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Research article

THE RELATIONSHIP BETWEEN ANTHROPOMETRY AND LEG FREQUENCY MOVEMENT IN THE EGGBEATER KICK UNDER EXTERNAL LOADS IN WATER POLO

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Abstract. *We intend to investigate whether specific anthropometric characteristics and/or frequency of leg movement are related to the water-polo players' ability to resist external pressure during the eggbeater kick. Twenty-four male water-polo players participated in this study. Preliminarily, the participants' anthropometric characteristics were measured. Thereafter, a 20-sec eggbeater kick test was conducted in order to determine the minimum load the participants could resist. On the day of the experiment, each participant performed the 20-sec eggbeater kick test, starting from 10 kg and thereafter with a progressive increase of 1 kg external load until peak external load (PEL) was reached. The external load the players could effectively resist before the failed effort was considered the PEL. Significant correlations between the majority of anthropometric characteristics and PEL were observed (r=0.38 to 0.62, P<0.05). Multiple regression analyses revealed that stature and body mass explained the total variance of PEL by 67% and 58% respectively (P<0.05), while frequency of leg movements were also significant predictors explaining more than 45% of PEL variance (P<0.05). The factor analysis showed that anthropometric characteristics and leg frequency movements totally explained 80.42% of the PEL variance. However, the multiple regression analysis based on scores from the factor analysis revealed that only anthropometric characteristics were significant predictors of PEL during the eggbeater kick, explaining more than 37% of the total variance (P<0.05). The present study indicates that anthropometric characteristics are more important predictors of the performance of the eggbeater kick.*

Key words: *Performance test, water-polo players, stature, body mass.*

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INTRODUCTION

During a water-polo match-play, players perform swimming movements from the horizontal and vertical position. The eggbeater kick is a fundamental skill that is used for the execution of vertical movements and is performed to keep the athlete afloat in an upright position while performing other skills such as passing, shooting, defending, and attacking. Namely, it consists of cyclical actions with the motion of the right and left lower limbs in opposite phases (Sanders, 1999).

Water-polo is characterized by a high presence of body contact between the players (Platanou, 2004). Several match-analysis studies have shown that dynamic body contacts or even wrestling are often performed between opponent players and specifically between center forwards and center defenders (Platanou & Geladas, 2006; Smith, 1991). In particular, center forwards have to wrestle in an attempt to gain a better position executing the eggbeater kick under an opponent's external pressure, which is often performed on his/her shoulders by center defenders in an attempt to gain a better position and to steal the ball. During this game situation, an effective eggbeater kick would result in a greater height maintenance that may allow for a successful turning or shot from the center-forward. Resistance against an opponent's pressure is dependent on the forces generated upwards to raise the body reacting on the rival's pressure. The eggbeater kick consists of cyclical actions with the motion of the right and left lower limbs. In this action, the frequency of leg movement might play a crucial role in height maintenance and in resistance against external pressure.

Many studies in other team-sports have demonstrated the importance of anthropometric characteristics in performance success (Wong, Chamari, Dellal, & Wisloff, 2009; Van den Tillar, & Ettema, 2004). In aquatic sports, it has been suggested that body mass and body length might affect the total energy cost in swimming (Kjendlie, Imgjer, Stallman, & Stray-Gundersen, 2004), that some anthropometric characteristics are related to the 100 m freestyle time in swimming (Geladas, Nassis, & Pavlicevic, 2005), and that a greater body size might be advantageous in order to obtain better position in the pool and to reach and control passes in water polo (Tsekouras, et al., 2005). Furthermore, it has been observed that the greater the body length, the higher the throwing velocity of female water-polo players (Platanou & Varamenti, 2011). However, to our knowledge, no data exist on the influence that anthropometric characteristics have on an effective eggbeater-kick performed under external loads in water-polo.

Accordingly, the aim of the present study was to investigate whether specific anthropometrical characteristics and/or frequency of leg movements are related to the water-polo players' ability to resist external pressure during the eggbeater kick. We hypothesized that water-polo players' anthropometrics in conjunction with leg frequency would affect performance during the eggbeater kick under external loads.

METHODS

Participants

Twenty-four male water-polo players (age: 23.5±3.0 years, body height: 182.31±7.39 cm, body mass: 84.67±9.85 kg) volunteered to participate in this study. All the participants were elite water-polo players who participated in the First Greek National Division Championship. Written informed consent was obtained from all the players before the commencement of the study. All the procedures had the approval of the local

Ethical committee and conformed to the Declaration of Helsinki. All of the participants were tested on 2 different occasions: a preliminary exercise test and the main experimental trial: the eggbeater kick performance test.

