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Vienna Test System measures failed to predict goal and passing efficiency during international water polo matches in world-class-level youth water polo players

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The main objective of this study was to determine whether Vienna Test System measures can reflect water polo players' offensive game performance. Thirty-six young male water polo players were divided into players selected for the youth national team (n=21) and players not selected (n=15). Composite scores were formed from the cognitive variables, and match performance indicators comprised goal and passing efficiency. No significant associations were observed between the composite scores and efficiency indicators; moreover, the composite scores failed to predict goal and passing efficiency in the multiple regression analyses. We did not find significant differences between the selected

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and nonselected groups, with the exception of mean reaction time in favour of the nonselected group (p<0.05). Vienna Test System did not reflect water polo game performance, therefore future researchers should consider the development and validation of sport-specific neuropsychological laboratory tests to obtain more relevant information about water polo players' perceptual-cognitive skills.

KEY WORDS: Perceptual-cognitive skills, Match performance indicators, Top-level athletes, Shooting accuracy.

During a real-time water polo game, players constantly receive updated information on teammate positions and ball paths, and they must inhibit planned actions when the chosen action might not be optimal (Kovačević et al., 2023). Since quick and accurate reactions must be precisely executed by players in an overstretched environment (Neuwirth & Benesch, 2012; Ong, 2017), appropriate decision-making skills and a high level of stress tolerance are required to perform at a superior level. Therefore, it is important to measure the level of perceptual-cognitive skills in laboratory circumstances to interpret expert performance in its totality and to identify elements and processes that determine successful performance.

Currently, it is unclear how to best assess perceptual-cognitive skills in a way that precisely reflects the demands of sport-specific performance in elite athletes (Mann & Savelsbergh, 2015; Pinder et al., 2015; Schumacher et al., 2018). In a comprehensive review article by Ong (2015), the Vienna Test System was used to examine the results of 22 studies comparing athletes of different sports and levels as well as various categories. Although the system proved to be a promising and suitable approach to measure perceptual-cognitive skills, future studies should consider whether the results of the Vienna Test System are transferable to real sport-specific situations. Based on previous findings (Baur et al., 2006; Ong, 2015; Zwierko, 2006), the author concluded that researchers should evaluate whether a test is appropriate for a particular sport and whether it can provide a proper indicator of an athlete's actual skills.

Despite the popularity of this tool in the field of sport psychology, research on water polo has mainly examined players' perceptual-cognitive skills using different methods and systems (Casanova et al., 2020; Kovačević et al., 2023; Quevedo-Junyent et al., 2011). For instance, Kovačević et al. (2023) found significant differences in cognitive performance and swimming tests among youth water polo players in favour of selected players on national teams compared to nonselected players. Based on laboratory results, cognitive functioning was a significant predictor of the selection of youth water polo players into the national team. In contrast, in a study by Quevedo-Junyent et al. (2011), the results did not show a significant difference between elite and subelite players in a dynamic visual acuity test despite the age difference. Therefore, it was suggested that future measurements should attempt to imitate real-world situations. To our knowledge, only Kioumourtzoglou et al. (1998) has evaluated water polo players using the Vienna Test System. These authors found that elite athletes performed significantly better than novices in perceptual-cognitive skills tasks. It is important to note that to date, a relationship has not been identified between Vienna Test System measures and different match performance indicators. Moreover, the results of the Vienna Test System have not been compared between elite and subelite water polo players.

Since understanding the parallelism between real water polo match performance and laboratory results is indispensable (Casanova et al., 2020), this study aimed to determine whether Vienna Test System measures are able to precisely reflect and predict offensive game performance in twenty-one world-class-level youth water polo players during international water polo matches. The first hypothesis of this study was that the perceptual-cognitive skills evaluated by the Vienna Test System positively correlate with the goal and passing efficiency recorded during water polo matches. This hypothesis was based on the study by Vestberg et al. (2012), which prospectively analysed the relationship between the quality of soccer performance (scored goals and successful assists) and executive function in young soccer players. These authors observed an association between cognitive flexibility and working memory measures and the number of goals scored. The authors suggested that the assessment of executive function with validated neuropsychological tests can determine whether a soccer player can perform at a superior level. The second hypothesis of the study was that there is a significant difference in match performance indicators recorded during water polo matches in the comparison of playing positions (wings and centre-backs). The second aim of the study was to compare the results of perceptual-cognitive skills obtained by the Vienna Test System between elite youth water polo players who were successfully selected into the youth national water polo team and nonselected players. This aim was based on contradictory findings in the literature in the comparison of elite and subelite athletes in individual sports measured by the Vienna Test System (Gierczuk et al., 2012; Johne et al., 2013; Sadowski et al., 2012) and the comparison of selected and nonselected players on the water polo national team evaluated by another psychomotor test (Kovačević et al., 2023). Therefore, the third hypothesis was that the perceptual-cognitive skills evaluated by the Vienna Test System show significant differences in favour of selected players. Data on perceptual-cognitive skills in water polo are scarce, so the third objective of the research was to provide reference data from top-level youth water polo players.

