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DIFFERENCES BETWEEN STANDARD AND SPORT-SPECIFIC COUNTER-MOVEMENT JUMPS IN HIGH-PERFORMANCE U18 MALE WATER POLO PLAYERS: A CROSS-SECTIONAL STUDY

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Abstract

Introduction: Vertical jump capacity is essential for evaluating lower-limb performance in water polo, especially under dryland testing conditions. While power or force is often implied, jumping height remains the primary measurable outcome in these protocols. Aim: This study aimed to compare vertical jump performance in U18 male water polo players using two jump types: the standard Counter-movement Jump (CMJ) and a modified "Frog Style" CMJ (CMJ-Frog), hypothesizing that the latter better reflects sport-specific lower-limb mechanics. Materials & Methods: A cross-sectional, within-subjects design was employed on a sample of 39 male water polo players from the Under-18 category (mean height: 183.02 ± 5.43 cm; mean weight: 75.20 ± 10.41 kg). Each athlete performed three maximal trials of two jump protocols: the standard Counter-movement Jump (CMJ) and the modified sport-specific CMJ-Frog. Jump height was measured using the OptoJump Next system. Data analysis comprised descriptive statistics and normality assessment using the Kolmogorov–Smirnov test. Inferential statistics were conducted via paired-samples t-tests to compare protocols within subjects, with effect sizes calculated using Cohen's d. Results: CMJ-Frog jumps yielded significantly higher values (37.43 ± 4.59 cm) than standard CMJs (34.17 ± 4.49 cm), t (38) = -7.46, p < .001, with a large effect size (d = 1.19). Conclusions: The CMJ-Frog style may serve as a more functionally relevant assessment for evaluating vertical jump capacity in Under-18 male water polo players, as it better reflects the mechanics of aquatic elevation during gameplay. It may offer a more specific alternative for performance testing and monitoring in aquatic athletes. Future studies should validate the CMJ-Frog protocol in senior players and investigate its relationship with in-water performance metrics.

Keywords*: vertical jump, water polo, CMJ, sport-specific testing, lower-limb performance, athletic performance, jump height*

INTRODUCTION

Vertical jump assessments are commonly employed to evaluate the power and performance of the lower limbs in both aquatic and land-based disciplines (RAMIREZ-CAMPILLO et al., 2022; DE VILLAREAL et al., 2015). Lower-limb strength and explosiveness are fundamental for sports that demand repeated high-intensity movements (RADULOVIĆ et al., 2022). In the context of water polo, achieving vertical elevation is crucial for executing key game actions, such as shooting, blocking, and maintaining a positional advantage (PLATANOU - VARAMENTI, 2011; MCCLUSKEY et al., 2010). Although water polo is performed in an aquatic environment, dryland assessment remains a common approach for evaluating neuromuscular performance (BĂLTEAN et al., 2025). This approach is beneficial for tracking adaptations to structured strength and power programs (TSOLTOS et al., 2023; KEINER et al., 2020). Among the available assessments, the counter-movement jump (CMJ) is frequently employed due to its simplicity, efficiency, and strong test-retest reliability (KNIHS et al., 2021). However, traditional CMJ protocols involve a predominantly linear approach, which does not accurately reflect the multi-directional mechanics of vertical propulsion in water (MELCHIORRI et al., 2015; ANNINO et al, 2021). In water polo, vertical lift is generated through the eggbeater kicks, a complex movement characterized by circular leg actions, high hip abduction, and external rotation (MELCHIORRI et al., 2015). This biomechanical discrepancy between dryland tests and aquatic performance limits the ecological validity of conventional CMJ protocols. To overcome this issue, previous studies have highlighted the need for sport-specific assessment methods (MARTIN et al., 2021; GEANTĂ - DE HILLERIN, 2023, 2025a). When tests fail to reproduce sport-specific demands, they may underestimate athletes' actual capacity or misdirect training interventions (RAMOS VELIZ et al., 2014; DE CASTO et al., 2021; GEANTĂ et al., 2025b). To address these limitations, a modified dryland protocol, the CMJ-Frog, has been developed. This variation incorporates a broader stance and greater hip abduction, aiming to simulate the bilateral force production and movement pattern of aquatic vertical trust (BĂLTEAN et al., 2025). The CMJ-Frog could represent an attempt to improve both the specificity and validity of dryland evaluations for water polo players (BĂLTEAN - DE HILLERIN, 2025). Recent research also suggests that in-water vertical jump performance is not strongly influenced by anthropometric factors, such as body density, which further supports the importance of neuromuscular testing on land (BALÁZS et al., 2025). Nevertheless, no study has yet directly compared the CMJ and CMJ-Frog in water polo athletes. Addressing this gap is crucial for developing accurate, sport-specific monitoring tools that more effectively support training prescription and performance evaluation. Therefore, the present study aimed to compare jump height outcomes between the traditional CMJ and the CMJ-Frog in professional water polo players. It was hypothesized that the CMJ-Frog would produce higher vertical jump values, owing to its greater biomechanical similarity with in-water propulsion mechanics.

