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RESISTIVE FORCE SELECTION DURING BRIEF CYCLE ERGOMETER EXERCISE: IMPLICATIONS FOR POWER ASSESSMENT IN INTERNATIONAL RUGBY UNION PLAYERS

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ABSTRACT

RESISTIVE FORCE SELECTION DURING BRIEF CYCLE ERGOMETER EXERCISE: IMPLICATIONS FOR POWER ASSESSMENT IN INTERNATIONAL RUGBY UNION PLAYERS. **Julien S Baker and Bruce Davies**. **JEP**online 2004;7(3):68-74. The purpose of this study was to examine power values generated during brief high intensity cycle ergometry exercise when the ergometer resistive forces were derived from total body mass (TBM) or fat free mass (FFM). International rugby union players (front row forwards; n = 8; and backs; n =8) volunteered as subjects. Body density was calculated from the sum of skin-folds using population specific regression procedures. Fat mass was determined from body density. Subjects were required to pedal maximally on a cycle ergometer (Monark 864) against randomly assigned resistive forces ranging from 70 g/kg - 95 g/kg for a 6 s period to determine optimal peak power outputs (PPO) for both the TBM and FFM protocols. PPO for backs and forwards using the TBM protocol were 1058 ± 84 Watts vs. 1293 ± 144 Watts, respectively (p < 0.01) Make sure all ± symbols are 12 font size. Using the FFM protocol the peak power output values increased (p < 0.01) Do not italicise this content for both groups (1163 ± 100 Watts for backs vs. 1481 ± 137 Watts for forwards). Differences (p < 0.01) were also observed between forwards and backs for cradle resistive forces and pedal revolutions (6.7 ± 0.6 kg TBM vs. 6.2 ± 0.5 kg FFM for backs; 8.4 ± 0.6 kg TBM vs. 7.3 ± 0.9 kg FFM for forwards; 143 ± 8.6 rev/min TBM vs. 147 ± 5.2 rev/min FFM for backs; 137 ± 8.2 rev/min TBM vs. 147 ± 5.2 rev/min FFM for forwards). The findings of this study indicate that rugby union forwards are more powerful than rugby union backs. Increased peak power output values observed during load optimisation procedures for FFM demonstrate that this protocol represents a method by which greater peak power can be consistently obtained during high intensity cycle ergometry.

Key Words: Cycle Ergometry, Load Optimization

INTRODUCTION

Exercise performance in sports that involve short bursts of intense exercise, such as sprinting or jumping, rely predominantly on the phosphagen and glycolytic energy systems. The ability to utilise the high-energy phosphate stores effectively may be considered as one aspect of "power". The total amount of energy available to perform work in a given energy system is referred to as the capacity of the system (11). Individual differences in power production may be the result of greater muscle mass, training status or a greater proportion of fast twitch fibres that possess higher phosphagen and glycolytic enzymatic activity (7).

The relationship between body composition and physical fitness is also of considerable importance in rugby football. Optimal performances during a game will only be achieved when the fat and fat free components of body composition are appropriate to meet the physiological and structural demands of performance. Therefore, it is conceivable that any physiological measurements performed on such a group of athletes may be influenced by differences in body composition regardless of weight. For example, measurements recorded following high intensity cycle ergometry may be highly related to individual subject fat free mass, or the mass of the muscles that perform the test (22). The assumption has been that the relationship between total body mass (TBM) and fat free mass (FFM) when calculating resistive forces for high intensity cycle ergometer performance is the same. However, variations in body composition between subjects may lead to spurious calculations of power output that may not be reflective of active muscle tissue. Consequently, the aim of this study was to investigate any differences in power profiles generated during brief high intensity cycle ergometry exercise when resistive forces were derived from TBM vs. FFM in a group of international rugby union players.

