

Original Article

The Effect of Shoulder Joint Isokinetic Muscle Strength, Endurance and Proprioception on Swimming, Agility and Sprint Performance in Water Polo Players

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Abstract

Objectives: Water Polo (WP) is a physiologically and physically demanding sport that involves frequent directional changes during swimming. **Methods:** This study, shoulder proprioception, muscle strength, and endurance were evaluated using an isokinetic dynamometer in 28 male Sports Club WP athletes competing in the WP 1st league. In addition, swimming, agility, and speed performance tests were performed. **Results:** There was a moderate negative correlation between shoulder joint muscle strength and the shuttle swimming test, WP agility test, and 20-m maximum speed swimming test (Peak Torque 60° respectively $r:-0.443$, $p:0.018$, $r:-0.490$, $p:0.008$, $r=-0.581$, $p:0.001$). In the multiple regression analysis performed in our study, ANOVA test results in Models 4, 5, and 6 showed that there was a significant relationship between shoulder joint muscle strength and shuttle swimming test and 20-m maximum speed swimming test (respectively, $F:2.912$, $p:0.044$, $F:5.004$, $p:0.005$). **Conclusions:** Our study determined that shoulder joint proprioception was not associated with swimming, agility and speed performance, shoulder joint isokinetic muscle strength affected swimming and speed performance but not agility, and shoulder joint endurance was associated with swimming, agility and speed performance in WP players.

Keywords: Isokinetic, Performance, Position sense, Proprioception, Water sport

Introduction

Water polo (WP) is a physiologically and physically demanding, high-strength, water-based contact sport that involves frequent changes of direction during swimming, with players constantly moving through the water¹. It is important for athletes to have sports-related skills such as wrestling with opponents, shooting and pulling themselves out of the water^{2,3}).

Isokinetic dynamometer is defined gold standard for muscle strength measurements⁴. The reliability and validity of this tool in the measurement of shoulder joint function make it popular among scientists⁵. The low availability of the tool, the difficulty of the test procedures, the high cost, the need for high motivation of the person being tested make the device difficult to use⁶. The balance of muscle strength between agonist and antagonist muscles in athletes is of fundamental importance for joint stability. Traditionally, isokinetic strength testing is considered an important tool for monitoring training adaptations by objectively measuring the ratio of strength balance between agonist and antagonist muscles⁷. Strength ratios and strength inadequacy in internal or external rotation are associated with shoulder injuries in WP⁸.

Proprioception is a concept of the human body first described by Charles Sherrington in 1906 as “the perception of joint movement and positioning in space in the absence of visual feedback”⁸. Proprioception relies on

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mechanoreceptors that convert mechanical energy into electrical nerve impulses. The central nervous system analyzes the impulse rate and frequency to interpret joint movement and position. Mechanoreceptors and proprioception play critical roles in healthy shoulder function. The interaction between these components enhances motor control and task performance. Proprioceptive dysfunction is associated with a higher rate of musculoskeletal injury, recurrence, and persistence of disability⁹.

WP is a very team sport with great physical and mental processes. Performance is an important parameter for water polo players due to the simultaneous use of neuromuscular stimuli³. When analyzing individual performance characteristics, many different factors should be considered and determined, not just one player's performance level alone. Although the number of studies focusing on. Although the number of studies on water polo has increased in recent years, the initial development process of players is complex. It requires deeper theoretical and practical knowledge¹⁰. There is not enough information in the literature regarding studies of factors affecting WP player performance. WP performance is thought to be important in terms of shoulder joint function, stroke and swimming speed. In the literature, there are few studies on WP because it is a new and specific area. In addition, there is a need for new researches due to the fact that evaluation methods in water have become easier with the increase in technology.

Although it has been a team sport since the Third Modern Olympic Games in St. Louis in 1904, there is little scientific literature on WP¹¹. Studies evaluating shoulder joint isokinetic muscle strength, endurance, and proprioception during WP games were not found. In addition, no studies have examined there the relationship between these tests and swimming, agility, and speed performance. Therefore, the aim of this study was to determine the effects of shoulder joint isokinetic muscle strength, endurance and proprioception on swimming, agility and sprint performance in water polo players. We hypothesize that higher shoulder joint isokinetic strength, endurance, and proprioception will positively correlate with better swimming, agility, and sprint performance in WP players.