Materials and Methods

Participants

The study included a total of thirty-six young male water polo players, who were divided into two groups: players who were selected for the youth national water polo team (selected group) and players who were not selected (nonselected group). The selected group included twenty-one young male top-level water polo players (18.3 ± 0.9 years, 189.3 ± 5.6 cm, 89.9 ± 8.3 kg; 12 wings, 9 centre defenders) who represented their country during two international tournaments (U19 LEN European Championships, Podgorica and FINA World Men's Youth Water Polo Championships, Belgrade) and successfully won different medals. The nonselected group included fifteen young male water polo players (18.6 ± 0.9 years, 189.1 ± 6.8 cm, 95.2 ± 15.7 kg; 10 wings, 5 centre defenders) who were members of the best eight teams in the current youth championships but were not selected for the national team during the training camp.

All athletes were physically and mentally healthy and read and signed informed consent documentation. The selected players had 10.6 ± 1.9 years of training experience, while the nonselected players had 10.4 ± 1.0 years. Both groups had a minimum of five water polo training sessions per week. The local ethics committee approved the study protocol (TE-KEB/11/2022), which was conducted according to the tenets of the Declaration of Helsinki. Participants or their guardians received written and verbal explanations of the study's aims and associated risks.

Procedures and Materials

Vienna Test indicators

We used a Vienna Test System (Scuhfried Gmbh, Moedling, Austria) system at a research centre specialising in assessing team sport athletes. The testing sessions were performed in the morning. Participants were asked not to train for 24 hours before the test and to avoid consuming caffeinated drinks the morning of the test. Coaches were also informed about the protocol.

The Vienna Test System is a valid and reliable tool for measuring psychological constructs, such as spatial orientation, anticipation, reaction, attention, peripheral perception, psychomotor ability and visuomotor coordination. Furthermore, the system has been used to determine differences between types of athletes and identify the effects of cognitive status on athletic performance (Ong, 2015).

The Choice Reaction Time test (RT/S3) measures the ability to react to critical stimulus combinations. Participants were instructed to place their index finger on the "start" button and immediately move their finger from this sensor towards a predetermined button when they recognised a specific stimulus combination (the colour yellow appearing on the monitor in conjunction with an acoustic signal). The participants were instructed to keep their finger on the key button in the absence of a signal. In this way, the mean reaction and motor times were assessed and identified during the test. The system calculated the mean reaction time as the time lapse between the appearance of the stimulus variations and the moment when the finger was moved from the "start" sensor. Mean motor time was calculated from the time lapse between the participant's finger leaving the sensor and the moment the appropriate button on the test panel was pressed. The duration of the test was 5-10 minutes.

The Stroop test (STROOP/S7) is a sensorimotor speed test designed to assess cognitive flexibility. Briefly, this test involves a mismatch between the written name of a colour and the colour used to present the name. We administered the test in the baseline condition of reading words and naming colours and the incongruent condition of colour-word and word-colour. Baseline performance was established using two conditions without interfering influences (congruent stimuli) and was related to two interference conditions (incongruent stimuli). The differences between the reaction times of interference and baseline conditions were used to calculate interference tendency. The percentage of incorrect answers was also analysed during interference conditions to determine whether a faster reaction time was associated with a greater failure incidence and longer reaction time. The respondents were required to respond as quickly as possible by pressing the appropriate button on the test panel. The test duration was 10-15 minutes, and 10-10 trials were conducted per condition for familiarisation (Chou et al., 2020; Horváth et al., 2022).

