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RESUMEN
Objetivo: El piragüismo es una modalidad deportiva cíclica que demanda grandes exigencias funcionales del tronco y de los miembros superiores y está caracterizada por un entrenamiento multilateral que pone especial énfasis en el desarrollo de la fuerza muscular. Este estudio pretende establecer las correlaciones existentes entre la fuerza máxima, la fuerza explosiva y la resistencia a la fuerza en los ejercicios de press banca y dorsal remo y la velocidad (V) media en kayak en las dos distancias olímpicas: 500 m y 1000 m.

Material y métodos: Siete kayakistas pertenecientes a la elite Portuguesa realizaron dos competiciones de 500 m y 1000 m, en una prueba de selección para la participación en el Campeonato del Mundo de la modalidad. Los tests de fuerza fueron realizados dos días después de las competiciones en agua. Los procedimientos estadísticos utilizados fueron: media, desviación típica, coeficiente de variación y coeficiente de correlación producto de Pearson. El nivel de significación estadística se fijó en el 5%.

Resultados: Se verificaron correlaciones positivas y significativas entre la V media en los 500 m (V500m) y la fuerza máxima absoluta (0.784; p<0.05) y la fuerza máxima relativa (0.795; p<0.05) en el test de dorsal remo; y entre la V1000m y la resistencia a la fuerza absoluta (0.865; p<0.01) y resistencia a la fuerza relativa (0.788; p<0.05) en el mismo ejercicio. No se obtuvieron correlaciones significativas entre ninguno de los tests de fuerza en press banca y las V1000m o V500m. Sólomente la masa corporal tuvo correlación positiva con V1000m (r=0.828; p<0.05).

Conclusión: Aunque se hayan obtenido correlaciones estadísticamente significativas entre algunas expresiones de la fuerza en el ejercicio de dorsal remo (bench-rowing) y la V media en las pruebas de 500 m y 1000 m, no podemos concluir que la mejora de la fuerza en dicho ejercicio se traduzca directamente en una mejora en el rendimiento en agua de los piragüistas. La correlación obtenida puede ser circunstancial. Estudios con mayor número de sujetos y diferentes niveles de rendimiento para poder confirmar o refutar nuestra postura.

Palabras clave: piragüismo; fuerza; rendimiento; antropometría.

ABSTRACT
Background: Kayaking is a cyclic sport which makes great demands on the upper part of the body and is characterized by multilateral training with special focus on strength development. So, the main purpose of this study was to establish the correlations among maximum-, explosive-, and endurance-strength in bench-press and bench-rowing, and average kayak velocity over two Olympic distances – 500m (V500) and 1000m (V1000). Other variables (age, body weight, height, seated-height, arms’ span, and years of practice) were also correlated with V500 and V1000.

Methods: Seven elite Portuguese kayakers performed two races – 500m and 1000m - in a selective contesting toward the participation in the World Championship. Strength tests were realized two days after the flat water races. Furthermore, anthropometric measurements were obtained in resting state. The statistical procedures utilized were: mean, standard-deviation, variance coefficient and the Pearson product-moment correlation coefficient. P < 0.05 was regarded as significant.

Results: There was a significant and positive correlation among V500 and absolute maximum strength (r = 0.784; p<0.05) and relative maximum strength (r = 0.795; p<0.05) on bench-rowing and among V1000 and absolute strength endurance (r = 0.865;p<0.01) and relative strength endurance (r = 0.788;p<0.05) in the same exercise. There were no significant correlations among any bench press strength tests results and V1000 or V500. Only body weight correlated positively with V1000 (r = 0.828; p<0.05).

Conclusion: In despite of the significant correlations verified among bench-rowing strength tests and V500 and V1000, we don’t want to conclude about the linear relationship between bench rowing strength capabilities and kayak performance. This correlation can be derived from the reduced number of the sample or other circumstantial reasons. However, further studies involving larger number of subjects with different levels of performance are needed, to confirm or reject our statement.

