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Performance conditional factors in rowing
Factores condicionales de rendimiento en remo

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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 performance using strength factors such as complementary performance predictor. Furthermore, anthropometric variables could be used to identify success in potential rowers.
Keywords: Chronojump-Boscosystem, performance, rowing, strength, anthropometry.

Resumen. La literatura ha establecido fuertes relaciones entre algunas medidas antropométricas y de fuerza con el rendimiento en remo. Sin embargo, estos estudios no han correlacionado el éxito de los remeros con valores absolutos (media de vatios) y valores relativos de peso (vatios por unidad de peso). El objetivo de este estudio fue correlacionar el rendimiento y la eficiencia con factores antropométricos y de fuerza. Veintidós remeros de élite (11 chicos y 11 chicas) participaron voluntariamente en este estudio. Se obtuvieron las medidas antropométricas y la composición corporal de cada remero. Los participantes realizaron un test de máximo esfuerzo de 2000 m en un remoergómetro Concept II y la fuerza de las extremidades inferiores fue evaluada con un protocolo de salto con una plataforma de contacto (Chronojump-Boscosystem, Barcelona, España). El rendimiento y la eficiencia en el test de remoergómetro correlacionó fuertemente con las características antropométricas de altura (r=0.873; r=0.815), peso (r=0.894; r=0.703), masa muscular (r=0.973; r=0.829) and masa libre de grasa (r=-0.705; r=-0.856). Sin embargo, las correlaciones positivas de los factores de fuerza con el rendimiento y la eficiencia en remeros no ha sido lo suficientemente fuerte para usarlos como factores de éxito. Este estudio concluye que los presente resultados proporcionan un argumento para que entrenadores y remeros incrementen el entrenamiento de fuerza y para que puedan utilizar las caracterpotenciales zadas para identificar remeros potnciales. de fuerza como predictores complementarios de rendimiento. no ha sido lo ísticas antropométricas como predictores de rendimiento y eficiencia en remo utilizando los factores de fuerza como predictores complementarios de rendimiento. Además, las variables antropométricas podrían ser utilizadas para identificar remeros potenciales.
Palabras clave: Chronojump-Boscosystem, rendimiento, remo, fuerza, antropometría.

Introduction

Rowing is a whole-body strength-endurance sport in which competitive distance of 2000 metres is completed in 6–7 minutes (Jürimäe et al., 2010). Aerobic metabolism is the predominant system with a 67% of the total, and the remaining 33% refers to the anaerobic component, being 21% alactic and 12% lactic (Mäestu, Jürimäe, & Jürimäe, 2005; Roth, Hasart, Wolf, & Pansold, 1983; Shin, Choi, Lim, Cho, & Lim, 2015). Rowers perform approximately 230–260 strokes per race (Pollock, Jones, Jenkyn, Ivanova, & Garland, 2012; Volianitis & Secher, 2009) with a rate of 32-38 strokes per minute and can get a mean power of 450-550 Watts per stroke (Penichet-Tomas, Pueo, & Jimenez-Olmedo, 2016; Steinacker, Lormes, Lehmann, & Altenburg, 1998).

Several studies have verified strong relationships between some strength (Sánchez-Sixto, & Floría, 2017), anaerobic and anthropometric measures (Borges, Ruiz, & Argudo, 2017) with performance. Rowers use almost all muscles of the body and those with higher height, weight and sitting height have more possibilities to reach better performance (Akça, 2014; Mikulic, 2009; Yoshiga & Higuchi, 2003a). In conditions of heavy side or head wind, relatively small body sizes made the rowers more susceptible in on-water competition performance (Bourgois, 2000).

Boat speed and rowers strength are closely correlated (McNeely, Sandler, & Bamel, 2005; Pérez-Treus, Lorenzo-Buceta, & García-Soidán, 2015). One of the keys to achieve the fastest competition distance is to optimize technique to increase efficiency of force production (Penichet-Tomás et al., 2012; Pollock et al., 2012). Training programs of elite rowers are composed of rowing, ergometer exercises, race pace work (Petibois, Cazorla, & Déléris, 2003) and spend 10-20% of total training time to strength work (Gee, Caplan, Gibbon, Howatson, & Thompson, 2016; Gee, Olsen, Berger, Golby, & Thompson, 2011).

