SVEUČILIŠTE U SPLITU
KINEZIOLOŠKI FAKULTET

NEVEN KOVAČEVIĆ

ANTROPOMETRIJSKA, FUNKCIONALNA I KOGNITIVNA OBILJEŽJA MLADIH VATERPOLISTA I NJIHOV UTJECAJ NA SELEKCIJU

DOKTORSKA DISERTACIJA

Mentor:
Izv. prof. dr. sc. Tea Galić

Split, 2025.

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PROCJENA KOGNITIVNIH I FUNKCIONALNIH SPOSOBNOSTI I SELEKCIJA MLADIH VATERPOLISTA POLAZNIKA KAMPOVA HRVATSKOG VATERPOLSKOG SAVEZA

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SAŽETAK

Vaterpolo je fizički zahtjevan ekipni sport, stoga su fizičke sposobnosti i antropometrijske karakteristike igrača važni čimbenici za postizanje dobre razine kvalitete u tehničko-taktičkim zadacima, kao i dobro razvijene kognitivne funkcije koje odražavaju zahtjeve njihove specifične igračke pozicije. Glavni cilj ove doktorske disertacije bio je procijeniti kognitivne funkcije, antropometrijske karakteristike i specifične plivačke sposobnosti mladih vaterpolista. Točnije, u prvoj studiji cilj je bio procijeniti utjecaj kognitivnih funkcija i specifičnih plivačkih sposobnosti na odabir mladih vaterpolista u nacionalnu vaterpolsku reprezentaciju. Studija 2 imala je za cilj utvrditi povezanost kronološke dobi s antropometrijskim karakteristikama i specifičnim funkcionalnim plivačkim sposobnostima u mladih vaterpolista U12. U Studiji 3 cilj je bio usporediti kognitivne funkcije između mladih vaterpolistica i vaterpolista te kontrolnih ispitanika – školske djece iste kronološke dobi koja nisu sudjelovala u organiziranim sportskim aktivnostima, dok je u Studiji 4 cilj bio usporediti kognitivne funkcije između mladih vaterpolistica i vaterpolista iste kronološke dobi. Konačno, u Studiji 5 cilj je bio usporediti kognitivne funkcije, antropometrijske karakteristike i specifične plivačke sposobnosti mladih vaterpolista na različitim igračkim pozicijama. U istraživanju su sudjelovali mlade vaterpolistice i vaterpolisti u dobi od 12 do 16 godina koji su pohađali razvojne kampove Hrvatskog vaterpolskog saveza te kontrolne ispitanike – školsku djecu iste kronološke dobi koja nisu sudjelovala u organiziranim sportskim aktivnostima. Testiranja su uključivala antropometrijska mjerenja (tjelesna masa, tjelesna visina, indeks tjelesne mase), specifične plivačke kapacitete (25 m kraul, 50 m kraul, 100 m kraul, 400 m kraul, 25 m vođenje lopte) i kognitivne funkcije procijenjene pomoću Stroop testa (Stroop Off Time, Stroop On Time, Stroop Off + Stroop On, Stroop On minus Stroop Off). Rezultati prve studije pokazali su da su mladi vaterpolisti odabrani u nacionalnu reprezentaciju postigli brže rezultate u Stroop OffTime (selektirani 62,99±10,21 s u odnosu na neselektirane 69,98±8,93 s, P=0,002) i Stroop OnTime (selektirani 75,61±15,85 s u odnosu na neselektirane 86,01±15,40 s, P=0,004) u odnosu na neselektirane igrače. Logistička regresijska analiza pokazala je značajnu povezanost između odabira mladih vaterpolista u nacionalnu reprezentaciju i rezultata plivanja u disciplinama 400 m kraul i 100 m kraul, kao i OffTime, OnTime i OnTime minus OffTime na Stroop testu. Rezultati studije 2 pokazali su da su igrači U12 rođeni u prvom tromjesečju godine pokazali veće vrijednosti tjelesne visine i težine od svojih mlađih vršnjaka rođenih u četvrtom tromjesečju godine (Q1 165,96±7,88 cm vs. Q4 159,46±5,44 cm, P=0,001; Q1 60,14±13,99 kg vs. Q4 51,35±7,09 kg, P=0,023), dok nije bilo statistički značajnih razlika u specifičnim funkcionalnim testovima plivanja između različitih dobnih skupina. U studiji 3 su mlade vaterpolistice i vaterpolisti pokazali bolju inhibiciju odgovora (Stroop On) (WP 65,33 ± 9,09 s vs. na kontrolni ispitanici 72,78 ± 11,97 s, P = 0,030) i psihomotorne sposobnosti (OnTime minus OffTime) (WP 7,22 ± 5,18 s vs. kontrolni ispitanici 14,13 ± 9,22 s) (P < 0,001) u odnosu na kontrolne ispitanike. U studiji su 4 mlade vaterpolistice pokazale bolju psihomotornu brzinu (Stroop Off) (vaterpolistice 61,79 ± 6,79 s vs. vaterpolisti 64,83 ± 8,31 s, P = 0,048) i inhibiciju odgovora (Stroop On) (vaterpolistice 73,44 ± 10,74 s vs. vaterpolisti 78,67 ± 14,82 s, P = 0,025) u odnosu na vaterpoliste. Rezultati studije 5 pokazali su razlike u kognitivnim funkcijama između igračkih pozicija – krilni napadači imali su bolje rezultate od središnjih napadača u StroopOff (krilni napadači: 57,14 ± 10,04 s vs. središnji napadači: 67,03 ± 9,72 s, P = 0,016) i u StroopOn (krilni napadači: 66,18 ± 15,86 s vs. središnji napadači: 80,24 ± 15,64 s, P = 0,019). Sveukupno, rezultati ove doktorske disertacije pokazali su da su psihomotorne sposobnosti, inhibicija, motorička brzina i kognitivna fleksibilnost važni prediktori za odabir mladih vaterpolista u nacionalnu vaterpolsku reprezentaciju. Osim toga, pokazane su značajne razlike u kognitivnim funkcijama između različitih igračkih pozicija, posebno između središnjih napadača i krilnih napadača. Nadalje, rezultati ove disertacije sugeriraju da djeca koja se bave vaterpolom razvijaju bolju kognitivnu fleksibilnost od školske djece iste dobi koja ne sudjeluju u organiziranim sportskim aktivnostima. Takvi rezultati pružaju vrijednu osnovu za osmišljavanje razvojnih programa treninga za mlade vaterpoliste općenito, kao i za različite igračke pozicije, uzimajući u obzir antropometrijske karakteristike, specifične funkcionalne plivačke sposobnosti i kognitivne funkcije koje utječu na igračku inteligenciju, a s ciljem poboljšanja sportske izvedbe.