Materials and Methods

Study Design

The methodological model of this study is a cross-sectional study.

Participants

This research was conducted with 28 male water polo players aged between 14 and 20 from the Selçuklu Municipality Sports Club competing in the Turkish Water Polo 1st League in Konya Province, between May and July 2024. Participants who met the inclusion criteria voluntarily participated in the study. Data were collected through face-

to-face interviews¹³.

The eligibility criteria in our study were based on previous studies. WP athletes participating in the study regularly train with their teams 4 times a week for 2 hours. They play 20-30 matches each season and participate in the highest league for their age group¹. Inclusion criteria: No muscle injury diagnosed in the last 2 months, 4 years or more experience in WP sport, and being a licensed WP player who trains at least 3 times a week^{3,14}. Exclusion Criteria: Not wanting to participate in the study and not training for more than 4 weeks were determined as exclusion criteria^{14,15}.

G*Power 3.1.9.2 program, it was determined that the calculation using the t-test independent groups with an effect size of 0.5, standard error of 0.05, and power of 80% should be performed with 28 participants¹⁶.

Outcome Measures

In this study, shoulder proprioception, muscle strength, and endurance were evaluated using an isokinetic dynamometer (Cybex Humac Norm (2009)) in Selçuk Municipality Sports Club WP team players who were competing in the Turkey WP 1st league. In addition, swimming, agility, and speed performance tests were performed. Physical (age, height, gender, body mass index), sociodemographic, marital status, income-expense balance, education level, dominant side, and throwing arm information were recorded.

Shoulder Proprioception Assessment

Before each test session, the dynamometer was calibrated according to the manufacturer's instructions. Before the tests, each participant was allowed to warm up with an active range of motion exercises for 5 minutes¹⁷. During the measurement, participants' eyes were covered with tape to eliminate visual stimuli, ear plugs were used to eliminate auditory stimuli, and a Johnsten pressure splint was placed on the forearm to eliminate tactile stimuli¹⁸. The participants were positioned in the supine position with the shoulder in 90° abduction and the elbow in 90° flexion, and their position position and movement sensations were evaluated. Measurements were performed on the dominant extremity determined using the Edinburgh Hand Preference Questionnaire¹⁹.

Position Sense Evaluation

The upper extremity passively was moved from the neutral position to the reference angle in the direction of internal and external rotation. Measurements were evaluated during 30°-60° internal rotation and 30°-60° external rotation¹⁸. The participant was held at the reference angle for 10 seconds. Then, passively moved back to the neutral position. Rested for 10 seconds. Then it was brought to the same point again. Afterward, it was waited for 10 seconds. The participant was asked to identify and determine this point in his mind. Afterward, it was brought to the starting

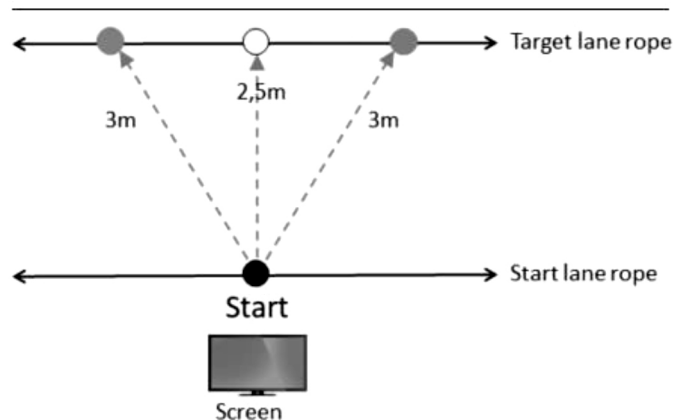


Figure 1. Water Polo Agility Test.

point and waited for 10 seconds. The participants were then instructed to repeat the position in which their upper limb was previously placed while considering the reference angle. The measurement was repeated 5 times for each reference angle. Two of these trials were recorded as learning trials, and the value of the three test trials was recorded as the result of the position sense test¹⁸. The average of these three trials was recorded.

Motion-Sense Evaluation

The dynamometer moved the limb from 0° to internal rotation, from 30° to forward internal rotation, from 0° from external rotation, and from 30° external rotation to forward external rotation. Since the evaluation was performed in athletes and healthy individuals, the dynamometer speed was chosen as 0.1°/sec for more precise measurement. Participants were asked to tell the assessor when they first felt the movement of the movement. The time in seconds from the beginning of the test until the participants felt the movement was recorded¹⁸.