Many authors have previously identified relationships between strength and power with rowing performance (Gee et al., 2012). Secher (1975) analyzed strength of different levels that rowers were able to generate in an isometric rowing simulation. Heavyweight international rowers generated an average of 204 kg of force, national rowers generated 183 kg, and club rowers generated 162 kg. Muscular endurance, power and strength measures seemed reliable predictors of ergometer tests used to evaluate rowers (Lawton, Cronin, & McGuigan, 2013)

Legs, back and arms segments do not exhibit the same force capacity (Baudouin & Hawkins, 2002). Rowers produced just under half of drive power with their legs, trunk swing almost one-third and arms less than one-fifth, all values according to stroke (Kleshnev & Kleshnev, 1998). Authors who have investigated lower limbs have used squat, jump squat and leg press exercises and reported significant relationships with performance in rowing ergometer (Akça, 2014; Chun-Jung, Nesser, & Edwards, 2007; Jürimäe et al., 2010).

However, studies have focused on different categories with absolute values of weight (i.e. lightweight, heavyweight…) and correlated anthropometric measures and lower limbs strength of the rowers with the result in a 2000 meters rowing test, using maximum and sub-maximum strength evaluation methodologies. To the knowledge of the authors, no study has correlated performance in a 2000 meter rowing race with absolute and relative weight values (watts per unit weight) using plyometric muscular action tests since this methodology is commonly used to evaluate strength, not to correlate it with rowing race performance (Gee et al., 2012, 2016).

Therefore, the aim of this study is to correlate performance in 2000 meters rowing ergometer test (watt average) and efficiency (watts per unit weight) with anthropometric characteristics, explosive strength and recruitment of muscle units, explosive elastic strength and

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coordination, 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) (Ferrer, 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 direct measurements systems (Pueo, Lipinska, Jiménez-Olmedo, 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/s^2) is gravitational acceleration: $MP = (g\ 2 \cdot Tt \cdot Ft) / [4n \cdot (Tt – Ft)]$. 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 them as predictors of performance and efficiency in 2000 m rowing ergometer test. Significance was set at $p<0.05$ and $p<0.01$.

Results

Participants' body measures were height 174.73±9.63 cm and weight 72.05±10.69 kg. In the 2000 m rowing test, they reached a power mean value of 247.32 ± 74.49 W with mean efficiency of 3.37±0.61 W/kg. Anthropometric data show a mean muscle weight of 57.79±10.51 kg and a percentage body composition of muscle 79.29±5.58 % and fat 17.35±5.59 %. Mean values, rowing ergometer performance and efficiency analysis are reported in Table 1. Analysis exposes strong correlations between 2000 m rowing test performance and height (*r*=0.837), weight (*r*=0.894), body muscle kilograms (*r*=0.973) and body fat percentage (*r*=-0.705). However, no correlation has been found with body muscle 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±5.52 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.

Table 1. Mean, Pearson correlation coefficients and p-value for each variable versus 2000 m race performance and efficiency.

	Mean ± SD	Performance	Efficiency
		r	*r*
Anthropometry			
Height (cm)	174.73±9.63	0.873 †	0.815 †
Weight (kg)	72.05±10.69	0.894 †	0.703 †
Body muscle (kg)	57.79±10.51	0.973 †	0.829 †
Body muscle (%)	79.29±5.58	0.495 *	0.584 †
Body fat (%)	17.35±5.59	-0.705 †	-0.856 †
Leg strength			
SJ (cm)	28.14±4.62	0.489 *	0.604 †
CMJ (cm)	30.08±5.32	0.560 †	0.709 †
RJ (cm)	21.52±5.52	0.523 *	0.652 †
Elastic index	1.94±2.19	0.329	0.447 *
Mechanical power (W/kg)	16.48±3.31	0.453 *	0.602 †
Resistance index	0.71±0.10	0.316	0.374

† Significance $p<0.01$; * Significance $p<0.05$

Discussion

Several studies have discussed that anthropometric characteristics may have influence on rowing success (Bourgois, 2000; Podstawski, Choszcz, Konopka, Klimczak, & 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-Gabarren & de Txabarri (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 less 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 (Lawton et al., 2013). Lawton 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 SJ, 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 anthropometrics 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

Akça, F. (2014). Prediction of rowing ergometer performance from functional anaerobic power, strength and anthropometric components. *Journal of Human Kinetics*, *41*, 133–142.

Baudouin, A., & Hawkins, D. (2002). A biomechanical review of factors affecting rowing performance. *British Journal of Sports Medicine*, *36*(6), 396–402.

