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Body composition considerations in the assessment of cycle ergometer derived anaerobic performance indices

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Abstract

The purpose of this paper is to outline and comment on high intensity cycle ergometer exercise protocols when resistive forces are based on lean tissue mass or fat free mass (FFM). Utilizing FFM appears to maximise the power potential of individual subjects and relates more closely to force velocity relationships. Further development of the protocol would be useful for the athletic, and for associated biochemical and clinical evaluation of high intensity exercise performance responses in various subject populations. Data obtained would provide more meaningful comparisons between individuals that would be realistic and independent of the fat component of body composition.

Keywords

Anaerobic performance; Fat free mass; Total body mass.

Introduction

In any physically demanding performance, the ability to create the potential for performing the greatest amount of work in the shortest time possible is of prime concern to athletes. This is of special importance for events that involve short bursts of intense activity. This ability is also useful for rehabilitation purposes and assessments of health status in non-athletic adult populations and children. This component may be termed power, and can be simply defined as the rate of doing work. It is the product of muscular force and speed of movement, and is an essential element needed for success in all sporting activities [1]. Specific definitions of power have been suggested. [2] describes power as:-

“The ability to move mass in the shortest possible time”

It is the conversion of energy derived from phosphogenic and glycolytic processes into muscular

power which has been used to quantify high intensity performances. Some confusion in terminology exits when assessing high intensity metabolism in terms of «capacity» and «power». High intensity peak power has been defined by [3] as:-

"The highest work value obtained during any 5 second period usually occurring in the first 5-secs of maximal exercise"

This is presumably related to the prominent phosphagen component of energy release. High intensity capacity has been defined by [3] as:-

"The total work performed during the entire high intensity exercise period"

This reflects the glycolytic, phosphagen and oxygen components of energy release [4].

Tests of high intensity power and capacity have been extensively used by exercise physiologists to help characterise athletic groups. However, there is little agreement as to one suitable test which can be considered as a valid indicator of both power and capacity as different test protocols measure different components of high intensity performance [5].

Measurements of these different characteristics can be achieved by computing either the amount of mechanical work that can be performed in a specified time, or by monitoring the time taken to perform a given amount of high intensity work [6]. The evaluation of high intensity power and capacity may also depend on the interpretation of experimental data. Details of units of measurement and data evaluation need to be examined closely prior to experimental data collection [7]. It appears that the amount of work performed during a intense maximal test depends on both glycolytic power and capacity.

High intensity performance has been assessed by cycling on stationary friction loaded cycle ergometers. [8] introduced a friction braked cycle ergometer test which was further developed at the Wingate institute in Israel and became known as the Wingate Anaerobic test (WANT). The prototype was announced by [9] and since its conception a comprehensive description has been published (Bar - Or, 1981). In test protocols using cycle ergometry where a single exercise bout is performed, it is important to set a resistive force that matches the capability of the muscle. In this way, true maximal power output can be measured at, or close to, optimal velocity. A number of authors have addressed the possibility of predicting the optimal resistive force from body mass. This issue however has not been fully resolved [10]. Drop loaded, cradle or friction loaded ergometers have permitted rapid applications of load and quantification of the subsequent values for power produced. In the original studies of [9] using Monark ergometers the loads were in the order of 75 $g.kg^{-1}$ total body mass. [3] declared that a higher optimal value namely 87 $g.kg^{-1}$ total body mass, produced greater power outputs. Several other researchers have indicated that these load ratios may still be too small, especially for athletes involved in sprint or power based activities [11,6]. Optimal values for resistive forces used during high intensity cycle ergometry testing have been traditionally based on Total-Body Mass (TBM) indices. These indices include both active muscle tissue and fat mass.

Resistive forces used which are currently inclusive of the fat component of body composition, may not be representative of the active tissue mass utilised during maximal cycle ergometer performance. Power measurements obtained during cycle ergometry may also include an unknown upper body contribution that influences the power profiles obtained [12]. Body size, structure and composition differ markedly among individuals suggesting that a standard ergometer load may not provide optimal resistance for different populations, and may also be individual specific. This suggests that the assessment of physique may need consideration when used in the evaluation of high intensity performance.

Therefore an optimisation protocol based on TBM computations may be less than accurate. Because of the individual variation found between subject body composition indices, it seems logical to develop a resistive force that reflects the active muscle mass used during experimental procedures that is individual specific. The exclusion of fat mass seems appropriate from any loading protocol that attempts to establish a relationship between power production and the capacity of active muscle. Performance in high intensity experimental procedures has been reported by [13] as being highly related to the subjects' lean body mass, or the mass of the muscles that perform the test. The direct method of determining the optimal force for individual subjects during high intensity cycle ergometry is to provide the subjects with a test protocol that requires them to perform the test repeatably, each time against a different breaking force until a maximal value for power is obtained [14]. An alternative semi-direct approach has been to assign a braking force that is based on individual subjects' TBM and a performance ratio (normally 75 $g.kg^{-1}$ total body mass [9]. The assumption has been that for most healthy individuals, the relationship between total body mass and muscle mass is similar.

