International Journal of Sports Physiology and Performance, **(Ahead of Print)**
https://doi.org/10.1123/ijspp.2025-0677

First Published Online: July 24, 2026

Human Kinetics
ORIGINAL INVESTIGATION

In-Water 505 Deficit as an Isolated Measure of Directional Performance and Asymmetry in Male Water Polo Athletes

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Purpose: To (1) assess the reliability of a newly developed in-water 505 test, (2) examine the relationships between the 505 performance, 505 change of direction deficit (CODD), and 10-m sprint times, and (3) quantify the magnitude of asymmetry in the 505 CODD and evaluate its association with 505 CODD in elite and highly-trained male water polo players. ***Methods:*** Twenty-one elite and highly-trained players (23.5 [6.2] y) completed an in-water 505 test and a 10-m sprint, from which the CODD was calculated. ***Results:*** The 505 test demonstrated moderate to good reliability (intraclass correlation coefficient: .72–.88). Linear regression analyses showed that the 10-m sprint explained 64.3% to 69.7% of the variance in 505 performance. In contrast, the 10-m sprint was not a significant predictor of the change of direction deficit. Significant differences between turning directions were observed ($P < .001$), and most individual asymmetry values exceeded the coefficient of variation of 3.17%, indicating detectable asymmetries. The CODD asymmetry did not predict performance on the dominant side but was a significant predictor on the non-dominant side ($\beta = -0.014$, $P = .039$). ***Conclusions:*** The in-water 505 test and its derived CODD are reliable tools and offer a more isolated assessment of change of direction ability in male elite and highly-trained water polo players than traditional agility tests. While the detectable asymmetries were unlikely to impair CODD performance, future research should investigate their potential impact on tactical advantages during match play.

Keywords: agility, symmetry, swimming, athletic performance, sprint performance

Water polo is an open-skilled team sport in which athletes must constantly interpret a rapidly changing environment and adjust their actions accordingly.[1] During play, athletes spend roughly one-third of their active time swimming, with most bouts of activity lasting less than 20 seconds while high-intensity efforts or sprints typically range from 7 to 14 seconds.[2] Although sprint speed is an important element of water polo performance, performance in water polo relies strongly on agility, as players must frequently change direction and reposition themselves in response to the ball, officiating decisions, and the constantly shifting actions of both teammates and opponents.[1]

Agility is defined as the ability to perform rapid, whole-body movements that involve changes-of-direction (COD) or speed in response to external stimuli.[3] Previous research has developed agility tests incorporating open-skilled tasks, requiring athletes to react to unpredictable sensory cues, rather than executing rehearsed patterns.[1,4–7] These stimuli include visual signals, such as lights displayed on a screen, as well as human-generated cues designed to replicate the demands of actual match play.[1,4–7] More complex test designs have integrated multichoice cognitive elements, requiring athletes to move in different directions based on the stimulus received, as well as multipositional (vertical and horizontal) and multidirectional tasks.[4,8] While these tests generally demonstrate good to excellent reliability (intraclass correlation coefficients [ICCs] ranging from .76 to .98) and capture water polo specific demands,[1,4,5,8] they do not clearly isolate the 2 key components of agility: the physical ability to change direction and the cognitive ability to respond to a stimulus. Dong et al[1] attempted to quantify the "agility cost" to capture the cognitive load associated with agility trials; however, this metric showed weak reliability. Consequently, its ability to discriminate between the physical and perceptual–cognitive components of COD performance remains limited.

As the physical component of agility, COD reflects an athlete's ability to decelerate, redirect movement, and reaccelerate.[3] Numerous tests have been developed to evaluate COD performance, with the 505 test being one of the most frequently used protocols in dry-land sports requiring agility.[3,9] Despite its excellent reliability (ICC = .80–.94),[10,11] research has demonstrated that only about 31% of the 505 test involves the actual directional change, while the remaining 69% reflects linear acceleration capacity.[12] This imbalance means that athletes with strong sprinting ability may perform well on the 505 test, potentially masking deficits in true COD performance.[12] To address this limitation, the COD deficit (CODD) was introduced as an alternative assessment.[13] This approach requires athletes to perform both a 505 test and a 10-m sprint, with the difference in times representing the deficit and thus providing a more isolated measure of COD performance.[13] Although widely used in land-based settings, this method has not yet been adapted for aquatic environments. Given that dry-land assessments do not accurately reflect in-water performance,[1] establishing an aquatic adaptation of the 505 test may offer practitioners a more valid means of assessing COD ability in water polo athletes.

