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Gender Differences in Cognitive Functions of Youth Water Polo Players

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Abstract

Water polo (WP) as a highly demanding contact team sport, requires from players to have well developed cognitive functions, similar as in other team sports. Following same rules for females and males it is important to realize differences between them, which may contribute to their sports success and help coaches to develop adequate training models. Therefore, the aim of this study was to compare cognitive functions between female and male youth WP players. There were 36 female (25%) and 106 male (75%) youth WP players aged 12 to 14 years enrolled in this study. Variables measured included anthropometric indices, specific functional swimming capacities and cognitive functions testings using the Stroop test. Females showed better psychomotor speed (Stroop Off) (females 61.79±6.79 s vs. males 64.83±8.31 s, p=0.048) and response inhibition (Stroop On) (females 73.44±10.74 s vs. males 78.67±14.82 s, p=0.025) than males. Female youth WP players showed better results in psychomotor speed, inhibitory control and motor speed compared to males, taking both age and gender into account. Such differences might be of interest for coaches in WP, as well as in different sports to help them develop appropriate training strategies for each athlete.

Keywords: *sports, water polo, children, executive functions*

Introduction

Cognitive functions

Cognition is the mental activity through which people acquire and process knowledge. It is affected by biological, environmental, experiential, social and motivational factors, as well as the pace and pattern of mental growth, including age-related changes (Gauvain & Richert, 2016). These processes include basic mental activities such as attention, sensation and perception, as well as more complex functions such as memory, problem solving, reasoning and executive function. Executive functions (EF) include attention, inhibitory control, decision making, planning and working memory (Zelazo, Carter, Reznick, & Frye, 1997). EF make it possible to mentally play with ideas, quickly and flexibly adapt to changed circumstances, take time to consider what to do next, resist temptations, stay focused and meet novel, unanticipated challenges which is necessary for playing many complex team sports on high level (Diamond, 2013). These skills begin to develop in early childhood, between the ages of 3 and 5 (Best & Miller, 2010), continuing through adolescence or even early adulthood and their development corresponds with changes in the frontal cortex of the brain (Davidson, Amso, Anderson, & Diamond, 2006). Adults, more than adolescents, appeared aware of making an inhibition error as they momentarily slowed their response for the next trial in order to prevent further error (Davidson et al., 2006; Gauvain & Richert, 2016), which suggests the contribution of metacognitive development even after adolescence. Another factor that may influence the age range of maturation is pubertal development. Pubertal changes are significant in adolescence and have been shown to have an effect on cortical maturation and sex differentiation in cog-

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nitive development (Roivainen, Suokas, & Saari, 2021).

Gender differences in cognitive abilities have been widely analyzed in the psychological and neuropsychological literature (Hyde, 2005; Benbow, 2010; Scheuringer, Wittig, & Pletzer, 2017; Roivainen et al., 2021). The gender similarities hypothesis asserts that males and females are similar on most, but not all, psychological variables meaning that men and women, as well as boys and girls, are more alike than they are different (Hyde, 2005; Benbow, 2010). Differences between cognitive abilities in men and women, girls and boys, are smaller than once thought, and probably occur largely due to either strategy differences, and/or societal expectations (Roivainen et al., 2021). There is a small difference in favor of males on the nonverbal, verbal and working memory subtests, while females outperform males on the psychomotor processing speed tests (Leahey & Guo, 2001; Benbow, 2010; Scheuringer, Wittig, & Pletzer, 2017) .

Researchers who underline biological differences in ability and interest may refer to puberty as partly responsible for the appaerance of gender differences in the high school years. From a neuro-psychological perspective, the strong sex differences in processing speed, particularly through early adolescence suggest intriguing possibilities for understanding the developmental and neurological bases of these differences (Hyde, 2005; Davidson et al., 2006; Best & Miller, 2010; Roivainen et al., 2021).