Ključne riječi: vaterpolo; školska djeca; mladi sportaši; kognitivne funkcije; psihomotorna sposobnost; inhibicija; igračke pozicije; antropometrijske karakteristike; plivačka izvedba

ABSTRACT

Water polo is a physically high-demanding team sport, therefore players' physical abilities and anthropometric characteristics are important factors to achieve a good level of quality in technical-tactical actions, as well as well-developed cognitive functions that reflect the requirements of their specific playing position. The main aim of this doctoral thesis was to evaluate cognitive functions, anthropometric characteristics and specific swimming capacities of youth water polo players. Specifically, in the first study the aim was to evaluate the influence of cognitive performance and specific swimming capacities on the selection of youth water polo players to the national water polo team. Study 2 aimed to determine the association of the chronological age with the anthropometric characteristics and specific functional swimming capacities in youth U12 male water polo players. In Study 3 the aim was to compare cognitive functions between female and male youth water polo players and the control subjects – school children of the same chronological age who did not participate in organized sports activity, while in Study 4 the aim was to compare cognitive functions between female and male youth water polo players. Finally, in Study 5 the aim was to compare the cognitive performance, anthropometric characteristics and specific swimming capacities of youth water polo players in different playing positions. Studies included female and male youth water polo players aged 12 to 16 years who attended the Croatian Water Polo Federation training camps and the control subjects – school children of the same chronological age who did not participate in organized sports activity. Testings included anthropometric measurements (body mass, body height, body mass index), specific swimming capacities (25 m front crawl, 50 m front crawl, 100 m front crawl, 400 m front crawl, 25 m dribbling) and cognitive performance using the Stroop test (Stroop Off Time, Stroop On Time, Stroop Off+Stroop On, Stroop On minus Stroop Off). The results of the first study indicated that youth water polo players selected to the national team performed faster in OffTime (selected 62.99±10.21 s vs. non-selected 69.98±8.93 s, P=0.002) and OnTime (selected 75.61±15.85 s vs. non-selected 86.01±15.40 s, P=0.004) of the Stroop test than non-selected players. Logistic regression analysis showed significant association between selection of youth water polo players to the national team and swimming results in 400 m crawl and 100 m crawl, as well as OffTime, OnTime and OnTime minus OffTime on the Stroop test. The results of the Study 2 showed that U12 players born in the first quarter of the year presented higher values of body height and weight than their younger peers born in the fourth quarter of the year (Q1 165.96±7.88 cm vs. Q4 159.46±5.44 cm, P=0.001; Q1 60.14±13.99 kg vs. Q4 51.35±7.09 kg, P=0.023), while there were no statistically significant differences in specific functional swimming tests between different age groups. In the study 3 youth water polo players showed better response inhibition (Stroop On) (WP 65.33±9.09 s vs. control subjects 72.78±11.97 s, $P=0.030$) and psychomotor ability (OnTime minus OffTime) (WP 7.22±5.18 s vs. control subjects 14.13±9.22 s) ($P<0.001$) than control subjects. In Study 4 female youth water polo players 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. The results of Study 5 showed differences in cognitive functions between playing positions – wings performed faster than center-forwards in both StroopOff time (wings: 57.14 ± 10.04 s vs. center-forwards: 67.03 ± 9.72 s, $p = 0.016$) and StroopOn time (wings: 66.18 ± 15.86 s vs. center-forwards: 80.24 ± 15.64 s, $p = 0.019$). Overall, the results of this doctoral thesis showed that psychomotor ability, inhibition, motor speed and cognitive flexibility were found to be important predictors for the selection of youth water polo players to the national water polo team. Additionally, it demonstrated significant differences between different playing positions in youth water polo players, specifically between center-forwards and wings. Furthermore, the findings of this study suggest that children who participate in high-level water polo develop better cognitive flexibility than school students who do not participate in organized sports activity. Such results provide a valuable foundation for establishing developmental recommendations for youth water polo players in general, as well as for different playing positions, aiming at improving players' performance. These recommendations should take into account anthropometric characteristics, specific functional swimming capacities and cognitive functions that influence players' game intelligence, which can be enhanced through properly designed training programs.

Keywords: water polo; school children; youth athletes, cognitive functions; psychomotor ability; inhibition; playing positions; anthropometric characteristics; swimming performance

STRUKTURA DISERTACIJE

Ova doktorska disertacija sastoji se od pet objavljenih znanstvenih radova:

1. Kovačević, N., Mihanović, F., Hrbić, K., Mirović, M., & Galić, T. (2023) Anthropometric Characteristics and Specific Functional Swimming Capacities in Youth U12 Water Polo Players. *Montenegrin Journal of Sports Science and Medicine,* 19(1), 29-34.
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5. Kovačević, N., Mihanović, F., Lušić Kalcina, L., Matijaš, T., & Galić, T. (2025). Positional Differences in Youth Water Polo Players: Cognitive Functions, Specific Swimming Capacities and Anthropometric Characteristics. *Journal of Functional Morphology and Kinesiology*, 10(2), 151.

