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Review Article

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Body Composition Considerations in The Assessment of Cycle Ergometer High Intensity (Anaerobic) Performance Profiles

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Abstract

This paper examines cycle ergometer generated power profiles when cradle resistive forces are calculated from total body mass (TBM) or fat free mass (FFM) body composition indices. Utilizing FFM as a resistive force during high intensity (anaerobic performance) cycle ergometry seems to maximize the power production of individual subjects and approximates more accurately muscle force velocity characteristics. Use of the protocol would provide benefits for the associated biochemical, clinical and performance evaluation of high intensity exercise responses in different populations. Data obtained using the FFM protocol would enable meaningful performance comparisons between and within populations that would be realistic, more specific and non-inclusive of the resistive force calculation errors associated with the fat component of body composition.

Keywords: Anaerobic performance, Fat free mass, Total body mass

Introduction

During physically demanding sports or activities, the potential to generate maximal high intensity performances is a prime concern for athletic populations. This is particularly important for sports requiring very short intense performances. The ability to generate high intensity performances is also important for rehabilitation purposes, and in the health assessment of the general population, adolescents and children. High intensity exercise ability has been classified as the ability to generate power. This term has been defined previously as the rate of performing work.

Power has two components and is the product of the muscle to generate muscular force in the fastest time possible. The generation of power is essential for human locomotion and is a requirement needed for success in any sports performance and daily life [1].

Definitions of power development have been previously suggested and Cerretelli, described power as [17].

"the ability to move mass in the shortest possible time".

Power development encompasses energy derived from the phosphagenic (ATP-PC) and glycolytic (anaerobic glycolysis) metabolic pathways into coordinated muscle activity which have been used to define high intensity activities. There has been some confusion when describing anaerobic activities in relation to the capacity and power of the metabolic systems. Anaerobic peak power has been further defined by Bar-Or, as [6].

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

This statement relates to the phosphagenic component of anaerobic energy provision. Anaerobic capacity has also been defined by Bar-Or, as [6].

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

This statement includes the phosphagenic metabolic pathway and also includes the glycolytic, and oxidative energy systems associated with energy release (Bouchard et al. [2].

Measurements of the components of power have been used by physiologists in the characterization of different athletic groups. There appears to be little agreement between physiologists as to a suitable test that is both valid and a reliable measure of anaerobic performance. There also seems to be limitations in test protocols that are deemed to be valid and reliable indicators of both power and capacity.

Different test protocols appear to evaluate different aspects of anaerobic performance and are specific for selective sport populations such as cyclists using cycle ergometry, and runners using treadmills [3].

Quantification of the various power characteristics are obtained by computing the mechanical work completed over a specified duration. Power can also be obtained by recording the time taken to achieve a maximal effort in a specified time, such as running a short distance as fast as possible (Winter et al. [4]. Anaerobic evaluation also depends upon experimental data interpretation. As a result, units of assessment and subsequent data analysis should be examined and considered prior to high intensity experimentation (Vandewalle et al.) [5]. Further to this, because the amount of work achieved during anaerobic exercise depends on both glycolysis and ATP-PC power and capacity, there needs to be consideration given to the role of the relative contributions from the energy systems to the power values obtained. This is particularly important in the assessment of anaerobic performances for specific athletic groups where performance times are short and intense but vary in duration and skill. These different durations will result in different energy contributions and may result in fluctuations in ATP-PC energy supply or anaerobic glycolysis.

Anaerobic activity has been traditionally assessed using stationary cycle ergometers. Cumming, was the first to introduce a friction loaded cycle ergometer protocol [18]. The protocol was refined further by researchers at the Wingate institute in Israel [15]. The new protocol became known as the Wingate Anaerobic test (WANT). This prototype was described by Aylon *et al.* (1974) and a detailed outline and specification has been published previously (Bar - Or, [9]. During the assessment of anaerobic performance using cycle ergometry where subjects are required to perform maximally for one exercise session, it is necessary to use cradle force resistances that closely match the capacity of the muscles to perform the test. This means that accurate and realistic high intensity power outputs are obtainable that comply with maximal velocities and the active muscle tissue of the subjects performing the test. Several authors have investigated the process of obtaining optimal resistive cradle forces that are used during high intensity cycle ergometry from total body mass. This issue still needs to be resolved and many discrepancies exist due to different body composition characteristics between athletic populations, adolescents, and the general public (Bar-Or,) [7].