Cognitive functions and sports

It is hypothesized that physical activity has a positive effect on cognitive functions, which is partly due to the physiological changes in the body (Mann, Williams, Ward, & Janelle, 2007; Gauvain & Richert, 2016). In addition, both motor and cognitive skills may have a similar developmental timetable with accelerated development during childhood (Anderson, 2002). To date, the literature supports the causal link between regular physical activity and brain development particularly in the prefrontal cortical area (Best & Miller, 2010). The long-term practice has also been observed in some perceptual motor skills, like reaction time, as well as EF in general (Mann et al., 2007; Best & Miller, 2010; De Waelle, Laureys, Lenoir, Bennett, & Deconinck, 2021). Moreover, playing high-level team sport games demands well-developed cognitive functions (Kamijo et al., 2011; Bidzan-Bluma & Lipowska, 2018; De Waelle et al., 2021), contributing to their development in general.

Cognitive functions and water polo

Water polo as a highly demanding physical contact team sport, has been developing in recent years for both, boys and girls (Noronha et al., 2022). All activities during the game take place in water, with frequent changes of high-intensity actions separated by moderate-intensity and lower-intensity tasks. Players constantly move through the field using different swimming intensity, receiving, dribbling and passing the ball, as well as shooting accurately on the goal and acomplishing many complex technical-tactical actions (Smith, 1998; Botonis, Toubekis, & Platanou, 2019). They need to have well developed cognitive functions such as anticipation, problem solving and decision making, inhibition and cognitive flexibility, similar as in other team sport games (Botonis et al., 2019; Melchiorri, Triossi, Bianchi, Tancredi, & Viero, 2022). Kovačević et al. (2023) showed superiority of children playing water polo in cognitive functions (psychomotor speed, inhibitory control and motor speed) over their sedentery peers of the same chronological age.

Following same rules in female and male water polo (except smaller dimensions of the field and smaller ball for females) (Canossa et al., 2022) it is important to realize differences between girls and boys, female and male players which may contribute to their sports success at certain age and help coaches to develop adequate training models. Falk et al. were subjectively evaluated cognitive functions of youth water polo players by the coaches during only 2-3 games each season, indicating better scores by the players selected to the youth national team (Falk et al., 2004). Also, Kovačević et al. showed better cognitive functions of the selected players, objectively evaluated using the Stroop test (Kovačević et al., 2023). Those recent studies evaluated only cognitive functions of selected youth water polo players, without the comparison between girls and boys, presenting the research gap and the need for more studies about cognitive functions of youth water polo players (Falk et al., 2004; Kovačević et al., 2023). In many countries girls and boys in early years train together and play in mixed teams. Since pubertal development tends to begin earlier for girls than boys (girls: ages10-12; boys: ages12-14), girls achieve their full athletic development and potentials earlier than boys. Still, boys are on average 7-10 % higher than girls, with stronger upper body, contributing to motor and functional capacities (Thibault et al., 2010).

Properly directed stimuli in this developmental phase have maximum efficiency, but impropperly loaded stimuli may also lead to morphological and functional disturbances. Therefore, it is important for coaches to be aware of gender differences and capacities in youth athletes in order to avoid the wrong influence on their development, giving them convenient opportunity to develop their skills and potentials for playing water polo on high level.

Therefore, the aim of this study was to compare cognitive functions between female and male youth water polo players of the same chronological age. It was hypothesized that female youth water polo players would show better cognitive functions, especially concerning cognitive flexibility and inhibition.

Methods

Participants

This cross-sectional study was conducted in full accordance with the ethical principles, including the World Medical Association Declaration of Helsinki and it was approved by the Ethical Committee of the University of Split School of Medicine, Split, Croatia (No: 2181-198-03-04-19-0053). Informed consent was obtained from parents or legal guardians of children participating in the study after they were introduced to the background and the aim of the study.