Shoulder Muscle Strength and Endurance Assessment

Participants were asked to refrain from any physical activity training or exercise the day before the test to avoid fatigue. Before each test session, the dynamometer was calibrated according to the manufacturer's instructions²⁰. To ensure balance and isolate shoulder movement as much as possible, participants were secured to the chair with the device's straps over their shoulders, chest, and hips. Verbal encouragement was given to ensure maximum effort²⁰.

The isokinetic muscle strengths of the internal and external rotators were assessed using the Cybex Humac Norm Isokinetic System (2009) in concentric mode at 60°/sec-180°/sec. The participants were positioned in a supine position with the shoulder in 90° abduction and the in

90° flexion. After a warm-up consisting of 4 submaximal repetitions at 60°/s, the participants rested for 60 seconds. They completed a period of 4 maximal repetitions^{19,21}. A 180°/s warm-up consisting of 4 submaximal repetitions, rested for 60 s, and completed a period of 15 maximal repetitions. 60°/s was preferred to assess muscle strength and 180°/s to assess endurance²². After the test, the internal and external rotation absolute peak torques, total work, and internal/external rotation ratios at angular velocities of 60°/sec and 180°/sec were calculated on the computer. Peak torque values are recorded in (Nm)²³. Peak torque of 60°/180° IR/ER tests were used to evaluate muscle strength. Muscle endurance was evaluated using total work at 60°/180° IR/ER.

Swimming Performance Measurement

Water Polo Shuttle Swim Test: Swimming performance was measured using the WP shuttle swim test. It is a measure of the ability of WP players to move effectively in water²⁴. It includes two swimming sets of 120 meters at maximum speed with a 90-second rest between each set and a 90-second. Each set consists of 7 repetitions and swims in the following order: 1 x 40 meters, 2 x 20 meters, and 4 x 10 meters. The rest time between repetitions should be the same as the load time (load-to-rest ratio 1:1). The swimming area is defined as 10 meters between two lines. For swim sets longer than 10 meters, the swimmer athlete must complete the target distance by returning²⁵. The total time is recorded.

Measuring Agility Performance

Water polo Agility Test: (In-Water Agility: Stop and Go-Agility and Jump and Go-Agility) (Stop and Go (SG) and Jump and Go (JG)).

Measurement agility performance was measured

Table 1. Physical and sociodemographic characteristics of the participants (n=28).

Physical characteristics	M	SD	Min	Max
Age (Year)	16.32	1.93	14.00	20.00
Height (cm)	175.04	5.00	155.00	192.00
Weight (kg)	45.00	11.86	67.54	88.00
BMI (kg/m ²)	16.85	3.10	16.85	31.55
Sociodemographic characteristics		n (%)		
Education level				
Primary school	0 (0)			
Secondary school	6 (21.4)			
High school	17 (60.7)			
University	5 (17.9)			
Income-Expense Balance				
Equal	8 (28.6)			
Income>expense	19 (60.7)			
Income<expense	1 (3.6)			
Dominant and evaluated party				
Right	27 (96.4)			
Left	1 (3.6)			

n: The number of participants. *M*: Mean. *SD*: Standard Deviation. *Min*: Minimum. *Max*: Maximum. *BMI*: Body Mass Index

using the water tube agility test. Athletes warmed up a standardized pool for 20 minutes. All athletes completed performed at least 4 trials. The athletes were tested 3 times, and the color and order of stimuli were randomly selected in each test. By pre-setting the 3 trials to be used for each test, we ensured that the distances covered (23 m for SG, 15 m for JG) were the same for each participant. Therefore, each player completed the same test trials in a randomized order. For this test, 3 target balls (number 4 WP balls) were mounted inside the WP hats and tied to a single-strand rope 1.66 m apart, with the center ball 2.5 m perpendicular to the starting ball and the 2 outer balls 3 m from the starting ball (Figure 1). A television screen was placed on the pool deck in line with the starting ball and the middle target to display color stimuli corresponding to the colors of the hats on the balls. The athlete's athletes started in a horizontal position facing the screen, with their heads touching the start ball. The test began with the practitioner's whistle, simultaneously showing the first stimulus on the screen²⁵. The player then moved toward moved the ball of color shown on the screen to touch it with his hand. After touching the ball, he returned to touch the starting ball with his hand. This cycle continued throughout the test. In the test, players were required to touch the starting ball 4 times in total. The tester triggered a new stimulus each time the player touched the starting ball. A test was considered completely finished when the athletes returned and touched the starting ball for the last time²⁶. The completion time was recorded.

