International Journal of Performance Analysis in Sport

ISSN: 2474-8668 (Print) 1474-8185 (Online) Journal homepage: http://www.tandfonline.com/loi/rpan20

Vertical jump and shot speed, efficacy and accuracy in water polo

Sofia Canossa, J. Arturo Abraldes, M. Susana Soares, J. Ricardo Fernandes & Júlio M. Garganta

International Journal of Performance Analysis in Sport
2016, 16, 64-79.

Vertical jump and shot speed, efficacy and accuracy in water polo

Sofia Canossa[1], J. Arturo Abraldes[1,2], Susana M. Soares[1,3], Ricardo J. Fernandes[1,3] and Júlio M. Garganta[1]

[1] Center of Research, Education, Innovation and Intervention in Sport, Faculty of Sport, University of Porto, Porto, Portugal.
[2] Department of Physical Activity and Sport, Faculty of Sports Sciences, University of Murcia, Murcia, Spain.
[3] Porto Biomechanics Laboratory, University of Porto, Porto, Portugal.

Abstract

We have evaluated water polo vertical jump and shooting success determinants, their interplay, identified its main variables and proposed a predictive model. Twenty-two sub-elite players (23.23±7.22yrs and 13.0±5.4yrs of experience) were tested for absolute vertical jump (146.41±6.96cm), relative jump (considering trunk and upper limb length) and handgrip strength (54.97±5.26kgf). Shooting speed (radar), efficacy and accuracy (%) were also assessed. Players with higher trunk and upper limb length were those who had less elevation out of the water (R=-0.60,p=0.004) and relative jump and body mass were the explanatory main variables of absolute vertical jump (r^2=0.41,p=0.003). Shot speed to goal was 18.66±1.37 and 18.37±1.27m.s^{-1} (with and without previous displacement), with players attaining 50.0±33.7 and 59.09±34.02% of shot efficacy. Towards canvas target, shot speed was 17.47±1.61 and 17.26±1.69m.s^{-1}, and players were 24.6±18.5 and 27.3±20.0% accurate. Handgrip strength was highlighted as the main variable for shot speed situations and predictive models were found, which did not occur regarding efficacy and accuracy 'without displacement'. However, a model has been found for shot accuracy toward canvas 'with previous displacement' (r^2=0.34; p=0.003) in which handgrip strength is focused. Results found are important to monitoring and better plan the training process for the enhancement of team performance.

Keywords: Performance indicators, predictive models, field tests, monitoring of training.

1. Introduction

In team sports one major topic of interest is the identification of performance indicators (Hughes and Bartlett, 2002; Hughes et al., 2006; Lames and McGarry, 2007), allowing coaches to better plan and enhance teams' performance. This interest has expanded in water polo, increasing notational game analysis in male (e.g. Takagi et al., 2005; Lupo et al., 2010, 2012a,b) and female (e.g. Enomoto et al., 2014; Gomez et al. 2014a; Lupo et al., 2014) elite teams. Further works had focus on youth levels (Lupo et al., 2015), and attempted to identify the keys of success in elite players (e.g. Mujika et al., 2006; Melchiorri et al., 2011; Stirn et al., 2014). Conversely, the study of less successful national teams, competing regularly to qualify for high level events (e.g. Olympic Games, World and European championships), is scarce (e.g. Gobbi et al., 2013; Melchiorri et al., 2014). As less talented teams outnumber elite teams, the evaluation of less skilled players performance indicators would be important for overall water polo improvement. This could be useful to better understand differences between teams and their enhancement needs. Also, gathering information on water polo performance determining variables may help coaches in the players' selection and in the establishment of better training plans (Gomez et al., 2014b). Therefore, complementarily to the implementation of notational analysis, the application of field tests is essential (Royal et al., 2006; Stevens et al., 2010; Kondrič et al., 2012).

Regarding performance variables, vertical jump and shooting skill are recognized as very important abilities to achieve success during a water polo match (Zinner et al., 2010). In fact, maximal body elevation from the water is vital not only to pass and shoot the ball, but also to prevent opposing actions through defensive block and interceptions (Platanou, 2006; McCluskey et al., 2010; Kondrič et al., 2012). Complementarily, shooting speed is essential for the throw efficiency (Ferragut et al., 2011a; Platanou and Varamenti, 2011), since the faster the ball is thrown, the less time the goalkeeper has to defend it (Van der Wende, 2005). In addition, by the imperative need to score, throwing accurately is seen as a success performance indicator in elite water polo (Kos et al., 2010; Vila et al., 2011; Escalante et al., 2013). Maximal handgrip strength is also an important parameter (McCluskey et al., 2010; Ferragut et al, 2011a), not only to grapple the opponents, but also to well grippe the ball to an efficient back and forward swing for speeding the ball in the shooting action (Van der Wende, 2005). Body mass should also be considered, since top players are considered primarily mesomorphic, standing out the muscle-skeletal development. Large body volume and even overweight are considered an advantage for water polo performance efficiency (Dopsaj and Aleksandrović, 2009; Ferragut et al., 2011b; Canossa et al., 2014a)

For the understanding of the preponderance that variables of technical and tactical nature can have over successful water polo actions, it is worth noting that performance indicators can interact between themselves (Hughes and Bartlett, 2002; Gomez et al., 2014b), creating a dialectical relationship and combined influence, as may be the case between the vertical jump and the shot speed on the shot efficacy (ratio between number of shots performed and goals achieved). As this interplay between technical and tactical variables is unknown in water polo (Alcaraz et al., 2012), it would be helpful for coaches to better understand how performance indicators are related and, in the case of combined influences, what is its magnitude. The current study is the first that assesses the considered performance indicators all together in water polo and search for their interplay. In fact, it would be useful to have explanatory models regarding critical performance indicators, allowing predictive equations to be set. This could be useful particularly to predict players' performance and better promote team development, especially for teams that aim to qualify for international top events as European Championships.