The Visged test (VISGED/S11) was used to determine short-term visual memory. This test can provide information about the orientation level of participants in a real-life environment. The objective of the test required the respondents to correctly memorise and recall the positions of various symbols (e.g., a book for library and a cross for hospital) presented for a short time on a city map. After the familiarisation trials, the city map was initially presented with specific symbols marked. Subsequently, the participants were presented with an empty city map and asked to mark the previous location of a symbol using a mouse attached to the system. The correct location of the symbol was displayed immediately after the respondent submitted a mark to provide performance feedback. The test duration was 20-25 minutes. A high measurement precision score indicated that the respondent could memorise more information items (Horváth et al., 2022).

The Signal test (SIGNAL/S3) is used to examine the visual differentiation of relevant signals among irrelevant distractor signals displayed on a screen. Since this test was longer than the other tasks, long-term focused attention was also assessed. We used a short signal duration (S3) with white dots across a black background screen. During the test, some of the dots disappeared randomly and new dots appeared. The participants were required to react with a key-press response whenever four dots formed a square as a programmed stimulus constellation. The participants executed familiarisation trials before the test to ensure adequate knowledge of the nature of the test. The test duration was 15-20 minutes. The number of incorrect and missed reactions and the mean recognition time were calculated as the main variables (Zwierko & Lesiakowski, 2014).

The Determination test (DT/S1) assessed the participants' reactive stress tolerance, reaction speed and attention level in situations requiring continuous and rapid responses to varying stimuli. Specifically, five coloured buttons (yellow, white, blue, green, red), two foot pedals (left, right) and two acoustic tones (high, low) were the stimuli. The participants were instructed to react as quickly and precisely as possible in response to the stimuli by pressing the appropriate button on the response panel and to use the foot pedals when instructed by the computer. The stress factor of the test was the need to sustain varying, continuous, and rapid responses to rapidly changing stimuli. The test duration was 5-8 minutes. The number of correct, incorrect, and missed reactions and the median reaction time were evaluated (Horváth et al., 2022; Ong, 2017).

Match performance indicators

The matches were recorded by an expert video analyst who used the same video camera (Panasonic HDC-TM20, Japan) positioned at the pool midline. We used a match analysis system to determinate match performance outcomes (MatchStudio 1.55.0, Sportdigit, Italy). The recorded videos were analysed by an expert video analyst. The performance indicators of total playing time, goal number, goal/minute, goal efficiency, total pass number, total pass/minute and passing efficiency were evaluated during matches. The goal efficiency was calculated as the sum of goals scored/sum of shots on goal attempt (%), referred to as variables related to goal-scoring performance. The passing efficiency was calculated as the sum of every successful pass/sum of every pass attempt (%) related to variables associated with passing performance.

Statistical Analysis

Data were processed using SPSS 25.0 (SPSS Inc., Chicago, IL, USA) and are reported as the mean ± SD. We checked each variable for normal distribution using the Shapiro-Wilk test.

For the assessment of the relationship between general perceptual-cognitive skills and offensive performance indicators, composite scores were formed based on the results of the Vienna Test. Individual test elements for each cognitive variable described in the Materials and Methods section were z scored and the mean z score value was computed for each test, resulting in five composite cognitive scores: the Determination test score (DT), Reaction Time test score (RT), Signal test score (SIG), Stroop test score (STR), and Visged test score (VIS). Passing efficiency and RT were not normally distributed and were log-transformed. We determined the Pearson product moment correlations among the seven variables in the initial analyses. The magnitude of correlations was quantified using the thresholds recommended by Hopkins et al. (2009), i.e., 0 – 0.1 as small, 0.1 – 0.3 as moderate, 0.3 – 0.5 as large, 0.5 – 0.7 as very large and 0.9 – 1 as extremely large correlation. The main analysis comprised a multiple regression approach to predict goal or passing efficiency using the five composite cognitive scores.

Independent-samples t tests and Mann-Whitney U tests were used in cases of normal or non-normal distribution, respectively, to determine the difference between the selected and nonselected group mean values for the Vienna Test results. The same analysis methods were used to assess the differences among playing positions in terms of match performance indicators. The level of significance was set at $p < 0.05$ for all analyses.

Results

The five composite scores of perceptual-cognitive skills failed to predict goal ($F = 2.0$, $p = 0.133$) and passing efficiency ($F = 1.6$, $p = 0.231$) in the multiple regression analyses. Of the five cognitive measures, only SIG was associated with goal efficiency, while the other four cognitive scores did not explain the additional variation (Table I). Of the five cognitive measures, STR was associated with passing efficiency, while the other four cognitive scores did not explain the additional variation (Table I).