Measurement of Speed Performance

20-m Sprint Swimming Test

Speed performance was measured in the 20-with sprint swim test. In a 25-indoor swimming pool, maximum sprint swimming times were recorded for a distance of 20 meters. Athletes were instructed to start the sprint with a whistle or signal and were placed 1 m away from the wall before the start signal was given for water ball specificity. The markers (0 and 20 m) were placed at the start and end of the sprint. A video camera was used to record the test. The time was calculated from the recorded video with a flashing light synchronized to the start of the test. Before the test, athletes performed a standard warm-up consisting of 5 min of submaximal swimming followed by semi-fast sprints (2 sets of 15 m). Three trials were completed with 5-min rest between each trial trials. The mean of the times obtained in the 3 trials was used for subsequent statistical analyses^{27,28}.

Statistical Analysis

The SPSS for Windows 29.00 computer package program is used for all statistical analyses. Data were checked for accuracy and normal distribution. Intraclass correlation coefficients were used to report best practices along with 95% confidence intervals (CIs) and standard errors. Descriptive statistical information was presented as mean and standard deviation ($X \pm SD$) for measured values and number (n) and percentage (%) for non-measured values.

Table 2. Shoulder joint proprioception, muscle strength, endurance, swimming, agility, speed and performance tests (n=28).

Shoulder joint proprioception	M±SD	Min	Max	Skewness		Kurtosis	
				Statistic	Std.Error	Statistic	Std.Error
Sense of movement							
0°-IR (°)	1.75±0.89	1.00	4.00	1.22	0.44	1.14	0.86
0°-IR (Sec.)	22.11±8.09	10.00	45.00	0.90	0.44	0.98	0.86
30°-IR (°)	1.82±0.94	1.00	4.00	0.95	0.44	0.42	0.86
30°-IR (Sec.)	24.32±9.93	13.00	50.00	0.98	0.44	0.44	0.86
0° ER (°)	1.86±0.76	1.00	4.00	0.80	0.44	1.04	0.86
0° ER (Sec.)	24.82±9.98	8.0	48.00	0.56	0.44	0.55	0.86
30° ER (°)	1.89±0.74	1.00	3.00	0.17	0.44	-1.06	0.86
30° ER (Sec.)	24.07±8.93	7.00	42.00	0.12	0.44	-0.74	0.86
Position sense							
30° IR (°)	4.06±2.14	0.66	8.00	0.39	0.44	-0.84	0.86
60° IR (°)	3.70±1.88	1.00	9.33	1.38	0.44	2.11	0.86
30° ER (°)	5.15±2.21	1.00	9.33	-0.59	0.44	-0.44	0.86
60° ER (°)	5.31±2.55	1.00	9.33	0.08	0.44	-1.27	0.86
Shoulder Joint Muscle Strength							
Peak Tork 60° IR	39.00±11.18	18.00	62.00	0.07	0.44	-0.56	0.86
Peak Tork 60° ER	27.25±9.26	12.00	49.00	0.73	0.44	0.33	0.86
Peak Tork 180° IR	32.86±10.39	13.00	56.00	0.11	0.44	-0.42	0.86
Peak Tork 180° ER	22.79±9.18	2.00	45.00	0.52	0.44	1.46	0.86
Shoulder Joint Endurance							
Total Work 60° IR	321.14±93.97	168.00	483.00	0.137	0.44	-1.03	0.86
Total Work 60° ER	234.25±76.70	73.00	422.0	0.71	0.44	1.45	0.86
Total Work 180° IR	658.97±248.61	185.00	1008	-0.15	0.44	-0.92	0.86
Total Work 180° ER	511.82±197.93	175.00	956	0.53	0.44	0.10	0.86
Swimming, agility and speed performance tests							
Shuttle Swimming Test (Sec.)	164.25±10.79	143.80	185.44	-0.23	0.44	-0.26	0.86
Waterpolo Agility Test (Sec.)	39.87±4.74	32.68	47.40	0.12	0.44	-1.39	0.86
Twenty-Meter Maximal Sprint Swim (Sec.)	12.65±1.33	10.37	47.40	0.509	0.44	-0.65	0.86

N: The number of participants. M: Mean. SD: Standard Deviation. Min: Minimum. Max: Maximum, IR:Internal Rotation, ER:External Rotation Sec.: Second.