1. UVOD

1.1. Vaterpolo

Vaterpolo je uz nogomet jedan od najstarijih olimpijskih ekipnih sportova, koji je prvi put uvršten u olimpijski program 1900. godine na Olimpijskim igrama u Parizu, a od tada (uz izuzetak 1904. godine) je ostao u olimpijskom programu sve do današnjih dana. Svjetska plivačka organizacija (franc. *Fédération Internationale de Natation*, FINA) utemeljena je 1908. godine, a 2022. godine ime je promijenjeno u *World Aquatics*. Krovna europska organizacija, Europski plivački savez (franc. *Ligue Européenne de Natation*, LEN) utemeljena je 1926. godine, a također mijenja ime 2022. godine u *European Aquatics* (Bauer, 2010.). Pravila vaterpolske igre tijekom vremena znatno su se promijenila, uz najnovije izmjene i dopune koje su se počele primjenjivati 2025. godine (Aquatics, 2025), što igru čini dinamičnijom i još zahtjevnijom. Utakmicu igraju dvije momčadi, svaka sa šest igrača u polju i jednim vratarom, tijekom četiri perioda od 8 minuta u vodi na terenu veličine 25 x 20 metara, za žene i muškarce, uz minimalnu dozvoljenu dubinu vode od 1,80 m do 2,00 m (Aquatics, 2025). Klasifikacije igrača u polju temelje se na njihovim pozicijama na terenu i uz vratara uključuju četiri igračke pozicije: središnji napadač – centar (engl. *center-forward*, CF), središnji branič – bek (engl. *center-backward*, CB), vanjski napadač (engl. *driver*, D) i krilni napadač (engl. *wing*, W). Različite uloge na različitim pozicijama tijekom igre neminovno dovode do razlika u vrsti aktivnosti, ukupnom prijeđenom prostoru u igralištu u metrima, isplivanim dionicama različitim intenzitetom i opterećenju pri izvršavanju postavljenih tehničko-taktičkih zadataka. Radnje i aktivnosti igrača ostvaruju se različitim tehnikama plivanja i različitim energetskim manifestacijama od umjerenog, submaksimalnog do maksimalnog intenziteta. Analizom strukture igre s aspekta energetske i informacijske komponente dokazano je da je vaterpolo jedan od najzahtjevnijih sportskih igara. *Bleacher Report* (Siddell, 2018.) ga je 2018. godine proglasio najtežim sportom na svijetu temeljem šest parametara: snage, izdržljivosti, brzine, koordinacije, agilnosti tj. fizičke spremnosti. Od igrača se traži visoka razina funkcionalnih i motoričkih sposobnosti, specifična plivačka vaterpolska tehnika, tehničko-taktičkih znanja i vještina, situacijska igračka inteligencija, predviđanje i prepoznavanje igre protivnika (anticipacija) i mentalna snaga (psihička stabilnost), kako bi odgovorili izazovima visokoga stresa što ih jedna utakmica nosi (Botonis, Toubekis, & Platanou, 2019; T. Platanou, 2009.; T. Platanou & Geladas, 2006; Smith, 1998). U vaterpolu za vrijeme utakmice po svim situacijskim fazama i parametrima napada i obrane nema mogućnosti pasivnog odmora, nema momenta čvrstog oslonca, što uvjetuje neprekidnu aktivnost cijelog mišićnog sustava s naglaskom na rad donjih ekstremiteta. Također, potreban je visoki stupanj automatizacije tehnike izvođenja specifičnih vaterpolskih kretnji i prebacivanja tijela u prostoru (Alcaraz i sur., 2012; Aleksandrović, Radovanović, Okičić, Madić, & Georgiev, 2011). Većina dosadašnjih istraživanja u području vaterpola uglavnom se usredotočila na antropometrijske (Ferragut i sur., 2011; Kondrič, Uljević, Gabrilo, Kontić, & Sekulić, 2012; Lozovina, Durović, & Katić, 2009; F. H. Tan, Polglaze, Dawson, & Cox, 2009), funkcionalne i motoričke karakteristike vaterpolista (Melchiorri, Castagna, Sorge, & Bonifazi, 2010; Melchiorri, Padua, i sur., 2010; Sekulic i sur., 2016) ili tehničko-taktičke zahtjeve vaterpolske igre na terenu (Escalante, Saavedra, Mansilla, & Tella, 2011; Escalante i sur., 2012; Escalante i sur., 2013).

