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Original Article

Assessing the physical performance of underwater rugby world champions: A comparative analysis between expert and novice players

LAURA MARTÍNEZ-DELGADO[1], YURLEIT CATHERINE MONTOYA-PELÁEZ[2], SAMUEL GAVIRIA ALZATE[3], WILDER GEOVANNY VALENCIA-SÁNCHEZ[4,*]
[1,2,4]Instituto Universitario de Educación Física y Deporte, Universidad de Antioquia UDEA, Calle 70 No. 52-2, Medellín, COLOMBIA
[3]Facultad de Educación, Universidad de San Buenaventura-Medellín, Carrera 56C N° 51-110, Medellín, COLOMBIA

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Abstract:
Introduction: While previous studies have primarily focused on the perceptual and cognitive abilities of expert and novice players, the literature on underwater rugby (UWR) lacks studies on the physical elements influencing performance. This gap in knowledge necessitates a physical perspective to establish benchmarks set by experts, serving as crucial references for scientists as well as players aspiring to achieve peak levels in this sport. *Objectives:* The primary goal of this study was to conduct a comprehensive comparison between UWR experts and novices, specifically examining their performance in aerobic and anaerobic power, fatigue index, maximum strength, nonlinear underwater displacement, flexibility, and body composition. *Methods:* A total of 24 male players, consisting of 11 experts (World Champions, Austria 2019, Tier 5) and 13 novices (Tier 2), participated in this descriptive, quantitative, and nonexperimental study.
The evaluation encompassed a diverse set of assessments, including Course Navette tests, sprint-based running, static maximal strength, flat bench press maximal strength, underwater direction change, shoulder flexibility, and bioimpedance. The tests were conducted over a 14-day period, ensuring optimal recovery between each assessment. *Results:* Anthropometric variables did not exhibit statistically significant differences between the expert and novice groups. However, significant variations were observed in various physical variables such as maximum force in the flat bench press, maximum power, minimum power, average power, fatigue index, and nonlinear displacement.
Particularly significant were the large effect sizes observed in nonlinear underwater displacement, mean power, and maximum force in the flat bench press. *Conclusions:* The identified variables emerged as pivotal determinants of high performance in UWR. This comparative analysis between expert and novice players provides valuable insights for practitioners and sport scientists. It offers a foundation for the development of more effective research projects and targeted training programs, specifically designed to enhance performance in UWR.
Keywords: **body composition, muscle strength, anaerobic test, aerobic fitness, fatigue, goniometer**

Introduction

Underwater rugby (UWR) is a sport that seamlessly combines cooperation and opposition dynamics (González, 2020). In this sport, two teams engage in dynamic play within a shared three-dimensional space (Fig. 1), located beneath the surface of a swimming pool. The dimensions of the playing area typically range from 12 to 22 m in length, 8 to 12 m in width, and a depth of 3.5 to 5 m. Each player's essential diving equipment comprises a mask, fins, and a snorkel (Gaviria, 2019; González, 2020; Vásquez, 2014).

The primary objective in UWR is to insert a ball into the opposing team's goal while simultaneously thwarting the opponent's progress and defending one's own goal (Ospina & Trujillo, 2013; Soto et al., 2018). Goals are strategically positioned at both ends on the pool's bottom surface (Ates et al., 2017; Gaviria, 2019; Maldonado, 2010; Ospina & Trujillo, 2013).

A UWR team comprises 15 players, with each game played by 12 individuals, 6 actively participating in the water and the remaining 6 as substitutes. The dynamic nature of the game requires frequent substitutions during play, with an additional three reserve players available for exchange at the coach's discretion and with referee's approval (Soto et al., 2018; Vásquez, 2014).

Corresponding Author: WILDER GEOVANNY VALENCIA-SÁNCHEZ, E-mail: wilder.valencia@udea.edu.co

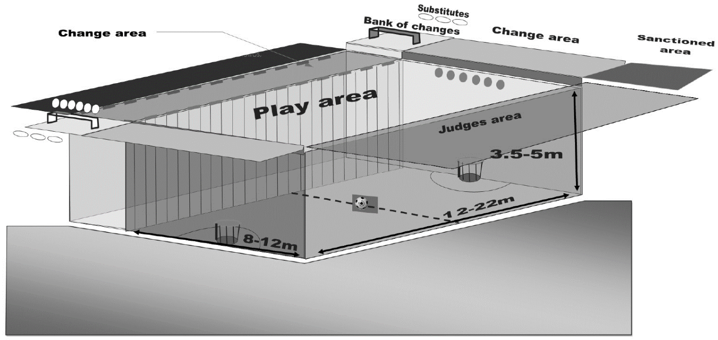

Fig. 1. UWR playing area

In physical terms, UWR is a sport characterized by considerable physical, physiological, and metabolic demands, encompassing both aerobic and anaerobic requirements (Soto et al., 2018; Vásquez, 2014). This is primarily due to the challenges of underwater environment, which necessitates players to maintain strong lung capacity, a high oxygen intake, and a rapid rate of recovery (Ospina and Trujillo, 2013). The impact of hypoxia further influences the technical, tactical, and physical aspects of the game. Consequently, players involved in UWR experience brief intervals of previous inhalation and oxygen retention during actual gameplay, lasting for a maximum of 20–45 s. Then, players have to surface for a breath and swiftly submerge again to resume playing (Ospina & Trujillo, 2013; Soto et al., 2018).