Table II shows the descriptive values of the assessed offensive match indicators and cognitive measures with the comparison of playing positions (wings and centre-backs).

Table III shows the group mean ± SD values of perceptual-cognitive skill variables with the comparison of selected (n = 21) and nonselected (n = 15) youth water polo players. The OMRZ was found to be significantly longer in selected players than in nonselected players ($p < 0.05$).

Discussion

The first aim of the study was to determine whether Vienna Test System measures were able to precisely reflect game performance indicators in twen-

TABLE I
Summary Of Multiple Regression Analyses For Predicting Goal Efficiency And Passing Efficiency In 21 World-Class-Level Male Youth water polo players

Dependent variable – **Goal efficiency**					
Predictors	Beta1	Beta2	t	p	r
Constant	54.7	-	16.1	<0.001	-
DT	-1.6	-0.06	-0.2	0.837	-0.05
RT	6.2	0.17	0.8	0.452	-0.03
SIG	-13.0	-0.58	-2.5	0.027	-0.42
STR	10.4	0.33	1.2	0.252	0.27
VIS	4.7	0.30	1.3	0.206	0.24
Dependent variable – **Passing efficiency**					
Predictors	Beta1	Beta2	t	p	r
Constant	2.0	-	189.5	<0.001	-
DT	-0.4	-0.50	-1.6	0.124	-0.13
RT	0.0	0.18	0.8	0.448	-0.07
SIG	0.0	-0.23	-0.9	0.371	-0.28
STR	0.1	0.68	2.4	0.033	0.33
VIS	0.0	-0.06	-0.3	0.800	0.06

Note. DT: Determination test score, RT: Reaction Time test score, SIG: Signal test score, STR: Stroop test score, VIS: Visged test score
Beta 1, unstandardised beta coefficient
Beta 2, standardised beta coefficient

TABLE II
Descriptive values for each variable measured in international competitions in 21 world-class-level male youth water polo players with the comparison of wings (n=12) and centres-backs (n=9)

	Wings (12)		Centres-Backs (9)	
Variable	Mean	±SD	Mean	±SD
Total playing time, min	130.45	38.53	134.75	73.09
Goal, number	12.50	6.35	9.22	6.82
Goal/minute, number	0.09*	0.04	0.06	0.02
Goal efficiency, %	50.40	14.95	57.92	16.78
Total pass, number	107.25	48.13	76.11	68.42
Total pass/minute, number	0.81*	0.17	0.50	0.29
Passing efficiency, %	94.02	5.41	89.76	11.76

Note. Goal efficiency: computed from the sum of goals scored/sum of shots on goal attempt, Passing efficiency: computed from the sum of every successful pass/sum of every pass attempt.
*Significant difference from centres-backs; $p < 0.05$

ty-one world-class-level youth water polo players during international water polo matches. The five composite scores entered in the multiple regression analysis failed to predict goal and passing efficiency (Table I). Therefore, our hypothesis that there is a positive correlation among perceptual-cognitive skills measured by the Vienna Test System and offensive match performance indicators was not confirmed. Our hypothesis was based on findings from studies reported in other team sports, where an association was found among generally assessed perceptual-cognitive skills and on-field performance (Andrade et al., 2020; Gonçalves et al., 2020; Kováč, 1996; Vestberg et al., 2012). Andrade et al. (2020) reported an association between a measure of tactical behaviour efficiency and attention among young soccer players using the COG test measured by the Vienna Test System. In another study, Gonçalves et al. (2020) found that the number of omitted reactions measured by the peripheral perception test in the Vienna Test System was significantly associated with the efficiency of offensive and defensive tactical behaviours. The authors concluded that narrower peripheral perception reduces tactical behaviour efficiency. It should be noted that the indicators used in our study, albeit similar to those used by Vestberg et al. (2012), failed to incorporate game intelligence or tactical behaviour in its totality, which might cover and measure players' performance more specifically. However, goal and passing efficiency indices overlook offensive and defensive tactical behaviours that are difficult to capture by simple score indices. Although goal and passing

Table III
Group Mean And SD Values For Each Variable Of Perceptual-Cognitive Skills Measured By Vienna Test System With comparison of results among selected (n=21) and nonselected (n=15) youth water polo players

