Bulletin of the *Transilvania* University of Braşov
Series IX: Sciences of Human Kinetics • Vol. 18(67) No. 2 – 2025
https://doi.org/10.31926/but.shk.2025.18.67.2.4

# COMPARATIVE ANALYSIS OF LOWER LIMB PEAK ISOMETRIC FORCE AT DIFFERENT JOINT ANGLES IN YOUTH WATER POLO ATHLETES

**A.I. BĂLTEAN[1,2] V.A. GEANTĂ[1,2]**

***Abstract:*** *This study aimed to compare lower-limb peak isometric force characteristics in water polo players using the Takei back and leg dynamometer. Two testing positions were employed: full knee extension and 90-degree knee flexion. A total of 38 athletes were assessed, divided into U16 and U18 age groups. While no statistically significant differences were found between age groups, highly significant intra-group differences emerged between test positions ($p < .001$), with substantially greater force values recorded in full extension. These results underline the influence of joint angle on isometric strength outcomes and highlight the importance of standardizing test positions in strength assessment protocols for water polo players.*

***Key words:*** *water polo, sport performance assessment, force dynamometer*

## 1. Introduction

In high-performance aquatic sports such as water polo, players must perform repeated explosive actions such as vertical jumps, overhead passes, and defensive blocks, often from an unstable, submerged position [8], [3]. The ability to generate rapid and effective lower-limb force is therefore a critical part of game performance [12], [15]. Studies have shown that players spend approximately 65% of match time in a vertical position [11], highlighting the importance of vertical propulsion and in-water stability for successful performance. Muscle strength and power are commonly assessed using dry-land protocols; however, these may not fully reflect performance in aquatic environments due to the altered biomechanics associated with water resistance and buoyancy [7], [16]. This limitation is particularly relevant in water polo, where movement patterns are unique and involve force generation in multidirectional and non-standard planes of motion [1], [14]. As a result, laboratory-based assessments should be carefully

[1] Doctoral School of Sport Science and Physical Education, National University of Science and Technology Politehnica Bucharest, Pitesti University Center, Pitesti, Romania
[2] "Aurel Vlaicu" University of Arad, Faculty of Physical Education and Sport, Arad, Romania

designed to ensure that they are sensitive to the specific neuromuscular demands of the sport [13].

Isometric testing has appeared as a reliable method for assessing maximal voluntary contraction under controlled conditions [6] with applications in both research and elite sports settings.

Hand-held dynamometers have gained popularity due to their portability and ease of use [18]. The Takei dynamometer is a widely set up tool in this category and has been employed in various physical fitness and isometric strength assessments [19]. Its use in water polo has the potential to capture performance-relevant force characteristics when standardized test positions are applied.

However, there is limited evidence regarding the specific effects of joint position on isometric strength outputs in water polo players, particularly during knee extension tests. Understanding whether different test angles (e.g., full extension vs. 90° knee flexion) yield distinct force values could inform more correct athlete profiling and training load prescription. Furthermore, the comparison of different age groups may help contextualize age-related performance differences in isometric strength within the developmental pathway of youth water polo.

The present study aimed to compare peak isometric knee extension force between two standardized joint angles in youth water polo players, using the Takei dynamometer. Additionally, differences between U16 and U18 athletes were explored to decide whether age-related variations in strength could be detected under these test conditions.

## 2. Materials and Methods

*Study design*

This study employed a cross-sectional comparative design to examine peak isometric lower limb force in youth male water polo players across two joint positions. The aim was to find strength differences based on knee joint angle (full extension vs. 90° flexion) and age category (U16 vs. U18) using standardized dynamometry testing.

*Participants*

A total of 38 competitive male water polo players were recruited and divided into two age groups: U16 (n = 19, age 14–15 years) and U18 (n = 19, age 16–17 years). All participants were engaged in regular training at least four times per week and had a minimum of three years of competitive experience. Athletes with lower-limb injuries or musculoskeletal conditions within the past six months were excluded. The U16 group had a mean height of 181.32 ± 6.07 cm and body mass of 74.74 ± 14.07 kg, while the U18 group had a mean height of 184.32 ± 3.28 cm and body mass of 79.58 ± 8.17 kg. All participants and, where appropriate, their legal guardians provided informed consent prior to participation in the study.