UWR players predominantly perform acyclic underwater movements characterized by changes in direction, speed, intensity, and distance, encompassing diverse actions such as displacements, disputes, turns, and blocks (Vásquez, 2014). These movements generate a state of weightlessness, hydrostatic pressure, and increased lung capacity, highlighting manifestations of strength, resistance, speed, and flexibility (Soto et al., 2018; Vásquez, 2014). This study focused on the physical aspects of UWR, aiming to identify variables crucial for achieving high performance. Notably, a focus on maximum strength in the hands and forearms is emphasized, because it facilitates superior control over ball grip (Ates et al., 2017). Additionally, the significance of both anaerobic and aerobic power is underscored, because these factors enable rapid and repetitive movements essential throughout the game (Soto et al., 2018; Vásquez, 2014). Recognizing the pivotal role of directional agility in sporting success, this study aligns with a study by Brughelli et al. (2008), who asserted that the ability to change direction is a decisive factor in player selection, distinguishing between elite and subelite players (Alzate et al., 2021). Shoulder flexibility is also considered, prompted by a coach's recommendation from the Champions World (2019) who stressed the high demand for shoulder flexibility in both offensive and defensive maneuvers (Gaviria, personal communication, 2021). This exploratory variable is evaluated to validate the coach's perception, filling a gap in the UWR literature.

In UWR, players need to have high levels of physiological, motor, anthropometric, and psychological factors, while also incorporating technical and tactical factors (Ates et al., 2017). Determining the optimal performance benchmarks for each factor crucial for an expert-level player is imperative. This comprehensive understanding is pivotal in unraveling the intricacies of UWR, particularly in terms of physical performance, thereby advancing the overall knowledge of the sport.

Comparisons between expert and novice players have traditionally centered around perceptual and cognitive abilities (Chen et al., 2022; Debarnot et al., 2014; Ericsson & Towne, 2010; Farrington-Darby & Wilson, 2006; Kalyuga et al., 2012; Russo & Ottoboni, 2019). Despite extensive literature searches in Spanish, English, Portuguese, and Turkish, no studies have been identified regarding the physical elements crucial for performance in UWR, including aerobic and anaerobic power, fatigue index, maximum strength, nonlinear underwater displacement, and flexibility. Thus, establishing benchmarks based on the performance of experts is crucial from a physical standpoint, serving as invaluable references for both scientists and players aspiring to attain the highest levels in this sport.

In Colombia, UWR has been practiced since 1991, marked by significant sporting achievements, as highlighted by Ospina and Trujillo (2013). Notably, the men's delegation secured two world club titles in 2018 and 2019, claiming the World Cup championship in 2019 and achieving a commendable third place in the same competition in 2015. The women's delegation won a club world title in 2010 and achieved third places in the World Cup in 2003, 2015, and 2019.

Though UWR as a worldwide sport has existed since 1978, originally serving as a means to maintain the physical fitness of scuba divers during winter (Gaviria, 2019; Soto et al., 2018), the body of published scientific studies on this unique sport remains limited. Existing research is sparse, as indicated by previous studies (Alzate et al., 2021; Ates et al., 2017; Gaviria, 2019; González, 2020; Ospina & Trujillo, 2013; Vásquez Gómez, 2014).

Given the abovementioned issues, this study aimed to compare the performance of experts and novices in UWR across key parameters, including aerobic and anaerobic power, fatigue index, maximum strength, nonlinear underwater displacement, flexibility, and body composition.

Materials and methods

Participants and design

This study adopted a descriptive, quantitative, and nonexperimental approach (Hernández-Sampieri et al., 2018). The sample, drawn through convenience sampling rather than a probabilistic method (Hernández-Sampieri et al., 2018), comprised individuals affiliated with the Colombian UWR team as well as the Orcas and Ecomares clubs in Medellín, Colombia. The study enrolled 12 male expert players and 14 male novice players. To assess the likelihood of committing a type II error, data from Ates et al. (2017) and Rincón et al. (2020) were utilized. These studies calculated the maximal oxygen consumption of healthy elite and adult UWR players, respectively, revealing a mean difference of 45.5 and 52.7, a standard deviation of 7.6, and a group size of 12 subjects. With a $Z\beta = -1.187$, $p = 0.1190$, and a power of $1-\beta = 0.881$, the power of this study was determined to be 88.1%.

Selection criteria

The expert group comprised members of the UWR Colombian team who actively participated in the 2019 World Cup. In contrast, the novice group consisted of players from two UWR clubs, each with an average experience of less than three years. Of note, these novices lacked any experience in elite championships, and their coach perceived their play performance as low. Prior to participation, all players were required to sign an informed consent form. Exclusion criteria for both groups encompassed a history of osteomuscular disease within the preceding two months, any cardiovascular disease, testing positive for the SARS-CoV-2 virus, or failure to complete the prescribed trials. The criteria for determining the level of experience for subject coaches were adapted from Sánchez-López et al. (2014). In accordance with the participant classification framework, players classified as experts fell under Tier 5, denoted as World Class, while those categorized as novices fell under Tier 2, labeled as Trained/Developmental (McKay et al., 2022).