METHODS

International rugby union players (n = 16) volunteered as subjects. Physiological characteristics of the players are given in Table 1. The subjects were further divided into two position categories: backs (n = 8; three scrum halves, three outside halves and two full backs; body mass 76 ± 7 kg; body fat 12 ± 2 %) and front row forwards (n = 8; three loose head props, three tight head props and two hookers; body mass 94 ± 6 kg ; body fat 14 ± 2%). The study procedures were approved by the university Ethics Committee, and before testing all subjects read and signed an approved informed consent. Prior to data collection subjects were fully habituated and familiarised to the experimental procedures on three occasions at the same time of day as the actual tests (morning testing). The experimental design consisted of a single blind randomised crossover design. Two rest days with no physical activity preceded each test and subjects attended the laboratory following a standard breakfast of toast and water. A recovery period of one week was observed between experimental conditions. For six weeks prior to data collection, and throughout the study, subjects refrained from additional vitamin and dietary supplementation. No appreciable deviations from their normal eating habits were recorded during this period (Nutri-Check).

Terminology

Throughout the study peak power output (PPO) refers to the highest 1s value of power attained during each 6 s sprint.

Force velocity test

A force velocity test was performed to determine optimal resistive forces for both TBM and FFM protocols (12). Briefly, the test consisted of six short maximal sprints (6 to 8 s) against randomly assigned resistive forces (70, 75, 80, 85, 90 and 95 g/kg). The resistive force that produced the highest PPO for both the TBM and FFM protocol was considered optimal. Successive exercise bouts were separated by a 5 min rest period. Care was taken to ensure that the resistive force applied to the cradle of the ergometer corresponded to the force applied at the flywheel. Therefore, cradle resistive forces exceeding 9 kg were not used (10). A cycle ergometer (Monark 864) was calibrated prior to data collection (5). Saddle heights were adjusted to accommodate partial knee flexion of between 170° to 175° (with 180° denoting a straight leg position) during the down stroke. Feet were firmly supported by toe clips and straps. All subjects were instructed to remain seated during the test and were verbally encouraged to perform maximally. All subjects performed a standardised 5-min warm up (12). Subjects were given a rolling start at 60 rev/min for a 5 s period prior to resistive force application. On the command 'go', the subjects began to pedal maximally, the resistive force was applied, and data capture initiated. Indices of performance were calculated from flywheel revolutions using an inertia corrected computer program (5). Data transfer was made possible using a mounted sensor unit and power supply attached to the fork of the ergometer in a position located opposite the flywheel. The sampling frequency of the sensor was 18.2 Hz.

Anthropometric Measures

Nude body mass, stature and body composition were determined using calibrated weighing scales (Seca, UK), stadiometer (Seca, UK) and anthropometric procedures, respectively. Body mass was measured to the nearest 0.1 kg and stature to 0.1 cm. Skinfold thickness measurements were taken on the left side of the body at the biceps, triceps, sub-scapular and suprailiac sites using Harpenden callipers (standard error of measurement recorded at the four sites was 0.2 mm, 0.3 mm, 0.2 mm and 0.2 mm respectively). Although the authors acknowledge the reservations in obtaining body fat estimates derived from skinfolds, recent research in our laboratory has indicated no significant difference ($p > 0.05$) between body fat values obtained during hydrostatic weighing and skinfold thicknesses in 20 young male volunteers. These findings are in agreement with other researchers (16). All skinfold measurements were taken with the subjects standing in a relaxed position. Three thicknesses were taken with the median being used as the criterion measure. Skinfold measurements were transformed into body density values for rugby union players (3) and % body fat using specific equations (18). Fat free mass was calculated by subtracting fat mass from total body mass.

Statistical procedures

Data were examined using a computerised statistical package (SPSS, Surrey England). Confirmation that all dependent variables were normally distributed was assessed via repeated Kolmogorov-Smirnov tests. Changes in selected dependent variables power outputs, pedal revolutions and resistive forces as a function of condition (TBM vs. FFM) or as a function of playing group (forwards vs. backs) were assessed using a 2-way mixed design ANOVA (player group 2 levels x protocol 2 levels followed by a post hoc Tukey test). The degree of linear relationship between variables was examined using Pearson's correlational analysis. Significance was accepted at the $p < 0.05$ level.