Testing procedures

Preliminary testing

Several days before the main experiment, a preliminary exercise test was conducted in order to determine the minimum external load (kg) that the participants could resist during the eggbeater kick with hands in the water. For this purpose, loads were placed in a diving belt that was positioned on the participants' shoulders. In particular, ten participants performed a 20-sec eggbeater kick with hands in the water. The loads progressively increased per 5 kg in each attempt until the participants could not resist it. Twenty seconds is considered to be the maximal time a player is under external pressure executed by an opponent after two consecutive offences in water-polo. It was found that the minimum load that the players could resist was ~10 kg and consequently it was chosen as the baseline load for all participants.

A day prior to the main experimental test, the participants' anthropometric characteristics were measured. All of the measurements (arm length, forearm length, hand length, lower limb length, biceps girth at rest and after contraction and foot length) were performed according to the anatomical standards set by Ross & Marfell-Jones (1991). Body mass was measured without shoes on a standing scale (Bilance Salus, Italy) that was calibrated to 0.1 kg. Stature was measured without shoes on a wall-mounted stadiometer (Bilance Salus, Italy) with an accuracy of 0.001 m.

The eggbeater kick performance test

On the day of the experiment, after a 10-minute standardized warm-up (400-m freestyle swimming, 100-m breaststroke swimming), each participant was instructed to perform the eggbeater kick, starting from the baseline load of 10 kg placed on their shoulders, which lasted for 20 seconds. Thereafter, a progressive increase of 1 kg external load was performed until the participants could not resist the load as exhibited by touching the water with their mouth. The external load the players could effectively resist before the failed effort was considered as the PEL. Each attempt lasted for 20 sec, which began and terminated with a whistle blow and was interspersed with a 5-min passive rest. Additionally, during the 20-sec eggbeater kick test, the number of movements of both legs was counted. The leg movements during the eggbeater kick were monitored underwater by a video-camera (Panasonic MS5, Japan). Thereafter, slow-motion analysis was used to count the players' leg frequency.

Statistical analysis

Statistical analysis was performed with SPSS for Windows, version 16 (SPSS, Inc., Chicago IL, USA). Data are reported as means ± SD. Before using parametric statistical test procedures, the normality of the data was verified by the Kolmogorov-Smirnov test. Pearson's (for parametric variables) or Spearman's (for non-parametric variables) correlation was employed to detect significant correlations between anthropometrics and maximal external loads. A forward stepwise multiple regression and factor analysis were used to identify factors that determine the maximum external loads during the eggbeater kick. The threshold for significance on all the tests was set at $p=0.05$.

RESULTS

The participants' anthropometric characteristics, the PEL and the frequency of leg movements are presented in Table 1. An average load of 14.86±3.51 kg was identified as the PEL, while the respective number of leg frequency during the 20-sec eggbeater kick test was found to be 35.88±2.68 repetitions/20sec.

Table 1 Anthropometric characteristics, PEL and legs frequency movement during the eggbeater kick test. Values are means±SD. Δ biceps= difference in bicep girth between rest and during contraction, PEL=peak external load, reps=repetitions.

Variables	Mean Values
Body weight (kg)	84.67 ± 9.85
Stature (cm)	182.31± 7.39
Arm length (cm)	80.52 ± 5.52
Forearm length (cm)	47.20 ± 3.80
Hand length (cm)	20.07 ± 2.63
Lower limb length (cm)	93.32 ± 5.38
Knee length (cm)	49.88 ± 10.86
Foot length (cm)	10.83 ± 1.49
Bicep girth at rest (cm)	31.55 ± 3.33
Bicep girth during contraction (cm)	35.38 ± 3.44
Δ biceps (cm)	3.83 ± 1.38
PEL (kg)	14.86 ± 3.51
Legs frequency (reps/20 sec)	35.88 ± 2.68

The Kolmogorov-Smirnov test revealed that all variables were normally distributed except for knee length (p=0.02). Consequently, a non-parametric correlation (Spearman R) was used to identify correlations between knee length and other anthropometrics. Pearson's correlation showed that the majority of the anthropometric variables significantly correlated with the PEL. In particular, the variables that exhibited the most significant correlations with the maximum load that the players could resist were: stature, body weight, arm length, forearm length, bicep girth at rest and during contraction, lower limb length, and foot length (Table 2). No significant correlations were observed between hand length, knee length, and the difference (Δ) in bicep girth between rest and during contraction with PEL (p>0.05).

Two different multiple regression models were tested. The first multiple regression model with independent variables of the stature, hand length, difference between biceps at rest and during contraction, foot length, and frequency of legs, revealed that only stature and frequency of legs were significant predictors of PEL, explaining 67% and 45% of the variance of PEL (p=0.01 and p=0.03, respectively, Table 3). In the second multiple regression model, the replacement of stature with body weight demonstrated that only body weight and leg frequency movement were significant predictors of PEL, explaining 58% and 48% of the variance of PEL (p=0.00 and p=0.01, respectively, Table 3).