Bias control

The selection of participants for this study involved meticulous adherence to inclusion and exclusion criteria, ensuring a homogeneous sample among both the expert and novice groups. Rigorous measures were taken, employing valid and reliable measuring instruments. Pilot tests for each measurement, along with their respective protocols for the study variables, were conducted to identify and address any potential challenges in test execution. To ensure precision and consistency, two evaluators underwent thorough training for test administration. The subjects were familiarized with each assessment, and the evaluators provided motivational feedback, fostering an environment conducive to optimal player performance. Recognizing potential confounding variables, such as sleep duration and eating habits, proactive measures were implemented. Recommendations regarding these variables were communicated to the subjects from the study's outset, with particular emphasis on the days leading up to the measurements. This approach aimed to guarantee optimal test performance by minimizing the impact of extraneous factors.

Measures

Sociodemographic

The demographic information, including age, years of experience, weekly training frequency, and study eligibility criteria, was collected using an ad hoc, predesigned survey.

Anthropometric

To evaluate the body composition of UWR players, measurements of body height, body mass, muscle mass index, and fat mass percentage were conducted. A stadiometer (206, Seca, Germany), securely affixed to the wall with a measurement range of 200 cm and an accuracy of one millimeter, was employed. Additionally, a bioimpedance device (HBF-516, Omron, Japan) was utilized, featuring an error range of 2.2–3.3% for body fat. Data collection adhered to the protocol outlined by Alvero et al. (2009).

The measurement of standing body height was conducted with each subject positioned without shoes, feet and heels together, buttocks and upper back against the wall, and the head aligned in the Frankfort plane—ensuring the orbital arch was horizontally aligned with the ear tragus (Norton & Olds, 2007). For body mass measurement, individuals stood upright with minimal clothing, bare feet on the scale, arms at their sides, not holding on, head elevated, and eyes looking straight ahead (Norton & Olds, 2007). To calculate body fat percentage and muscle percentage, gender, body height, and body mass data were input into the bioimpedance equipment. Subjects assumed an upright position with bare feet on the pads of the analyzer equipment, hands clenched, and arms extended over the electrodes of the device (Wang et al., 2013). The procedures followed recommendations outlined by Alvero et al. (2009, p. 168): a fasting period of at least 4 h, avoidance of strenuous exercise within the previous 12 h, urination 30 min before the test, abstinence from alcohol for 48 h, refraining from diuretics for 7 days, and removal of all metallic elements (watches, rings, bracelets, earrings, piercings, etc.) during the evaluation.

Aerobic power

Aerobic power, defined as the capacity to generate energy per unit of time using aerobic pathways, is best indicated by maximal oxygen consumption (VO2max) (La Valle, 2000). The evaluation of aerobic power employed the Course Navette protocol developed by Leger et al. (1988). This protocol involves traversing a 20-meter distance marked by two parallel lines, starting at a speed of 8.5 km/h and incrementing by 0.5 km/h every minute in response to an auditory signal (Fig. 2). During the test, the athlete stands behind a designated line, facing the direction indicated by the next line. Upon the commencement of the auditory signal, the athlete moves toward the next line, awaiting the subsequent signal to repeat the process. The test continues until the athlete fails to reach the designated line in time when the signal sounds. This indirect assessment of VO2max, as described by Gadoury and Leger (1986), has become a widely reported and accepted method in the literature for over three decades, especially in team sports owing to its alignment with the displacement characteristics in such sports. The protocol has an intraclass correlation coefficient of 0.95 and a coefficient of variation of 5.7%, showcasing its reliability compared to direct tests (García & Secchi, 2014).

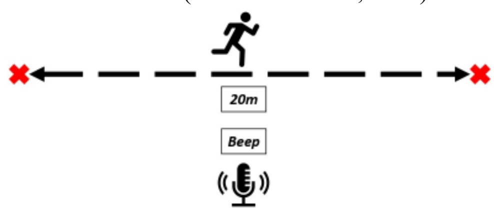

Fig. 2. Visual depiction of the Course Navette protocol

Anaerobic power

Anaerobic power, denoting the capacity to rapidly generate energy through the phosphagen pathway, which operates without the need for oxygen (Green, 1994), was assessed using the running-based anaerobic sprint test (RAST) developed by Draper and Whyte (1997) (Fig. 3). Before initiating the test, the subjects' body mass (kg) was determined, followed by a 10-min warm-up and a recovery period of 3–5 min prior to the test commencement. During the RAST, the participants positioned themselves at one end of the track, awaiting the start signal to execute six sets of 35-m sprints at maximum speed. After each sprint, a 10-s interval was allowed for returning to the starting point and initiating the subsequent sprint. One evaluator recorded the time taken for each 35-m sprint, while another recorded the 10-s recovery time (Walker, 2016). The RAST has an intraclass correlation coefficient of 0.88 (Zagatto et al., 2009), and its validity was confirmed through systematic review against the 30-s Wingate anaerobic test (Nara et al., 2022).

