Journal of Advanced Sport Technology 1(2):30-32

Technical Research

Designing Smart Treadmill for athletic endurance training

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ABSTRACT

Using treadmill and cycle ergometers are the best methods of endurance training and choosing best training intensity is very crucial in endurance exercise training. According to more than one decade of our research experiences, it is possible to determine optimum personal training intensity based on estimation of person's anaerobic threshold. A hardware and software has been developed to monitor the heart rate and control the treadmill speed and slope. Software provided utilities to record the individual information (e.g. name, age, gender, weight and maximum and resting heart rate) and graphical curves of treadmill (speed, slope, work, power) and real-time heart rate. In this method, heart rate was used to draw the heart rate-time curve during an exhaustive graded maximal intensity exercise to find the best treadmill speed and slope in his/her anaerobic threshold. In this study, ten male athletes (19.3±1.7 years; 88.50±4.43 kg; 182.0±3.7 cm) recruited. Validity and reliability of this method have been evaluated by gas analysis every 5 seconds to determine anaerobic threshold and compare it with the Heart Rate Deflection Point (HRDP) calculated by the software on a standard Treadmill protocol during two sessions with one week rest. Bland-Altman and Intraclass Correlation Coefficients (ICC) was used to find any agreement between the two methods and Test-Retest was used to prove the reliability of the method. There was a very high agreement between two methods (±1.96; 95% CI = -16.5 to +37.5 b/min) and calculate anaerobic threshold had a positive and significant correlation ($r=0.932$; $p<0.001$). Feasibility of design a hardware and software and validity and reliability of estimated individual anaerobic threshold ascertained. It is a reasonably low price hardware and software recommendable to implement in future treadmill manufacturing.

Keywords: Design and manufacture, Hardware, Software, Treadmill, Cardiorespiratory fitness.

Introduction

Accurate and reliable fitness evaluation, especially cardiorespiratory fitness is among the issues of interest to researchers in the field of sport science [1, 2]. In this regard, designing and manufacturing of various sport equipment including devices for estimating cardiorespiratory fitness have always been important and due to its importance, extensive studies have been conducted [3]. Treadmill is generally an electric powered device with selectable speed for walking and running in one place. According to Sports & Fitness Industry Association, treadmills continue to be the largest selling exercise equipment category by a large margin [1]. Advanced sport treadmills enable to run different preloaded exercise protocols and display or record heart rate to estimate energy expenditure. This National project financially supported by the Center of High-Tech Industries of the Iranian Ministry of Industry, Mine and Trade to design an smart treadmill for athletes and exercise activity. This project is the fruit of two decade research in determining fitness level base on heart rate changes during exercise.

The anaerobic threshold (AT), also called the “lactate threshold,” is the exertion level between aerobic and anaerobic training. The AT is the point during exercise when body must switch from aerobic to anaerobic metabolism. The fitter athlete can exercise longer with the aerobic system before the anaerobic system needs to take over. It is possible to improve aerobic efficiency and thus raise AT by doing high-quality aerobic

work at a level just below the current AT. Therefore, many athletes and coaches have devised complicated training plans to increase this value.
The AT varies from person to person, and, within a given individual, sport to sport. Untrained individuals have a low AT (approximately 55 % of VO2 max), and elite endurance athletes, a high AT (approx. 80 - 90% of VO2 max). AT is considered to be somewhere between 85% and 90% of maximum heart rate (HR_{max}). The most accurate method of determining AT is carrying out under laboratory conditions. This generally costs money and usually means regular blood samples are taken to measure the amount of lactate in the blood during the workout. Several different protocols are used to measure it, and each produces results that are slightly different from those yielded by the other methods. There is also evidence that the lactate threshold is sensitive to conditions such as fatigue and, therefore, changes a bit from day to day. It is advisable to estimate AT every eight to six weeks.

Heart Rate Deflection Point and Anaerobic Threshold
The heart rate deflection point (HRDP) is a deviation point at the linear relationship between heart rate and work load is evinced during progressive incremental exercise testing. In 1982, Conconi and colleagues suggested that this phenomenon could be used as a noninvasive method to assess the anaerobic threshold [4]. Although the HRDP may be assessed in field or laboratory settings, the degree of HR deflection is highly dependent upon the type of protocol used.

Results
We developed $S.D_{max}$ method and reported to be an accurate and reliable alternative to the traditional, cumbersome, expensive, and time-consuming lactate method. Our results showed that when whole the HR data points in the HR-Time curve was used it would lead to an underestimation of the determined HRDP, which is in contrast with the recommendation of Hofmann *et al.*. They recommended that the slope of the regression line will be affected if it includes the whole HR data points previous to the linear segment in the HR-time curve, which may possibly lead to overestimation of the HRDP.
The outcomes of this project was a simple and reliable method in estimation of anaerobic threshold and develop a training method by using a treadmill and design a software to implement the assessment technique of anaerobic threshold as well as software facilities for daily training. Using treadmill and cycle ergometers are the best method for control training but choosing best training intensity is crucial. According to one decade of our research experiences, it is possible to determine optimum personal training intensity based on person's anaerobic threshold. In this method, hear rate is used to draw heart rate-time curve during a graded maximal intensity exercise to find the best treadmill speed and slope in his/her anaerobic threshold and follow specific treadmill training every day. The software and hardware is implemented in an embedded system and it is ready to implement in suitable treadmills.