Borges, P. J., Ruiz, E., & Argudo, F. M. (2017). Relationship among anthropometric parameters, maximal grip and throwing velocity in youth water polo players. *Retos. Nuevas Tendencias En Educación Física, Deporte Y Recreación, 31*, 212-218.

Bourgois, J. (2000). Anthropometric characteristics of elite male junior rowers. *British Journal of Sports Medicine*, *34*(3), 213–216.

Chun-Jung, C. J., Nesser, T. W., & Edwards, J. E. (2007). Strength and power determinants of rowing performance. *Journl of Exercise Physiology Online*, *10*(4), 43–50.

Cosgrove, M. J., Wilson, J., Watt, D., & Grant, S. F. (1999). The relationship between selected physiological variables of rowers and rowing performance as determined by a 2000m ergometer test. *Journal of Sport Sciences*, *17*(11), 845–852.

Feros, S. A., Young, W. B., Rice, A. J., & Talpey, S. W. (2012). The effect of including a series of isometric conditioning contractions to the rowing warm-up on 1,000-m rowing ergometer time trial performance. *Journal of Strength and Conditioning Research*, *26*(12), 3326–3334.

Ferrer, M. C. (2007). Efectos de dos métodos de entrenamiento de fuerza sobre el Índice de Bosco en jugadoras de balonmano de División de Honor. *Retos. Nuevas Tendencias En Educación Física, Deporte Y Recreación*, (11), 33–36.

García, C., Sánchez, M., & González, J. J. (2016). Combined strength and jump exercises training, effects on the vertical jump performance in a group of senior elite male volleyball players during a complete competition season. *Retos. Nuevas Tendencias En Educación Física, Deporte Y Recreación, 29*, 140-143.

Gee, T. I., Caplan, N., Gibbon, K. C., Howatson, G., & Thompson, K. G. (2016). Investigating the effects of typical rowing strength training practices on strength and power development and 2,000 m rowing performance. *Journal of Human Kinetics*, *50*, 167–177.

Gee, T. I., Olsen, P. D., Berger, N. J., Golby, J., & Thompson, K. G. (2011). Strength and conditioning practices in rowing. *Journal of Strength and Conditioning Research*, *25*(3), 668–682.

Gee, T. I., Olsen, P. D., Fritzdorf, S. G., White, D. J., Golby, J., & Thompson, K. G. (2012). Recovery of rowing sprint performance after high intensity strength training. *International Journal of Sport Scence & Coaching*, *7*(1), 109–120.

Guével, A., Boyas, S., Guihard, V., Cornu, C., Hug, F., & Nordez, A. (2011). Thigh muscle activities in elite rowers during on-water rowing. *International Journal of Sports Medicine*, *32*(2), 109–116.

Izquierdo-Gabarren, M., & de Txabarri, R. G. (2010). Physiological factors to predict on traditional rowing performance. *European Journal of Applied Physiology*, *108*(1), 83–92.

Izquierdo-Gabarren, M., González De Txabarri Expósito, R., García-Pallarés, J., Sánchez-Medina, L., De Villarreal, E. S., & Izquierdo, M. (2010). Concurrent endurance and strength training not to failure optimizes performance gains. *Medicine & Science in Sports & Exercise*, *42*(6), 1191–1199.

Jürimäe, T., Perez-Turpin, J. A., Cortell-Tormo, J. M., Chinchilla-Mira, I. J., Cejuela-Anta, R., Mäestu, J., … Jürimäe, J. (2010). Relationship between rowing ergometer performance and physiological responses to upper and lower body exercises in rowers. *Journal of Science and Medicine in Sport*, *13*(4), 434–437.

Kleshnev, V., & Kleshnev, I. (1998). Dependence of rowing performance and efficiency on motor coordination of the main body segments. *Journal of Sport Science*, *16*(5), 419–419.

Lawton, T. W., Cronin, J. B., & McGuigan, M. R. (2013). Strength, power, and muscular endurance exercise and elite rowing ergometer performance. *Journal of Strength and Conditioning Research*, *27*(7), 1928–1935.

Mäestu, J., Jürimäe, J., & Jürimäe, T. (2005). Monitoring of performance and training in rowing. *Sport Medicine*, *35*(7), 597–617.

Martínez, M. A., Sánchez-Villegas, A., Toledo, E. A., & Faulin, J. (2014). *Estadística amigable* (3ª Edición). Barcelona: Elsevier.