We aimed to assess vertical jump and shot speed, efficacy and accuracy of sub-elite players, national team members placed at 18th in the European ranking and evidence, within selected variables, those who are determinant for these success performance indicators. In addition, an explanatory model for each performance indicator will be proposed to assist the training process. It was hypothesized that vertical jump skill have influence on shot speed and that handgrip strength is determinant of shot speed, efficacy and accuracy, whether is carried out with or without prior displacement. We also hypothesized that the considered performance indicators can be explained by a model whereby explanatory equations can be set.

2. Methods

2.1. Participants

Twenty-two sub-elite water polo players, members of a national team, which is 18th in European ranking, were tested (23.23±7.22 yrs, 13.0±5.4 yrs of water polo experience, 179.36±5.76 cm of body height, 142.93±6.92 cm of hip joint to fingertip distance or the measure of players' trunk and upper limb length and 76.89±8.71 kg of body mass). Subjects represented all field roles of play. The procedures of the experimental protocol were previously explained and a written informed consent was also obtained. Study followed the Declaration of Helsinki and was approved by the Institutional Review Committee from the local University.

2.2. Testing procedures

Tests were selected and adapted from specialized literature (e.g. McCluskey et al., 2010; Platanou and Botonis, 2010; Royal et al., 2006) and applied in the end of the season. Also, testing design was planned to get closer to game conditions and respect players competitive and training level (Van der Wend, 2005). Players' body mass and body height were measured with a calibrated digital scale and a stadiometer (Seca, Germany). To assess and observe differences between player's trunk and upper limb length, the distance from hip joint to fingertip was measured with the upper limb fully raised overhead using an inextensible fiberglass tape measure (Holtain Ltd., United Kingdom). This measurement was used to calculate the relative vertical jump, which allowed knowing how much players raised their hips above the water surface (Tan et al., 2009). In addition, handgrip strength was assessed with a portable, adjustable, digital Grip Strength Dynamometer (Takei Scientific Instruments Co., LTD, Japan), being the best record between three attempts with players dominant hand (three min of rest in-between), considered for further analysis (Alcaraz et al., 2012). After these measurements, tests in the water were conducted.

After 20 min of low intensity swimming, vertical jumps to the jumping device, ball handling and free shots towards goal and canvas, players underwent vertical jump test (protocol adapted from Platanou, 2005, 2006; Tan et al., 2009). A graduated board (marked from 90 cm to 190 cm), built with high-density sponge, was suspended in the backstroke flags cable (with two plastic cable ties) at 63 cm above water surface.

Players on the side and beneath the board, in basic water polo position (body immersed to acromion level) were instructed to jump highest possible and touch the board with their hand (dactylion). Testing continued until player failed to improve on his best mark over two consecutive trials being highest jump considered for analysis (Tan et al., 2009). Jump test was videotaped, in a sagittal plane, with a digital video camera (Sony, handycam HDR-PJ530) supported on a fixed tripod. Subsequent video analysis was performed by the image freezing at highest point of the player's hand contact with board (Platanou, 2006). Relative jump was calculated ([“absolute jump” height/ distance from hip joint to fingertip] x 100), in which 100% meant that player raised his hip to water surface level in the jump (Tan et al., 2009).

To assess shot speed and shot efficacy, players had three attempts each of a penalty shot to the goal (without previous displacement) in the presence of a goalkeeper, in a random order, with three min of interval between attempts. Afterwards, players carry out more three shots on the penalty mark after previous displacement, performing three upper limbs cycles in water polo front crawl while leading the ball technique, or, head-up front crawl (shot to goal with previous displacement). A radar with a sensitivity of 0.045 $m.s^{-1}$ and 10 Hz of register frequency (Inc., Flat Salkerpro, Texas, USA) was used to measure shot speed, placed behind the goal at a distance of 10 m (Vila et al., 2011) and a digital video camera, placed at 8 m from the goal (Figure 1), videotaped the shot action. All shot results were notated using specific categorization: (i) goal; (ii) post or failure (ball collided with the goal post, crossbar or stayed in the water); (iii) out (ball went out of the pool without touching any part of the goal or goalkeeper); (iv) defended by the goalkeeper. Coefficient of shot precision regarding the goal face (excluding shots through which the ball hit the post, crossbar or gone out) was used: Shot precision = [(goals and shots defended by the goalkeeper x 100) /total number of shots]. Also, shot efficacy was calculated using the formula: Shot efficacy = [(number of goals x 100) / number of shots] (Argudo et al, 2008; Alcaraz et al., 2012).

For the shot speed and accuracy, a canvas (pre-designed target) measuring 110.5 cm x 299.5 cm, with eight holes with diameter allowing the ball to pass through, was attached to the front of the goal (Royal et al., 2006) covering all its frontal surface area (Figure 1). After being familiarized with the canvas during the warm up, players had five attempts to shoot from the penalty mark in a random order (shot toward canvas without previous displacement). Subjects were instructed to shot to the holes on the corners, upper to bottom (Platanou and Botonis, 2010). Afterwards, players carried out another five shots after prior displacement to the penalty mark, performing three upper limbs cycles in head-up front crawl (shot toward canvas with previous displacement). Excluding the category “defended” the same categorization was used to record shot results and to calculate the accuracy as the formula: shot accuracy = [(number of balls introduced in the holes x 100) / number of shots]. In addition, differences of shooting speeds between testing situations (to goal vs. toward canvas target) were searched.