	Selected (21)		**Nonselected (15)**	
Variable	Mean	±SD	Mean	±SD
DT/S1 – MDRT, msec	720	50	690	50
DT/S1 – SFA, number	49.43	19.06	55.80	16.61
DT/S1 – ZV, number	248.00	26.49	243.47	27.95
RT/S3 – OMMZ, msec	149.71	27.80	133.60	40.98
RT/S3 – OMRZ, msec	387.52*	58.56	338.00	54.67
SIGNAL/S3 – MDT, msec	780	70	740	70
SIGNAL/S3 – SUMA, number	15.81	5.99	16.60	8.16
SIGNAL/S3 – SUMF, number	4.10	3.30	4.27	2.05
STROOP/S7 – DRTF24, msec	100	80	100	40
STROOP/S7 – MDRTF1, msec	630	60	620	60
STROOP/S7 – MDRTF3, msec	800	140	780	80
STROOP/S7 – MDRTF4, msec	720	10	700	80
STROOP/S7 – SUMFF1, %	4.48	3.22	4.67	3.48
STROOP/S7 – SUMFF2, %	5.19	4.01	5.20	2.83
STROOP/S7 – SUMFF3, %	5.38	5.09	6.73	4.15
STROOP/S7 – SUMFF4, %	5.19	3.33	5.53	4.03
VISGED/S11 – AI, score	2.36	1.40	2.14	1.60

Note. MDRT: median reaction time, SFA: sum of incorrect and missed, ZV: correct, OMMZ: mean motor time, OMRZ: mean reaction time, MDT: mean recognition time, SUMA: missed, SUMF: incorrect, DRTF24: naming interference tendency, MDRTF1: median for reaction times, reading (baseline), MDRTF3: median for reaction times, reading (interferenz), MDRTF4: median for reaction times, naming (interferenz), SUMFF1: percentage of incorrect reactions, reading (baseline) SUMFF2: percentage of incorrect reactions, naming (baseline), SUMFF3: percentage of incorrect reactions, reading (interferenz), SUMFF4: percentage of incorrect reactions, naming (interferenz), AI: performance of visual memory
*Significant difference from nonselected; $p < 0.05$

efficiencies are complex indicators and include various skills (e.g., visual recognition, decision-making, motor control, ball handling technique, joint flexibility), these are easy to assess practically and can provide a proper approximation for coaches to determine performance quality (Vestberg et al., 2012).

In this study, a comparison of different playing positions was conducted (Table II). Among the descriptive values, goal/minute and total pass/minute showed significant differences in favour of wings, which confirmed our second hypothesis. The results can be unequivocally interpreted based on the nature of the sport; in a time-restricted environment, there are positional differences and requirements in the abilities of playing positions in water polo. While centre players perform more transitions between vertical and horizontal body positions and spend more time in contact with opponents than other field players, wings perform more overhead shots (Smith, 1998) and rapid ball circulation with great variability of passing and shooting attempts.

Our second aim was to compare the perceptual-cognitive skill results of players selected for the youth national water polo team with the results of nonselected players assessed by the Vienna Test System based on discrepancies in the findings of previous studies (Gierczuk et al., 2012; Johne et al., 2013; Sadowski et al., 2012). We did not find a significant difference in the variables of perceptual-cognitive tests between selected and nonselected groups except for mean reaction time in favour of the nonselected group (Table III). Therefore, the hypothesis related to this topic was not confirmed. Based on the findings of this study, it seems that the Vienna Test System cannot sensitively distinguish between the highest competitive levels of water polo players in this age group. One possible explanation is that even nonselected players participated in the first eight teams in the local championship, which is among the strongest, most equalised championships in the world. In contrast to our results, Kovačević et al. (2023) measured cognitive flexibility, motor speed, inhibition and psychomotor ability using a different laboratory test and concluded that these predictors are significant in the selection process of youth water polo players to national teams in favour of selected players. With regard to the contradictory findings between our study and the aforementioned studies, it can be concluded that age difference probably had an effect since older athletes have more sport experiences, which may cause greater differences in the various levels of athletes (Ong, 2015). This argument seems to be acknowledged by the study of Johne et al. (2013), who compared the complex reaction time of female fencers of different sport levels and ages. The authors concluded that fencers with more sport experience perform better in various reaction time tests evaluated by the Vienna Test System. Nonetheless, comparison and interpretation of the results in relation to the related literature is difficult due to the contradictory findings. For instance, in the median reaction time of the DT test, nonselected water polo players substantially outperformed non-medal-winning taekwondo competitors evaluated by Sadowski et al. (2012). In contrast, in the incorrect and missed answers task of the DT test, the athletes measured by Sadowski et al. (2012) performed substantially better than players of both groups in our study, who were chronologically older than the taekwondo junior athletes.