*Instrumentation*

Lower-limb isometric strength was assessed using the Takei TKK 5401 back and leg dynamometer (Takei Scientific Instruments Co., Ltd., Niigata, Japan), a widely used hand-held device for isometric testing. The device provides force values in kilograms-force (kgf) and has been validated in various strength assessment contexts [19].

*Testing Procedure*

Isometric strength testing was conducted to evaluate maximum voluntary isometric contraction (MVIC) of the lower limbs using two joint positions. The first position involved the knee in near-full extension (approximately 180°), referred to as Pf-ExL-TK. The second position, denoted as Pf-Ex90-TK, was performed with the knee flexed at exactly 90°, a posture verified using a manual goniometer to ensure consistency across participants.3

Table 2

*Independent Samples t-Test Results Comparing U16 and U18 Groups for Isometric Lower Limb Force*

| | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | | d |
| | | | | | | | | Lower | Upper | |
| Pf-ExL-TK (kgf) | 3.27 | 0.079 | 0.647 | 36 | 0.522 | 9.4 | 14.52 | -20.05 | 38.85 | 0.21 |
| Pf-Ex90-TK (kgf) | 3.31 | 0.077 | 0.297 | 36 | 0.768 | 2.21 | 7.44 | -12.88 | 17.3 | 0.10 |

Note. Pf-ExL-TK = peak force in full knee extension; Pf-Ex90-TK = peak force at 90° knee flexion; *d* = Cohen's d; CI = confidence interval. Values are expressed in kilograms-force (kgf).

No statistically significant differences were found between age groups for either position. For the full extension test (Pf-ExL-TK), the result was $t$ (36) = 0.65, $p$ = .522, with a small effect size ($d$ = 0.21). Similarly, for the 90° flexion position (Pf-Ex90-TK), $t$ (36) = 0.30, $p$ = .768, and $d$ = 0.10, also indicating a poor effect.

Table 3

*Paired Samples t-Test Results Comparing Full Extension and 90° Flexion Positions within Each Age Group*

| Group | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t | df | Sig. | d |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lower | Upper | | | | |
| U18 | Pf-ExL-TK (kgf) - Pf-Ex90-TK (kgf) | 130.90 | 43.26 | 9.92 | 110.04 | 151.75 | 13.18 | 18 | .001 | 3.02 |
| U16 | Pf-ExL-TK (kgf) - Pf-Ex90-TK (kgf) | 123.71 | 33.25 | 7.62 | 107.68 | 139.73 | 16.21 | 18 | .001 | 3.72 |

Note. Both groups showed significantly higher isometric force in the full extension position ($p$ < .001). Pf-ExL-TK = peak force in full knee extension; Pf-Ex90-TK = peak force at 90° knee flexion; *d* = Cohen's d; CI = confidence interval; Values are expressed in kilograms-force (kgf).

In both U18 and U16 groups, significantly higher force values were observed in the full extension position compared to the 90° flexion position. For the U18 group, the difference was $t(18) = 13.18$, $p < .001$, with a mean difference of 130.90 ± 43.27 kgf, and a very large effect size ($d = 3.02$). The U16 group showed a similar pattern: $t(18) = 16.21$, $p < .001$, with a mean difference of 123.71 ± 33.25 kgf, and $d = 3$.

## 4. Discussion

This study aimed to compare lower-limb peak isometric force characteristics in youth water polo players using the Takei dynamometer, with a focus on differences between joint positions (full knee extension vs. 90° flexion) and age groups (U16 vs. U18).

Results showed that both U16 and U18 athletes produced significantly greater peak isometric force in the full knee extension position compared to the 90° flexion position ($p < .001$), with large effect sizes ($d > 3$). These findings underscore the substantial influence of joint angle on force output, aligning with previous biomechanical research that highlights the importance of muscle length-tension relationships and best leverage in force production [6], [9].