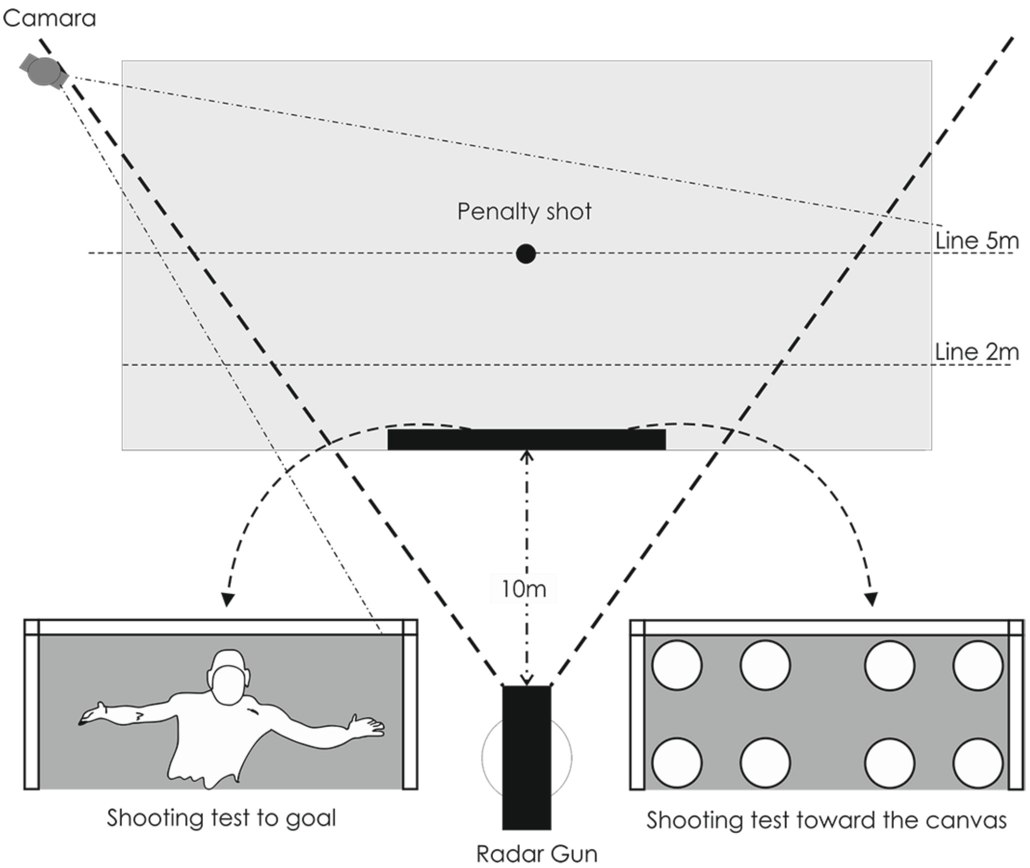

Figure 1. Schematic representation of shooting tests to goal and toward canvas target.

2.3. Variables

To analyze the interplay between performance indicators, variables previously taken as dependent were also seen as independent variables in further analysis, as shown in Table1.

Table1. Variables taken for the analysis of the interplay between performance indicators

Dependent variables	Situations		Independent variables
Absolute vertical jump	for a graduated board		body mass, handgrip strength, relative jump.
Shot speed	to goal and canvas	without and with prior displacement	absolute vertical jump, body mass, handgrip strength.
Shot efficacy	to goal	without displacement	absolute vertical jump, body mass, handgrip strength, shot speed assessed without displacement to goal
		with prior displacement	absolute vertical jump, body mass, handgrip strength, shot speed with prior displacement to goal.
Shot accuracy	toward canvas target	without displacement	absolute vertical jump, body mass, and handgrip strength, shot speed without displacement to canvas.
		with prior displacement	absolute vertical jump, body mass, handgrip strength, shot speed with prior displacement to canvas.

2.4. Statistical Analyses

Means ± *sd* and frequencies of occurrence were calculated for descriptive data analysis and the normality of the sample distributions was checked. The test-retest reliability (ICC ≥ 0.85) between trials was confirmed (a two-way random model was applied). To examine players vertical jump capacity, Pearson correlation between general physical characteristics, absolute and relative vertical jump values was implemented. To compare shooting speeds between testing situations ANOVA test for independent measurements was applied and then multiple comparisons through the Bonferroni test was implemented. To establish explanatory models, multiple linear regression was used with enter method, for crude calculated values (obtaining the Pearson correlation product) and, afterwards, with the stepwise regression method. Through this, main independent variables in the model were exposed with their final adjusted r^2. The constant (ß) and confident interval (CI) were considered and explanatory equations of dependent variables were represented. Criterion for significance was set at $p \leq 0.05$. Statistical power for the *n* size was considered (Power adj – 0.3-0.6; p >0.05).

3. Results

Players' maximal handgrip strength was 54.97±5.26 kgf, they reached 146.41±6.96 cm (130.0–161.0 cm) in their absolute vertical jump and obtained 102.6±5.8% (91.2-110.9%) in the relative jump. In addition, a negative correlation was found between players hip joint to fingertip distance and their relative jump value (R= -0.60; p=0.004). Furthermore, body mass has shown a significant predictive value of R^2 with absolute jump (R^2=0.20; p=0.035), as well as relative jump (R^2=0.32, p=0.007) and handgrip strength (R^2=0.21, p=0.033). Within these variables, the handgrip strength was excluded from the model and body mass results evident in 13% (p=0.031) together with relative jump in 28% (p=0.006). Thus, concerning explanatory models, absolute jump is 41% explained by the interplay between body mass and relative jump (R^2=0.41; p=0.003). For its prediction the explanatory equation can be applied: absolute vertical jump = 58.3 + 0.62 (relative jump) + 0.31 (body mass). In addition, regarding shot speed, shot efficacy and shot accuracy, tests results are shown in Table 2. Complementary, shot precision regarding goal face was 63.63 and 63.64% in shots with and without previous displacement to goal with goalkeeper.