In our study, the Determination test (setting S1) was used to evaluate stress tolerance, which is one of the most significant factors in sporting success (Ong, 2017; Patmore, 1986). Notably, the median reaction time, the sum of correct, incorrect and missed answers and the percentage scores (Table III) aligned with previously published data on team sport athletes (Csáki et al., 2016; Kiss & Balogh, 2019; Ong, 2017).

The mean motor time measured by the Reaction time test (setting S3) in our study (Table III) was comparable in both groups to that reported by Fózer-Selmeci et al. (2016), but was substantially longer than the time reported by Krawczyk et al. (2018). The results of the mean reaction time (Table III) in the case of the selected group were similar, but the nonselected group assessed in our study was substantially better than the athletes evaluated by Fózer-Selmeci et al. (2016). It should be noted that the results of both groups evaluated in our study were substantially longer than the athletes evaluated by Krawczyk et al. (2018). A possible explanation may be that Krawczyk et al. assessed handball goalkeepers, a player position that requires fast responses to the opponent's ball handling, which may potentially explain this discrepancy.

The results of the Stroop test (setting S7) (Table III) were compared to the findings of Horváth et al. (2022), who measured car racing drivers at baseline and postintervention. The results for the water polo players were similar to the findings of car racing drivers, with the exception of the SUMFF3 test, which was relatively better even at the baseline assessment of individual athletes. After the intervention, SUMFF3 and SUMFF4 were substantially better for the athletes assessed by Horváth et al. (2022), which can be explained by the positive effects of systematic reactive agility training with light-based stimuli during the 6-week period.

The results of the Visged test (setting S11) (Table III) were comparable to the findings of Horváth et al. (2022).

Our results for the Signal (setting S3) (Table III), Stroop and Visged tests provide potential references for comparison between data from different team sport athletes. Overall, the findings of this study are novel for the assessed sport and can be used as a reference for world-class-level youth water polo players. The results demonstrated that only handball goalkeepers performed substantially better in the RT test, while the findings for the rest of the tests reported in the literature were in line with the results of our study. Since we did not obtain remarkable differences in the comparison of various sports, we can conclude that the Vienna Test System cannot sensitively distinguish dominant sports-related perceptual-cognitive skills and athletes' profiles among various sports above a professional level. Moreover, it is possible that Vienna Test measures might fail to represent match situations, as indicated by the lack of correlation between match performance indicators and a wide battery of laboratory scores.

This study has some limitations that must be addressed. First, while water polo is a popular team sport, only a few teams reach the top international level. Although we analysed data recorded during two major international competitions, the level of play varied greatly between matches. It should be noted that players in key situations of a world-class team may perform without high mental load even in critical situations during most matches, which may bias the results. Therefore, in the future, researchers should collect goal and pass data about matches of teams with similar strength levels. Second, while our study relied on two objective performance components that could be well controlled (Vestberg et al., 2012), previous water polo studies applied a greater number of performance indicators to assess the differences among seasons and matches with different overall results (Iglesias-Pérez et al., 2017; Ordóñez et al., 2015).

Conclusion

Goal and passing efficiency recorded during international water polo matches were not associated with perceptual-cognitive skills recorded by the Vienna Test System among world-class-level youth water polo players. The findings of our study indicate that Vienna Test System measures are not able to precisely reflect and predict water polo players' offensive game performance. Future research should consider the development and validation of various sport-specific neuropsychological laboratory tests to obtain more relevant information about water polo players' perceptual-cognitive skills. The novelty of this study is that twenty-one world-class-level water polo players (medallists at two different international tournaments) were recruited, evaluated, and compared to nonselected players, providing reference data for top-level youth water polo players' perceptual-cognitive skills. We encourage future studies to report data from perceptual-cognitive measurements and to explore and predict their connection to water polo game performance. A better understanding of the interaction between these variables could help coaches design more accurate game strategies and tactics based on the individual capabilities of players. In regard to match performance evaluation, we emphasise the importance of developing specific match analysis indicators that can effectively reflect perceptual-cognitive performance during water polo games.

