mean and standard deviations. For determination of the confidence limits and practical assessment aimed to make inferences about true values of assessing the agreement between the continuous respiratory gas measurements and Narita target heart rate equation, Hopkins's spreadsheets was used by the means of Paired Samples T Test<sup>[17, 18]</sup>. Due to the Intraclass Correlation Coefficient (ICC) advantages over correlation coefficient,<sup>[19]</sup> the ICC was used to assess the agreement between gas measurements and Narita target heart rate equation.

## RESULTS

Descriptive characteristics of the subjects such as body composition and physiological variables summarized in Table 1. Mean and peak Vco<sub>2</sub>, Vo<sub>2</sub>, RER, heart rate values, time to exhaustion, and phase of exhaustion were also indicated in Table 2.

Mean and standard deviation of gas measurements

**Table 1:** Descriptive characteristics of the subjects

Variables	Mean (SD)
Age (years)	19.07 (1.15)
Height (cm)	174.91 (5.98)
Weight (kg)	63.79 (8.13)
Fat (%)	13.61 (8.86)
Lean Body Mass (kg)	53.49 (10.66)
Resting Heart Rate (b/min)	81.23 (15.21)
Vo <sub>2</sub> max (ml/kg/min)	51.32 (6.47)

SD: Standard Deviation

**Table 2:** GXT Peak values for Vco<sub>2</sub>, Vo<sub>2</sub>, heart rate, time to exhaustion and phase of exhaustion

Variables	Mean (SD)
Vco <sub>2</sub> (l/min)	6.24 (9.81)
Vo <sub>2</sub> (l/min)	2.77 (0.39)
(Vco <sub>2</sub> /Vo <sub>2</sub> ratio) (%)	1.32 (0.06)
Heart Rate (b/min)	97.36 (7.48)
Time to Exhaustion (min)	14.17 (1.59)
Phase of Exhaustion (No)	5.19 (0.59)

SD: Standard Deviation

and Narita target heart rate equation are shown in Table 3. The P value entered into Hopkin's spreadsheet to obtain confidence limit and the chance that the true difference was drawn from Paired Samples T-Test. Analysis of difference between gas measurements and Narita target heart rate equation revealed that the Narita target heart rate equation most likely underestimates the measured anaerobic threshold in sedentary young boys (Table 3).

Results showed poor agreement between the criterion method and Narita target heart rate equation (ICC= 0.035).

Our surprising finding in this study was that the Narita target heart rate equation revealed the first breakpoint in the RER curve (Vco<sub>2</sub>/Vo<sub>2</sub>) as an AT (Fig. 1). It seems that the Narita equation is a valid model for determination of first lactate turn point (LTP<sub>1</sub>) instead of AT.

## DISCUSSION

The magnitude of difference between gas measurements and Narita target heart rate equation revealed that the Narita target heart rate equation most likely underestimates the measured anaerobic

threshold. This fact is reflected in light of the poor agreements between two methods for determining AT. Considering the Narita target heart rate equation variables as well as study AT determination procedure, it seems that the measurement errors could not be responsible for the poor agreement between the criterion method and the Narita equation.

The onset of dynamic exercise produces reflex changes in efferent autonomic activities that increase HR. These neurocirculatory responses have been attributed both to reflexes arising within the exercising muscle and to neural impulses arising within the central nervous system, associated with the volitional component of exercise [20].

The physiological mechanisms of the deflection point in heart rate-work rate relationship are not yet completely clarified; however, it has been suggested that it is an artifact produced through execution of the incremental test protocol rather than a physiological phenomenon [21]. Similarly, it has been shown that HRDP irrespective of dependence on beta<sub>1</sub>-receptor sensitivity, is mainly related to the testing protocol and the method of turn point determination [22].