Table 2 Correlation coefficients between anthropometric characteristics and PEL PEL=peak external load, Δ biceps= difference in bicep girth between rest and during contraction, * statistically significant at $p<0.05$, ** statistically significant at $p<0.01$.

Anthropometric characteristics	PEL
Body weight	0.55*
Stature	0.59**
Arm length	0.62**
Forearm length	0.42*
Hand length	0.14
Lower limb length	0.42*
Knee length	0.15
Foot length	0.19
Bicep girth at rest	0.26
Bicep girth during contraction	0.38
Δ biceps	0.33

Table 3 Multiple regression results for the prediction of variance in peak external weight during the eggbeater kick from two different regression models

Dependent variable	Independent Variable	β	Beta	P	R^2	Overal P
Model 1					0.52	0.014
PEL (kg)	Stature (cm)	0.56	0.67	0.016		
	Leg frequency (reps/20sec)	0.29	0.45	0.003		
Model 2					0.48	0.026
PEL (kg)	Weight (kg)	0.19	0.58	0.005		
	Leg frequency (reps/20sec)	0.59	0.48	0.015		

The factor analysis revealed three factors that predicted 80.42% of the PEL variance. The first factor and the second factor included all anthropometric variables measured and were found to share variables with similar loadings (Table 4).

Table 4 Varimax rotated factor matrix for the three-factor solutions

	1st solution factor	2nd solution factor	3rd solution factor
Body weight	0.61	0.48	0.31
Stature	0.68	0.55	0.32
Arm length	0.82	0.48	0.11
Forearm length	0.84	0.23	0.03
Limb length	0.64	0.38	0.45
Knee length	0.06	-0.85	0.14
Foot length	0.82	0.10	0.08
Biceps at rest	0.91	-0.08	0.11
Biceps during contraction	0.90	-0.11	0.11
Legs frequency	-0.06	0.09	-0.95

The third factor included the leg frequency variable only. Based on scores of the factor analysis, a third multiple regression model was run with the PEL as the dependent variable and the scores from the factor analysis referring to the three factors as the independent variables (Table 5). It was observed that only the anthropometric characteristics were significant predictors of PEL, explaining 45% and 37% of the variance, respectively.

Table 5 Multiple regression results for the prediction of variance in peak external load during the eggbeater kick from the factor analysis scores

Dependent variable	Independent variable	β	Beta	P	R^2	Overal P
Model 3					0.38	0.019
PEL (kg)	Factor score 1	1.47	0.45	0.019		
	Factor score 2	1.22	0.37	0.048		
	Factor score 3	-0.73	-0.22	0.225		

DISCUSSION

The eggbeater kick with external pressure executed by opponents is an action that is observed frequently during a water-polo game. Leg frequency and anthropometric variables have been proposed to affect the effectiveness of the eggbeater kick. We investigated the extent to which the anthropometric variables and leg frequency movement affect the PEL during the eggbeater kick. To accomplish our goal, we simulated the external pressure that is executed by opponents during an eggbeater kick with progressively added loads which were placed on the participants' shoulders. The present results indicate that significant correlations exist between the PEL a player can resist during an eggbeater kick with the majority of the participants' anthropometric characteristics. Moreover, it was observed that PEL during an eggbeater kick under external loads is depended on both the frequency of the legs and the anthropometrics; but the latter seem to be more significant predictors of PEL during an eggbeater kick.

A basic finding of the present study is that the majority of anthropometric characteristics were moderately (r=0.38 to 0.62) but significantly associated with PEL (Table 2). Most importantly, the first multiple regression model revealed that the participants' stature and body mass accounted for 67% and 58% of the PEL total variance, respectively (Table 3). This probably implies that taller and heavier water-polo players exhibit greater performance in the eggbeater kick under external load. It seems that greater body size is an advantageous component for water-polo players in order to win several battles in which one player executes external load on another. Many studies in other team-sports have demonstrated the importance of anthropometric characteristics in performance success (Wong, et al., 2009; Van den Tillaar, et al., 2004). It has been suggested that body mass and body length affect the total energy cost of swimming (Kjendlie, et al., 2004) and that a great body size might be advantageous for water-polo players in order to obtain a better position in the pool, and to reach and control passes (Tsekouras, et al., 2005). Furthermore, it has been demonstrated that body lengths significantly correlated with throwing velocity of female water-polo players (Platanou & Varamenti, 2011).