Cradle or friction loaded cycle ergometers allow the rapid application of resistive forces. This provides immediate calculation of power values produced. During the original studies of Aylon et al. (1974) who used Monark cycle ergometers the resistive forces were derived from total body mass using a ratio of 75 $g.kg^{-1}$ total body mass. Dotan and Bar-Or, suggested that greater optimal ratios of 87 $g.kg^{-1}$ total body mass, would produce larger power profiles [19].

Other studies have suggested that the load ratios proposed are too small. This is particularly true for muscular athletes who are involved in powerful activities such as sprinting (Nakamura et al. [20]; Winter et al. [4]. Values used for cradle resistive forces during experimental anaerobic cycle ergometry, traditionally have been generated from total-body mass (TBM) ratio indices, and most of the cycle ergometer research studies have used this methodology. Unfortunately, the indices used include both active muscle mass and the non-active fat component of body composition.

Cradle resistive forces that are inclusive of the fat component, will not represent active muscle mass contributing to maximal ergometer power outputs, and will introduce an error into the power profiles and calculations generated. Values for power recorded following leg cycle ergometry performance are also confounded further by an upper body contribution to tests using cycle ergometers that influence the leg power profiles obtained [12]. Subjects performing the tests have large differences in body morphology, including structure and composition. These components are markedly different between individuals and athletes, and result in body composition deficiencies when using a standard resistive force ratio. This indicates that standard ergometer resistive force ratios may not be providing optimal resistances for different populations, and as a result provides inaccuracies in power profiles obtained. This further indicates that the resistive forces used need to be individual specific and that the measurement of body composition needs to be established prior to the evaluation of anaerobic ability.

As a result, anaerobic optimization protocols utilizing TBM for resistive force computation will introduce errors into resistive force calculation that are not representative of active muscle tissue or individual power capacities.

Because of the individual variations between and within subject body composition parameters, a logical way forward in the assessment of anaerobic performance is to design and test a cradle resistive force that represents active muscle tissue used during high intensity exercise experimentation. Removing the fat mass component from resistive force selection protocols to establish relationships for power outputs and the potential for active muscle to contract maximally seems appropriate. The ability to perform during anaerobic experimental protocols has been reported by Van Mil et al. as being related to individual subject's active muscle mass, or to the ability of the muscles contributing to test results [21].

Direct methods for the determination of optimal forces for individuals during anaerobic cycle ergometry have resulted in optimization protocols. The objective is to provide a test protocol that represents resistive forces that are specific and individualized for subjects performing the test. The protocol requires subjects to randomly perform cycle ergometer tests for 5 seconds repeatably against different resistive forces until a maximal power value is achieved (Dotan et al.; Evans et al. [10, 19]. The resistive forces are selected in a random fashion and adequate rest periods are provided between each test. The resistance that provides the maximal power value in a 5 second period is then used in the full 30 second test. A different approach, and an approach that is used traditionally, is to derive a cradle resistive force calculated from individual subjects body mass and a performance ratio (normally 75g.kg-1 total body mass Aylon et al. [8]. Previously, it was thought that relationships between TBM and lean tissue mass in healthy subjects was the same.
As outlined previously, this assumption is not true and lean tissue mass and fat mass values may be even more spurious in

populations including the athletic, the emaciated, the overweight and clinically obese. These individuals will all have very different lean and fat mass ratios. If included in resistive force computations these differences will result in resistive force estimation errors providing incorrect values for anaerobic performance and making comparisons within and between groups very difficult.