MATERIAL & METHODS

RESEARCH DESIGN

In this study, we used a cross-sectional, within-subjects design to examine variations in vertical jump performance among male youth water polo players. Two testing conditions were applied: the traditional CMJ and a modified version known as the "Frog-Style" CMJ (CMJ-Frog). The CMJ-Frog was chosen due to its closer biomechanical resemblance to sport-specific lower-limb actions (BĂLTEAN - DE HILLERIN, 2025), typically executed in water polo, particularly those involving explosive leg extension from crouched or partially submerged positions. All measurements were conducted during a single standardized testing session to ensure consistency across participants and conditions.

PARTICIPANTS

A total of 39 high-performance junior male water polo players (in the Under-18 category, all aged 18 years) voluntarily participated in the study. All participants were active members of Romanian First League water polo teams, and several were also members of

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the Romanian national U18 water polo squad. Each athlete had a minimum of three years of continuous, structured training experience and participated in a professional aquatic conditioning program that included components specific to strength and vertical jump training. All participants were cleared for unrestricted physical activity by certified sports physicians and had no injuries or illnesses at the time of the data collection.
Inclusion criteria consisted of: (1) active roster status in a professional water polo team, (2) minimum three years of consistent training, and (3) availability to complete both jump assessments under standardized conditions. Exclusion criteria included: (1) any musculoskeletal injuries within the previous three months, (2) current illness or medication that could affect neuromuscular performance, and (3) failure to complete the whole testing protocol. The study protocol was approved by the institutional ethics committee (Protocol No. 327/02/06.2025) and conducted in accordance with the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment. Since all participants were 18 years or older at the time of the study, parental consent was not required. The sample size reflects the limited number of professional junior water polo players in the Romanian First League and the voluntary nature of participation, as not all eligible athletes agreed to take part in the study.

PROCEDURE AND ASSESSMENT

To assess lower-limb performance through jump height, each participant performed two types of vertical jumps under controlled testing conditions: the standard Counter-movement Jump (CMJ) and the modified CMJ-Frog. Although jump height is an indirect measure, it is widely accepted as a practical proxy for evaluating neuromuscular performance in athletic populations (MA et al., 2025; MORIN - SAMOZINO, 2016). In the CMJ trial, players began in an upright standing position and executed a maximal vertical jump by performing a rapid downward movement immediately followed by an explosive upward extension (BĂLTEAN - DE HILLERIN, 2025).

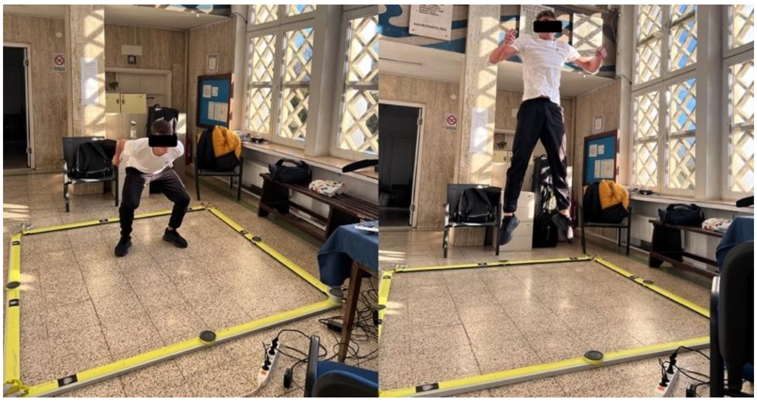

Figure 1: CMJ Assessment with the OptoJump System

In the CMJ-Frog condition that we proposed, participants began in a deep squat position with both hands placed on the ground in front of their bodies. Starting from a static squat stance, participants produced a maximal vertical take-off, eliminating both countermovement and arm swing to isolate lower-limb power output (see Figure 2). This variation was selected for its biomechanical similarity to vertical thrust patterns observed in water polo, emphasizing hip abduction and bilateral push-off, which are typical of in-water propulsion.