There were 36 female (25%) and 106 male (75%) youth water polo players included in this study. All of them were participants in the Croatian Water Polo Federation training camps during the playing seasons 2019/2020, 2020/2021, 2021/2022 and 2022/2023. Youth water polo players self-reported at least 2 years of training experience with 5 training sessions per week, lasting approximately 2 hours.

Measurements and procedures

Anthropometric Characteristics

The experimental setup included anthropometric measurements, specific functional swimming tests and cognitive functions testings. Anthropometric measurements were measured using digital scale and stadiometer while participants wore only light clothes and variables measured included body mass and body height. Body mass index (BMI) was calculated as body mass (kg) divided by height squared (m2).

Cognitive Functions

For cognitive functions testings The EncephalApp_ Stroop application was used. A detailed description of the test can be found in previous studies by Kovačević et al. (Kovacevic et al., 2023; Kovačević, Mihanović, Lušić Kalcina, et al., 2023). In the present study identical procedures were followed. Participants were taken in groups of 10 to a room free of distractions and individually given an explanation of the task, as well as a demonstration and a brief practice session. Subjects were told to use the hand they preferred. The following four variables of the Stroop test were included in the analysis: Stroop OffTime, primarily assessing psychomotor ability, Stroop OnTime, a measure of response inhibition and motor speed, OnTime minus OffTime, the measure of cognitive processing controlling for psychomotor speed and OffTime plus OnTime, showing a composition measure of psychomotor speed and response inhibition (Bajaj et al., 2013; Scarpina & Tagini, 2017).

Specific Functional Swimming Tests

Specific functional swimming tests included 25 m crawl, 50 m crawl, 100 m crawl, 400 m crawl and 25 m ball dribbling. The players were instructed to swim at maximum speed for each test performing various distances and styles in 25-m swimming pool, starting at the sound signal from the water and they were timed with hand-held digital stopwatch (Longines, Saint-Imier, Switzerland). They were allowed to push-off the wall at the start and after the turn, but a flip turn was not allowed. For 25 m dribbling the ball players were instructed to dribble the ball from wall to wall of the swimming pool, without throwing it and to touch the wall with one hand, as previously described in the study of Kovačević et al. (Kovačević, Mihanović, Hrbić, Mirović, & Galić, 2023).

Statistical analyses

Data analyses were performed using statistical software MedCalc for Windows, version 19.4. (MedCalc Software, Ostend, Belgium). Continuous data were presented as mean±standard deviation while categorical variables were presented as whole number and percentage. The Kolmogorov-Smirnov test was used to assess normality of data distribution. Differences in anthropometric variables, cognitive functions and specific functional swimming capacities between female and male youth water polo players were tested using independent samples t-test with the correction for unequal variances (Welch-test) with the statistical significance was set at $p<0.05$. Additionally, a multiple regression analysis was used to determine a relationship between selected independent variables (age, gender) with the outcomes of the Stroop test as dependent variables (StroopOn Time, StroopOff Time, Offtime plus Ontime, Ontime minus Offtime).

Results

There were 36 female (25%), mean age 13.13±0.78 years and 106 male (75%) youth water polo players (WP) with the mean age 12.92±0.79 years (p=0.158). Descriptive statistics of the whole study sample is presented in Table 1.

Table 1. Descriptive Statistics for Total Sample of Participants

	Variables	Total study sample N=142
Anthropometric characteristics	Age (years)	12.99±0.78
	Body height (cm)	168.19±8.09
	Body mass (kg)	60.43±13.03
	Body mass index (kg/m2)	21.25±3.73
Cognitive functions	StroopOff time (s)	64.08±8.07
	StroopOn time (s)	77.40±14.09
	StroopOff plus StroopOn time (s)	141.48±21.33
	Ontime minus Offtime (s)	13.32±8.48
Specific functional swimming capacities	Crawl, 25 m (s)	15.51±1.44
	Crawl, 50 m (s)	33.82±3.20
	Crawl, 100 m (s)	75.08±7.46
	Crawl, 400 m (s)	350.98±33.98
	Dribbling, 25 m (s)	16.09±1.81

Note Data are presented as mean±standard deviation.