RESULTS

Physiological and anthropometric characteristics of the subjects are presented in Table 1.

Table 1. Age and physiological characteristics of subjects (n=16).

Variable	*Mean ± SD*
Age (yr)	21 ± 2.0
Stature (cm)	181 ± 8.0
Mass (kg) Backs	76 ± 7.0
Mass (kg) Forwards	94 ± 7.0
Fat (%) Forwards	14 ± 2.0
Fat (%) Backs	12 ± 2.0
Fat Mass Forwards (kg)	13 ± 6.0
Fat Mass Backs (kg)	9 ± 7.0

Peak Power Output

Significant differences were noted between both front row forwards and backs ($p < 0.01$) for peak power output when the TBM and FFM protocols were compared. The power outputs obtained were consistently greater using the FFM protocol (see Figure 1). The forwards were also significantly ($p < 0.01$) more powerful than the backs independent of the protocol used. Squared correlation coefficient values (R^2) obtained between power outputs and resistive forces for both TBM and FFM protocols indicated that the FFM protocol accounted for more of the variance in performance than the TBM protocol ($R^2 = 64\%$ TBM vs. $R^2 = 81\%$ FFM for backs ; $R^2 = 56\%$ TBM vs. $R^2 = 72\%$ FFM for forwards).

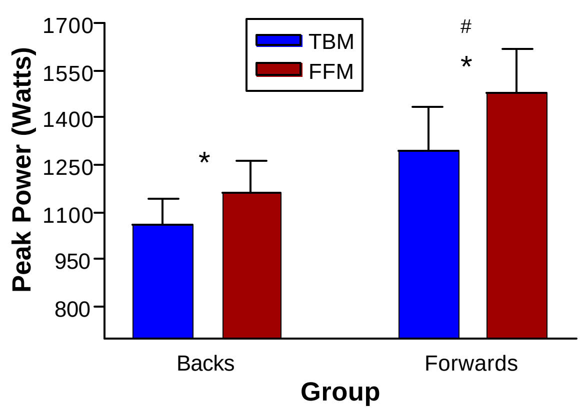

Figure 1. Differences in peak power generated between backs and forwards when resistive forces were calculated from total body mass (TBM) or fat free mass (FFM). *=p<0.05 between TBM and FFM methods; #= p<0.05 between forwards and backs for both methods.

Resistive Force Selection

Significant decreases ($p < 0.01$) in resistive forces were observed between forwards and backs when the TBM and FFM protocols were compared. The resistive forces used for the backs were significantly ($p < 0.01$) lighter than the forwards independent of protocol. The FFM resistive force selection used for the forwards was significantly greater than the TBM resistive force used for the backs ($p < 0.01$; see Figure 2).

Pedal Revolutions

Significant ($p < 0.01$) increases in pedal revolutions were recorded using the FFM protocol for both forwards and backs when compared to TBM. The backs also produced greater pedal velocities ($p < 0.01$) than the forwards during the TBM condition. There were no differences in pedal revolutions recorded between forwards or backs for the FFM exercise condition ($p > 0.05$; see Figure 3).

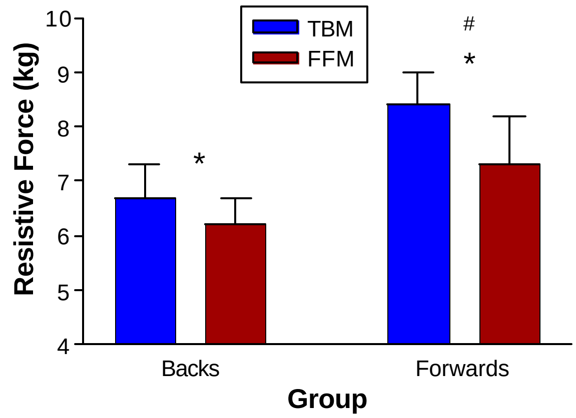

Figure 2. Differences between Forwards and Backs when resistive forces were calculated from total body mass (TBM) as opposed to fat free mass (FFM). *=p<0.05 between TBM and FFM methods; #= p<0.05 between forwards and backs for both methods.