Figure 2: CMJ Frog Assessment with the OptoJump System

Before data collection, all players performed a standard warm-up consisting of dynamic movements, including five minutes of low-intensity aerobic exercises, mobility drills, and submaximal jumps, to ensure neuromuscular activation. Each participant realized three maximal attempts of both jump methods, separated by 60 seconds of passive recovery to maintain performance quality and reduce fatigue effects. The best jump height recorded in each condition was retained for statistical analyses, following current methodological recommendations for reliable assessment of vertical jump performance (MARKOVIC et al., 2004). All jumps were performed bilaterally and recorded using the Microgate OptoJump Next System (MICROGATE, n.d).

STATISTICAL ANALYSES

Descriptive statistics (mean ± standard deviation) were calculated for all outcome measures. The Kolmogorov–Smirnov test was used to verify the normality of the data distribution. Since all variables met assumptions for normality, parametric tests were deemed appropriate. Paired-samples t-tests were conducted to compare CMJ and CMJ-Frog performance within subjects. Effect sizes were calculated using Cohen's d (COHEN, 2013) and interpreted according to standard thresholds: small (≥0.20), medium (≥0.50), and large (≥0.80). All analyses were performed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY, USA), with statistical significance set at $p < 0.05$.

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RESULTS

Table 1: Mean values for anthropometric and jumping variables

Variable	Mean	Std. Deviation
Height (cm)	183.02	5.43
Weight (kg)	75.20	10.41
CMJ (cm)	34.17	4.49
CMJ-Frog (cm)	37.43	4.59

***Note**. Height = participant's height (cm); Weight = participant's weight (kg); CMJ = counter-movement jump (cm); CMJ-Frog = frog-style counter-movement jump (cm). Values are expressed in centimeters for height and jumps, and kilograms for weight.*

Descriptive statistics revealed that the jump height in the CMJ condition was 34.17 ± 4.49 cm. In contrast, in the CMJ-Frog condition, it was 37.43 ± 4.59 cm, as presented in Table 1 (mean difference: 3.26 cm in favor of the sport-specific variation).

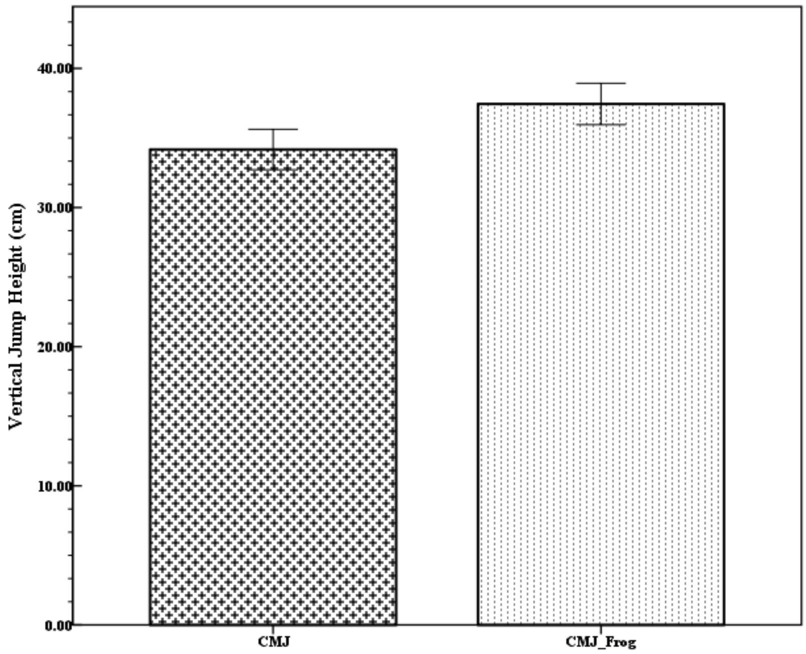

Figure 3: Mean value for Jumping types

Table 2: Paired differences within-subjects of jumping performance

Variable	*Mean*	*Std. Deviation*	*Std. Error Mean*	*95% C.I. Lower*	*95% C.I. Upper*	*t*	*df*	*Sig. (2-tailed)*	*d*
CMJ (cm) – CMJ-Frog (cm)	*3.26*	*2.73*	*.43*	*-4.15*	*-2.38*	*-7.46*	*38*	*.001*	*1.19*

***Note.** CMJ = counter-movement jump; CMJ_Frog = frog-style counter-movement jump; t = t-value; df = degrees of freedom; Sig. = two-tailed p-value; d = Cohen's d. Values in centimeters. Results are significant at p < .05.*

The results from the paired-samples t-test showed that the difference in jump height between the two conditions was statistically significant, t (38) = -7.46, p < .001. The 95% confidence interval for the mean difference ranged from –4.15 to-2.38 cm, indicating a reliable effect across participants (N = 39). The effect size was Cohen's d = 1.19, which

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represents a significant effect according to established benchmarks (Cohen, 2013). This suggests that the CMJ-Frog protocol produced meaningfully greater vertical jump performance compared to the standard CMJ.