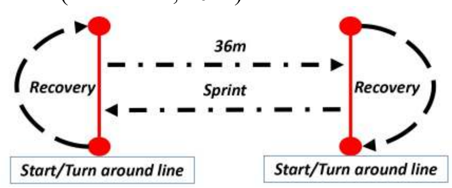

Fig. 3. Description of the RAST

Maximum strength

Maximum strength, defined as an individual's capacity to voluntarily generate the greatest tension in a muscle group (Weineck, 2005), was assessed through the maximum repetition of the bench press using a protocol derived from Baechle and Earle (2008) and de Lucio and Castañeda (2004) with slight modifications in distribution. The procedure commenced with a 10-min warm-up focusing on joint mobility. Subsequently, 10 repetitions of the technique were performed with a light load. Following this, a series of six repetitions at 50%, five at 60%, four at 70%, three at 80%, and two at 90% were executed. After a two-minute rest, the subject proceeded with 95% and 100% loads to determine the maximum repetition (1RM). The 1RM test has robust reliability between tests and retests, with an intraclass coefficient of agreement ranging from 0.64 to 0.99 (median ICC = 0.97) and a coefficient of variation ranging from 0.5% to 12.1% (median CV = 4.2%). These findings were confirmed through a systematic review (Grgic et al., 2020).

Maximum static strength

The maximum static strength test for the hand and forearm was conducted using a standard hydraulic hand dynamometer, with an accuracy exceeding 98% at 200 lb (Baseline Enterprises Inc., USA), following the protocol outlined by Gordillo and Yopasa (2018). The subject initiated the test with a warm-up, after which the dynamometer needle was zeroed to align with the hand's characteristics. In a bipedal stance, the subject held the dynamometer in a straight line with the forearm, allowing it to hang without making contact with the leg. The participant exerted the maximum force possible on the dynamometer without allowing the hand or arm to touch the body or any other object. This process was repeated three times with the same hand, with a 30-s recovery between each attempt, and the highest value was recorded. The Jamar manual dynamometer employed for this test has an intraclass correlation coefficient exceeding 0.71 for grip, tip pinch, key pinch, and palmar pinch (Mathiowetz et al., 2000).

Shoulder flexibility

Flexibility, defined as the capacity of an individual to perform movements with the maximum possible extension in one or several joints (Magnusson & Renström, 2006; Weineck, 2005), was assessed using goniometry following the protocol proposed by Di Santo (2018) for shoulder flexion and extension. To measure shoulder flexion, the subject assumed a supine position on a flat surface without a pillow. The hands and forearms were positioned neutrally, with the thumbs facing the ceiling. Subsequently, the assessor positioned the center of the goniometer transfer device on the acromion, aligning the horns with the radius. The assessor then guided the joint to its maximum flexion, keeping one horn directed towards the trunk while moving the other to the point of maximal flexion in the direction of the radius (Fig. 4). For shoulder extension measurement, the subject lay prone on a stretcher on a flat surface, ensuring the shoulder joint was elevated off the support. The evaluator, aligning the goniometer transfer center on the acromion with the horns directed toward the trunk, observed as the subject extended the joint to its limit. The evaluator kept one horn directed toward the trunk and moved the other to the point of maximum extension in the radius's direction (Fig. 5). The goniometer is an instrument that is known for its validity and reliability (Norkin & White, 2019). Shoulder flexion has an intraclass correlation coefficient of 0.96, while that of shoulder extension is 0.98 (Greene & Wolf, 1989; Norkin & White, 2019).

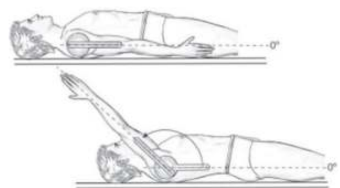

Fig. 4. Body position during shoulder flexion [Adapted from Valle and Franco (2015, p. 9)]

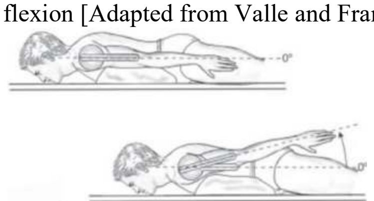

Fig. 5. Body position during shoulder extension [Adapted from Valle and Franco (2015, p. 10)]

Underwater nonlinear displacement

The underwater nonlinear displacement capacity, representing underwater change of direction (Alzate et al., 2021), was evaluated using the underwater change of direction test. This test involves executing nonlinear underwater displacements between three floating elements, each at a height of one meter, supported by three ballasts arranged linearly with a separation of 2.25 meters. The athlete initiates the displacement from the base point with a sound signal, maneuvering through zigzag floating objects (Fig. 6) (Alzate et al., 2021). The time is recorded from the start signal until the subject touches the end point with his/her hand (Alzate et al., 2021). During the test, the participants are prohibited from getting help from any surface, not finishing the test, or making contact with the floating elements using their body or fins (Alzate et al., 2021). The intraclass correlation coefficient for the male population demonstrates substantial reliability ($r = 0.74$, $p < 0.01$), and the overall test reliability is deemed acceptable (Cronbach's Alpha = 0.73) (Alzate et al., 2021).

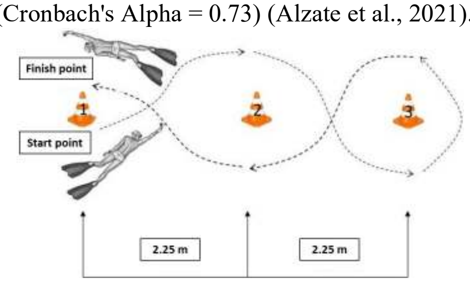

Fig. 6. Visual representation of underwater nonlinear displacement [Adapted from Alzate et al., 2021, p. 181]

Testing schedule

The tests were conducted over a span of 14 days, ensuring optimal recovery intervals between each session (Table 1).