DISCUSSION

Power profiles obtained in this study were greater than those reported by Winter et al. (25) for male physical education students (1007 ± 135 Watts). Higher values were also recorded than those outlined by Nakamura et al. (15) for a group of Japanese physical education students (930 ± 187 Watts). The variation in power profiles obtained may be the result of training status and unknown genetic factors that are independent of body mass (17). The higher values obtained for front row forwards in comparison to the backs in this study may be related to the optimisation procedure, with the higher resistive forces used for the forwards in both the TBM and FFM protocols. These values may be indicative of the specific performance demands of rugby football that involve front row forwards in intense periods of rucking, mauling and scrummaging. The backs may possess greater speed, but the forwards tend to concentrate on intense strength and power orientated activities during training, resulting in the development of greater absolute power. The smaller body mass values combined with the playing and training specificity of the backs may not require the same overall power prerequisites as the front row forwards. The findings of this study confirm this suggestion. Furthermore, recent research in our laboratory (1) has identified a significant upper body contribution during the assessment of leg power output using cycle ergometry. The upper body may have contributed to the values for power obtained for both forwards and backs, but the relative contribution in the assessment of leg power may have been higher in the forwards. Both forwards and backs showed increases in performance when optimised for FFM.

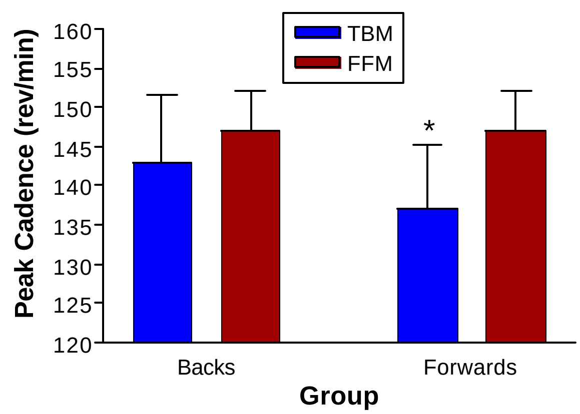

Figure 3. Differences recorded for pedal revolutions for Forwards and Backs when resistive forces were calculated from total body mass (TBM) and fat free mass (FFM). It is interesting to note that there were no differences observed in pedal revolutions between forwards and backs for the FFM protocol (p > 0.05). *=p<0.05 between TBM and FFM methods for Backs.

The values recorded in this study indicate that the optimisation procedure used for FFM produces lower optimal resistive forces resulting in higher power outputs. The higher power outputs observed are attributable to increases in maximal pedal revolutions. These findings are in agreement with the suggestions of Wilkie (23,24) who stated that force should be matched to the capacity of active muscle tissue to exploit fully the force-velocity relationship. Differences in performance ($p < 0.01$) were observed between forwards and backs for power output, cradle resistive forces and pedal revolutions ($p < 0.01$). The higher power output measures obtained compared to the TBM method, may also underline the inconsistent muscle mass to total body mass relationship found in individual subjects. For example, the total fat mass measured in forwards and backs was 13 ± 6 kg and 9 ± 7 kg respectively. The resistive force transferred to the ergometer cradle, using the TBM model of resistive force selection includes the fat component of body composition, and may not represent accurately the active muscle tissue utilised during experimental test performance. The overestimation of load results in a decrease in cadence, which has a negative effect on the power profiles produced. In addition, the FFM protocol may represent a more finite way of externally loading the ergometer cradle during an optimisation protocol with smaller absolute increases in resistive force being applied at any individual loading stage. This procedure appears to be able identify any subtle changes in power output as they occur.