Van Mil et al. observed resistive forces calculated from TBM were poor performance indicators during optimal force measurement [21]. The findings from the study may be reflecting the inconsistencies in lean muscle mass to TBM ratios in individuals. This may have provided inaccurate power outputs and measurement errors in associated biochemistry profiles in previous studies. In relation to the differences observed for the power profiles generated using TBM or FFM cradle force resistances, Baker et al. investigated power profiles, and selected biochemical parameters [22]. The blood profiles investigated included; lipid hydroperoxides (LH), malondialdehyde (MDA), creatine kinase (CK), myoglobin (Mb) and blood lactate ([La)]B) pre and following 30 s of maximal anaerobic cycle ergometry. All measurements were repeated at 24 and 48 hours post exercise.

Cradle resistive forces for individual subjects during the study were obtained using optimization procedures for resistive force selection. TBM and FFM body composition indices were determined using hydrostatic weighing techniques. In addition to the biochemical measures outlined previously, further measures including alpha-tocopherol (AT), retinol (R) and uric acid (UA) were quantified to examine antioxidant activity in relation to the different cradle resistive forces.

During the study cardiac troponin (CK) was evaluated to investigate any potential myocardial injury and confirm that any increases in CK concentrations were the consequence of muscle activity only. Significant differences ($P<0.05$) were recorded for peak power values, pedal revolutions and cradle resistive forces when comparisons were made between protocols [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 increased post-exercise for the TBM protocol ($P<0.05$). These values were higher when compared with concentrations for FFM ($P<0.05$). LH and MDA values decreased 24 h post-exercise.

CK concentrations also increased post-exercise for both protocols with higher values noted for TBM ($P<0.05$). Reductions were observed 24 h post-exercise. Mb values were elevated post-exercise for TBM and were greater than FFM ($P<0.05$). Values decreased 24 h later ($P<0.05$).

AT and UA values decreased post-exercise for both protocols ($P<0.05$) and increased 24 h later ($P<0.05$). No changes were observed for R at any of the blood sampling stages. [La)]B increased ($P<0.05$) post-exercise for both protocols, and decreased 24 h later ($P<0.05$). Findings from the study indicated that larger power outputs are possible with minimal oxidative and muscle damage when resistive forces are derived from FFM compared to TBM. Baker et al. further investigated the anaerobic capacity of subjects that were overweight and obese during cycle ergometer exercise of 10 s duration using resistive forces derived from TBM or FFM [23]. Subjects were allocated to either protocol using a randomization protocol. Body composition characteristics were determined using hydrostatic weighing.

Male University students (age 22.3 +/- 2 yrs, body fat 27.1 +/- 2%) volunteered as subjects for the study (n = 11). Significant differences ($P < 0.01$) in peak power outputs (PPO) were recorded between protocols (1029 +/- 98 W TBM vs. 1397 +/- 146 W FFM). The study findings indicated that larger power output values were obtained using the FFM cradle protocol. These findings demonstrated that the FFM cradle protocol seems to maximize adenosine triphosphate-phosphocreatine (ATP-PC) as an energy source with less reliance on the anaerobic glycolytic pathway when compared to TBM during 10 seconds of high intensity activity (See Fig 1)

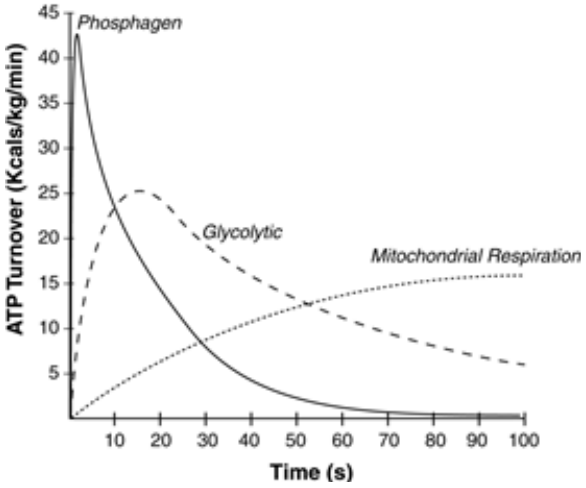

Figure 1: Metabolic energy system interactions. It should be noted that the energy systems do not provide energy independently of each other. The relative contribution of each system differs depending on intensity and duration of the physical activity being performed. In relation to this, the FFM protocol when compared to the TBM protocol seems to be maximizing the ATP-PC phosphagen systems energy contribution to the tst. This can be evidenced by increases in pedal revolutions and greater Peak Power Outputs[11].