Male youth water polo players were significantly taller than female players (male 169.75±8.06 cm vs. female 165.61±6.01 cm, p=0.002), while there were no significant differences in body mass and BMI (Table 2). Considering cognitive functions, female youth water polo players performed faster compared to male players in three out of four variables od the Stroop test, while male players performed faster in most of the specific functional swimming tests, which is presented in Table 2. A multiple regression analysis showed that age of participants contributed significantly to the prediction of higher cognitive performance measured by StroopOff Time (p<0.001, R2=0.107), StroopOn Time (p<0.001, R2=0.123), StroopOff plus StroopOn Time (p<0.001, R2=0.126) and StroopOnTime minus OffTime (p=0.004, R2=0.074), while gender did not show significant predictive value for the results of the Stroop test (Table 3).

Table 2. Comparison of Results of Anthropometric Variables and Specific Functional Swimming Capacities Between Female and Male Youth Water Polo Players

	Variables	Female WP N=36	Male WP N=106	p
Anthropometric characteristics	Age (years)	13.13±0.78	12.92±0.79	0.158
	Body height (cm)	165.61±6.01	169.75±8.06	0.002*
	Body mass (kg)	59.49±13.20	61.64±12.74	0.389
	Body mass index (kg/m2)	21.61±4.29	21.31±3.57	0.679
Specific functional swimming capacities	Crawl, 25 m (s)	16.41±1.37	15.18±1.34	0.868
	Crawl, 50 m (s)	35.75±3.34	33.09±1.47	<0.001*
	Crawl, 100 m (s)	79.25±7.53	73.64±7.03	<0.001*
	Crawl, 400 m (s)	375.32±36.19	341.98±29.44	<0.001*
	Dribbling, 25 m (s)	17.85±1.50	15.45±1.47	<0.001*

Note Data are presented as mean±standard deviation; *Independent samples t-test with the correction for unequal variances (Welch-test); p<0.05.

Table 3. Multiple Regression Analysis Showing the Predictive Status of Age and Gender on Cognitive Performance

	Coefficient	SE	t	p
StroopOff time				
Gender	2.521	1.502	1.678	0.096
Age	-2.879	0.848	-3.396	<0.001
	R^2=0.107; R^2-adjusted=0.094; F=8.120; P<0.001			
StroopOn time				
Gender	4.173	2.602	1.604	0.111
Age	-5.567	1.469	-3.791	<0.001
	R^2=0.123; R^2-adjusted=0.110; F=9.495; P<0.001			
StroopOff plus StroopOn time				
Gender	6.693	3.931	1.703	0.091
Age	-8.445	2.219	-3.807	<0.001
	R^2=0.126; R^2-adjusted=0.113; F=9.783; P<0.001			
StroopOn minus StroopOff time				
Gender	1.652	1.613	1.024	0.308
Age	-2.688	0.911	-2.952	0.004
	R^2=0.074; R^2-adjusted=0.060; F=5.405; P=0.006			

Note Coefficient – multiple regression coefficient; SE – standard error; t – test statistic; R^2 – coefficient of determination; R^2-adjusted – coefficient of determination adjusted for the number of independent variables in the regression model; F – F-statistic; *Significant difference between the groups, p<0.05.

Discussion

The findings of the current study indicate that female youth water polo players showed better psychomotor ability, inhibition and motor speed, as well as a composition measure of those variables, measured by the Stroop test compared to male youth water polo players. Age of the participants showed significant predictive value for the cognitive functions of youth water polo players, while gender did not contribute to the prediction of the results on the Stroop test.