Cronbach's coefficient and item-total correlation were used to analyze the measurement tools. Conformity of the data to normal distribution was determined by the Kolmogrov-Smirnov Test, Skewness, and Kurtosis tests (-+2)²⁹. Pearson correlation analysis was performed to determine the relationship between shoulder proprioception and shoulder internal and external muscle strength, swimming ability, agility, and speed. In addition, multiple regression analysis was performed to determine the relationship between shoulder proprioception, muscle strength, endurance and swimming, agility, and speed performance³⁰. The results were evaluated using a 95% confidence interval and significance level <0.05³¹.

Results

This study, it was determined that all 28 participants, aged between 14 and 20 years, were male, single, had marital status, and were students, and the dominant side was 96.4% right (Table I). It was observed that the parameters evaluated in our study followed a normal distribution (Table II).

It was determined that there was no significant relationship between shoulder joint proprioception and shuttle swimming, WP agility test, and 20-meter maximum speed swimming test (p>0.05) (Table III). In addition,

Table 3. Determination of the effects of shoulder joint proprioception, muscle strength, endurance on swimming, agility, speed and performance tests by Spearman's and Pearson correlation.

Shoulder joint proprioception	Swimming, agility and speed performance tests					
	Shuttle Swimming Test		Waterpolo Agility Test		Twenty-Meter Maximal Sprint Swim	
Sense of movement	r	p	r	p	r	p
N=28						
0°-IR	0.222	0.256	0.340	0.077	0.284	0.143
30°-IR	-0.020	0.921	0.196	0.319	0.113	0.566
0° ER	0.029	0.883	0.164	0.404	0.117	0.552
30° ER	-0.47	0.814	0.252	0.196	0.022	0.911
Position sense						
30° IR	-0.059	0.766	-0.011	0.955	0.079	0.689
60° IR	-0.155	0.432	0.168	0.394	0.129	0.514
30° ER	0.035	0.858	0.025	0.899	0.002	0.992
60° ER	0.122	0.535	0.083	0.676	0.136	0.491
Shoulder Joint Muscle Strength						
Peak Tork 60° IR	-0.443*	0.018	-0.490**	0.008	-0.581**	0.001
Peak Tork 60° ER	-0.382*	0.045	-0.458*	0.014	-0.477*	0.010
Peak Tork 180° IR	-0.445*	0.018	-0.515**	0.005	-0.621**	<.001
Peak Tork 180° ER	-0.481**	0.010	-0.299	0.122	-0.506**	0.006
Shoulder Joint Endurance						
Total Work 60° IR	-0.439*	0.019	-0.393*	0.039	-0.544**	0.003
Total Work 60° ER	-0.353	0.066	-0.360	0.060	-0.437*	0.020
Total Work 180° IR	-0.540**	0.003	-0.551**	0.002	-0.717**	<.001
Total Work 180° ER	-0.551**	0.002	-0.570**	0.002	-0.638**	<.001

*N: The number of participants. M: Mean. SD: Standard Deviation. Min: Minimum. Max: Maximum, IR:Internal Rotation, ER:External Rotation Sec.: Second, p <0.05. r: Pearson correlation coefficient. ***= Correlation is significant at the 0.001 level. *= Correlation is significant at the 0.05 level.*

in the multiple regression models 1, 2, and 3, which were established to determine the relationship between shoulder joint proprioception and shuttle swimming, WP agility, and 20-m maximum speed swimming tests, no significant relationship was found ($p>0.05$) (Table IV). In this study, a moderate negative correlation was found between shoulder joint muscle strength and the shuttle swimming test, WP agility test, and 20-m maximum speed swimming test (Peak Torque 60° IR respectively, $r:-0.443$, $p:0.018$, $r:-0.490$, $p:0.008$, $r:-0.581$, $p:0.001$) (Table III). In the multiple regression analysis performed in our study, ANOVA test results in Models 4, 5, and 6 showed that there was a significant relationship between shoulder joint muscle strength and swimming shuttle test and 20-m maximum speed swimming test (Respectively, $F:2.912$, $p:0.044$, $F:5.004$, $p:0.005$), while there was no significant relationship between WP agility test ($F:2.293$, $p:0.090$) (Table IV). The adjusted R^2 in the model summary shows the generalizability of the model. It was determined that the effect of shoulder joint muscle strength on other outcome

measures explained 33.6% ($r^2=0.336$), 28.5% ($r^2=0.285$), and 46.5% ($r^2=0.465$) of the total variance in with the shuttle swimming test, WP agility test, and 20-m maximum speed swimming performance, respectively (Table IV).