Key words: kayaking; strength; performance; anthropometry.
INTRODUCTION

Strength exercises are normally introduced in basic training programs for endurance sports, typically in rowing, swimming, and canoeing. The main objectives for strength training in these sports are to improve basal force as well as to reduce the deleterious effect of endurance adaptations in basal force what presumably can affect performance. It’s supposed that strength training can negatively interfere with specific adaptations induced by endurance training and vice-versa. Some studies verified the deterioration of strength levels by concurrent training of strength and endurance (13) while others verified that concurrent training doesn’t affect strength gains (4). Sale et al. (26) verified that concurrent training did not interfere with strength or endurance development, in comparison to strength or endurance training alone. Dudley & Djamil (10), stated that concurrent training (strength + endurance) decreased maximal knee-extension torque at higher speed of contraction while the same movement at low speed was not affected. In this study (10) it was verified that strength training does not impair maximal aerobic power developed by endurance training. Other studies demonstrated that strength training can improve performance in short-term endurance exercises (4 to 6 min) as well in more prolonged endurance exercises (12, 13,14). However, Kramer et al. (18) have shown that the combination of strength and endurance training attenuates performance improvements and physiological adaptations typical of single-mode training. Even in elderly patients with COPD, the improvement in muscle strength does not translate into additional improvement in exercise performance or muscle fatigability when compared to that achieved by endurance exercise alone (21). We think that exercise mode can justify part of the differences showed in literature. In that sense, Chtara et al. (7) have shown that circuit training can improve aerobic capacity while strength training with heavier loads seems to be incompatible with endurance improvement (4).

Typically, strength training involves large muscle groups, performing high loads with few repetitions directed to improvement of the capability to develop high muscular tensions. However, endurance sports utilize different resistance-training regimes with varied combinations of high- and low-intensity exercises, and different velocities of contraction.

Kayaking strength training searches for the biomechanical profile developed in water, selecting strength exercises that can simulate the specific tension of the stroke (9).

Understanding the relationship between strength and performance in water has potential implications for training. The purpose of this study was to verify the correlation among maximum-strength, explosive-strength, and endurance-strength obtained in two designed specific strength exercises – bench press and bench rowing – and kayaking performance (average velocity) obtained in the two Olympic flat water distances – 500-m and 1000-m. Complementary, other variables (age, body weight, height, seated-height, arms’ span, and years of practice) were also correlated with water performance.

METHODS

Subjects

Seven elite Portuguese kayakers, simultaneously finalists in the two Olympic racing distances (500-m and 1000-m) in a selective competition toward the participation in the World Championship, participated in this study. The subjects participated with their own kayak (K1) and paddle. The subjects were informed about the design of the study and, after informed about the eventual risks and discomfort, they gave a signed consent prior to the start of the study. The study was conducted according to the declaration of Helsinki and was approved by the Ethics Committee of
the Scientific Council of the Sport’s Faculty of the University of Porto, Portugal.

**Water Tests Procedures**

The subjects performed, individually, two races, 500-m and 1000-m. Racing timing was converted into mean velocity (m/s). Wind and water conditions as well as weather conditions were neglected because impossible to control, however all the subjects performed in the same external conditions that didn’t change during testing time.

**Strength Tests Procedures**

Strength tests were accomplished two days after the selective races on water. Strength tests (maximum-strength, explosive-strength and endurance-strength) in the two selected exercises - bench press and bench rowing - were recorded in video to assess the distance covered during each repetition. Maximum-strength test performed the maximum number of repetitions with a 90 kg load. Maximum strength given by one repetition maximum (1 RM) was indirectly determined using a conversion table (24).

Explosive-strength test was realized using a load corresponding to 50% of maximum-strength, performing the maximum number of repetitions during 30 s at maximal speed. Endurance-strength test was realized using a load corresponding to 50% of maximum-strength, performing the maximum number of repetitions till fatigue. To assess total work (kgm or kgm/s) and relative work (kgm/kg body weight or kgm/s/kg) the amplitude of movement for each repetition, was registered.

**Statistical Analyses**

The statistical procedures utilized were: mean, standard-deviation, variance coefficient and the Pearson product-moment correlation coefficient. The p<0.05 criterion was used for establishing statistical significance.

**RESULTS AND DISCUSSION**

Mean velocities obtained in the water races over 500-m (V500) and 1000-m (V1000) are presented in table 1.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (±SD)</th>
<th>Correlation with V500</th>
<th>Correlation with V1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>V500</td>
<td>4.60 ± 0.19 m/s</td>
<td>0.647</td>
<td>0.480</td>
</tr>
<tr>
<td>V1000</td>
<td>4.15 ± 0.18 m/s</td>
<td>0.729</td>
<td>0.244</td>
</tr>
</tbody>
</table>