When using the 505 test, practitioners can assess COD ability in both the right and left turning direction, allowing the quantification of functional asymmetry.[14] A plethora of research in land-based sports has explored functional asymmetries[15–18] and their potential association with athletic performance.[19–21] While some studies have reported negative associations between interlimb jump

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asymmetries and 505 performance ($r = .52–.85$),[10,11] others identified moderate negative relationships between COD asymmetry and COD ability in both turning directions ($r = .50–.63$, $P \leq .02$).[22,23] Recent work by D'Hondt et al[24] further suggested that athletes who can change direction with similar speed and efficiency on both sides may possess a tactical advantage, as opponents are less able to target a consistently weaker turning direction. Despite these insights, research on asymmetry in aquatic sports, including water polo, remains limited, and asymmetry in aquatic COD performance has yet to be determined.

The present study has 3 primary objectives: (1) to assess the reliability of a newly developed in-water 505 test; (2) to examine the relationships between 505 CODD, 505 performance, and 10-m sprint times to determine the influence of linear sprint speed on 505 and 505 CODD; and (3) to quantify the magnitude of 505 CODD asymmetry and explore its association with 505 performance in elite and highly trained male water polo players. We hypothesized that (1) the in-water 505 test would demonstrate moderate-to-good reliability; (2) CODD would exhibit weaker associations with sprint performance than total 505 time, reflecting its ability to more effectively isolate true COD ability; and (3) measurable side-to-side asymmetries would be present.

Methods

Subjects

Twenty-one elite and highly trained male water polo players aged 15–37 years were recruited through convenience sampling from 5 clubs competing in the Belgian Super League. To be eligible, participants had to be male athletes classified as elite or highly trained according to McKay's framework.[25] Players were excluded if they reported any upper or lower limb injury. All participants received full information about the study's purpose and procedures before providing written informed consent. The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Medical Ethics Committee of the Vrije Universiteit Brussel and UZ Brussel (B.U.N. 143201836107).

Design

An observational cross-sectional design was employed in the present study. Anthropometric and swimming assessments were conducted on separate days. Test–retest reliability was evaluated in one of the 5 participating clubs. For this purpose, a standardized testing order was implemented, with at least 48 hours between swimming sessions to assess reliability. To ensure consistent testing conditions, all participants were scheduled at the same time of day and completed the assessments in an identical order. For the swimming protocol specifically, the 505 test was always performed first ((in both directions, starting with the right), followed by the 10-m sprint, with a minimum of 10 minutes of passive recovery provided between tests to minimize fatigue effects.

Methodology

Participants were instructed to abstain from alcohol for 48 hours prior to testing and avoid vigorous physical activity for at least 12 hours beforehand. Additionally, before the anthropometric assessments, players were asked to refrain from eating or drinking for 4 hours and to avoid diuretics for 7 days. All players were also required to urinate within 30 minutes before anthropometric testing to ensure accurate measurements.

Basic Anthropometry

Stature and body weight were measured to the nearest 0.1 cm (SECA 213) and 0.1 kg (RADWAG WLT 60/120/X/L3), respectively, in accordance with the International Standards for Anthropometric Assessment.[26]

505 CODD Performance Test

The 505 CODD performance assessment included a straight 10-m sprint test as well as 2 505 tests (one with a left turn and one with a right turn). Prior to testing, participants completed a standardized warm-up. The warm-up began with 200 m of easy swimming, consisting of 100-m front crawl and 100-m breaststroke kick in a medley format. Athletes then performed two 25-m swims with a progressively faster pace from start to finish, leaving every 45 seconds. This was followed by 2 sets of a shuttle-style task: 15 m of swimming, a turn, a 5-m return, another turn, and a final 15 m, all completed at a submaximal intensity with a 1-minute interval between departures. The warm-up concluded with two 25-m repetitions composed of a 15-m maximal sprint followed by 10 m of relaxed swimming, also starting each minute. Recovery between drills was limited to the brief pause needed for verbal instructions.