The results of our study are in accordance with some previous research showing that there is only a small difference in favor of males on the nonverbal, verbal, and working memory subtests, while females outperform males on the psychomotor speed tests (Camarata & Woodcock, 2006; Scheuringer, Wittig, & Pletzer, 2017; Roivainen et al., 2021). Hyde found that 78% of the studies showed sex differences to be small or negligible, even in areas classically held to robustly distinguish between males and females (Hyde, 2005). Differences between cognitive abilities in men and women, girls and boys, are smaller than once thought, and probably occur largely due to either strategy differences, and/or societal expectations (Sanders, 2013).

It could be speculated that differences between female and male youth water polo players in cognitive functions in our study occured because of the females' earlier development and pubertal maturity. Physical growth referring to changes in the body (such as height, weight, or hormonal changes) are usually the result of maturation, environmental experiences, or some interaction between these two factors.

It also involves neurological and sensory development, such as increased visual acuity and mastery of motor skills (Ferrari & Fernando, 2005). Researchers who emphasize biological differences in ability and interest may cite puberty and the differences that accompany it as partly responsible for the emergence of gender differences in the high school years. In the study of Upadhayay et al. (Upadhayay & Guragain, 2014) hormonal status influence on cognitive functions of female and male students was investigated. In Stroop test (executive task), during postovulatory phase, females had higher accuracy rates while they read colour interferences than males. This might have been caused by the effect of hormone, progesterone, which was probably responsible for modulating the female executive functions at this phase of the cycle and favoured females to properly discriminate the different colours and also be able to execute the tasks better than males (Upadhayay & Guragain, 2014). This clarified the fact that in tasks which required fine motor skills, females showed the highest efficiency (in postovulatory phase) as compared to males, while male cognitive functions (attentional, perceptual, executive and working memory) were comparable to those of the female preovulatory phase cognitive functions. This might be due to the analogous actions of testosterone (male) and oestrogen (female preovulatory) on the brain (Upadhayay & Guragain, 2014).

Although there has long been an interest in sex differences in cognitive abilities (Hyde, 2005; Camarata & Woodcock, 2006) and although a number of different cognitive factors have been suggested as correlates to this sex difference, there have been relatively little data exploring sex differences across development from preschool into elderly adulthood using comprehensive measures of cognitive abilities and related achievement areas. Such differences are of interest both from a theoretical perspective towards understanding different and convergent neuropsychological development in males and females and from an applied perspective as any consistent developmental differences in males and females may have important performance outcomes (Camarata & Woodcock, 2006). Such differences might be of interest of coaches in different sports where children participate together at the early age because it can help to develop appropriate training strategies for each athlete.

Since the age significantly influences cognitive functions which begin to develop from the ages of 3 and 5 (Best & Miller, 2010), corresponding with changes in the frontal cortex, while performance on more complex tasks does not mature until adolescence or even early adulthood (Anderson, 2002; Davidson et al., 2006; Roivainen et al., 2021), it would be expected that girls would otperform boys in the age of 12 to 14 years old because their pubertal development starts earlier. On the contrary, boys in our study were significantly taller than girls and showed better motor and specific functional swimming capacities. It is well known that males have longer limb levers, denser bones, greater muscle mass and strength, and greater aerobic capacity, while females exhibit less muscle fatigability and faster recovery during endurance exercise (Thibault et al., 2010). Boys show better motor abilities, especially in the motor dimensions under the primary influence of the movement regulatory mechanism (coordination, agility and balance) and energy supply regulation mechanism (strength/power), while girls at this age and older achieve better results in measures assessing flexibility which is an ability primarily under the influence of the synergy and tonus regulation mechanisms (Holden, 2004; Hyde, 2005; Roivainen et al., 2021). Such physiologic sex-based differences have led to a gap in sports performance between females and males in all sports (Holden, 2004; Ferrari & Fernando, 2005), therefore maybe better cognitive functions can help girls to compete with boys in the early age of sports training, giving them both possibilities to develop their capacities as much as possible.