Table 1. Mean velocities (±SD) over 500-m and 1000-m

Correlations among several parameters and performance in water are presented in table 2. It was verified a positive and significant correlation between V1000 and body weight (b.w.). This study also demonstrated a significant and positive correlation between maximum-strength (kg and kg/kg b.w.) in bench-rowing and V500 and endurance-strength (kgm and kgm/kg b.w.) in bench-rowing and V1000. No significant correlation was obtained among V500 and V1000 and any strength expression in bench-press.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (±SD)</th>
<th>Correlation with V500</th>
<th>Correlation with V1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.7 ± 2.9</td>
<td>0.600</td>
<td>-0.357</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>78.2 ± 2.5</td>
<td>0.464</td>
<td>0.828*</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.8 ± 4.2</td>
<td>0.104</td>
<td>0.224</td>
</tr>
<tr>
<td>Seated height (cm)</td>
<td>93.1 ± 2.8</td>
<td>0.099</td>
<td>-0.103</td>
</tr>
<tr>
<td>Arms' spam (cm)</td>
<td>188.2 ± 5.0</td>
<td>0.223</td>
<td>0.387</td>
</tr>
<tr>
<td>Years of practice</td>
<td>9.7 ± 3.7</td>
<td>0.596</td>
<td>0.323</td>
</tr>
</tbody>
</table>

Table 2. Correlations among strength tests, anthropometric parameters, age and years of practice and V500 and V1000 (* Significant p<0.05 ** significant p<0.01).
Discussion

High individual performance in sprint kayaking is not directly dependent upon anthropometric parameters. Although, Ackland et al. (1) have demonstrated that participants in Olympic sprint paddling events can be considered as homogeneous in shape and physical size, out of Olympic participants, several studies (table 3) stated remarkable differences in averages values for height and body weight of elite kayakers.

<table>
<thead>
<tr>
<th>Country and Reference</th>
<th>Age (years)</th>
<th>Body weight (kg)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portugal(n=7) Present study</td>
<td>23.7 ± 2.9</td>
<td>78.2 ± 2.5</td>
<td>180.8 ± 4.2</td>
</tr>
<tr>
<td>Australia(n=13) Telford &amp; Cunningham (30)</td>
<td>22.5 ± 2.4</td>
<td>80.4 ± 3.7</td>
<td>180.4 ± 4.4</td>
</tr>
<tr>
<td>Hungary(n=9) Csende et al. (8)</td>
<td>26.0 ± 2.7</td>
<td>87.4 ± 6.3</td>
<td>184.5 ± 9.1</td>
</tr>
<tr>
<td>Italy(n=7) Faina et al. (11)</td>
<td>23.0 ± 6.0</td>
<td>74.0 ± 11.0</td>
<td>177.0 ± 8.0</td>
</tr>
<tr>
<td>Sweden(n=6) Tesch (31)</td>
<td>22.0 ± 3.0</td>
<td>80.0 ± 6.0</td>
<td>185.0 ± 6.0</td>
</tr>
</tbody>
</table>

Table 3 Biometrical characterization of elite kayakers from different countries

In kayaking, in despite of the exceptions, elite are usually taller and heavier than non elite (12). Over the last years elite paddlers’ morphology trends toward a more compact and robust physique (1). Kayakers with higher lean body mass and lower fat mass compared with lighter kayakers, can have potential benefits despite of the greater inertia they display. In rowing, the more successful lightweight rowers were those who had lower body fat and greater total muscle mass (29). About 90% of hydrodynamic drag depends on boat shape and total wetted surface area while the remaining 10% depends on air resistance determined by cross-sectional area of paddlers plus shell (3). Although, from Newton laws, the greater the body mass the greater the force required to overcome its inertia, it seems that some added weight can be positive to kayak displacement. This statement can be particularly important for crews with two or four kayakers because smaller boats have larger drag coefficients, because they are shorter, their Reynolds numbers are smaller, and consequently the surface friction is larger (19).

In human powered water paddling sports (rowing, kayaking, canoeing) that have pulse type propulsion with the speed of the boat rising and falling with each stroke, it’s believed that added weight (increased inertia), under some conditions, with skilled athletes, can result in increased average speed. Comparing with swimming, kayak shell floats on water surface and has a low pressure drag what corresponds to better overall efficiency; for kayaking wetted surface area is the major determinant of drag (23) and is mainly determined by weight (paddler plus boat). As drag resistance only increases about 10% for a 20% increase in weight (27), inertial advantages for heavier paddlers can be justified.

In relation to Hungary elite, normally finalist and medallists in the great international competitions, the subjects of our study are lighter what can mean lesser muscle mass and strength. Misigoj-Durakovic & Heimer (22) stated that elite paddlers, in relation to height, present a high percent of lean body mass whose importance for performance was highlighted by Shephard (28). Because they carry more muscle mass, larger individuals tend to have higher absolute strength than smaller individuals what can have positive effect on performance.