Table 1. Testing schedule

Day	Variable	Test
One	Sociodemographic	Ad hoc survey
Two and three	Static maximum force	Dynamometry
Four	Anthropometry	Bioimpedance
Five and six	Maximum strength	Flat bench press one repetition maximum
Seven and eight	Flexibility	Shoulder goniometry
Nine and ten	Aerobic power test	Course Navette
Eleven and twelve	Nonlinear displacement capability	Change of direction underwater
Thirteen and fourteen	Anaerobic power	Run-based anaerobic sprint test

Statistical analysis

In the univariate analysis, the Shapiro–Wilk test (n < 50) was employed to assess the normal distribution of quantitative variables. Parametric tests were applied for normally distributed data, and the results were presented as the means ($\bar{X}$) and standard deviation (SD). Non-parametric tests were utilized for non-normally distributed data, with the results presented as the median (Med) and interquartile range (IQR). For two independent samples (experts vs. novices), Student's t-test was applied for variables with a normal distribution, while the Mann–Whitney U test was used for variables with a non-normal distribution. Effect sizes were calculated and interpreted using the criteria: <0.20 (null), 0.2–0.6 (small), 0.6−1.2 (moderate), 1.2−2 (large), 2−4 (very large), and >4 (extremely large) (Hopkins, 2004; Turner et al., 2016). For variables exhibiting a non-normal distribution, the effect size was computed using U / mn for the Mann–Whitney U test (Ventura-León, 2016) and was interpreted as follows: ≤ = 0.0 no effect; ≥ 0.56 small; ≥ 0.64 median; ≥ 0.71 large (Grissom, 1994). Statistical analyses were performed using the "Statistical Package for the Social Sciences (SPSS)" version 28 for Windows (Illinois, USA), with an alpha value ≤ 0.05 ($p \leq 0.05$) and a reliability of 95%. Imputation of missing data for each variable was performed based on their distribution characteristics.

Ethical aspects

This project was endorsed by the Research Ethics Committee of the University Institute of Physical Education and Sports (CEI-IUEFD) at the University of Antioquia, registered in Act #084 on September 27, 2021.

Results

Figure 7 shows the flowchart illustrating the study process. A total of 32 UWR players started the process, and 24 subjects successfully completed it.

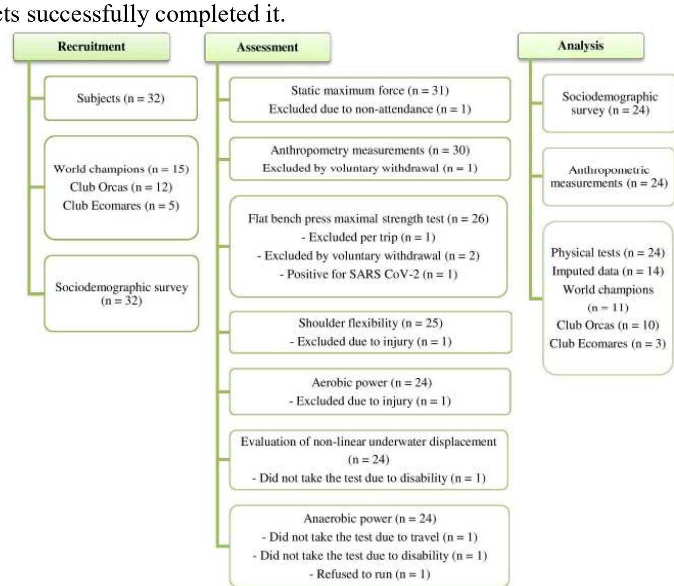

Fig. 7. Flowchart illustrating the study process

The inferential analysis of anthropometric variables is presented in Table 2. Comparison of the expert and novice groups in variables such as age, body height, body mass, body mass index (BMI), body fat mass, and body muscle mass did not reveal statistically significant differences (p > 0.05). However, a trend toward statistical significance was observed in body mass (t = 1.85; p = 0.078). Regarding the effect size in anthropometric variables, muscle mass exhibited a null effect (ES < 0.2), while age, body fat mass, and BMI demonstrated a small effect (ES = 0.2–0.6). Additionally, body mass and body height displayed a moderate effect size (ES = 0.6–1.2).

Table 2. Bivariate analysis of anthropometric variables in expert and novice groups

Variable	Experts (n = 11)		Novices (n = 13)		Difference of means	95%CI	*t*	*p*-value	ES
	Mean	SD	Mean	SD		LL: UL			
Age (years)	32.16	6.19	28.8	7.83	3.36	−2.7: 9.42	1.15	0.26	0.47
Body height (cm)	176.27	4.17	173.08	5.88	3.19	−0.01: 0.07	1.50	0.14	0.62
Body mass (kg)	85.06	12.47	76.75	9.53	8.32	−0.99: 17.63	1.85	0.078	0.76
BMI (kg/m^2)	27.35	3.78	25.67	3.58	1.66	−1.44: 4.8	1.11	0.27	0.46
Body fat mass (%)	19.34	6.24	20.75	6.69	−1.41	-6.9: 4.11	−0.52	0.60	−0.22
Muscle mass (%)	39.8	3.77	39.35	3.49	0.45	−2.62: 3.53	0.30	0.76	0.12

