©Journal of Sports Science and Medicine (2006) CSSI, 42-46
http://www.jssm.org

Combat Sports Special Issue

Research article

VARIATION IN RESISTIVE FORCE SELECTION DURING BRIEF HIGH INTENSITY CYCLE ERGOMETRY: IMPLICATIONS FOR POWER ASSESSMENT AND PRODUCTION IN ELITE KARATE PRACTITIONERS

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Published (online): 01 July 2006

ABSTRACT

The purpose of this study was to measure power values generated in elite karate fighters during brief high intensity cycle ergometry when resistive forces were derived from total - body mass (TBM) or fat - free mass (FFM). Male international karate practitioners volunteered as participants (n = 11). Body density was calculated using hydrostatic weighing procedures with fat mass ascertained from body density values. Participants were required to pedal maximally on a cycle ergometer (Monark 864) against randomly assigned loads ranging from 70 $g \cdot kg^{-1}$ – 95 $g \cdot kg^{-1}$ (using a TBM or FFM protocol) for 8 seconds. The resistive force that produced the highest peak power output (PPO) for each protocol was considered optimal. Differences ($p < 0.05$) in peak power outputs were found between the TBM and FFM experimental condition (1164 ± 137 W *vs.* 1289 ± 145 W respectively). Differences were also recorded ($p < 0.01$) between pedal velocity and applied resistive forces (127 ± 8 rpm *vs.* 142 ± 7 rpm; 6.6 ± 1 kg *vs.* 5.5 ± 1 kg, respectively). No differences ($p > 0.05$) were observed between time to PPO, or heart rate when the TBM and FFM protocols were compared. The findings of this study suggest that when high intensity cycle ergometer resistive forces are derived from FFM, greater peak powers can be obtained consistently in karate athletes. Resistive forces that relate to the active muscle tissue utilised during this type of exercise may need to be explored in preference to protocols that include both lean and fat masses. The findings have implications for both exercise prescription and the evaluation of experimental results concerning karate athletes.

KEY WORDS: Anaerobic performance, body composition.

INTRODUCTION

Performances that principally involve short bursts of heavy exercise, such as karate combat rely predominantly on the immediate (ATP-Pc) and short-term (glycolysis) energy production systems. The ability to utilise high-energy phosphate stores very quickly during karate performance is desirable and may be considered as one aspect of "power" (Inbar et al., 1996). Individual differences in power production may be the result of greater muscle mass, or a greater proportion of fast twitch fibres which posses higher ATP-Pc enzymatic activity (Dotan and Bar-Or, 1983). Performance during high intensity cycle ergometry may be highly related to individual fat - free mass, or the mass of the muscles that perform the test (Baker et al., 2001; Van Mil et al., 1996). Methods for quantifying and measuring high intensity performance have received considerable attention in recent years. The assumption has been that the relationship between total - body mass (TBM) and fat - free mass (FFM) is the same. However, variations in body composition between participants may under or over estimate resistive forces used in high intensity cycle ergometry power assessment. This may lead to spurious calculations of power. During karate training and competition, emphasis is placed on the development of powerful techniques delivered in the fastest time possible. We have demonstrated previously that karate fighters possess high anaerobic ability (Baker et al., 1995). In a more recent study, Baker et al. (2001) observed that greater power outputs were obtainable when resistive forces were derived from FFM during high intensity cycle ergometry. The aim of this study was to investigate any variation in power profiles generated in a group international karate practitioners during brief high intensity cycle ergometry exercise, when resistive forces used were derived from TBM and FFM.

METHODS

Male karate practitioners (n = 11) volunteered as participants. Each member of the group was selected on the basis that they had competed at either Welsh or British International level and had trained actively in Karate three times a week for at least four years. The average year's of training for the group was 6 ±1.9 yrs. The study was approved by the local ethics committee and before experimental data collection all participants read and completed an informed consent form. Prior to testing participants were fully habituated to the experimental procedures, on three occasions, at the same time of day as the actual tests (morning between 9.00. and 11.00.am). The study was designed using a single blind randomised crossover design.

Two rest days with no physical activity (including karate competition and training) preceded each test and participants attended the laboratory following a 12 h overnight fast. For six weeks prior to data collection, and throughout the study, participants refrained from additional vitamin and dietary supplementation. No appreciable deviations from their normal eating habits were recorded during this period (Nutri-Check, Health Options LTD, Eastbourne, UK).

Terminology

Throughout the study peak power output (PPO) refers to the highest 1s value of power attained during each 8 s sprint.