Table 2. Shot results, shot efficacy and shot accuracy indices. Also, shot speed and standard deviation ($m.s^{-1} \pm sd$) and min-max values achieved in the four test situations: with and without previous displacement to the goal with goalkeeper and toward the canvas target. Difference of shooting speeds (*) between testing situations (to goal vs. toward canvas target) with p=0.000

Test situations	To goal, with goalkeeper		Toward canvas	
	Shot without displacement (n=66)	Shot with displacement (n=66)	Shot without displacement (n=110)	Shot with displacement (n=110)
Out (%)	7.58	12.12	11.82	10.91
Post (%)	28.79	24.24	63.64	61.82
Defended (%)	13.64	4.55	-	-
Efficacy/Accuracy (%)	50.00±33.73	59.09±34.02	24.55±18.45	27.30±20.00
min-max %	0-100	0-100	0-60	0-80
Shot Speed ($m.s^{-1}$)	18.66±1.37*	18.37±1.27*	17.47±1.61	17.26±1.69
min-max ($m.s^{-1}$)	15.83-21.94	15.56-22.22	14.40-21.10	14.40-21.10

As it can be seen in Table 3, significant predictive R^2 value was found between shot speed and handgrip strength in all shooting situations. Nonetheless, handgrip strength importance is not evident in final model regarding shot to goal with previous displacement in which body mass is the independent variable that stands out. In addition, regarding shot toward canvas with previous displacement, absolute jump had a predictive crude value of R^2 with shot speed, even though its importance was not evident in the final model.

Table 3. Results of linear regression analysis of shot speed in each test situation. Final model description with variables highlighted and significant predictive values (p<0.05)

	Crude				Adjusted	
Explanatory variable	R	R^2	b (95% CI)	p-value	p-value	R^2
Body mass (kg)						
ShSp to G	0.33	10.8	0.05 (-0.02 to 0.11)	0.136	-	-
ShSp Despl to G	0.50	24.7	0.07 (0.01 to 0.13)	0.019	0.019	20.9
ShSp to Canv	0.23	5.1	0.04 (-0.04 to 0.12)	0.311	-	-
ShSp Despl to Canv	0.28	7.8	0.05 (-0.03 to 0.12)	0.208	-	-
Handgrip (N)						
ShSp to G	0.51	25.7	0.01 (0.00 to 0.02)	0.016	0.016	22.0
ShSp Despl to G	0.45	20.0	0.01 (0.00 to 0.02)	0.037	-	-
ShSp to Canv	0.50	25.4	0.02 (0.00 to 0.03)	0.017	0.017	21.7
ShSp Despl to Canv	0.47	21.9	0.01 (0.00 to 0.02)	0.028	0.028	17.9
Absolute jump (cm)						
ShSp to G	0.30	8.9	0.06 (-0.03 to 0.14)	0.177	-	-
ShSp Despl to G	0.38	14.4	0.07 (-0.01 to 0.15)	0.082	-	-
ShSp to Canv	0.41	16.8	0.09 (-0.00 to 0.18)	0.058	-	-
ShSp Despl to Canv	0.44	19.3	0.09 (0.00 to 0.17)	0.041	-	-
Final model results						
ShSp to G	R=0.51; R^2=22.0; p=0.016					
ShSp Despl to G	R=0.50; R^2=20.9, p=0,019					
ShSp to Canv	R=0.50; R^2=21.7; p=0.017					
ShSp Despl to Canv	R=0.47; R^2=17.9, p=0,028					

Legend: (ShSp) shot speed; *(ShSp to G)* ShSp to goal without previous displacement; *(ShSp Despl to G)*, ShSp to goal with previous displacement, *(ShSp to Canv)* ShSp to canvas without previous displacement and *(ShSp Despl to Canv)* ShSp to canvas with previous displacement.

Concerning explanatory models, shooting speed (with or without previous displacement) can be explained mainly through the importance of handgrip strength (18 to 22%). An exception was found for shot to goal with previous displacement in which the final model highlights the body mass (Table 3). Through models found, shooting speed can be predicted by explanatory equations: (i) shot speed to goal without previous displacement = 11.92 + 0.01 (handgrip); (ii) shot speed to goal with previous displacement = 12.86 + 0.07 (body mass); (iii) shot speed toward canvas without previous displacement = 9.62 + 0.02 (handgrip); (iv) shot speed toward canvas with previous displacement = 10.41 + 0.01 (handgrip).

Regarding shot efficacy (in both tests situations) and shot accuracy toward canvas without previous displacement, no variable was evident, although, in this latest situation a predictive significant trend is seen regarding absolute jump (R^2=0.17, p=0.058). Thereat, no models were found in these three mentioned situations. Nevertheless, a significant predictive value of R^2 was found regarding shot accuracy toward canvas with previous displacement with the handgrip strength (R^2=0.37, p=0.007). Thus, a model has been found, in which the handgrip strength is highlighted (R^2=0.34; p=0.003). Its explanatory model is expressed by the equation: Shot accuracy with previous displacement= -100.71 + 0.24 (handgrip).