BMI = body mass index; SD = standard deviation; 95%CI = 95% confidence interval; LL = lower limit; UL = upper limit; ES = effect size

For the physical variables, significant differences (p ≤ 0.05) were observed between the expert and novice groups in the maximum static force in the left hand, maximum power, minimum power, average power, and fatigue index. Additionally, the maximum static force in the right hand demonstrated near statistical significance (*p* = 0.08) (Table 3). Conversely, no statistically significant differences (p > 0.05) were noted in right shoulder flexion, right shoulder extension, left shoulder flexion, and VO2max. Regarding the effect size, it was large for the flat bench press one-repetition maximum, maximum power, and average power (ES = 1.2–2). Moderately substantial effect sizes (ES= 0.6–1.2) were observed for the maximum static force in the left and right hands, minimum power, and fatigue index. Right shoulder flexion (RSF) and VO2max presented a small effect size (ES= 0.2–0.6), while other physical variables [right shoulder extension (RSE) and left shoulder flexion (LSF)] demonstrated a null effect size (ES < 0.2).

Table 3. Bivariate analysis of physical variables in expert and novice groups

Variable	Experts (n = 11)		Novices (n = 13)		Difference of means	95%CI LL: UL	*t*	*p*-value	ES
	Mean	SD	Mean	SD					
RHSMF (kg)	52.09	6.68	45.38	10.82	6.70	−1.08:14.50	1.78	0.088	0.73
LHSMF (kg)	48	5.97	42.85	9.56	5.15	−1.74: 12.05	1.54	0.13	0.63
1RM in FBP (kg)	104.82	23.16	73.15	22.19	31.66	11.97: 51.35	3.33	0.003*	1.37**
RSF (°)	156.55	9.59	160.23	10.17	−3.68	−12.10: 4.73	−0.90	0.37	−0.37
RSE (°)	43.91	10.43	45.15	7.39	−1.24	−8.81: 6.32	−0.34	0.73	−0.14
LSF (°)	155.91	8	156.38	12.61	−0.47	−9.62: 8.67	−0.10	0.91	−0.04
VO2max (ml/kg/min)	38.97	5.01	36.83	7.9	2.14	−3.58: 7.87	0.77	0.44	0.32
Maximum power (W)	667.65	120.98	509.01	151.90	158.64	40.80:276.49	2.79	0.011*	1.14**
Minimum power (W)	329.7	79.68	247.98	102.03	81.71	3.09:160.33	2.15	0.042*	0.88
Average power (W)	487.86	81.83	348.81	113.14	139.04	53.97: 224.11	3.39	0.002*	1.39**
Fatigue index (W/s)	9.21	3.46	6.58	2.58	2.63	0.07: 5.19	2.13	0.045*	0.87

SD = standard deviation; 95% CI = 95% confidence interval; LL = lower limit; UL = upper limit; RHSMF = right hand static maximum force; LHSMF = left hand static maximum force, 1RM in FBP = flat bench press one repetition maximum; RSF = right shoulder flexion; RSE = right shoulder extension; LSF = left shoulder flexion; VO2max = maximal oxygen consumption; ES = effect size; * = statistically significant differences (*p* ≤ 0.05); ** = effect size in large difference

The extension of the left shoulder did not exhibit statistically significant differences (*p* > 0.05) between the expert and novice groups (Table 4). However, nonlinear underwater displacement, the practice time in years, and the weekly practice time in hours showed statistically significant differences between both groups (*p* ≤ 0.05). The effect size for nonlinear displacement and the time of rugby practice in years was large (ES ≥ 0.71), whereas left shoulder extension and weekly practice time in hours had a small effect size (ES ≥ 0.56).

Table 4. Bivariate analysis of physical and practice time variables with a non-normal distribution of expert and novice groups

Variable	Experts (n = 11)		Novices (n = 13)		Difference of medians	U	*p*-value	ES
	Median	IQR	Median	IQR				
Left shoulder extension (°)	42	30	45	10	−3	61.50	0.55	0.43
Nonlinear underwater displacement (s)	6.85	0.65	8.92	1.98	−2.07	0.001	<0.001*	6.99**
Rugby practice time (years)	13	7.0	0.87	0.42	12.13	<0.001	<0.001*	6.99**
Weekly practice time (h)	10	3.0	8	1	2	34	0.030*	0.23**

IQR = interquartile range; ES = effect size; * = statistically significant difference ($p \leq 0.05$); ** = effect size in large difference