In this study, a moderate negative correlation was found between shoulder joint muscle endurance and the shuttle swimming test, WP agility test, and 20-m maximum speed swimming test (Total work 180° IR $r:-0.540$, $p:0.003$, $r:-0.551$, $p:0.002$, $r:-0.717$, $p:<.001$, respectively) (Table III). In the multiple regression analysis conducted in our study, there was a significant relationship between the ANOVA shuttle swimming test, WP agility test, and 20-m maximum speed swimming test in Models 7, 8, and 9 (respectively, $F:3.896$, $p:0.015$, $F:3.786$, $p:0.017$, $F:7.157$, $p:<.001$) (Table IV). The adjusted R^2 in the model summary shows the generalizability of the model. It was determined that the model explained 40.4% ($r^2=0.404$) of the total variance in the effect of shoulder joint endurance on other outcome measures with the shuttle swimming test, 39.7% ($r^2=0.397$) with the WP agility test, and 55.5% ($r^2=0.555$)

Table 4. Determination of the effects of swimming, agility, speed and performance tests on shoulder joint proprioception, muscle strength and endurance properties by multiple regression Analysis.

Multiple Regression Analysis							
N=28	Model Summary					ANOVA	
	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson	F	p
Model 1 (SJP-SST)	0.351	0.123	-0.246	12.04	1.352	0.333	0.942
Model 2 (SJP-WAT)	0.489	0.239	-0.082	4.93	1.706	0.745	0.652
Model 3 (SJP-TMSS)	0.478	0.229	-0.096	1.39	1.255	0.704	0.685
Model 4 (SJMS-SST)	0.580	0.336	0.221	9.52	1.833	2.912	0.044
Model 5 (SJMS-WAT)	0.534	0.285	0.161	4.33	2.025	2.293	0.090
Model 6 (SJMS-TMSS)	0.682	0.465	0.372	1.05	2.029	5.004	0.005
Model 7 (SJE -SST)	0.636	0.404	0.300	9.03	1.810	3.896	0.015
Model 8 (SJE -WAT)	0.630	0.397	0.292	3.98	2.319	3.786	0.017
Model 9 (SJE -TMSS)	0.745	0.555	0.477	0.96	1.607	7.157	<.001

N: The number of participants, SJP: Shoulder Joint Proprioception, SJMS: Shoulder Joint Muscle Strength, SJE: Shoulder Joint Endurance, SST: Shuttle Swimming Test, WAT: Waterpolo Agility Test, TMSS: Twenty-Meter Maximal Sprint Swim.

with the 20-m maximum sprint swimming performance (Table 4).

Discussion

This is the first descriptive study in the literature investigating the effects of shoulder joint proprioception, isokinetic muscle strength, and endurance on swimming, agility, and speed performance in WP players. Our results are important in terms of determining the causes affecting performance and endurance which is important in WP players. Results showed that shoulder joint proprioception was not related to swimming, agility, and speed performance, shoulder joint isokinetic muscle strength affected swimming and speed performance but not agility, and shoulder joint endurance was related to swimming, agility, and speed performance in WP players.

Proprioception has been discussed in medical literature since 1906. Although the complex interaction between proprioception and shoulder function is not fully understood, shoulder proprioception may contribute to shoulder pathology³². Although studies have shown a strong correlation between coordination and agility in ball sports, an athlete's ability to perform movements efficiently and quickly depends on the activation of stabilization muscles⁸. It has also been reported that there is a relationship between proprioception and high levels of performance⁹. Increased soft tissue tension in the shoulder, the athlete's proprioception may also be affected⁹.