4. Discussion

This study aimed to assess vertical jump and shot speed, efficacy and accuracy of sub-elite water polo players, members of a European national team and evidence, within selected variables, those who are determinant for these success performance indicators. This is the first study that assesses considered performance indicators all together, seasch for their interplay, looking for explanatory models where main variables can be highlighted. As to absolute vertical jump, our data are similar to those achieved by top players from Youth age group (16 to 18 yrs old) (Kondrič et al., 2012; Uljević et al., 2013; Stirn et al., 2014), but lower than Junior national team members (19 and 20 yrs old), Senior elite (older than 20 yrs) and also first division players (Platanou, 2006; Zinner et al., 2010), which may indicate lower jumping ability of our players regarding Senior counterparts from other countries, even from not elite players. The negative correlation found between hip joint to fingertip distance vs. relative jump, as well the relative jump range values, evidences that players with a longer trunk and upper limb are those who have less elevation out of the water. In fact, 8.8% do not raise their hips out of water surface.

Regarding the above mentioned, it is expected taller players have higher absolute jump values than their shorter teammates, which does not mean that they have greater body lifting capacity, as can be seen in present relative jump results. Although the not proven prominence of absolute vertical jump over other performance indicators, it remains a core competence for successful players, since higher body elevation means stronger opposition in the game. In fact, lesser competitive level players were already reported as having poor capability in jumping (Platanou, 2005; Gobbi et al., 2013) and this may be due to a fewer requirement of that ability in lower game level, but also may indicate lack of lower limb power or strength. However, some studies emphasize that jumping ability mostly depends on technical skills, in which eggbeater kick must be proficient, rather than pure explosive power (Platanou, 2005; McCluskey et al., 2010; Stirn et al., 2014). By this, training of strength or power in the absence of improved skill in propulsion out of the water may be completely ineffective (McCluskey et al., 2010). Present players reduced jumping capability is a disadvantage compounded by the fact that they compete in the national team with regular presence in the qualifying rounds for European Championships, needing to perform game actions against higher level teams.

Shooting speeds to goal achieved by present players are similar to collegial level and elite players in shots performed behind the 5m line in “real game” situation (Ferragut et al., 2011b; Alcaraz et al., 2012). However, other studies about tests with penalty shots (on elite but also on national level players), report higher shot speeds (Ferragut et al., 2011b; Melchiorri et al., 2011; Idrizović et al., 2013). Differences can be wide considering the reported $24.1 \pm 1.5 ms^{-1}$ (max $-29.8 ms^{-1}$, min$-21 ms^{-1}$; Melchiorri et al., 2011), which reveal the fragility of present players shot action, being shooting speed focused as vital for match outcome (Van der Wende, 2005; Ferragut et al., 2011a; Vila et al., 2011). Furthermore, current shot speed decline between to goal vs. toward canvas conditions suggests that players sacrifice speed to achieve precision. This is in line with other researches when test conditions changed (shot with vs. without goalkeeper) (Van der Wende, 2005; Ferragut et al., 2011a) and with the goal face not covered with a canvas. Present players may not be familiarized with a canvas target, which may explain decline found in shooting speed and point a gap in their training process.

Regarding shooting toward goal efficacy, in a research where national level players had to perform penalties shots to a goal divided with a grid in 18 spaces, 81% of shot success was achieved, which decreased significantly (62%) when added a field defender in the situation, showing that success is affected when shot skill is performed closer to real game situations (Van der Wende, 2005). In fact, in preliminary stages of high-level competitions, efficacy between winners and losers (42.1±10.4 vs. 25.3±9.2%) was different (Escalante et al., 2013). Regarding "real game", present efficacy values seem to be higher than those found in high-level competitions shots, either from winning or defeated teams (Escalante et al., 2013; Canossa et al., 2014b) in shots performed from several distances, field zones and against elite goalkeepers whose performance was recognized as discriminating factor between winners and losers (Escalante et al., 2013). In present study, goal defense was held by one of the bests goalkeepers in the country where present study took place, however, he has lower level than their elite counterparts, which likely has influenced shot efficacy results and that added to fact that tests did not occur in "real game" explains disparity found between current efficacy values with those from literature. This feature can be pointed as limitation of current research.

In addition, current players shot precision seems low given values achieved by elite players in "real game" (max–82%; Alcaraz et al., 2012). This may indicate difficulty in throwing accurately and in fact, analyzing present shot accuracy, values tend to be lower than those found in male and female elite junior players in tests that also had used a target (30 and 40%; Royal et al., 2006; Stevens et al., 2010, respectively). Likewise, they tend to be lower than young players with two to three yrs of water polo experience and players with six to eight yrs of experience (53.0±13.9 and 80.0±14.7%, respectively) in a research which concluded that 'experienced players' parameter was a significant predictor of shooting accuracy (Platanou and Botonis, 2010). However, present players have higher age and sport experience than those more 'experienced players', which raises questions about their training process.

Following the above subject, players' preparation should focus on accuracy improvement when they are shooting, reason why daily sessions should include drills to improve it (Platanou and Botonis, 2010), which should not be limited to just shoot at a target. Practice should be structured to replicate perceptual information available during competition and expose players to a variety of tasks. Expert performers show ability to adapt and have greater flexibility when facing movement constraints in a variety of situations (Van der Wende, 2005). Although there some researchers' conviction that shot effectiveness mostly depends on accuracy (Platanou and Botonis, 2010), there are no research studies correlating shot accuracy with shot efficacy and in present study, when exploring data, this correlation was not found, which raises the question if the most accurate players are really the most effective in the game. In addition, results show an improvement trend of accuracy percentages when shot toward canvas has included prior displacement, which is in disagreement with those who state that shooting accuracy is negatively affected by previous swimming (Platanou and Botonis, 2010). Present opposite tendency, both for accuracy as to efficacy, might be explained by a positive effect on players shot technical skill due to acceleration induced by displacement, enhancing amplitude of body segments.