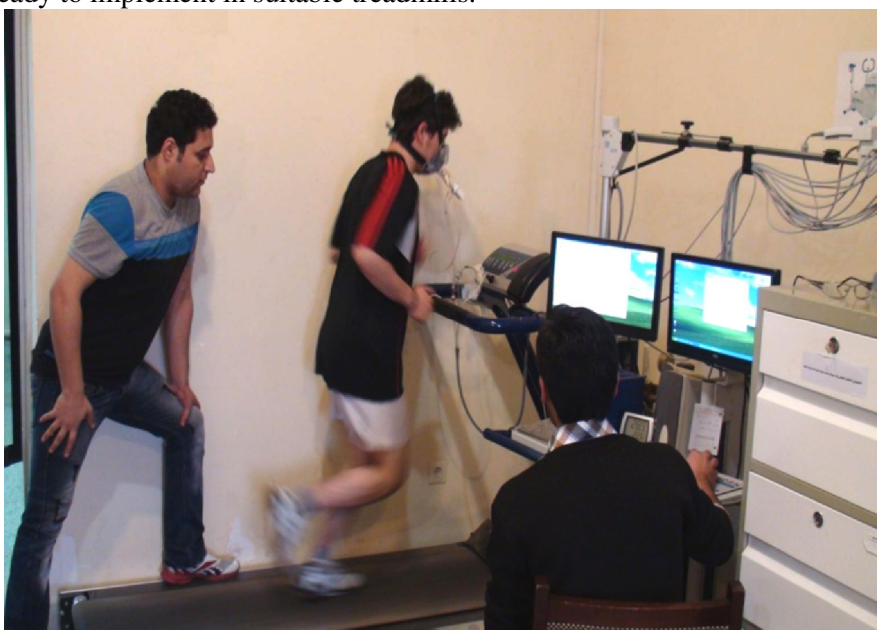

Figure1. Validity and reliability testing.

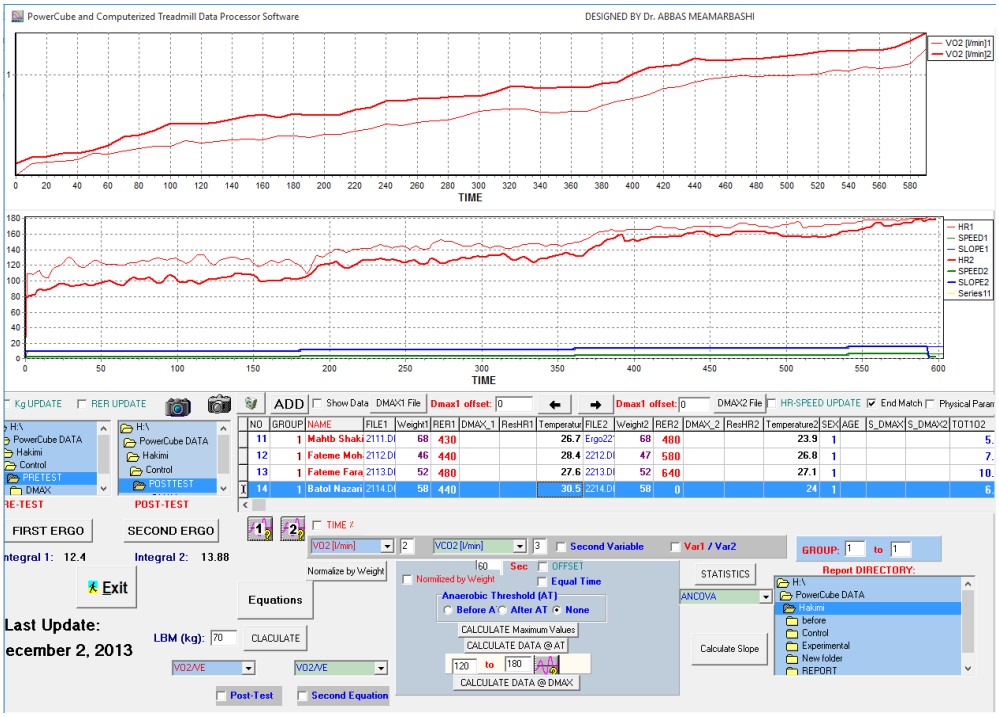

Figure 2. Main menu of the program during exercise.

Smart Treadmill Features:

- Determine anaerobic threshold by using a specific heart rate monitoring method.
- Automatic control of the treadmill speed, slope and duration.
- Record the individual information, treadmill speed, slope, duration, work, power, real time heart rate during trainings.
- Simple custom-design training programming.

Conclusion

Following extensive experimental research on the estimation of anaerobic threshold and then implication of these findings in a hardware and software to build an instrumented treadmill, now feasibility of design a hardware and software to estimate individual anaerobic threshold ascertained. It is a low price hardware and software recommendable to implement in future treadmill manufacturing.

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