In this study, the fat component of body composition was relatively small for both groups. This can be explained by the fact that all subjects were international rugby players and were healthy and young. The differences observed for power output may have altered if the experimental population had been selected from the undernourished, the aged or the obese. Vanderwalle et al. (21) recorded values of approximately 125 revs/min for adult sprinters and 105 revs/min for male recreational runners. The values recorded in this study were higher, and these observed differences illustrate clearly the detrimental effect on the attainable speed profile and subsequent power calculations when loading procedures are based on TBM computations.

Correlation of coefficient values obtained between power outputs and resistive forces for both protocols, for both forwards and backs, indicated that the FFM method accounted for more of the variance in performance than the TBM protocol. The significant differences found between loading procedures for TBM and FFM and the R^2 values obtained suggest that the FFM protocol represents more closely the active tissue utilised during experimental high intensity exercise. As for all force velocity relationships in humans, morphological factors contribute to force and power measurements, and may bias or improve power profiles (21). Force velocity relationships are also interrelated to factors that modify longer duration performances such as the efficiency of oxygen utilisation, muscular blood flow or perceived exertion (13).

The brief exercise period used in this study for both the TBM and FFM protocols would have resulted in minimal oxygen consumption, therefore only small disruptions in force velocity relationships would have occurred. Power is the composite product of two factors (strength and speed) and can take virtually an infinite number of values. Therefore, a range of results are possible with varying contributions from both strength and speed, especially when the criterion is optimisation of absolute maximal power (11). This is true in the present study greater power was achieved by increasing the resistive force and by increasing the number of pedal revolutions for both the TBM and FFM protocols. With the increasing load, recruitment of more motor units with more muscle fiber per motor unit is most important until the load becomes excessive, then an increase in the firing rate becomes the most prominent mechanism for the development of muscular force (14). Within the range of the force velocity interrelationships, those associated with maximised short-term power should be expected to most closely approximate the maximum single contraction as defined by the classical force velocity curve (9). The observable inter-subject differences recorded for TBM and FFM protocols may be related to individual inability to generate high levels of velocity. There may be many reasons for this including the proportion of fast twitch fibers (type II) in the exercising muscle, and differences in physiological and biochemical factors that relate to genetics, playing position and training status. Thorstensson et al. (20) have confirmed a greater proportion of type II fibers in athletes engaged in activities requiring short lived or sprint orientated power outputs.

The higher pedal revolutions recorded in this study for FFM suggests that this protocol facilitates a 'maximisation of contraction potential' that may be related to speed and is independent of fiber type when compared to TBM. Unfortunately, because of the brief nature of exercise duration during the exercise task and maximal recovery employed between exercise bouts, information relating to fatigue profiles for either the TBM or FFM protocol was unimpressive. Maximising power output during short duration cycle ergometry is further complicated by the circular motion of the pedals which affects the nature of force application, and increases in the degree of the skill and co-ordination required for the given motion sequence frequency (19). However, the habituation and familiarisation periods employed prior to data collection in this study would have minimised this problem for both protocols. In conclusion, existing optimisation procedures need to be reassessed if true power output is to be attained. Increased

PPO values resulting from higher pedalling rates during optimisation procedures for FFM may maximise muscle contraction dynamics. These findings are in agreement with other researchers (4, 22, 11, 6, 2,) who have recorded similar relationships to the findings observed in this study. Namely, that during high intensity cycle ergometry exercise, the power profiles generated are related to the subjects FFM or to the mass of the muscles that perform the test. If this is true, the total capacity, power and relative contribution of the energy systems involved during experimental high intensity cycle ergometer exercise may need re - evaluating.

CONCLUSIONS

Findings from this study indicate that the present loading methods used for cycle ergometry that are inclusive of TBM underestimate significantly ($p < 0.01$) attainable maximal power outputs in international rugby union players. Procedures that give realistic values and relate to the active muscle tissue utilised during this type of exercise may need to be explored in preference to methods that include both lean and fat masses.

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