Concerning explanatory model found for absolute vertical jump, players may improve their jump capacity (in 0.93 cm) if they get better their relative jump (1 cm) and increase their body mass (1 kg). This enhancement value is not high, but it allows predict players' improvement and may complement assessment process. Despite the obvious correlation between relative and absolute jump, coaches should be aware that evaluating player's jumping ability must take into account their physical dimensions and relative ability of rise out of water surface. Complementarily, body mass featured in model can be explained by relevance for players in having high strength levels and buoyancy, which provides better conditions for body floatability and it is considered a positive factor for water polo efficiency (Dopsaj and Aleksandrović, 2009; Uljević et al., 2013). Body mass has been associated to the successful players physical profile due game nature and its high levels of strength requirement (Tsekouras et al., 2005; Dopsaj and Aleksandrović, 2009; Idrizović et al., 2014).

Concerning shooting speed models, handgrip strength is highlighted in three of four tested situations, which is in accordance with literature (Van der Wende, 2005; Ferragut et al., 2011a) constituting relevant information for training programs. Moreover, according to equation found in shot toward canvas without previous displacement, player handgrip strength improvement of 100 kgf may lead to 2 $m.s^{-1}$ shot speed improvement. In addition, regarding shot toward canvas with previous displacement, although absolute jump was excluded from final model, predictive crude value of R^2 indicate its relative importance for shot speed. Although in female players this correlation was observed (McCluskey et al., 2010), in males was not found (Platanou, 2005; Royal et al., 2006; Zinner et al., 2010). As suggested by literature rather than players needing to reach a maximum height, an optimal height for each player may exist to achieve a better ball speed (Van der Wende, 2005; Royal et al., 2006).

Regarding shot to goal with previous displacement, body mass was highlighted, which is not in total disagreement with other models found for shooting speed, since beyond body mass being responsible for greater body acceleration on the displacement it can also be indicative of higher levels of strength. Although in some studies on elite players, body mass did not correlate with shooting speed (Ferragut et al., 2011a; Melchiorry et al., 2011), other authors argue that shot speed depends directly on maximal strength and that players with bigger body mass produce higher levels of maximal dynamometric force (Idrizović et al., 2014). In addition, previous research involving players of the same competitive level and nationality of present subjects has shown that those players where significantly different from their elite counterparts in anthropometrical parameters, as the body mass and body size (Canossa et al., 2011). Smaller body segments as the arm span tends to generate lower acceleration to ball in the shooting skill (Canossa et al., 2011), which helps to explain present players' tendency for lesser shooting speed values regarding other studies. Furthermore, current handgrip values seem similar to those found in elite players (Ferragut et al., 2011a; Alcaraz et al., 2012), which leads to infer that present trend for lower shot speeds, beyond body mass, may have to do with technical issues and movement coordination (Abraldes et al., 2014).

Finally, handgrip strength is highlighted as main variable in final model concerning shot accuracy toward canvas with previous displacement, which is in accordance with literature. Correlation between handgrip strength and shooting speed to goal with goalkeeper was found in elite players, which may have occurred by the fact that players have to direct the shot to score (Ferragut et al., 2011a). This emphasize the statement that ball control is vital in shot action, which is linked to ability to grip the ball (Van der Wende, 2005) giving importance to isometric handgrip strength (Abraldes et al., 2014). Furthermore, beyond tactical actions, water polo is conditioned by high level of players' motor fitness, wherein individual actions effectiveness depends, among other things, on high level of co-ordination (Garbolewski and Starosta, 2002). Some authors explain that junior elite players can maintain accuracy and speed when submitted to shooting tasks with progressive increase of fatigue, sacrificing some technical aspects, as the height out of the water and keeping the elbow angle and position prior to release (Kos et al., 2010). This strategy is accomplished by skilled players capable of self-regulation that allows them to optimize performance under challenging conditions (Royal et al., 2006), which reinforces the idea that coordination ability and a well-developed technical skill are critical for water polo players.

5. Conclusions

Present study suggests current players' improvement need regarding technical-tactical aspects focused, for which, their training process requires reinforcement and to be revised. Monitoring training process and taking in account models herein described can help teams to raise their game quality and approach their competitive level to those presented by other national teams. Although identification of some considered variables as main core of performance indicators, as hand grip strength and body mass, study hypotheses were not fully confirmed. Nevertheless, it was possible to extract predictive equations to assist coaches in their training process regarding vertical jump, shot speed and shot accuracy (preceded by displacement). Since this is the first water polo study that assesses considered performance indicators, all together, searching for their interplay and trying to find out predictive equations, for a better knowledge and understanding of present subject, further studies with other groups need to be developed. It would be important for scientific community invest more effort researching players' evaluation comprising determinants of performance indicators and their interplay.

6. References

Abraldes, J., Canossa, S., Soares, S., Fernandes, R.J. and Garganta, J.M. (2014), Relationship between hand grip strength and shot speed in different competitive level water polo players (abstract). **Revista de Ciencias de la Atividade Física y del deporte**, 9 (25 – suplemento), 143.

Alcaraz, P.E., Abraldes, J.A., Ferragut, C., Vila, H., Rodríguez, N. and Argudo, F. (2012), Relationship between Characteristics of water polo players and efficacy indices, **Journal of Strength and Conditioning Research**, 26, 1852-1857.