Force velocity test

A force velocity test was performed to determine optimal resistive forces for the TBM and FFM protocol's (Jaskolska et al., 1999). Briefly, the test consisted of six short maximal sprints of 8 s duration against randomly assigned resistive forces (70, 75, 80, 85, 90, 95 $g \cdot kg^{-1}$ TBM or FFM). The resistive forces used were multiplied by the individual participants TBM or FFM to obtain appropriate ergometer cradle resistive forces for each protocol. The resistive force that produced the highest PPO was considered optimal for each experimental condition. Successive exercise bouts were separated by a 5 min active rest period and comprised of participant's pedalling at 45 rpm with no resistive force on the ergometer cradle. Care was also taken to ensure that the resistive force applied to the cradle of the ergometer during experimental test conditions corresponded to the force applied at the flywheel. Recent research in our laboratory has identified a discrepancy in resistive force transmission for cradle resistive forces exceeding 9kg (Baker et al., 2005). Therefore, cradle resistive forces greater than 9kg were excluded from the study. A cycle ergometer (Monark 864) was calibrated prior to data collection (Coleman, 1996). 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. The same saddle height was used for both protocols. Feet were firmly supported by toe clips and straps. All participants were instructed to remain seated during the test and were verbally encouraged to perform maximally. All performed a standardised 5 minute warm up prior to data (Jaskolska et al., 1999). Participants were given a rolling start at 60 rpm for a 10 secs period subsequent to resistive force application. On the command 'go', the participants began to pedal maximally, the resistive force applied simultaneously, and data capture initiated. Indices of performance were calculated from flywheel revolutions using an inertia corrected computer program (Coleman, 1996). 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 underwater weighing procedures. Body density was assessed as described by Behnke and Wilmore, (1974). Relative body fat was estimated from body density using the equation of Siri (1956). Residual lung volume was measured using the simplified oxygen rebreathing method as outlined previously (Wilmore et al., 1980).

Statistical procedures

Data were examined using a computerised statistical package (SPSS). Conformation that all the dependent variables were normally distributed was assessed via repeated Kolmogorov-Smirnov tests. Differences between groups were analysed using Student's paired samples T-Test. Significance was accepted at the $p < 0.05$ level.

RESULTS

Physiological and anthropometric characteristics of participants are given in Table 1. Differences ($p < 0.05$) in peak power output (PPO) were found between the TBM and FFM protocols (1164 ± 137 W *vs.* 1289 ± 145 W respectively). Differences were also recorded ($p < 0.01$) between pedal velocity and resistive forces (127 ± 8 rpm *vs.* 142 ± 7 rpm; 6.6 ± 1.0 kg *vs.* 5.5 ± 1 kg respectively). No differences ($p > 0.05$) were observed for the time to reach PPO (3.2 ± 3.0 s *vs.* 3.0 ±1.0 s respectively), or heart rate (176 ± 8 bpm *vs.* 175 ± 8 bpm respectively) when the TBM and FFM exercise conditions were compared.

Table 1. Age and physiological characteristics of participants (n = 11). Data are means (±SD).

Age (yrs)	22.0 (1.36)
Height (m)	1.81 (0.08)
Mass (kg)	78.8 (10.3)
Fat (%)	16.5 (4.6)
Fat Free Mass (kg)	66.5 (7.0)

DISCUSSION

Differences ($p < 0.05$) in PPO were found between the TBM and FFM method of resistive force selection. The values recorded for PPO when the resistive forces reflected the FFM component of body composition indicate that karate practitioners have high peak powers when compared to other groups. Peak power profiles obtained in this study were greater than those reported in the literature. Specifically values were greater than data reported by Baker et al. (1995) among a sample of male karate fighters (1159 ± 110 W), Winter et al. (1991) among a sample of male physical education students (1007 ± 135 W), Nakamura et al. (1985) for a group of Japanese physical education students (930 ± 187 W) and greater than those reported by Vanderwalle et al. (1985) on a French sample (813 ± 137 W). The greater power outputs recorded in this study may be the result of the optimisation procedures used. However, the increases may also be attributed to individual training status and unknown genetic factors that may be independent of resistive force selection. The values recorded indicate that the FFM protocol produces lower optimal resistive forces (6.6 ± 1.0 kg TBM *vs.* 5.5 ± 1.0 kg FFM $p < 0.01$) resulting in higher power outputs, attributable to increases in maximal pedal velocity (127 ± 8 rpm TBM *vs.* 142 ± 7 rpm FFM $p < 0.01$). 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 participants. For example, total body mass values measured in this study were 78.8 ± 10.3 kg. The total fat % of the participants was 16.5 ± 4.6, demonstrating clearly the problems associated with optimisation procedures that are inclusive of the fat component of body composition. This problem may be more pronounced in populations with higher body fat values. The resistive force transferred to the ergometer cradle, based on TBM values does not represent accurately the active muscle tissue utilised during experimental conditions. These values may overestimate resistive force requirements, resulting in a decrease in pedal revolutions which has a negative effect on the power profiles produced. The FFM protocol may also represent a more finite way of externally loading the ergometer cradle. The more sensitive FFM load increases appear to be able to isolate and identify small changes in pedal velocity that the TBM protocol disregards. Vanderwalle et al., (1985) recorded values of 125 rpm for adult sprinters and 105 rpm for male recreational runners. The values recorded in this study for karate fighters were higher (127 ± 8 rpm TBM *vs.* 142 ± 8 rpm FFM) and reflects the high anaerobic nature of the discipline.