All swimming tests were performed 3 times, with at least 10 minutes of recovery between trials. During the 10-m sprint test, players swam from a starting buoy to a buoy positioned 10-m ahead, covering the distance as quickly as possible. In the 505 test, players sprinted 5 m to a buoy and, once their entire body had passed it, performed a 180° turn and sprinted back to the starting point. In both tests, players began with a stationary, horizontal position, with their whole body behind the starting buoy (see Figure 1). Timing was recorded using a handheld stopwatch accurate to 0.01 seconds and was stopped when the player's entire body passed the finish buoy. The CODD was calculated by subtracting the time recorded in the 10-m sprint test from the time recorded in the 505 test.

Calculation of COD Asymmetry Magnitude

In this study, the dominant performance value was defined as the best overall result on the 505 CODD test, regardless of turn direction (ie, right or left). The nondominant performance value

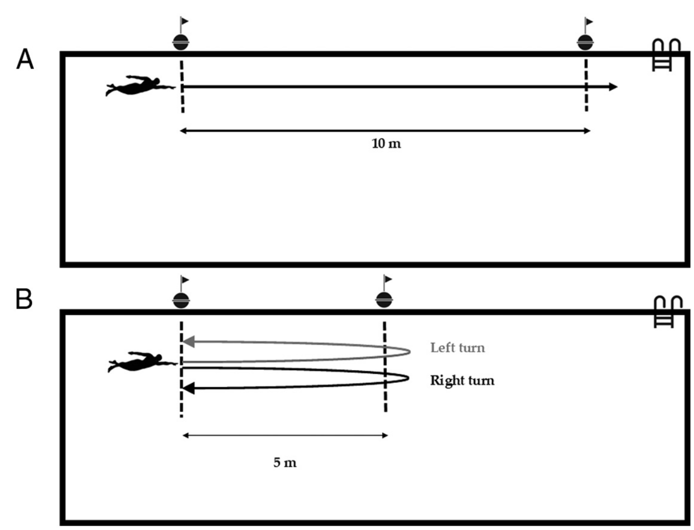

Figure 1 — Illustration of the 10-m sprint test (A) and the 505 test, performed in both the right and left directions (B).

was defined as the best result in the opposite 505 CODD direction. The magnitude of asymmetry (in percentage) was calculated using the percentage difference method:

$$\frac{\text{Dominant performance value} - \text{Nondominant performance value}}{\text{Dominant performance value}} \times 100$$

Statistical Analysis

The statistical analyses were performed using IBM SPSS Statistics (version 31, IBM Corp). The normality of all variables was assessed using the Shapiro–Wilk test and visually confirmed by histograms and Q–Q plots. Test–retest reliability was evaluated in a subsample of 10 players using ICCs derived from the same data set. Both single-measure [ICC(2,1)] and average-measure ICCs were calculated, with 95% confidence intervals, using a 2-way random-effects model assessing consistency. Additionally, the standard error of measurement (SEM), minimal detectable change, standard error of prediction, and coefficient of variation (CV) were calculated. ICC values were interpreted as <.50 = poor, .50 to .74 = moderate, .75 to .90 = good, and >0.90 = excellent.[27] The SEM, calculated as SD × $\sqrt{(1\text{–ICC})}$, represented the expected variability in an individual's observed score around their true score.[28] The minimal detectable change was quantified as 1.96 × $\sqrt{2}$ × SEM, which reflects the smallest change that can be interpreted as a true difference rather than measurement variability.[29] The standard error of prediction, calculated as SD × $\sqrt{(1\text{–ICC}^2)}$, indicated the variability expected if an individual repeated the test, taking their initial performance into account.[28] The CV was calculated as (SD/mean) × 100.[30] Simple linear regression models were used to determine the proportion of variance in 505 test and 505 CODD test explained by 10-m sprint performance, as well as to assess associations between CODD asymmetry and 505 performances. All assumptions required for linear regression, including linearity, homoscedasticity, independence of residuals and normality of residuals, were checked and met. Finally, a Paired samples *t* test was used to examine differences between dominant and nondominant 505 CODD sides. Hedges *g* correction effect sizes with 95% confidence intervals were calculated and classified as 0.0 to 0.20 = trivial, 0.20 to 0.60 = small, 0.60 to 1.20 = moderate, 1.20 to 2.00 = large, 2.00 to 4.00 = very large, >4.00 = near perfect.[31] Statistical significance was set at $P < .05$.

Results

The study included a total of 21 elite and highly trained male water polo players. For practical reasons, test–retest reliability was assessed in a subset of 10 players. Descriptive characteristics of the total group of participants are presented in Table 1.