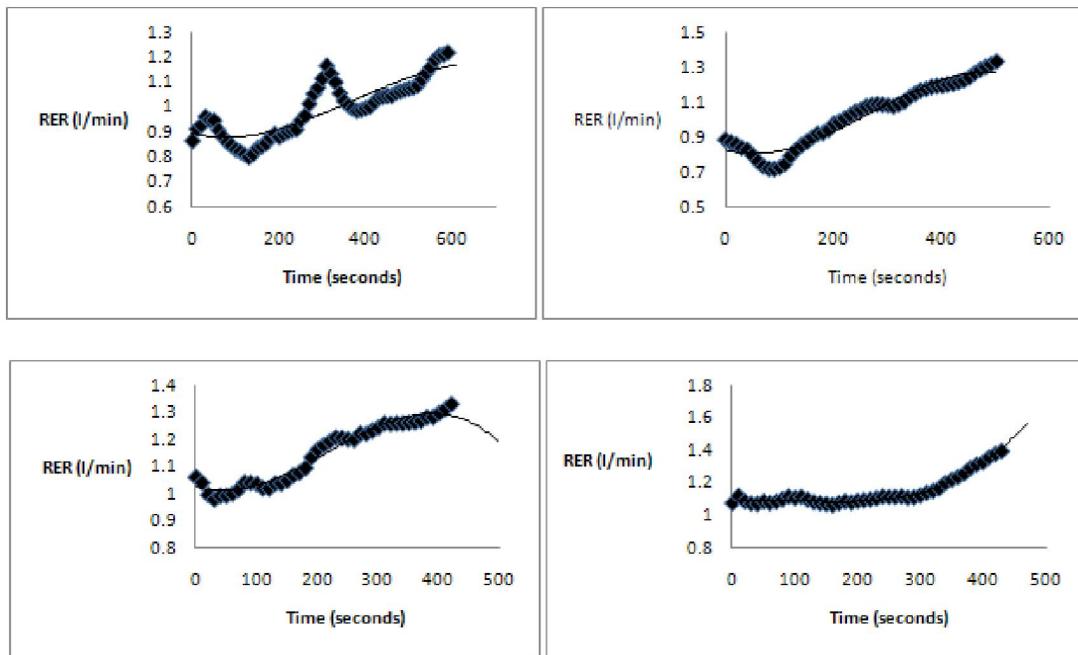
It should be noted that the term 'anaerobic threshold' is synonymously used for both the first and the second anaerobic threshold, bearing a great potential for confusion. These differences in the methodological approach have led to controversy on the physiological

**Table 3:** Difference of the gas measurements and Narita target heart rate equation methods in determination of the AT

Narita [Mean (SD)]	gas measurements [Mean (SD)]	Difference; ± 90% confidence limit*	Benefit (%)	Negligible (%)	Harm (%)	Practical Assessment
130.08(10.6)	168.8(15.4)	38.1; (18)	99.8	0.2	0.0	Most likely

AT: anaerobic threshold / SD: Standard Deviation

\*90% CL: add and subtract this number to the mean effect to obtain the 90% confidence limits for the true difference. Chances of benefit or harm were assessed as follows: <1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely; 25-75%, possible; 75-95%, likely; 95-99%, very likely; >99%, almost certain.



**Figure 1:** RER curve during the GXT protocol in the subjects

basis of what is called the 'AT' and even more confusion concerning the noninvasive determination of the AT via gas exchange parameters during exercise [23,24].

In the Narita target heart rate equation, the resting HR, age, and sex of subjects were considered as affecting factors. According to the literature it seems that AT is a multi-factorial phenomenon that is affected by a battery of internal and external variables. The physiological mechanisms that govern the HRDP phenomenon are complex and do not rely just on the resting HR, age and sex. In addition, all of the independent variables in the Narita equation refer to the resting state of subjects. Factors such as cardiorespiratory fitness ( $V_{O_2max}$ ), heart rate performance curve (HRPC) during GXT testing protocols as well as maximum heart rate (MHR) may have an important role in the AT assessment which was neglected in the Narita equation. Physical fitness level (sedentary vs. active) and kinds of sport activities may also have significant influence on the predicted AT. However, it should be noted that small sample size in the study may be considered as a study limitation. On the other hand, data collecting procedures and novelty

of study strengthened our findings. According to our study results, the Narita target heart rate equation can be used for determination of the aerobic threshold ( $LTP_1$ ). Using the Narita equation aiming for adequate training intensity and target heart rate is misleading.

## CONCLUSION

Generally, according to our results the Narita target heart rate equation most likely underestimates the measured AT. It seems that the Narita target heart rate equation is a good predictor of aerobic not AT which can be investigated in the future studies.

