Abstract. Literature has established strong relationships between some anthropometric and strength measures with rowing performance. However, these studies have not correlated rower’s success with absolute (watt average) and relative weight values (watts per unit weight). The aim of this study was to correlate performance and efficiency in rowing with anthropometric and strength factors. Twenty-two elite rowers (11 male and 11 female) volunteered to participate in this study. Anthropometric measurements and body composition was obtained for each rower. Participants performed 2000 m maximal effort on a Concept II rowing ergometer and strength lower extremities were evaluated with jump height protocol using a jump mat (Chronojump-Boscosystem, Barcelona, Spain). Performance and efficiency in rowing ergometer test strongly correlated with anthropometric characteristics of height ($r$=0.873; $r$=0.815), weight ($r$=0.894; $r$=0.703), body muscles ($r$=0.973; $r$=0.829) and free body fat ($r$=0.705; $r$=0.856). However, positive correlations of strength factors with performance and efficiency in rowers have not been strong enough to use them like success predictors. This study concludes that present results provide an argument for coaches and rowers to increase strength training and to use anthropometric characteristics to predict rowing efficiency and use strength factors as such complementary performance predictor. Furthermore, anthropometric variables could be used to identify success in potential rowers.

Keywords: Chronojump-Boscosystem, performance, rowing, strength, anthropometry.
coordinating, mechanical power, and anaerobic lactic and alactic metabolism of lower extremities.

Methodology

Subjects

Twenty-two elite rowers (11 male, 11 female) volunteered to participate in this study. They were informed of the experimental procedures, previously approved by the research ethics committee of the University of Alicante, and any potential risks involved. Subjects were training regularly 5-7 times per week for the last 3-5 years. Measurements took place at the finishing of the competition period. The mean ± SD characteristics of these rowers were age: 25.5 ± 3.7 years old; height: 174.7 ± 9.6 cm; and weight: 72.1 ± 10.7 kg.

Procedure design

Rowers performed 2000 meters maximal rowing test on rowing ergometer (Model D, Concept 2, Inc., Morrisville, VT, USA) (Akça, 2014; Gee et al., 2016). All rowers were familiarised with the instrument since they have used extensively during their everyday training. Before the test, participants warm up by rowing sub-maximally for five minutes (Gee et al., 2012), followed by a series of joint mobility exercises and dynamic stretches for the main muscle groups.

Strength and power of lower extremities were evaluated with three squat jumps (SJ), three countermovement jumps (CMJ) (Ferrero, 2007; Gee et al., 2012, 2016; Asencio, Sánchez, & González, 2016), and one repeat jump (RJ), using a jump mat (Chronojump-Boscosystem, Barcelona, Spain), which has been demonstrated as valid and reliable against other indirect measurements systems (Paco, Lipińska, Jiménez-Orlindo, Zmijewski, & Hopkins, 2016).

For SJ, rowers flexed knees to 90 degrees, held this position for 3 seconds and performed the jump without any countermovement. In CMJ tests, participants began from a standing position, with hands on hips, to make an eccentric movement bending legs to an angle of 90 degrees to jump, immediately after, as high as possible. Last test was RJ, during 30 seconds, following the same indications as the CMJ but continuously.

The elastic index was calculated with the difference between two jumps (SJ and CMJ). Mechanical Power (MP) (W/kg) was calculated with Test time (Tt = 30 s), Flight time (Ft) and number of jumps (n), where g (9.81 m/s²) is gravitational acceleration: MP = (g 2 · Tt · Ft) / [4n · (Tt – Ft)]. To calculate the Resistance Index (RI) to fast strength, the average height reached in RJ was related to CMJ height: RI = RJ / CMJ.

Data analysis

The Statistical Package for Social Sciences (SPSS) v.22 software was used to analyse data. A Kolmogorov-Smirnov normal test was which resulted in a normal distribution, so the statistical test applied was Pearson correlation coefficient (r) to determine the relationships with performance of all measured parameters. Variables that correlated higher than 0.70 have been considered as enough strong associations (Martínez, Sánchez-Villegas, Toledo, & Faulin, 2014) to determinate higher than 0.70 have been considered as enough strong associations with performance (Gee et al., 2016; Akça, 2014; Feros, Young, Rice, & Talpey, 2012). Literature that collects studies that correlated strength, power and muscular endurance measures from weight room exercises seemed to be strong predictors of specific ergometer tests used to assess elite rowers (Lawn et al., 2013; Lawn et al. (2013) and Russell, Le Rossignol, & Sparrow (1998) claimed that absolute maximal strength, but not relative maximal strength (kilograms, body fat percentage (r=−0.705). However, no correlation has been found with muscle mass percentage (r=0.495). On the other hand, efficiency also strongly correlates with height (r=0.815), weight (r=0.703), body muscle kilograms (r=0.829) and body fat percentage (r=0.856), but not with body muscle percentage (r=0.584).