Test–retest reliability results are presented in Table 2. Mean ICC values ranged from poor to moderate (.46–.72) for single measures and from moderate to good (.72–.88) for average measures for the 10-m sprint and 505 COD performance on both sides. For the 10-m sprint and 505 COD performance, the SEM, standard error of prediction, and CV% ranged from 0.1 to 0.3, 0.2 to 0.3, and 1.66 to 3.31, respectively.

All simple linear regression results are presented in Table 3. Performance on the 10-m sprint was a significant predictor of 505 performance ($P < .001$), accounting for 64.3% to 69.7% of the variance. In contrast, the 10-m sprint did not significantly predict CODD on either side ($P = .742$–$.946$) (ie, Figure 2).

Table 1 Descriptive Statistics for the Demographic, Anthropometric, and Sport-Specific Characteristics of the Elite and Highly Trained Male Water Polo Players (n = 21)

	Mean (SD)
Age, y	23.5 (6.2)
Weight, kg	81.4 (11.6)
Height, cm	183.6 (7.7)
Body mass index, kg/m^2	24.1 (2.4)
Weekly training hours, h	7.5 (2.9)
Years of experience, y	13.8 (6.2)
Change-of-direction deficit asymmetry, %	13.98 (11.08)

All individual CODD asymmetry scores are displayed in Figure 3. The mean CODD asymmetry was 14.0% (11.1%). Performance was significantly better on the dominant side compared to the nondominant side ($t = -5.085$, $P < .001$, $g = -1.067$ [–1.586 to –0.533]).

Discussion

Over the past decades, agility assessments in water polo have increasingly incorporated COD actions and responses to external stimuli, aligning with the broader definition of agility.[1,3–7,32,33] However, such approaches do not isolate the physical quality of COD itself.[13] To address this limitation, the present study introduced a newly developed in-water 505 test from which the CODD was derived. The primary objective was to assess the reliability of the 505 test in elite and highly trained male water polo players. Additionally, we aimed to examine the relationships between 505, 505 CODD, and 10-m sprint performance in order to evaluate the contribution of linear speed to each measure and the extent to which true COD ability was isolated. Finally, the magnitude of 505 CODD asymmetry was quantified and its association was assessed with 505 CODD performance.

Given that tests such as the 10-m sprint and 505 test introduce fewer sources of variability compared with agility protocols that incorporate a perceptual–cognitive component, higher reliability might reasonably be expected.[1] However, the reliability values observed in the present study were similar or slightly lower, with average-measures ICCs ranging from .72 to .88 and SEM values between 0.1 and 0.3.[1,4,5,8,33] Both the 10-m sprint and 505 COD represent a high ecological validity with the average sprint efforts ranging between 7 and 9 seconds, respectively.[2] However, the short duration of these tests may increase sensitivity to small variations in execution or measurement, particularly with manual timing. Even minor inconsistencies can therefore affect reliability. These findings suggest that multiple trials should be administered and averaged to obtain more stable performance estimates, and that future assessments may benefit from more precise timing methods such as touchpads or video analyses.

Consistent with findings from the dry-land 505 test,[12] the 10-m sprint performance was a significant predictor of 505 test performance, explaining 64.3% to 69.7% of the variance. In contrast, the 10-m sprint performance did not significantly predict CODD, indicating that linear swim speed had limited impact on CODD performance. Many COD tests contain a substantial proportion of linear sprinting, which allows players with strong straight-line swimming ability to compensate for shortcomings in actual COD

Table 2 Raw Test Data As Well As Test–Retest Reliability Data for All Swimming Performance Tests in Water Polo Players (n = 10)

Tests	Mean (SD) T_1	Mean (SD) T_2	Mean (SD) T_3	ICC (95% CI) SM	ICC (95% CI) AM	MDC	SEM AM	SEP AM	CV %
10-m sprint, s	7.35 (0.40)	7.03 (0.40)	7.45 (6.89)	.46 (.07–.80)	.72 (.18–.93)	0.6	0.2	0.3	3.31
505—R, s	9.22 (0.34)	8.93 (0.34)	9.12 (0.35)	.72 (.39–.91)	.88 (.66–.97)	0.3	0.1	0.2	1.66
505—L, s	9.44 (0.48)	8.88 (0.39)	9.05 (0.43)	.52 (.13–.83)	.76 (.30–.94)	0.8	0.3	0.3	3.17

Abbreviations: 505, 505 test performance; AM, average measures; CI, confidence interval; CV, coefficient of variation; ICC, intraclass correlation coefficient; L, left turn; MDC, minimal detectable change; R, right turn; SEM, standard error of measurement; SEP, standard error of prediction; SM, single measures; T_1, first test trial; T_2, second test trial; T_3, third test trial.