Argudo, F.M., Ruiz, E. and Ignacio, J. (2008), Influence of the efficacy values in

numerical equality on the condition of winner or loser in the 2003 Water Polo World Championship, **International Journal of Performance Analysis in Sport**, 8(1), 101-112.
Canossa, S., Abraldes, J.A., Soares, S., Vila, H., Ferragut, C., Rodríguez, N., Argudo, F., Fernandes, R.J. and Garganta, J.M. (20014a), Contrasting morphology and training background in water polo teams of different competitive level, **Motriz. The Journal of Physical Education. UNESP,** 20(3), 272-279.
Canossa, S., Abraldes, J.A., Castro, J.P., Susana, S., Fernandes, R.J. and Garganta, J.M. (2014b), Shot velocity and technical-tactical variables in elite water polo: Australia versus finalist teams in the 2013 World Championships. In B. Mason (Ed) **Handbook of abstracts of XIIth International Symposium on Biomechanics and Medicine in Swimming** (pp. 202**).** Canberra: Australian Institute of Sport.
Canossa, S., Abraldes, J.A., Ferragut, C., Vila, H., Rodríguez, N., Figueiredo, P., Argudo, F., Fernandes, R.J. and Garganta, J.M. (2011), Kinanthropometrics and training background of different level center and outside water polo players. **Portuguese Journal of Sport Sciences**, 11 (Suppl.4), 43.
Dopsaj, M. and Aleksandrović, M. (2009), Basic anthropomorphological characteristics of elite senior Serbian water polo players according to field position, **International Journal of Fitness**, 5(2), 47-57.
Enomoto, I., Kobayashi, D., Suga, M., Minami, T. (2014), Performance analysis of elite female water polo teams in the 2013 World Championships. In B. Mason (Ed) **proceedings of XIIth International Symposium on Biomechanics and Medicine in Swimming** (pp. 296-300). Canberra: Australian Institute of Sport.
Escalante, Y., Saavedra, J.M., Tella, V., Mansilla, M., García-Hermoso, A. and Domínguez, A.M. (2013), Differences and discriminatory power of water polo game-related statistics in men in international championships and their relationship with the phase of the competition, **Journal of Strength and Conditioning Research,** 27(4), 893–901.
Ferragut, C., Abraldes, J.A., Vila, H., Rodríguez, N., Argudo, F.M. and Fernandes R.J. (2011b), Anthropometry and throwing velocity in elite water polo by specific playing positions, **Journal of Human Kinetics**, 27, 31–44.
Ferragut, C., Vila, H., Abraldes, J.A., Argudo, F., Rodriguez, N. and Alcaraz, P.E. (2011a), Relationship among maximal grip, throwing velocity and anthropometric parameters in elite water polo players, **Journal of Sports Medicine and Physical Fitness**, 51, 26-32.
Garbolewski, K. and Starosta, W. (2002), Level and Conditions of Selected Motor Co-Ordinations and Jumping Abilities Among Advanced Water-Polo Players, **Journal of Human Kinetics,** 8, 17-21.
Gobbi, M., D'ercole, C., D'ercole, A. and Gobbi, F. (2013), The components of the jumps in expert and intermediate water polo players, **Journal of Strength and Conditioning Research**, 27(10), 2685-9.
Gómez, M.A., DelaSerna, A., Lupo, C. and Sampaio, J. (2014a), Effects of Situational Variables and Starting Quarter Score in the outcome of elite women's water polo game quarters, **International Journal of Performance Analysis in Sport,** 14(1), 73-83.
Gómez, M.A., DelaSerna, A., Lupo, C. and Sampaio, JE. (2014b), Effects of Game

Location, Quality of Opposition and Starting Quarter Score in the outcome of elite water polo quarters, **Journal of Strength and Conditioning Research** [Epub ahead of print].

Hughes, M.D. and Bartlett, R.M. (2002), The use of performance indicators in performance analysis, **Journal of Sports Science**, 20, 739-754.

Hughes, M.D., Appleton, R., Brooks, C., Hall, M. and Wyatt, C. (2006), Notational analysis of elite men's water-polo. In H. Dancs, M. Hughes and P. O'Donoghue, (Eds) **Book of Proceedings of 7th World Congress on Performance Analysis of Sport** (pp. 137–159). Szombathely, Hungary: International Society of Performance Analysis of Sport.

Idrizović, K., Calleja-Gonzáles, J. and Kontić, D. (2014), Relationship between morphological parameters and throwing velocity, maximal force and swimming speed in elite male water polo players, **SportLogia**, 10(1), 11–20.

Idrizović, K., Milošević, D. and Pavlović, R. (2013), Physiological differences between top elite and elite water polo players, **Sport Science**, 6(2), 59-65.

Lames, M. and McGarry,T. (2007), On the search for reliable performance indicators in game sports, **International Journal of Performance Analysis in Sport,** 10, 1-18.

Ligue Européenne de Natation (LEN). European Water Polo Championships, Past and Present Results. Available at: http://www.len.eu/default.aspx

Lupo, C., Tessitore, A., Minganti, C. and Capranica, L. (2010), Notational Analysis of Elite and Sub-Elite Water Polo Matches, **Journal of Strength and Conditioning Research**, 24(1), 223–229.

Lupo C., Condello, G., Tessitore, A. (2012a), Notational analysis of elite men's water polo related to specific margins of victory, **Journal of Sports Science and Medicine,** 11, 516-525.

Lupo, C., Minganti, C., Cortis, C., Perroni, F., Capranica, L., Tessitore, A. (2012b), Effects of competition level on the centre forward role of men's water polo, **Journal of Sports Sciences**, 30(9), 889-897

Lupo, C., Condello, G., Capranica, L. and Tessitore, A. (2014), Women's water polo world championships: technical and tactical aspects of winning and losing teams in close and unbalanced games, **Journal of Strength and Conditioning Research,** 28(1), 210–222.