Leg strength tests resulted in mean jumps height of 28.14±4.62 cm for SJ, 30.08±5.32 cm for CMJ and 21.52±5.32 cm for RJ. Analysis of lower limbs strength by means of SJ tests, which assess explosive strength and recruitment of muscle units, showed no correlation with performance (r=0.489) and efficiency (r=0.604). Similarly, CMJ tests, which assess explosive strength, recruitment of muscle units, reuse of elastic energy and muscular coordination, resulted in a lack of correlation with performance (r=0.560). Finally, analysis of RJ test, which evaluates mechanical power and lactic and alactic anaerobic metabolism, also showed no correlation with performance (r=-0.523) and efficiency (r=-0.652) in 2000 m rowing test. None of the correlations can be considered strong enough to choose it as performance or efficiency predictors, except CMJ test with efficiency (r=0.709).

Analysis of jump tests revealed a mean elastic index value of 1.94±2.19, mechanical power 16.48±3.31 W/kg and resistance index to fast strength of 0.71±0.10. Mechanical power obtained with the RJ test results does no correlate with performance (r=0.453) and efficiency (r=0.602). On the other hand, elastic index of the extensor muscles of legs also fails to correlate with efficiency (r=0.447). Therefore, no significant values of correlation between resistance index to fast strength and performance or efficiency in 2000 m rowing test were found.

Discussion

Several studies have discussed that anthropometric characteristics may have influence on rowing success (Bourgois, 2000; Podstawski, Choszcz, Konopka, Klímač, & Starczewski, 2014; Yoshiga & Higuchi, 2003b). Agreeing with the results of the current study higher body height, body weight, body muscle kilograms and less body fat are strongly correlated with 2000 m rowing ergometer test. These data coincide with Izquierdo-Gabarre & de T xabari (2010) where rowers with higher body mass (p<0.05) and fat free body mass (p<0.05) reach shorter time in the 2000 m test (p<0.05). Most successful rowers in the study made by Mikulic (2009) were taller and heavier, with higher sitting height and lower fat mass than performance rowers in 6000 m rowing ergometer test. Furthermore, these significant correlations do not only happen in studies with highest level rowers but also with university rowers (Akça, 2014; Cosgrove, Wilson, Watt, & Grant, 1999) in which results body height and body mass were strongly correlated with rowing ergometer performance. Yoshiga & Higuchi (2003a) also find strong correlations between rowing success and height, body mass, fat-free mass and bilateral leg extension in their study with 332 rowers.

Results of the last studies show significant relationships between strength values and performance (Gee et al., 2016; Akça, 2014; Feros, Young, Rice, & Talpey, 2012). Literature that collects studies that correlated strength, power and muscular endurance measures from weight room exercises seemed to be strong predictors of specific ergometer tests used to assess elite rowers (Lawn et al., 2013; Lawn et al. (2013) and Russell, Le Rossignol, & Sparrow (1998) claimed that absolute maximal strength, but not relative maximal strength (kilograms,
Newton, or watts per unit weight), is a strong discriminator of rowing. However Izquierdo-Gabarren et al. (2010) carried out an eight-weeks concurrent strength and endurance-training program using a moderate number of repetitions not to fail and demonstrated increases in strength, muscle power and rowing performance. Knee extension represents the main force-producing activity of the stroke (Pollock et al., 2012) and strength and power leg appear to be an essential physical characteristics in rowing (Gee et al., 2012). Furthermore, it is important to emphasize not only the importance of knee extension but also the gain produced by the countermovement of legs in stroke cycle where mainly quadriceps and hamstring muscles are applied (Guével et al., 2011). However, although this study shows a positive correlation between SI, CMJ and RJ tests with performance demonstrating the importance of leg strength, associations are not strong enough to use only jump tests results to predict performance in 2000 m rowing ergometer test. Only the height reached in the CMJ test has been strongly correlated with the efficiency in 2000 m rowing ergometer test, in accordance with Chun-Jung et al. (2007), where rowers jumped 42.6±10.7 cm in CMJ test and also correlated significantly with 2000 m rowing test.

Conclusions

The current study identifies anthropometric characteristics like performance factor of rowing performance. High height and weight are good predictors of performance and efficiency in rowing ergometer. Rowers with higher muscle mass and less percentage of body fat reached better performance and efficiency. Leg strength has to be trained and increased in rowers with the aim to improve rowing performance. Although explosive elastic strength strongly correlates with efficiency in rowing ergometer, explosive strength, explosive elastic strength and power do not seem to be a good predictor of performance and efficiency in 2000 m rowing ergometer test. These strength manifestations can be considered as complementary performance and efficiency predictors to others, such as anthropometric characteristics.

We conclude that these results provide an argument for coaches to submit their rowers to endurance strength training and power muscular training but not to use strength as only performance predictors. Furthermore, anthropometric variables could be used to identify success in potential rowers.

References