Table 3 Summary of Simple Linear Regression Analyses Examining the Relationships Between Change-of-Direction Performance, Change-of-Direction Performance Deficit, 10-m Sprint Performance, and Change-of-Direction Deficit Asymmetry in the Total Sample (n = 21)

Dependent variable	Independent variable	Adjusted R^2	F	β_0	β	P
505 COD – D	10-m sprint	.643	36.994	2.462	0.948	**<.001**
505 COD – ND	10-m sprint	.697	47.028	1.861	0.990	**<.001**
505 CODD – D	10-m sprint	−.046	0.112	2.462	−0.052	.742
505 CODD – ND	10-m sprint	−.052	0.005	1.861	−0.010	.946
505 CODD – D	505 CODD asymmetry	.053	2.125	1.950	0.010	.161
505 CODD – ND	505 CODD asymmetry	.163	4.890	1.983	−0.014	**.039**

Abbreviations: COD, change-of-direction; CODD, change-of-direction deficit; D, dominant turning side; ND, non-dominant turning side. Note: significant predictors ($P < .05$) are bolded.

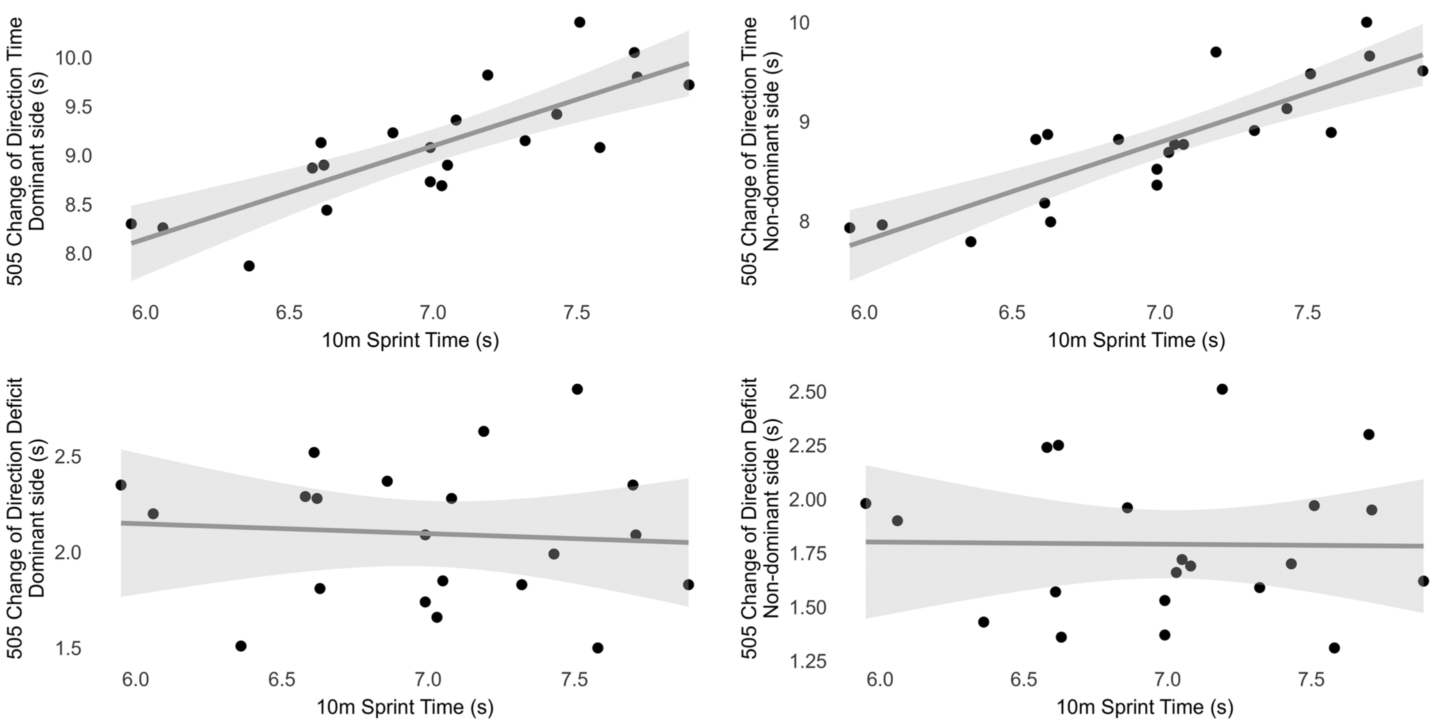

Figure 2 — Scatter plots illustrating the relationships between 10-m sprint time and 505 change-of-direction performance, as well as 505 change-of-direction deficit.