In this study, age, height, seated-height, arms’ spam, years of practice and body weight, didn’t correlate with V500. However, body weight showed a significant correlation with V1000. This find is corroborated by Fry & Morton (12) that verified a significant correlation between body weight and performance over 1000-m. While significant correlation between body weight and V1000 was verified, no significant correlation between body weight and V500 was found. Although shorter maximal efforts depend more on power and strength (17), there is no direct relationship
between power and muscle mass. The same study demonstrated that weightlifters showed 45-55% higher power values than road cyclists and controls, whereas the differences in maximal strength and muscle mass were only 15% and 20%, respectively (17).

It’s difficult to establish a direct relationship between muscle mass and kayaking performance because a more suitable neural control of the specific skills as well as the improvement of other factors (e.g. maximal aerobic power), can overpass eventual relative deficits in muscle mass (25).

There was no significant correlation between seated-height and V500 and V1000. Our results conflict with Fry & Morton (12), who demonstrated a significant correlation between seated-height and the performance over 500-m, 1000-m, 10,000-m and 42-km in kayaking.

We think that more important than seated-height it’s arm’s length that can determine optimal biomechanical conditions for paddling (2). Upper body dimensions, arms included, are greater in kayakers of international level compared with those of national level (33) what give additional mechanical advantages derived from lever’s length (34). However, our study didn’t verify any significant correlation between arms’ span and V500 or V1000.

Complementary to the main objective of this study, we verified no correlation between bench press and bench rowing tests. Both exercises didn’t correlate with each other for maximum-strength, explosive-strength and endurance-strength.

Mean values for maximum-strength and explosive-strength are greater in bench press while mean values for endurance-strength are greater in bench rowing. This can signify a greater biomechanical similarity between bench rowing and paddling in water. We refuse this hypothesis. This difference can only signify the emphasis putted on bench rowing training because its hypothetic similarity with paddling. We don’t accept the hypothesis for the greater transfer from bench rowing to specific kayaking skills.

Strength exercises for kayaking, even strength exercises done into water (e.g. exercises with additional resistances), are unspecific exercises whose efficacy is given by strength increase. To claim that bench rowing is more specific for kayaking than bench press is not to see the logics for intra- and inter-muscular coordination. To search the paddling specificity by strength exercises, as desired by Delaere (9), can end into a double frustration, be the transfer ineffectiveness be the inefficiency of strength training. Even an exercise, supposedly specific, as paddling in a basin, induces a electromyographic pattern different from that obtained in free paddling into water (6).

No significant correlation was obtained among bench press strength tests and V500 or V1000. The inexistence of correlation between water performance and bench press strength tests can derive from the reduced number of subjects, but can also signify the relative importance of strength in kayaking. We agree with Jeremy West (personal communication) when he pointed out that “weight training is not the most important type of training that a canoeist can do, canoeing is” (35). However, Wisloff et al. (36) find a strong correlation between maximum strength obtained in semi-squat and sprint and jump performance. Strength is more related with explosive and sprint skills than with the specific endurance imposed by kayak races over the distances of 500-m and 1000-m.

There was a significant correlation between bench rowing strength tests and V500 and V1000. Maximum strength correlated with V500 and endurance strength correlated stronger with V1000. These correlations are, for us, circumstantial, and don’t express a superior relationship between bench rowing and the specificity of paddling. Strength tests never can be seen as modulators of sport’s skills but only as the best means to assess strength condition. Specific skills must modulate strength
gains, improving propulsive force. The dynamic pattern of paddling is impossible to simulate in ergometric devices or with free weight strength exercises (6). Even, the addition of hydro brakes to the boat alters the hydrodynamics decelerating the boat during the air transfer phase what distorts technique (16). Strength training can improve paddler’s general physical fitness (20), but the actualization of the increased physical capabilities only can be done by sufficient training with specific loads directed toward the optimal technique. Kayaking performance (flat water races) is supported by high muscular strength of the upper part of the body, anaerobic capacity and endurance in addition to a great aerobic power (31). A great aerobic power in addition to a great anaerobic capacity not absolute strength, are for us the main physical capabilities that determine performance in kayaking. Strength per se is not so important in endurance sports. This thesis is corroborated by Tesch & Lindeberg (32) who compared kayakers with bodybuilders, weight-lifters and power-lifters in a progressive arm-crank endurance exercise; kayakers showed greater exercise tolerance expressed by lower blood lactate concentrations for different exercise intensities despite lower levels of strength.

The anthropometric parameters as well as the years of practice seem not to be relevant for kayaking performance.

CONCLUSIONS

We can conclude that albeit our data point out to a significant correlation between some strength indices in bench rowing tests and V500 and V1000, we doubt about the linear relationship between any kind of strength expressions and kayaking performance. However, the reduced number of the sample don’t permit us to be more assertive and other studies are need to confirm or infirm our statement.

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