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REFERENCES

Andrade, M., Víllora, S., Casanova, F., & Teoldo da Costa, I. (2020). The Attention as a Key Element to Improve Tactical Behavior Efficiency of Young Soccer Players. *Revista de Psicologia del Deporte*, 29, 47-55.

Baur, H., Müller, S., Hirschmüller, A., Huber, G., & Mayer, F. (2006). Reactivity, stability, and strength performance capacity in motor sports. *British Journal of Sports Medicine*, 40, 906-910; discussion 911. doi: 10.1136/bjsm.2006.025783

Casanova, F., Tavares, F., Fernandes, R., Canossa, S., Víllora, S., Teoldo da Costa, I., . . . Pereira, R. (2020). Representativeness of Offensive Scenarios to Evaluate Perceptual-Cognitive Skills of Water Polo Players. *Central European Journal of Sport Sciences and Medicine*, 29(1), 11-19. doi: 10.18276/cej.2020.1-02

Chou, C.-C., Chen, K.-C., Huang, M.-Y., Tu, H.-Y., & Huang, C.-J. (2020). Can Movement Games Enhance Executive Function in Overweight Children? A Randomized Controlled Trial. *Journal of Teaching in Physical Education*, 39(4), 527-535. doi: 10.1123/jtpe.2019-0165

Csáki, I., Fózer-Selmeci, B., Bognár, J., Szájer, P., Zalai, D., Géczi, G., . . . Tóth, L. (2016). New measurement method: Examination of psychological factors with Vienna System among soccer players. *Testnevelés, Sport, Tudomány*, 1(1), 8-20. doi: 10.21846/TST.2016.1.1

Fózer-Selmeci, B., Nagy, E., Csáki, I., Tóth, L., & Bognár, J. (2016). Labdarúgó-akadémisták pályán betöltött pozíciójához szükséges pszichológiai készsége vizsgálata és elemzése számítógépes pszichológiai tesztrendszerrel (Vienna Test System). *Alkalmazott Pszichológia*, 16(3), 97-115. doi: 10.17627/ALKPSZICH.2016.3.97

Gierczuk, D., Bujak, Z., Rowiński, J., & Dmitriyev, A. D. (2012). Selected Coordination Motor Abilities in Elite Wrestlers and Taekwon-Do Competitors. *Polish Journal of Sport and Tourism*, 19(4), 230-234. doi: 10.2478/v10197-012-0022-1

Gonçalves, E., Noce, F., Barbosa, M. A. M., Figueiredo, A. J., Hackfort, D., & Teoldo, I. (2020). Correlation of the peripheral perception with the maturation and the effect of the peripheral perception on the tactical behaviour of soccer players. *International Journal of Sport and Exercise Psychology*, 18(5), 687-699. doi: 10.1080/1612197X.2017.1329222

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, 41(1), 3-13. doi: 10.1249/MSS.0b013e31818cb278

Horváth, D., Négyesi, J., Györi, T., Szücs, B., Tóth, P. J., Matics, Z., . . . Rácz, L. (2022). Application of a Reactive Agility Training Program Using Light-Based Stimuli to Enhance the Physical and Cognitive Performance of Car Racing Drivers: A Randomized Controlled Trial. *Sports Medicine - Open*, 8(1), 113. doi: 10.1186/s40798-022-00509-9

Iglesias-Pérez, M., Ordóñez, E., & Touriño, C. (2017). Game-Related Statistics in the Spanish Water Polo League: Differences between Seasons. *Retos*, 33, 228-232. doi: 10.47197/retos.v0i33.56007

Johne, M., Poliszczuk, T., Poliszczuk, D., & Dąbrowska-Perzyna, A. (2013). Asymmetry of Complex Reaction Time in Female Épée Fencers of Different Sports Classes. *Polish Journal of Sport Tourism*, 20, 25-34. doi: 10.2478/pjst-2013-0003

Kioumourtzoglou, E., Kourtessis, T., Michalopoulou, M., & Derri, V. (1998). Differences in several perceptual abilities between experts and novices in basketball, volleyball and water-polo. *Perceptual and Motor Skills*, 86(3), 899-912. doi: 10.2466/pms.1998.86.3.899