performance.[13] However, our findings underscore that CODD more effectively isolates true COD ability and provides a more accurate assessment when the aim is to evaluate COD performance independently of sprint capacity and perceptual and cognitive factors. For instance, a player who improves linear swim speed but not COD ability may record a faster total 505 time, while the CODD remains unchanged or even increases if the player cannot control the higher entry speed.[13]

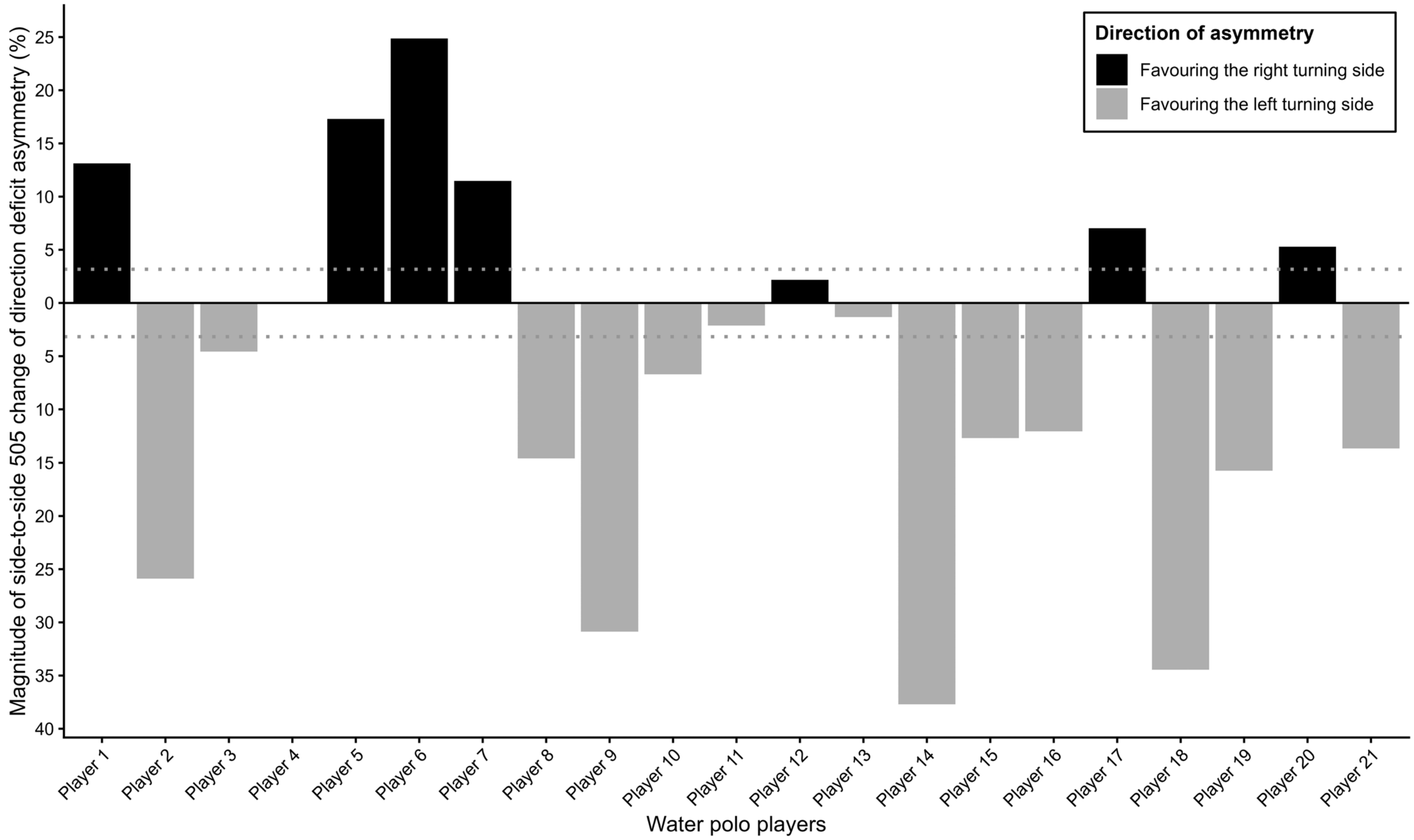

Figure 3 — Individual asymmetry magnitudes for the 505 change-of-direction deficit with the dotted line representing the coefficient of variation (%).