The lack of statistically significant differences between the U16 and U18 groups, despite slightly higher average values in U18 athletes, suggests that age alone may not be a sufficient determinant of isometric strength when assessed in isolation. This aligns with findings by Noronha et al. [13], who reported that anthropometric and motor performance variables are more predictive of strength differences than chronological age in youth athletes.

The increased force saw in the full extension position may be attributed to optimal muscle length-tension properties and favorable biomechanical leverage at this joint angle [7]. Conversely, the 90° flexion position likely presents a mechanically disadvantageous position for the quadriceps, resulting in lower force outputs.

These findings highlight the importance of testing standardized joint positions to ensure reliable and comparable assessments of muscular strength [1], [18].

Furthermore, the use of the Takei back and leg dynamometer proved practical and reliable for field-based assessments, consistent with previous validation studies in athletic settings [16], [10], [5].

Considering the specific demands of water polo, especially movements like the eggbeater kick, dry-land isometric testing offers valuable insights, although it should be complemented by in-water assessments to better reflect sport-specific functional capacity [3]. Recent findings by Băltean et al. [2] further support this perspective, proving that short-term aquatic training can significantly improve in-water vertical jump performance and neuromuscular output, emphasizing the role of water-specific stimuli in developing functional strength.

The capacity to generate vertical force is critical in water polo for actions such as jumping, passing, and blocking [15-16]. Our findings in significant differences saw between joint positions suggest that tests conducted in full extension may better represent the leg extension phase during vertical thrust, which is fundamental for in-water performance.

Although age-related differences were minimal, joint position significantly influenced force production. These findings underscore the importance of standardized testing protocols in youth athletes from water polo field and support the application of back and leg

dynamometry as a practical, field-based assessment tool for them.

As a cross-sectional study, our research provides a time-specific assessment of isometric strength characteristics. Limitations include the absence of longitudinal tracking, the exclusion of in-water assessments, and the focus solely on male participants, which may restrict the generalizability of the results.

Future research should incorporate longitudinal methodologies to find strength development trajectories over time and to assess the efficacy of sport-specific training interventions in youth water polo athletes.

## 5. Conclusions

Joint angle plays a critical role in deciding isometric force output in youth water polo players, reinforcing the need for standardized testing protocols.

While no age-related strength differences were seen, practical assessments using field-based dynamometry remain valuable for checking athletic development. Integrating sport-specific testing, particularly in-water evaluations, is recommended for a more correct profile of functional performance

## Acknowledgements

The authors would like to thank the participating athletes and coaching staff for their collaboration and commitment throughout the testing process.

## Conflict of Interest

The authors declare no conflicts of interest related to the conduct or publication of this research.

## References

1. Alcaraz, P.E., Abraldes, J.A., Ferragut, C., et al.: Relationship between characteristics of water polo players and efficacy indices. In: *Journal of Strength and Conditioning Research* 26, 2012, No. 7, p. 1852–1857. https://doi.org/10.1519/JSC.0b013e318237ea4f
2. Bălțean, A.I., De Hillerin, P.J., Geantă, V.A.: *Effects of a Short-Term Aquatic Training Program on In-Water Vertical Jump Performance and Neuromuscular Output in Water Polo Players.* In: Sport Mont 23, 2025, No. 2, p. 101-107 https://10.26773/smj.250615
3. Botonis, P.G., Toubekis, A.G., Platanou, T.I.: *Physiological and Tactical On-court Demands of Water Polo*. In: Journal of Strength and Conditioning Research, 33, 2019, No. 11, p. 3188–3199. https://doi.org/10.1519/JSC.0000000000002680
4. Cohen, J.: *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Routledge, New York, 2013, p. 20-27 https://doi.org/10.4324/9780203771587
5. Eyuboglu, E., Aslan, C.S., Karakulak, I., Sahin, F.N.: *Is there any effect of non-suitable pull technique in back & leg dynamometers on the leg strength test results.* In: Acta Medica Mediterranea, *35*, 2019, No. 3, p. 1373–1378. https://dx.doi.org/10.19193/0393-6384_2019_3_211
6. Janik, F., Toulotte, C., Seichepine, A.L., et al.: *Isometric Strength Database for Muscle Maximal Voluntary Endurance Field Tests: Normative Data*. In: Sports Medicine -Open 7, 2021, No. 1, p. 47. https://doi.org/10.1186/s40798-021-00338-2