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**Conflict of interests:** None

## REFERENCES

- [1] Bodner ME, Rhodes EC. A review of the concept of the heart rate deflection point. *Sports Med* 2000;30:31-46.
- [2] Amann M, Subudhi A, Foster C. Influence of testing protocol on ventilatory thresholds and cycling performance. *Med Sci Sports Exerc* 2004;36:613-22.
- [3] Erdogan A, Cetin C, Karatosun H, et al. Non-invasive indices for the estimation of the anaerobic threshold of oarsmen. *J Int Med Res* 2010;38:901-15.
- [4] Fabre N, Balestreri F, Pellegrini B, et al. The modified dmax method is reliable to predict the second ventilatory threshold in elite cross-country skiers. *J Strength Cond Res* 2010;24:1546-52.
- [5] Fell JW. The modified D-max is a valid anaerobic threshold measurement in veteran cyclists. *J Sci Med Sport* 2008;11:460-3.
- [6] Folke M. Estimation of the lactate threshold using an electro acoustic sensor system analysing the respiratory air. *Medi Biol Eng Comp* 2008;46:939-42.
- [7] Hofmann P, Pokan R, Von Duvillard SP, et al. Heart rate performance curve during incremental cycle ergometer exercise in healthy young male subjects. *Med Sci Sports Exerc* 1997;29:762-8.
- [8] Bourgois J, Coorevits P, Danneels L, et al. Validity of the heart rate deflection point as a predictor of lactate threshold concepts during cycling. *J Strength Cond Res* 2004;18:498-503.
- [9] Ghosh AK. REVIEW ARTICLE-Anaerobic Threshold: Its Concept and Role in Endurance Sport. *Malays J Med Sci* 2004;11:24-36.
- [10] Bentley DJ, McNaughton LR, Thompson D, et al. Peak power output, the lactate threshold, and time trial performance in cyclists. *Med Sci Sports Exerc* 2001;33:2077-81.
- [11] Conconi F, Ferrari M, Ziglio PG, et al. Determination of the anaerobic threshold by a noninvasive field test in runners. *J Appl Physiol* 1982;52:869-73.
- [12] Kara M, Gökbel H, Bediz C, et al. Determination of the heart rate deflection point by the Dmax method. *J Sports Med Phys Fit* 1996;36:31-4.
- [13] Cheng B, Kuipers H, Snyder AC, et al. A new approach for the determination of ventilatory and lactate thresholds. *Int J Sports Med* 1992;13:518-22.
- [14] Narita K, Sakamoto S, Mizushige K, et al. Development and evaluation of a new target heart rate formula for the adequate exercise training level in healthy subjects. *J Cardiol* 1999;33:265-72.
- [15] Craig N, Walsh C, Martin DT, et al. Protocols for the physiological assessment of high-performance track, road and mountain cyclists. Physiological tests for elite athletes/Australian Sports Commission. Champaign (IL): Human Kinetics 2000; Pp:258-77.
- [16] Siahkhouhian M, Hedayatnejad M. Correlations of Anthropometric and Body Composition Variables with the Performance of Young Elite Weightlifters. *J Hum Kinetics* 2010;25:125-31.
- [17] Hopkins WG. Spreadsheets for analysis of controlled trials with adjustment for a subject characteristic. *Sportscience* 2006;10:46-50.
- [18] Hopkins WG. A Spreadsheets for deriving a confidence interval, mechanistic inference and clinical inference from a P. value. *Sportscience* 2007;11:16-20.
- [19] Portney LG, Watkins MP. Foundations of clinical research applications to practice. New Jersey: Prentice Hall Inc. 2000; Pp:560-7.
- [20] Tsuchimochi H, Matsukawa K, Komine H, et al. Direct measurement of cardiac sympathetic efferent nerve activity during dynamic exercise. *Am J Physiol Heart Circ Physiol* 2002;292: H1896-H1906.
- [21] Victor RG, Seals DR, Mark AL. Differential control of heart rate and sympathetic nerve activity during dynamic exercise. Insight from intraneural recordings in humans. *J Clin Invest* 1987;79:508-16.
- [22] Ozcelik O, Kelestimur H. Effects of acute hypoxia on the determination of anaerobic threshold using the heart rate-work rate relationships during incremental exercise tests. *Physiol Res* 2004;53:45-51.
- [23] Hofmann P, Pokan R. Value of the application of the heart rate performance curve in sports. *Int J Sports Physiol Perform* 2010;5:437-47.
- [24] Binder RK, Womisch M, Corra U, et al. Methodological approach to the first and second lactate threshold in incremental cardiopulmonary exercise testing. *Eur J Cardiovas Prev Rehabil* 2008;15:726-34.