Additionally, factor analysis revealed that apart from body mass and stature, notably anthropometrics and legs frequency play a crucial role in height maintenance during an eggbeater kick under external loads. In particular, the first factor revealed that arm length, forearm length, foot length, and bicep girth at rest and during contraction exhibited excellent loadings (Table 4). Stature, body mass, and arm length showed very good loadings and may be considered to contribute equally to the first and second factor, respectively. The fact that, although knee length is a basic anthropometric characteristic, it was selected in the second factor exhibiting excellent loading may imply that this parameter contributes significantly to PEL performance, regardless of the impact of other variables. The third regression model based on the scores from the factor analysis showed that anthropometrics play the most important role in performance during the eggbeater kick under external loads explaining together 82% of the total variance, while no significant impact for leg frequency was revealed (Table 5).

Although no significant correlation between legs frequency and PEL was observed ($r=0.35$, $p<0.05$), the first multiple regression model showed that the frequency of legs concurrently with body weight and alternatively the stature of the participants were significant predictors of PEL. In particular, it was observed that leg frequency explained 45% and 48% of the total variance of PEL in the two regression models, suggesting that the higher the leg frequency, the greater the PEL would be. Sanders (1999) found that squared foot velocity was strongly correlated with height maintenance in the eggbeater kick ($r=0.85$). The fact that the players of the present study with greater body size and knee length executed fewer leg movements during the 20-sec eggbeater kick test may be attributed to longer lower limbs, allowing them to perform a greater movement which results in a higher velocity. Accordingly, the latter seems to be very important in keeping the body in an elevated position. Moreover, it seems that players with longer lower limbs displace more mass of water per leg movement due to their greater surface area. In conclusion, the hypothesis that anthropometrics in conjunction with leg frequency affect the performance during the eggbeater kick under external loads is verified, notably anthropometrics seem to be more significant predictors.

It is known that the eggbeater kick is more a technical than a dynamic ability (Platanou, 2005). However, since the eggbeater kick was executed under increasing external loads, strength-related parameters could have affected the performance test. During a game, water-polo players often perform the eggbeater kick under external pressure. On this occasion, except for adequate technique and anthropometrics, performance may be determined by strength or physical fitness level. The players participated in the present study were well-trained athletes and as such, the maintenance of height achieved under external loads could have been determined by the participants' strength and/or fitness level. Moreover, our results cannot be applied to players with different training levels or experience. Future studies will establish whether PEL during an eggbeater kick is related not only to anthropometrics, but to the level of strength or training experience, as well.

Practical applications

The results of the present study indicate that anthropometric characteristics are more important predictors of performance during the eggbeater kick under external loads than leg frequency movement. In terms of leg frequency, coaches should target on flexibility improvement concurrently with the strength development of the muscles involved in the eggbeater kick technique. Consequently, a training schedule should comprise stretching and exercises with or without added loads during the eggbeater kick. Moreover, it seems that in talent selection, children with greater body size may be more appropriate for water-polo.

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ODNOS ANTROPOMETRIJE I FREKVENCIJE ROTACIONIH POKRETA NOGU POD USLOVIMA SPOLJAŠNJEG PRITISKA U VATERPOLU

Nameravamo da istražimo da li su specifične antropometrijske karakteristike i/ili učestalost pokreta nogu povezani sa sposobnošću vaterpolista da se odupru spoljašnjem pritisku tokom rotacionih pokreta nogu. U ovom istraživanju učestvovalo je dvadeset četiri vaterpolista. Preliminarno su izmerene antropometrijske karakteristike učesnika. Nakon toga, sproveden je 20-sekundni eggbeater kick test kako bi se utvrdilo minimalno opterećenje kome učesnici mogu da izdrže. Na dan eksperimenta, svaki učesnik je izvršio 20-sekundni eggbeater kick test, počevši od 10 kg i nakon toga sa progresivnim povećanjem spoljašnjeg opterećenja od 1 kg dok se ne postigne vršno spoljno opterećenje (PEL). Spoljašnje opterećenje kome su igrači mogli efikasno da se odupru pre nego što se neuspeli pokušaj smatra PEL. Uočene su značajne korelacije između većine antropometrijskih karakteristika i PEL (r=0,38 do 0,62, P<0,05). Višestruke regresione analize su otkrile da stas i telesna masa objašnjavaju ukupnu varijansu PEL za 67% i 58% respektivno (P<0,05), dok su učestalost pokreta nogu takođe bili značajni prediktori koji objašnjavaju više od 45% varijanse PEL (P<0,05). Faktorska analiza pokazala je da antropometrijske karakteristike i frekventni rotacioni pokreti nogu u potpunosti objašnjavaju 80,42% varijanse PEL. Međutim, analiza višestruke regresije zasnovana na rezultatima faktorske analize otkrila je da su samo antropometrijske karakteristike bile značajni prediktori PEL tokom rotacionih pokreta nogu, objašnjavajući više od 37% ukupne varijanse (P<0,05). Ova studija ukazuje na to da su antropometrijske karakteristike važniji prediktori performansi rotacionih pokreta nogu.

Ključne reči: *test performansi, vaterpolisti, telesna građa, telesna masa.*