DISCUSSION

This study aimed to compare two vertical jump protocols in high-performance junior water polo players in the Under-18 category: the standard CMJ and a modified sport-specific version (CMJ-Frog). The statistical analysis showed significantly better performance in the CMJ-Frog, supporting the hypothesis that greater movement specificity enhances the practical relevance of dryland assessments for aquatic athletes.

The key finding, a large effect size (d = 1.19) favoring CMJ-Frog, suggests that modifying test protocols to reflect sport-specific biomechanics can enhance both the sensitivity and real-world applicability of performance evaluations. (WEAKLEY et al., 2024). From a coaching perspective, such a difference represents a substantial performance gain that could meaningfully influence competitive outcomes. One likely explanation is the biomechanical similarity between the CMJ-Frog and in-water propulsion movements. The wider stance and lack of countermovement promote hip abduction and bilateral push-off, which are fundamental to vertical elevation in water polo (MELCHIORRI et al., 2015; ZINNER et al., 2015). These characteristics may stimulate muscle activation patterns that more closely mirror aquatic demands.

This interpretation aligns with previous research advocating for sport-specific and practically relevant testing protocols (BISHOP, 2008; MARTIN et al., 2021; RAMIREZ-CAMPILLO et al., 2022). In junior athletes, particularly those competing at the elite national level, assessments that accurately reflect the actual movement patterns of the sport are more informative for coaches and performance staff (REIMAN-MANSKE, 2009). From an applied perspective, the CMJ-Frog may offer a more accurate method for monitoring vertical power development in junior water polo. Compared to the standard CMJ, it could serve as a better indicator of sport-relevant adaptations, primarily when testing occurs in dryland environments. This has direct implications for periodization planning, load monitoring, and performance profiling in high-performance junior programs.

A significant strength of this study is its within-subjects design. This approach reduces inter-individual variability, allowing for a more controlled comparison between test protocols. Additionally, the use of validated equipment (OptoJump Next) ensured the reliability of data capture (MICROGATE, n.d.). Nevertheless, several limitations should be recognized in our study. The first one is the sample, which consisted exclusively of male players from a single age group. Although all participants were chronologically 18 years old, variations in biological maturation may still have influenced their physical and performance capacities within this youth cohort (NORONHA et al., 2022; KOVAČEVIĆ et al., 2023, 2025). For younger athletes, physical performance in tests such as the CMJ may vary considerably depending on biological maturation and test specificity (MELCHIORRI et al., 2022). The second limitation is that the assessment was performed on dryland. Although the CMJ-Frog mimics aquatic movements, it cannot fully replicate in-water neuromuscular conditions. Lastly, only jump height was analyzed. Incorporating kinetic and kinematic variables, as well as electromyography (EMG) data, would provide a more comprehensive understanding of neuromuscular function. Further research should investigate how CMJ-Frog performance correlates with in-water tasks, such as vertical blocking, shooting, or reactive elevation, in both junior and senior categories. Emerging tools, such as the Eggbeater Kick Anaerobic Test (EKAT), represent a promising alternative for directly assessing anaerobic capacity in water (VRDOLJAK et al., 2024). Additionally, examining force-time curves in relation to EMG activity may help clarify the underlying mechanisms of performance. Testing different subgroups (for example, goalkeepers, youth players, or athletes of varying competitive levels) would help determine the generalizability of the findings (KONTIĆ et al., 2025). In practice, strength coaches and performance staff working with junior water polo players should consider adopting the CMJ-Frog in their regular assessment protocols. Its biomechanical specificity to aquatic actions enhances its value for monitoring and individualized training decisions. As this study shows, simple modifications to traditional protocols can lead to meaningful improvements in functional relevance.

CONCLUSIONS

This study compared two vertical jump protocols, the standard CMJ and the sport-specific CMJ-Frog, in high-performance U18 water polo players. Our findings indicate that the CMJ-Frog provides a more accurate reflection of aquatic vertical propulsion biomechanics, resulting in significantly higher jump heights. These results highlight the importance of tailoring performance assessments to the specific functional demands of the sport and the corresponding competitive level. The CMJ-Frog represents a practical and relevant tool for coaches aiming to more precisely monitor explosive lower-limb capacity in junior water polo players, offering a more sensitive method for tracking training adaptations and tailoring performance programs. Future research should focus on validating the CMJ-Frog's utility across diverse age groups and competitive levels, as well as examining its relationship with actual in-water performance metrics.

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