Discussion

The objective of this study was to compare UWR experts and novices across various performance metrics, including aerobic and anaerobic power, fatigue index, maximum strength, nonlinear underwater displacement, flexibility, and body composition. The analysis of anthropometric variables revealed no statistically significant differences ($p > 0.05$) between experts and novices, although a notable trend in the mass emerged with a moderate effect size (ES = 0.76). Furthermore, the average body fat percentage for expert players was 19.34 (SD = 6.24), and for novices, it was 20.75 (SD = 6.69). These findings closely align with the results of a study conducted by Ates et al. (2017) on UWR, where various metrics such as body mass, body height, body fat percentage, skinfold thickness, length and girth measurements, strength, flexibility, respiratory functions, anaerobic capacities, and aerobic capacities were assessed in eleven male players from Turkey. Ates et al. (2017) reported an average body fat percentage of 19.7 (SD = 6.2) using electrical bioimpedance, along with a BMI of 26.9 kg/m² (SD = 4.1), with the value for experts of 27.35 kg/m² (SD = 3.78) and that for novices of 25.67 kg/m² (SD = 3.58). This suggests that the BMI and fat percentage values for both expert and novice players in our study are comparable to those observed in Turkish players. However, it is important to note the absence of scientific evidence describing the biotype of UWR players. Furthermore, Ates et al. (2017) reported a mean age of 23.5 years (SD = 4.4), a body mass of 89.3 kg (SD = 11.8), and a body height of 182.3 cm (SD = 4.8) for Turkish UWR players. In contrast, our study reported an average age of 32.16 years (SD = 6.19), a lower body mass of 85.06 kg (SD = 12.47), and a shorter body height of 176.27 cm (SD = 4.17). These differences can be attributed to variations in ethnicity between subjects from Europe and Latin America, as highlighted by Blue et al. (2021).

In the comparison of physical variables between experts and novices, the VO2max did not exhibit statistically significant differences ($p > 0.05$). Notably, experts (world champions) registered an average of 38.97 ml/kg/min (SD = 5.01), while novices recorded an average of 36.83 ml/kg/min (SD = 7.9). These values fall below those reported for female players in Colombia (44.3 ml/kg/min; SD = 5.45) (Ospina & Trujillo, 2013) and are 13.7 ml/kg/min lower than those of the Turkish players (52.7 ml/kg/min; SD = 9.49) assessed using a bicycle ergometer and a metabolic analyzer system (Ates et al., 2017). It is important to note that the UWR players in this study did not regularly engage in jogging or running, rendering the test non-specific. This lack of specificity stems from the test's deviation from the natural environment in which players compete—in the water. This deviation compromises the authenticity of the recorded values, making the test non-ecological (Chaytor & Schmitter-Edgecombe, 2003). Consequently, the observed performance in UWR appears to be comparatively lower than that in other sports.

In the anaerobic power test, statistically significant differences ($p < 0.05$) were found both in maximum, minimum, and average power, as well as in the fatigue index between experts and novices. The expert group demonstrated a mean power of 487.86 W (SD = 348.81), whereas novices registered a mean of 113.14 W (SD = 139.04) with a large effect size (ES = 1.39). Ates et al. (2017) conducted a similar assessment in Turkish players using the Wingate test, revealing a mean power of 623.4 W (SD = 61.2). It is observed that the values of the Turkish players were 135.54 W greater than those of the expert players who were world champions. It is essential to recognize that the measurement of this variable in both groups employed different tests, potentially contributing to the observed disparity in values.

On the contrary, the values obtained in the 1RM flat bench press test demonstrated statistically significant differences ($p < 0.05$) with a substantial effect size (ES = 1.37) favoring the group of expert players. This underscores the paramount importance of focusing on anaerobic strength and power capacity. As emphasized by Kenney et al. (2021), anaerobic training enhances movement efficiency and increases muscle buffering capacity, enabling the attainment of elevated levels of lactate in both muscles and blood. These adaptations, in turn, contribute to delaying the onset of fatigue. Walker (2016) further supports this, asserting that average power signifies an individual's ability to sustain effort for a specific duration, with higher results indicating greater anaerobic capacity. Hence, UWR is a multifaceted sport requiring a harmonious combination of anaerobic and aerobic systems to effectively regulate lactate production and removal (Soto et al., 2018).

In the case of specific tests in UWR, only the underwater non-linear displacement test was validated by Alzate et al. (2021). Unfortunately, no comparable studies exist against which the results of this investigation can be juxtaposed. However, the examination of the evaluated subjects revealed statistically significant differences ($p < 0.001$) in this variable, with a three-second difference between the groups and a large effect size (ES = 6.99). This discrepancy distinctly favors the expert group, indirectly signifying that a shorter completion time correlates with higher performance levels. This confirms that expert subjects demonstrate a superior ability to change direction (nonlinear underwater displacement), a skill honed through targeted training, which requires avoiding a direct clash with the rival. This training is crucial, especially in team sports (Chaouachi et al., 2012), and explains a strategic aspect of the world champions' success in 2019.

Their game strategy centered around swiftly maneuvering defensive blocks, highlighting their exceptional proficiency in avoiding direct clashes with opponents. The significance of underwater nonlinear displacement lies in its contribution to skillful movement, a pivotal element in navigating opponents and, to a large extent, preventing collisions. This strategic emphasis is particularly crucial due to anthropometric disparities with players from other (European) countries, particularly in mass and body height, placing champions at a disadvantage in direct confrontations. Consequently, the champions opted for rapid movements to create open spaces and capitalize on scoring opportunities.