This suggestion may explain why there were higher power outputs obtained for FFM compared to TBM. We suggest that tests of anaerobic cycle ergometer exercise should be based on fat free mass (FFM). This maximizes the anaerobic potential of individual subjects and represents more accurately force velocity relationships. We further propose that researchers should compare the FFM protocol with other validated measures of anaerobic ability and compare any differences observed. These include both biochemical and physiological measures. The further development and utilization of the protocol outlined here would provide clinical evaluations of anaerobic performance responses in various subject populations. This would provide data comparisons between subjects that would be realistic and not include the fat component of body composition.

Finally, in all experimental procedures the calculation of body composition is an important consideration when using the FFM protocol.

As a result, correct and accurate procedures for body composition measurement should be used to avoid errors in resistive force calculations [13].

Discussion

Protocols for cycle ergometer high intensity exercise have been subjected to new designs and engineering refinements since conception in 1974. The use of larger resistive forces to maximize anaerobic ability has been a challenge for researchers but is highly recommended [14]. Further studies are required to identify maximal braking force for different populations that include children, athletes, overweight individuals, the underweight and undernourished and special populations. More information regarding the neurochemical, skeletal muscle and physiological events in conjunction with cycle ergometry are needed to provide a greater understanding of anaerobic ability. The resistive forces traditionally used for cycle ergometer exercise have included both fat mass and lean tissue mass and has been in the range varying from 75 g.kg-1 to 130 g.kg-1 [11]. These resistances have also been the subject of the development of specific guidelines (British Association for Sport and Exercise Sciences; B.A.S.E.S[16]. Experimentally, their derivation probably involved optimization methodologies. The FFM methodology used for resistive force selection represents more closely the active muscle tissue used during the test and agrees with other researchers [11]. When applying the FFM protocol, any values obtained provide valid data sets for considering maximal resistive forces and therefore, reliable and accurate power values. Tharp et al. outlined that any power values recorded following anaerobic cycle ergometry are correlated to body mass [14]. They also suggested that heavier persons would produce greater power outputs. However, power values relative to FFM produce and provide a better index of anaerobic ability when comparisons are made between individual subjects.

Results from the studies presented here indicate that the larger the resistance the larger errors in transmission of force to the flywheel. This is especially true when the resistive forces are derived from TBM.

McInnis et al. (1999) stated that individuals who weigh the same may have very different body compositions. These differences not only demonstrate individual variations in body composition but also the specificity of training between active subjects and variations in the body compositions of the non-active general public.

Conclusion

FFM resistive force selection seems to demonstrate a more accurate an appropriate method of externally loading the cycle ergometer cradle. The methodology identifies subtle changes in resistive force application that results from relative load increments that are smaller and dont include the body composition fat component. The reduced resistive forces appear to adapt to the small changes in power profiles observed during an optimization procedure that is disregarded by the TBM protocol. The higher PPOs obtainable for FFM demonstrate that this protocol of resistive force selection does not compromise the capacity of active muscle. As a result the protocol provides maximal values for resistive load and maximizes pedal revolutions. Use of the TBM protocol, increases application of the braking force, and this results in a decrease in pedal revolutions contributing to an underestimation of power production. The relationships between correlation coefficients for power values obtained for both protocols (greater for FFM), and the differences observed for resistive forces for both protocols indicate that the FFM protocol approximates more closely to the active muscle tissue used during short term experimental anaerobic exercise. These findings need further consideration in anaerobic experimentation that uses drop loaded cycle ergometers.

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