Power, is the composite product of two factors, strength and speed, therefore a range of results are possible with varying contributions from both components, especially when the criterion is optimisation of absolute maximal power (Inbar et al., 1996). This is true in the present study as greater power was achieved by increasing the resistive force and by increasing the number of pedal revolutions for both the TBM and FFM protocols. The observable inter participant differences recorded for the TBM and FFM protocols may be related to individual inability/ability 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 which may be inclusive of each individual karate fighter’s tactics and relative training status. Thorstensson et al. (1975) found evidence to confirm a greater proportion of type II fibers in athletes engaged in activities requiring short lived or sprint performances. The findings of this study indicate that karate fighters could also be in this category of athletes. The higher power output observed for the FFM protocol may have resulted from an initial preferential recruitment of fast twitch motor units, which may be attributable to the increase in pedal revolutions observed using this protocol. Studies on intact human muscles have reported that individuals with muscles containing a high proportion of type II fibers are capable of faster contraction velocities, and therefore greater force output (McCartney et al., 1983; Thorsstenson et al., 1975), but are more prone to fatigue during repeated dynamic contraction. Fatigue was not measured in this study, but previous studies have indicated no differences in fatigue profiles when the TBM and FFM protocols were compared (Baker et al., 2001). Nilsson et al., (1977) recorded a strong correlation between ratios of electro myographic activity to power associated with fatigue, in individuals with a high percentage of type II fibers, suggesting that diminished force was due to selective fiber attenuation. The increase in power output observed when the participants were optimised for FFM may be associated with increased voluntary command of the supra spinal centres. This greater contribution may increase fiber recruitment, by the optimisation of individual motor unit firing frequency, and by the synchronisation of the firing patterns between the motor units themselves (MacDougall et al., 1991). The findings of this study suggest that existing optimisation protocols need to be reassessed if true power output is to be attained. Increased PPO values resulting from higher pedalling velocities during optimisation procedures for FFM appear to maximise muscle contraction dynamics. These findings are in contrast with previous authors (Katch, 1974) who reported that body mass and leg volume were of little predictive importance during the early portion of a high intensity cycle ergometer test. However, other researchers (Baker et al., 2001; Blimkie et al., 1988; Dore et al., 2001; Inbar et al., 1996; Van mil et al., 1996) have found similar relationships to the findings observed in this study. Namely, that during high intensity cycle ergometry the power profiles generated are related to the participants FFM or to the mass of the muscles that perform the test.

CONCLUSION

The findings of this study indicate that elite karate fighters have high anaerobic abilities and are capable of producing powerful contractions and greater peak power outputs when resistive forces reflect the lean tissue component of body composition. The results also demonstrate that the total capacity, power and relative contribution of the energy systems involved during experimental high intensity cycle ergometer exercise need re - evaluating. The present resistive forces used that are inclusive of TBM underestimate significantly attainable maximal power outputs in karate fighters. Procedures that give realistic values and relate to the active muscle tissue utilised during this type of exercise need to be explored in preference to methods that include both lean and fat masses. The findings have far reaching implications for exercise prescription, training programme design and evaluation of anaerobic performance assessment in athletic groups.

ACKNOWLEDGEMENTS

This work was supported by the British Karate Kyokushinkai (BKK) and by the International Federation of Karate (IFK).

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KEY POINTS

- Methods for quantifying and measuring high intensity performance using high intensity cycle ergometry have received considerable attention in recent years.
- The assumption has been that the relationship between total - body mass (TBM) and fat - free mass (FFM) is the same.
- However, variations in body composition between participants may under or over estimate cradle resistive forces used in high intensity cycle ergometry power assessment.
- This may lead to spurious calculations of power.
- The findings of this study demonstrate that the total capacity, power and relative contribution of the energy systems involved during experimental high intensity cycle ergometer exercise need re - evaluating.

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