Kiss, B., & Balogh, L. (2019). A study of key cognitive skills in handball using the Vienna test system. *Journal of Physical Education and Sport*, 19(1), 733-741. doi: 10.7752/jpes.2019.01105

Kovačević, N., Mihanović, F., Lušić Kalcina, L., Hrbić, K., Poklepović Peričić, T., Matijaš, T., & Galić, T. (2023). Influence of cognitive performance and swimming capacities on selection of youth water polo players to national team. *The Journal of Sports Medicine and Physical Fitness*, 63(1), 34-41. doi: 10.23736/s0022-4707.22.13592-9

Kováč, T. (1996). On the profile of young soccer talents: A preliminary study. *Studia Psychologica*, 38(1-2), 63-65.

Krawczyk, P., Bodasinski, S., Bodasinska, A., & Słupczyński, B. (2018). Level of psychomotor abilities in handball goalkeepers. *Baltic Journal of Health and Physical Activity*, 10(3), 64-71. doi: 10.29359/BJHPA.10.3.07

Mann, D. L., & Savelsbergh, G. J. P. (2015). Issues in the measurement of anticipation. In Baker, J., Farrow, D., (Eds.), *Routledge Handbook of Sport Expertise* (1st Edition) (pp. 166-175). London: Routledge. doi: 10.4324/9781315776675-15

Neuwirth, W., & Benesch, M. (2012). *Vienna Test System Manual: Determination Test (Version 35).* Moedling: Schuhfried.

Ong, N. (2015). The use of the Vienna Test System in sport psychology research: A review. *International Review of Sport and Exercise Psychology*, 8(1), 1-20. doi: 10.1080/1750984X.2015.1061581

Ong, N. (2017). Reactive stress tolerance in elite athletes: Differences in gender, sport type, and competitive level. *Cognition, Brain, Behavior: An Interdisciplinary Journal*, 21(3), 189-202. doi: 10.24193/cbb.2017.21.11

Ordóñez, E., Touriño, C., & Iglesias-Pérez, M. (2015). Offensive Performance Indicators in a Regular Season of Water-Polo. *International Journal of Performance Analysis in Sport*, 15(3), 1114-1123. doi: 10.1080/24748668.2015.11868855

Patmore, A. (1986). *Sportsmen under stress*. Victoria: Century Hutchinson Australia Pty Ltd.

Pinder, R., Headrick, J., & Oudejans, R. (2015). Issues and challenges in developing representative tasks in sport. In Baker, J., Farrow, D., (Eds.), *Routledge Handbook of Sport Expertise* (1st Edition) (pp. 269-281). London: Routledge.

Quevedo-Junyent, L., Aznar-Casanova, J. A., Merindano-Encina, D., Cardona, G., & Solé-Fortó, J. (2011). Comparison of dynamic visual acuity between water polo players and sedentary students. *Research Quarterly for Exercise and Sport*, 82(4), 644-651. doi: 10.1080/02701367.2011.10599801

Sadowski, J., Gierczuk, D., Miller, J., Cieśliński, I., & Buszta, M. (2012). Success factors in male WTF taekwondo juniors. *Journal of Combat Sports and Martial Arts*, 3, 47-51. doi: 10.5604/20815735.1047647

Schumacher, N., Schmidt, M., Wellmann, K., & Braumann, K. M. (2018). General perceptual-cognitive abilities: Age and position in soccer. *PLoS ONE*, 13(8), e0202627. doi: 10.1371/journal.pone.0202627

Smith, H. K. (1998). Applied physiology of water polo. *Sports Medicine*, 26(5), 317-334. doi: 10.2165/00007256-199826050-00003

Vestberg, T., Gustafson, R., Maurex, L., Ingvar, M., & Petrovic, P. (2012). Executive functions predict the success of top-soccer players. *PLoS ONE*, 7(4), e34731. doi: 10.1371/journal.pone.0034731

Zwierko, T. (2006). Selected aspects of anticipation of soccer players. *Studies in Physical Culture & Tourism*, 13, 189-191.
Zwierko, T., & Lesiakowski, P. (2014). Visuomotor processing after progressively increased physical exercise. *Central European Journal of Sport Sciences and Medicine*, 5(1), 2Manuscript submitted for publication March 2023. Accepted for publication September 20237-34.

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