This study found that shoulder joint proprioception was not related to swimming, agility, and speed performance in WP players. This is thought to be due to the nature of water cannon movements, compensation mechanisms

or the sensitivity of the measuring instruments. When similar studies in the literature were examined, Hams et al. emphasized that proprioceptive acuity in water is an important determinant of the athlete's shooting performance, but it cannot be an effective determinant alone³³. Freeston et al. showed that shoulder proprioception was not related to throwing performance and accuracy in elite adolescent baseball games³⁴. Our research findings are similar to those of Freeston et al. in terms of results. Xue-Dong Shang et al. did not determine a relationship between muscle strength and proprioceptive function in the internal and external rotation of the shoulder of the hand holding the racket in elite Chinese male table tennis players¹⁹. When the studies were examined, it was seen that proprioception was not related to shooting performance, but there was not enough research in this field. Therefore, it is thought that there is a need for high-quality research on proprioception and shooting performance.

This study, it determined that shoulder the joint isokinetic muscle strength of WP players was correlated with swimming and speed performance but not agility. It is thought that the fact that agility is not related to shoulder strength in WP may be due to possible biomechanical and physiological characteristics³⁵. Silva et al. found a significant negative correlation between shoulder extensor upper extremity muscle strength and agility in wheelchair rugby athletes. It has been shown shows that as the strength increases, the time required to complete the test is shorter; therefore, agility is improved³⁶. Wiażewicz et al. reported that shoulder muscle strength variables obtained in isokinetic measurement had a moderate or strong correlation with athletic performance in elite-level swimming men and women³⁷. Özer et al. According to the regression analysis results of their study conducted on 10 WP players aged 15-

17 years, no statistically significant difference was found between the 25-m swimming test and peak torque 60° for right and left shoulder internal and external rotation values³⁸. Pawlik et al. showed that the field, laboratory, and internal rotation isokinetic tests used in their research on female volleyball players had the strongest relationship with the effectiveness of the serving role in successful serve reception³⁹. Zinner et al. reported that the adductor, abdominal, and pectoralis muscles' muscle strength muscle was positively correlated with endurance and agility in water⁴⁰. The findings obtained in the current studies will reveal the relationship between the evaluation of WP performance indices both in and out of the water and the relationship between these parameters more clearly to better in evaluate the complex profile of WP players. When the literature is examined, it is seen that there are results that support and do not support our research. There are very few studies on this subject in literature. Specific study designs should be undertaken, such as more longitudinal studies, intervention-based research or examinations at different levels of competition.

This study determined that shoulder joint muscle endurance is related to swimming, agility, and speed performance. Zinner et al. observed a significant positive relationship between endurance agility and jump height in a study conducted by elite WP players³⁹. Shoulder joint muscle endurance among WP athletes is believed to improve swimming, agility, and speed performance. Therefore, endurance training may also affect WP performance. Water polo athletes and coaches can determine the training program by taking this information into consideration when creating a training program for their athletes.

To prevent bias in the outcome measurements of the study, blinding was done in terms of data coding, statistician and reporting. The data collection tools used in the research consist of scales whose validity and reliability have been tested. An expert in the field collected the data. In the study, exclusion and withdrawal from the study were defined. Appropriate statistical methods were used to analyze the data, and values such as effect size and confidence interval were calculated.

Our study was limited to a single sports club in Konya province, and data were collected from a single sports club. The age range was 14-20 years old. A similar age range is important for the formation of more homogeneous groups. In addition, the position playing of the players participating in the study was not considered in the evaluation.

Conclusion

This study, it was determined that shoulder joint proprioception was not related to swimming, agility and speed performance in water polo players. It was determined that shoulder joint isokinetic muscle strength affected swimming and speed performance, but not agility, and shoulder joint endurance was related to swimming, agility and speed performance.

Ethics approval

Ethical permission was obtained from the Necmettin Erbakan University Health Sciences Scientific Research Ethics Committee (Decision No: 2024/675). In addition, permission was obtained from the Konya Province and Konya Selçuklu Municipality sports club (Number: 2024/270). This study was conducted in accordance with the ethical principles of the Declaration of Helsinki 1964 and its later amendments.

Consent to participate

All participants, and where necessary their parents or legal guardians, provided written informed consent after receiving both verbal and written information of the research procedures, prior to the initiation of data collection (12).

Authors' contributions

Musa Çankaya and Serdar Büyükipekçi have given substantial contributions to the conception or the design of the manuscript, Musa Çankaya and Ökkaş Keretli to acquisition, analysis and interpretation of the data. All authors have participated to drafting the manuscript, author A revised it critically. All authors read and approved the final version of the manuscript.

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