McNeely, E., Sandler, D., & Bamel, S. (2005). Strength and power goals for competitive rowers. *Strength and Conditioning Journal*, *27*(3), 10–15.

Mikulic, P. (2009). Anthropometric and metabolic determinants of 6,000-m rowing ergometer performance in internationally competitive rowers. *Journal of Strength and Conditioning Research*, *23*(6), 1851–1857.

Penichet-Tomás, A., Jiménez-Olmedo, J. M., Saiz-Colomina, S., Jove-Tossi, M. A., Martínez-Carbonell, J. A., & Silvestre-García, M. (2012). Incidence injury analysis on rowers in the spanish mediterranean fixed bench championship 2012. *Journal of Human Sport and Exercise*, *7*(3), 648–657.

Penichet-Tomas, A., Pueo, B., & Jimenez-Olmedo, J. M. (2016). Relationship between experience and training characteristics with performance in non-Olympic rowing modalities. *Journal of Physical Education and Sport*, *16*(4), 1273–1277.

Pérez-Treus. S., Lorenzo-Buceta, H., & García-Soidán, J. L. (2015). Dynamical and kinematic evolution of the 200m test in senior sprint kayakers. *Retos. Nuevas Tendencias En Educación Física, Deporte Y Recreación*, *27*, 118-121.

Petibois, C., Cazorla, G., & Déléris, G. (2003). The biological and metabolic adaptations to 12 months training in elite rowers. *International Journal of Sports Medicine*, *24*(1), 36–42.

Podstawski, R., Choszcz, D. J., Konopka, S., Klimczak, J., & Starczewski, M. (2014). Anthropometric determinants of rowing ergometer performance in physically inactive collegiate females. *Biology of Sport*, *31*(4), 315–321.

Pollock, C. L., Jones, I. C., Jenkyn, T. R., Ivanova, T. D., & Garland, S. J. (2012). Changes in kinematics and trunk electromyography during a 2000m race simulation in elite female rowers. *Scandinavian Journal of Medicine and Science in Sports*, *22*(4), 478–487.

Pueo, B., Lipinska, P., Jiménez-Olmedo, J. M., Zmijewski, P., & Hopkins, W. G. (2016). Accuracy of jump-mat systems for measuring jump height. *International Journal of Sports Physiology and Performance*, *In press*.

Roth, W., Hasart, E., Wolf, W., & Pansold, B. (1983). Untersuchungen zur dynamic der energiebereitstellung während maximaler mittelzeitaus dauerbelastung. *Medicine and Sport*, *23*, 107–114.

Russell, A. P., Le Rossignol, P. F., & Sparrow, W. A. (1998). Prediction of elite schoolboy 2000m rowing ergometer performance from metabolic, anthropometric and strength variables. *Journal of Sports Sciences*, *16*(8), 749–754.

Sánchez-Sixto, A, & Floria, P (2017). Effects of combinated plyometric and resistance training in biomechanical variables of the vertical jump in basketball players. *Retos. Nuevas Tendencias En Educación Física, Deporte Y Recreación, 31*, 114-117.

Secher, N. H. (1975). Isometric rowing strength of experienced and inexperienced oarsmen. *Medicine and Science in Sports*, *7*(4), 280–283.

Shin, K.-Y., Choi, E.-H., Lim, J.-Y., Cho, A.-R., & Lim, Y.-H. (2015). Effects of indoor rowing exercise on the body composition and the scoliosis of visually impaired people: a preliminary study. *Annals of Rehabilitation Medicine*, *39*(4), 592–598.

Steinacker, J. M., Lormes, W., Lehmann, M., & Altenburg, D. (1998). Training of rowers before world championships. *Medicine & Science in Sports & Exercise*, *30*(7), 1158–1163.

Volianitis, S., & Secher, N. H. (2009). Rowing, the ultimate challenge to the human body - implications for physiological variables. *Clinical Physiology and Functional Imaging*, *29*(4), 241–244.

Yoshiga, C. C., & Higuchi, M. (2003a). Bilateral leg extension power and fat-free mass in young oarsmen. *Journal of Sports Sciences*, *21*(11), 905–909.

Yoshiga, C. C., & Higuchi, M. (2003b). Rowing performance of female and male rowers. *Scandinavian Journal of Medicine & Science in Sports*, *13*(5), 317–321.