The results of the multiple regression showed only predictive value of age on the outcomes of the Stroop test, which is in accordance with previous research. Although cognitive functions develop from early childhood to late adolescence and trough early adulthood (Anderson, 2002; Davidson et al., 2006; Gauvain & Richert, 2016), Huizinga et al. (2006) found continued improvement in both reaction time and accuracy measures on the Stop-Signal task and Eriksen Flankers task until age 15 and on a Stroop-like task (inhibiting saying a color word in order to state its conflicting font color) until age 21. Finally, adults, more than adolescents, appeared aware of making an inhibition error as they momentarily slowed their response for the next trial in order to prevent further error, which suggests the contributions of metacognitive development even after adolescence. Considering performance on the Stroop test there is an initial increase in reading errors from ages 6 to 10, followed by a substantial decrease in errors through age 17. This suggests that as word reading becomes more automatic from ages 6 to 10, inhibition of that process to say the color becomes more difficult, which negatively affects reading accuracy. Afterward, the inhibition mechanism needed may be mature enough to compensate for this reading automaticity (Zald & Iacono, 1998; Gauvain & Richert, 2016). Similarly, Davidson et al. (Davidson et al., 2006) found improvement from age 4 through adolescence. With increasing age, participants were more likely to slow down their responses on shift trials to ensure that they were responding accurately. Thus, improved metacognition – knowing that slowing helps performance and being able to detect when it is advantageous to do so may be one mechanism of developing accurate set shifting. The emergence of metacognition may also bring qualitative change when children learn to use feedback about errors to change their approach to the task (Anderson, 2002; Davidson et al., 2006). Knowing that such functions can be improved by physical activity and participation in sports, specially playing high-level team sport games (De Waelle et al., 2021), it would be advantageous to involve children, both girls and boys in organized sports activities early in their childhood for better and cognitive, social, and psychological development and better success later in school and in life (Best & Miller, 2010; Diamond, 2013; Bidzan-Bluma & Lipowska, 2018).

Strengths and limitations

Considering that studied variables are strongly influenced by the age of the subjects, given the existing developmental differences in functioning of the cognitive-motor areas, unique age distribution in both studied groups is one of the main strengths of this study.

Still, there are few major limitation of the present study. First is the nature of the sample. In general, the sample was quite small and had an uneven number of males and females, although used proportion is optimal compared to the number of female and male water polo players in general. Female superiority in psychomotor processing speed is associated with female superiority in fine motor speed; however, the underlying cause of the male/female gap in these skills remains unknown. In the present study we did not assess pubertal status which might influence the results, but future studies should examine the relationship between this factor and the rate of emergence of cognitive abilities in the type of cognitive domains evaluated in this study. Another limitation of the study is that processing speed was measured using one test instrument only, the Stroop test. We cannot rule out the possibility that some of the results may be test-specific to some extent. These features of the sample and methods call for caution when judging the generalizability of the results. Since studies about gender differences in cognitive functions are scarce, there is a need to confirm our results with more test instruments and larger sample of participants in future studies.

Conclusion

The present study supported the hypothesis that there are some differences in inhibitory control, working memory and cognitive flexibility between female and male youth water polo players. Female high-level youth water polo players showed better results in psychomotor speed, inhibitory control and motor speed compared to males, taking both age and gender into account.

Despite the limitations of this study, the presented results contribute to the issue of sport activities as a tool in the stimulation of cognitive development. Considering that EFs are skills essential for mental and physical health, success in school and in life, and cognitive, social, and psychological development, based on the results of this study it would be advantageous to encourage children, both girls and boys, to participate in organized sports activities. Still, additional research is needed to compare executive skills development among female and male youth water polo players controlling for different phases of menstrual cycle, since it is well-known that sex hormones might influence cognitive functions and the brain. Finally, it is important to stress that well-developed cognitive functions may serve only as one of the factors contributing to development of an elite water polo player, together with anthropometric and functional capacities, as well as game intelligence and self-confidence.

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Conflict of Interest
The author declares that there is no conflict of interest.

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