As linear speed appears to have less influence on CODD asymmetry than on standard 505 performance, previous land-based research has reported greater asymmetry magnitudes when using CODD compared with the traditional 505 test. Because total 505 time incorporates a substantial linear sprint component, asymmetries in sprint performance may obscure or distort true directional imbalances, potentially leading to misinterpretation of an athlete's COD asymmetry profile.[23] For this reason, asymmetry in the present study was assessed using the CODD. Significant differences were observed between the dominant and nondominant sides in the 505 CODD, with a mean asymmetry of 14%. For asymmetry to be considered detectable, previous work has proposed that its magnitude must exceed intralimb variability.[34] The maximal CV in our sample was 3.17%, a threshold surpassed by most athletes, indicating the presence of detectable asymmetries (see Figure 3). Although confirmation with 3-dimensional motion analysis is required, differences in joint coordination during approach and reacceleration, or variations in braking strategies between limbs, may contribute to these asymmetry magnitudes.[23]

In the present study, 505 CODD asymmetry was not significantly associated with 505 CODD performance on the dominant side, while a negative association was observed on the nondominant side. With a constant value of 1.983 and small negative beta value of −0.014, these results suggest that a 1% increase in asymmetry corresponds to a 0.014-second reduction in COD time, reflecting a trivial improvement in performance. Given the minimal effect, such asymmetry is unlikely to meaningfully influence COD ability for most athletes. While evidence remains mixed, some studies have reported that asymmetry in the dry-land 505 test can impair performance in both turning directions.[22,23] Considering these conflicting findings, CODD asymmetry appears unlikely to serve as a robust predictor of overall COD performance. Nevertheless, individuals with larger asymmetries, up to 37.7% in this study, may experience a strategic disadvantage that could potentially impair water polo performance.[24]

The present study is the first to implement the concept of CODD in water polo players. Because the sample comprised elite and highly trained players from the Belgian Super League, the number of participants was inevitably limited, which may have reduced statistical power. The use of such a specific population also limits the generalizability of the results to other sports or training levels. Timing for the 10-m sprint and 505 assessments was obtained with a manual chronometer. Given the small differences in performance between trials, more precise timing systems such as touchpads or video analyses could reduce measurement error and improve reliability. Finally, the cross-sectional design does not capture natural fluctuations in asymmetry over time.[14] Since asymmetry has been linked to performance decrements,[20] future studies with a longitudinal focus should investigate the potential effects of interventions, including land-based, aquatic, or mixed training approaches, as well as strength and power training methodologies, on CODD and water polo performance.

Practical Applications

Practitioners assessing water polo athletes are encouraged to use the in-water 505 CODD when the goal is to evaluate COD ability in an aquatic environment. To enhance measurement reliability, multiple trials should be administered, and timing should be captured with high-precision methods such as touchpads or video-based analysis. Given that COD asymmetry may impair water polo performance from a tactical standpoint,[24] practitioners may consider monitoring side-to-side differences with CODD, along with efforts to develop proficiency in both turning directions. Future studies should investigate whether targeted in-water drills (eg, repeated turns without wall assistance) and interventions aimed at reducing functional dryland asymmetries (eg, in jumping or strength), which have been reported to affect 505 CODD performance on land,[10,11] could improve COD performance in water.

Conclusions

In summary, this study introduced a newly developed in-water 505 test and its derived CODD in elite and highly trained male players. The moderate to good reliability, together with its ability to distinguish COD performance from linear sprint speed, offer a potentially superior evaluation of COD performance compared to the agility water polo tests commonly cited in literature. Furthermore, the presence of detectable asymmetries in CODD highlights its value for profiling athlete movements characteristics. Although these asymmetries showed limited influence on overall COD ability, larger asymmetries may present a strategic disadvantage in match situations. Therefore, future research employing experimental study designs should investigate the impact of larger CODD asymmetries on performance outcomes.

Acknowledgment

The authors would like to the participants for participating in this study.

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