7. Keiner, M., Rähse, H., Wirth, K., Hartmann, H., et al.: *Influence of Maximal Strength on In-Water and Dry-Land Performance in Young Water Polo Players.* In: Journal of Strength and Conditioning Research 34, 2020, No. 7, p. 1999–2005. https://doi.org/ 10.1519/JSC.0000000000002610
8. Kovačević, N., Mihanović, F., Lušić Kalcina, L., et al.: *Positional Differences in Youth Water Polo Players: Cognitive Functions, Specific Swimming Capacities and Anthropometric Characteristics*. In: Journal of Functional Morphology and Kinesiology, 10, 2025, No. 2, p. 151. https://doi.org/10.3390/jfmk10020151
9. Kozinc, Ž., Smajla, D., Trajković, N., et al.: *Reliability of easyforce dynamometer for assessment of maximal knee and hip strength, and comparison to rigid isometric dynamometers with external fixation*. In: Measurement in Physical Education and Exercise Science 26, 2022, No. 3, p. 232–244. https://doi.org/ 10.1080/1091367X.2021.2019037
10. Lockie, R.G., Wakely, A.M., Dawes, J.J., et al.: *The relationships between muscular strength and power with throwing velocity in high school boys water polo players following a strength training block*. In: Facta Universitatis, Series: Physical Education and Sport, 2023, No. 1, p. 099–110. https://doi.org/ 10.22190/FUPES230318008L
11. Lozovina, V., Lozovina, V., Pavicic, L.: *Analysis of certain indicators of the load in the play of guard in today water polo*. In: Acta Kinesiologica 4, 2010, p. 90–97.
12. McGrath, T.M., Waddington, G., Scarvell, J.M., et al.: *The effect of limb dominance on lower limb functional performance--a systematic review.* In: Journal of Sports Sciences 34, 2016, No. 4, p. 289–302. https://doi.org/ 10.1080/02640414.2015.1050601
13. Noronha, F., Canossa, S., Vilas-Boas, J.P., et al: *Youth Water Polo Performance Determinants: The INEX Study.* In: International Journal of Environmental Research and Public Health, 19, 2022, No. 9, p. 4938. https://doi.org/10.3390/ijerph19094938
14. Özer, E., Soslu, R.: *Examination of Lower and Upper Extremity Isokinetic Strength Parameters and Speed Performance of Water Polo Athletes*. In: Turkish Journal of Sport and Exercise 23, 2021, No. 2, p. 159–164.
15. Platanou, T.: *On-water and dryland vertical jump in water polo players*. In: The Journal of Sports Medicine and Physical Fitness 45, 2005, No. 1, p. 26–31.
16. Sanders, R.: *A model of kinematic variables determining height achieved in water polo 'boosts'*. In: Journal of Applied Biomechanics 15, 1999, p. 270–283. https://doi.org/10.1123/jab.15.3.270
17. Shahidi, S.H., Özkaya, I., Karakaş, Ç.S., Taşkıran, Y., Esformes, J.I.: Validity and Reliability of Isometric Muscle Strength using the Powrlink Portable Device. In: *International Journal of Strength and Conditioning* 3, 2023, No. 1. https://doi.org/10.47206/ijsc. v3i1. 237
18. Stark, T., Walker, B., Phillips, J.K., Fejer, R., Beck, R.: *Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: a systematic review*. In: PM&R: The Journal of Injury, Function, and Rehabilitation 3, 2011, No. 5, p. 472–479. https://doi.org/ 10.1016/ j.pmrj.2010.10.025
19. Takei Scientific Instruments.: *Product Manual: Digital Dynamometer T.K.K. 5401*. Tokyo, Japan, 2020. p. 3