McCluskey, L., Lynskey, S., Leung, C.K., Woodhouse, D., Briffa, K. and Hopper, D. (2010), Throwing velocity and jump height in female water polo players: Performance predictors, **Journal of Science and Medicine in Sport**, 13(2), 236-240.

Melchiorri, G., Padua, E., Padulo, J., D´Ottavio, S., Campagna, S. and Bonifazi, M. (2011), Throwing velocity and kinematics in elite male water polo players, **Journal of Sports Medicine and Physical Fitness**, 51, 541-546.

Melchiorri, G., Viero, V., Triossi, T., De Sanctis, D., Padua, E., Salvati, A., Galvani, C., Bonifazi, M., Del Bianco, R., Tancredi, V. (2014), Water polo throwing velocity and kinematics: differences between competitive levels in male players, **The Journal of Sports Medicine and Physical Fitness** [Epub ahead of print].

Mujika, I., McFadden, G., Hubbard, M., Royal, K. and Hahn, A. (2006), The Water-Polo Intermittent Shuttle Test: A Match-Fitness Test for Water-Polo Players, **International Journal of Sports Physiology and Performance**, 1, 27-39.

Platanou, T. (2005), On water and dry land vertical jump in water polo players, **Journal of Sports Medicine and Physical Fitness**, 45, 26-31.

Platanou, T. (2006), Simple 'in-water' vertical jump testing in water polo, **Kinesiology**, 38(1), 57-62.
Platanou, T. and Botonis, P. (2010), Throwing accuracy of water polo players of different training age and fitness levels in a static position and after previous swimming. In PL. Kjendlie, R.K. Stallman and J. Cabri (Eds) **Book of Proceedings of the XIth International Symposium for Biomechanics and Medicine in Swimming** (pp. 281-283). Oslo: Norwegian School of Sport Science
Platanou, T. and Varamenti, E. (2011), Relatioships between anthropometric and physiological characteristics with throwing velocity and on water jump of female water polo players, **Journal of Sports Medicine and Physical Fitness**, 51(2), 185 – 193.
Kondrič, M., Uljević, O., Gabrilo, G., Kontić, D. and Sekulić, D. (2012), General Anthropometric and Specific Physical Fitness Profile of High-Level Junior Water Polo Players, **Journal of Human Kinetics**, 32: 157-165.
Kos, H., Rynkiewicz, M., Zurek, P., Zabski, S. and Rynkiewicz, T. (2010), Maximal strength and strength accuracy in water polo players from the Polish junior national team, **Studies in Physical Culture and Tourism**, 17(4), 307-313.
Royal, K.A., Farrow, D., Mujika, I., Halson, S.L., Pyne, D. and Abernethy, B. (2006), The effects of fatigue on decision making and shooting skill performance in water polo players, **Journal of Sports Science**, 24(8), 807 – 815.
Stevens, H., Brown, L., Coburn, J.W. and Spiering, B.A. (2010), Effect of Swim Sprints on Throwing Accuracy and Velocity in Female Collegiate Water Polo Players, **Journal of Strength and Conditioning Research**, 24(5), 1195–1198.
Stirn, I., Strmecki, J. and Strojnik ,V. (2014), The Examination of Different Tests for the Evaluation of the Efficiency of the Eggbeater Kicks. **Journal of Human Kinetics**, 41, 215-226.
Tan, F., Polglaze, T., Dawson, B. and Cox, G. (2009), Anthropometric and fitness characteristics of elite Australian female water polo players, **Journal of Strength and Conditioning Research**, 23(5), 1530-6.
Takagi, H., Nishijima, T., Enomoto, I. and Stewart, A.M. (2005), Determining factors of game performance in the 2001 world Water polo Championships, **Journal of Human Movement Studies**, 49, 333-352.
Tsekouras, Y.E., Kavouras, S.A., Campagna, A., Kotsis, Y.P., Syntosi, S.S., Papazoglou, K. and Sidossis, L.S. (2005), The anthropometrical and physiological characteristics of elite water polo players, **European Journal of Applied Physiology**, 95(1), 35-41.
Uljević, O., Spasic, M. and Sekulic, D. (2013), Sport-specific motor fitness tests in water polo: reliability, validity and playing position differences, **Journal of Sports Science and Medicine**, 12(4), 646-654.
Van der Wende K. (2005), The effects of game-specific task constraints on the outcome of the water polo shot. In Institute of Sport and Recreation Research. **Thesis submitted in partial fulfillment of the degree of Master of Health Science (**pp. 1-87). New Zeland: Auckland University of Technology.
Vila, H., Abraldes, J.A., Alcaraz, P.E., Rodríguez, N. and Ferragut C. (2011), Tactical and shooting variables that determine win or loss in top-Level in water polo, **International Journal of Performance Analysis in Sport,** 11, 486-498.
Zinner, C., Focke, T., Sperlich, B., Krueger, M. and Mester, J. (2010), Competition

specific diagnostics and results for elite water polo players. In PL. Kjendlie, R.K. Stallman and J. Cabri (Eds) **Program & Book of Abstracts of XIth International Symposium for Biomechanics and Medicine in Swimming** (pp. 121). Oslo: Norwegian School of Sport Science.

Acknowledgments: to the Portuguese Swimming Federation, North of Portugal Swimming Association and respective coaches and players.

Corresponding author:

Sofia Canossa
Center of Research, Education, Innovation and Intervention in Sport (CIFI2D),
Faculty of Sport, University of Porto, Portugal.
Rua Dr. Plácido Costa, 91, 4200-450 Porto, Portugal
Telefone: +351 (22) 0425200
Fax: +351 (22) 5500689
E-mail: scanossa@fade.up.pt