In the case of maximum static force in the right hand, experts demonstrated an average of 52.09 kg (SD = 6.68), while novices recorded an average of 45.38 kg (SD = 10.82), indicating a 6.7 kg difference with a trend toward statistical significance. In comparison, the data for the same parameter for Turkish elite players showed an average of 50.1 kg (SD = 3.0) (Ates et al., 2017). This discrepancy of 1.99 kg below the expert value and 4.72 kg above the novice value in this study, measured with a hand dynamometer, may be attributed to the elite team's strategic approach of playing with an open ball. This strategy entails exclusively supporting the ball on the wrist, avoiding use of the forearm, biceps, and wrist (Gaviria, personal communication, 2021). The purpose behind this approach is to expedite ball release in the face of opponent collisions, facilitating swift passes, movements, and quick play instructions (Gaviria, personal communication, 2021). Furthermore, in the variable of maximum static force in the left hand, experts recorded a higher mean of 48 kg (SD = 5.97) compared to novices with a mean of 42.85 kg (SD = 9.56). In comparison with Turkish elite players, the experts registered an average of 47.3 kg (SD = 4.3) (Ates et al., 2017), reflecting a difference of 0.7 kg less than the world champions.

The variance in static strength with the left hand may be influenced by challenges in laterality arising from immersion in an aquatic environment with noticeable pressure changes, affecting the perception of balance. Novice players, in the process of learning the sport, may focus more on handling the ball with their dominant hand, often the right hand. Expert players, with greater sports practice experience (13 years vs. 0.87 years for novices), exhibit superior laterality control. The gripping, receiving, and passing gestures with the hands are crucial in UWR, impacting game outcomes. Higher values in hand strength can confer advantages, as emphasized by Ates et al. (2017), highlighting that maximum strength in the hand and forearms contributes to enhanced ball control. Coordination and conditional skills, including strength, are pivotal factors in achieving sporting success.

Concerning the variable of right shoulder flexion, no statistically significant differences were observed between the two groups ($p > 0.05$). The experts demonstrated a mean of 156.55° (SD = 9.59), while the novices exhibited a mean of 160.23° (SD = 10.17). Additionally, in the extension of the right shoulder, the experts displayed a mean of 43.91° (SD = 10.43), and the novices had a mean of 45.15° (SD = 7.39). Similarly, in left shoulder flexion, the experts reported a mean of 155.91° (SD = 8), and the novices recorded a mean of 156.38° (SD = 12.61). Consequently, it can be concluded that shoulder flexibility does not significantly impact performance in this sport because the novice group exhibited a broader range of shoulder flexibility than the expert group.

Regarding the time spent playing rugby in years, there were significant differences ($p < 0.05$) with a large effect size difference (ES = 6.99). The experts recorded a median of 13 years (IQR = 7), while the novices had a median of 0.87 years (IQR = 0.42). This aligns with Ericsson's theory (Ericsson, 2006), asserting that extensive experience in sports fosters mastery, leading to elevated performance levels.

Consequently, the expert players in this study, owing to their considerable experience in UWR, secured world championships at the national team level and the club world championship three consecutive times. However, because there is no precise scientific criteria defining expert or novice athletes in UWR, further research is needed to delineate the characteristics and skills acquired by individuals over time to more precisely identify elite performance levels. Moreover, statistically significant differences were observed between both groups ($p < 0.05$) concerning weekly practice time among the experts, with a median of 10 h (IQR = 3), and the novices, with a median of 8 h (IQR = 1). Nonetheless, it should be noted that not all players reaching expert status and achieving high performance adhere strictly to this training frequency because success in sports is not governed solely by training hours. Ericsson (2006) underscores that while consistent practice enhances an individual's skills, various factors, including innate talents, mental abilities, and genetic predispositions, play pivotal roles in influencing progress.

Conclusions

When comparing expert and novice UWR players, no statistically significant differences were identified in the variables of age, body height, BMI, body fat, and muscle mass. Although there was a slight tendency towards statistical differences in body mass, these variables may not be relevant for this sport modality owing to pronounced anthropometric differences with players from other countries, especially those in Europe. Interestingly, these differences did not emerge as determining factors in Colombian rugby, as evidenced by the championship victory, notably in the final against Norway in 2019.

This study found significant differences in several variables, including maximum force in the flat bench press, maximum power, average power, minimum power, fatigue index, underwater nonlinear displacement, practice time in hours, and practice time in years, when comparing expert and novice groups. Particularly noteworthy were the large effect sizes observed in nonlinear underwater displacement, practice time in years, mean power, and maximum force in the flat bench press. Although there was a tendency towards statistical significance in the maximum static strength of the right hand, the effect size magnitude (moderate) between the right and left hands was similar. Notably, no statistically significant differences were detected in the other physical variables.

These identified variables emerge as pivotal factors influencing high performance in UWR, underscoring the need to focus the training process and closely monitor its progression. The comparative analysis between expert and novice players serves as a valuable resource for practitioners and sports scientists, providing insights that can guide the design of more effective research projects and targeted training programs, specifically tailored to optimize performance in UWR.

Recommendation

We recommend conducting another parallel study, differentiating subjects based on playing positions. This approach is essential to delineate the sport according to positional roles, providing insights into the specificity and characteristics inherent in each role. Additionally, selecting measurement instruments that closely mimic real game conditions within the aquatic environment is encouraged. The scientific community is invited to contribute to the validation of an instrument for assessing VO2max in aquatic settings, thus promoting the development of an "ecological test." Lastly, we suggest incorporating technical–tactical variables to complement the understanding of differences between expert and novice players in this sport.

Conflicts of interest

The authors report no conflicts of interest.

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