This is not the case and may be compromised further in populations that include the athletic, the undernourished and the obese. All these individuals will have different lean tissue and fat mass ratios. This may result in power estimation errors during high intensity exercise performance tasks. [13] found that cradle resistive forces computed from TBM values were poor predictors of optimal force assessment. The differences observed may reflect the inconsistent muscle mass to TBM ratio in individuals and may provide spurious power outputs and inconsistencies in related biochemical profiles. In relation to this statement [15] compared power outputs, and blood concentrations of lipid hydroperoxides (LH), Malondialdehyde (MDA), Creatine Kinase (CK), Myoglobin (Mb) and Lactate ([La]B) following 30 s of maximal cycle ergometry when resistive forces were derived from total-body mass (TBM) or fat-free mass (FFM). Individual cradle resistive forces were derived using optimization procedures for resitive force selection. TBM and FFM were determined using hydrostatic weighing techniques. Alpha-tocopherol (AT), Retinol (R) and Uric Acid (UA) concentrations were also measured to qualify the activity of antioxidants.

Cardiac troponin levels were determined to exclude myocardial damage and to verify that any CK was predominantly derived from skeletal muscle. Differences ($P<0.05$) in peak power output, pedal velocity and resistive forces were observed when the TBM and FFM protocols were compared [953 (114) W vs 1,020 (134) W; 134 (8) rpm vs 141 (7) rpm; 6 (1) kg vs 5 (1) kg respectively). LH and MDA concentrations increased immediately post-exercise during the TBM protocol only ($P<0.05$) and were greater when compared to FFM ($P<0.05$). LH and MDA values decreased 24 h post-exercise. Increases in CK concentrations were recorded

immediately post-exercise for both the TBM and FFM protocols with greater concentrations recorded for TBM (P<0.05). Decreases were observed 24 h post-exercise. Mb concentrations were greater immediately post-exercise for the TBM protocol and were greater than those recorded for FFM (P<0.05). Values decreased 24 h later (P<0.05). AT and UA concentrations decreased immediately post-exercise for both protocols (P<0.05) and increased 24 h later (P<0.05). There were no changes observed in R concentrations at any of the blood sampling stages. [La)]B increased (P<0.05) immediately post-exercise for both protocols, and decreased 24 h later (P<0.05). The results of the study suggest that greater power outputs are obtainable with significantly less oxidative stress and muscle disruption when resistive forces reflect FFM mass as opposed to TBM. [16] further examined power outputs and blood lactate concentrations ([La-]B) following 30 s of traditional maximal cycle ergometry without using optimization procedures for Total-Body Mass (TBM) or Fat-Free Mass (FFM). Differences (P < 0.05) in Peak Power Output (PPO), Pedal Velocity (PV) and Resistive Forces (RF) were observed when the TBM and FFM protocols were compared (953 +/- 114 W vs. 1020 +/- 134 W; 134 +/- 8 rpm vs. 141 +/- 7 rpm; 6 +/- 1 kg vs. 5 +/- 1 kg, respectively). Blood lactate values ([La-]B) increased (P < 0.01) postexercise for both protocols and were significantly greater for TBM (10.6 +/- 1.2 mmol.l-1 vs 11.6 +/- 1.1 mmol.l-1, P < 0.05).

These findings indicate that the FFM resistive force protocol may maximise Adenosinotriphosphate-Phosphocreatine (ATP-PC) utilisation with smaller contributions from anaerobic glycolysis when compared with TBM.

This suggestion may explain the higher power outputs obtained for FFM when compared to the TBM protocol These results have important implications fpr power profiles, related biochemistry and clinical pathologies in the assessment of high intensity exercise performance.

We suggest that tests of high intensity cycle ergometer exercise should be based on lean tissue mass or Fat Free Mass (FFM), that maximises the power potential of individual subjects and relates more closely to force velocity relationships and active muscle mass.

We further suggest that researchers should compare the FFM protocol with existing accepted physiological and biochemical measures of high intensity performance, and investigate any differences observed. The further development of the protocol outlined here would be useful for both the athletic and clinical evaluation of high intensity exercise performance responses in various subject populations. Data obtained would provide meaningful comparisons between individuals that would be realistic and independent of the fat component of body composition. Finally, the calculation of body composition is an important consideration when using the FFM protocol. As a result, correct and accurate procedures for body composition assessment should be used to avoid errors in resistive force calculations [17].

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