U potrazi za time što točno definira vrhunske sportaše i razlikuje ih od manje uspješnih ili onih koji se sportom bave rekreativno, osim već spomenutih antropometrijskih, fizioloških, funkcionalnih ili kondicijskih kapaciteta, utvrđeno je da psihološki čimbenici poput motivacije, samopouzdanja i koncentracije također utječu na uspjeh u sportu (Mahoney, Gabriel, & Perkins, 1987; Mann, Williams, Ward, & Janelle, 2007; Rowley, Landers, Kyllo, & Etnier, 1995; L. Verburgh, Scherder, van Lange, & Oosterlaan, 2016; Williams & Reilly, 2000a). Tijekom posljednjih desetljeća sve je veći interes za pitanje je li mozak vrhunskih sportaša drugačiji u pogledu strukture i funkcije (Faubert, 2013). Danas je općeprihvaćeno da za uspjeh u sportu sportaš treba imati kombinaciju izvanrednih funkcionalnih sposobnosti (aerobni i anaerobni kapacitet), motoričkih sposobnosti (brzina, okretnost, koordinacija, snaga i preciznost), specifičnih tehničkih i taktičkih vještina te psiholoških i emocionalnih karakteristika (adaptacija, emocionalna kontrola i samoefikasnost), kao i kognitivnih funkcija povezanih sa strategijom igre, poput percepcije, izvršnih funkcija, pozornosti, brzine reakcije, anticipacije i donošenja odluka (Bertollo, Saltarelli, & Robazza, 2009; Brigitta Kiss, 2019; Pietro, 2018; Sarmento, Anguera, Pereira, & Araújo, 2018; H. E. Scharfen & Memmert, 2019). Budući da danas svi vrhunski igrači pokazuju odgovarajuće fizičke i tehničke sposobnosti, kognitivne funkcije prave značajnu razliku među igračima, pozicionirajući ih u potpuno različite atletske dimenzije (Mann i sur., 2007). Sposobnost donošenja brzih odluka očekuje se od igrača u većini sportova, posebno u slučaju brzih i dinamičnih sportskih igara poput vaterpola. Takve vještine omogućuju igraču da odabere najprikladniju radnju za danu situaciju tijekom igre (H. E. Scharfen & Memmert, 2019; Voss, Kramer, Basak, Prakash, & Roberts, 2010).

O kondicijskoj pripremi u vaterpolu uglavnom je sve poznato, koje testove za procjenu inicijalnog kondicijskog statusa sportaša, kada i kako koristiti te kako isti poboljšati kroz rad u vodi i na suhom. Slično je i s tehničko-taktičkom pripremom koja je usko povezana s kondicijskom pripremljenosti igrača. Međutim, o radu na poboljšanju psihičkih funkcija, osobito kognitivnih malo se zna te ne postoje znanstveni ili stručni radovi koji bi mogli uputiti trenere kako u izradi plana i programa sportaša u vaterpolu uvrstiti i trenažne sadržaje za poboljšanje kognitivnih funkcija.

1.2. Antropometrijske karakteristike i funkcionalne sposobnosti vaterpolista

Dobro je poznato da su antropometrijske značajke vaterpolista usko povezane s visokom razinom izvedbe, utječući na intenzivne napadačke i obrambene akcije na svakoj igračkoj poziciji (Ferragut i sur., 2011; Kondrič i sur., 2012). Također je poznato da izražena tjelesna visina i veći raspon ruku omogućuju igraču da učinkovitije dosegne i kontrolira loptu, ali i protivnika (Ferragut i sur., 2011). Visoka natjecateljska izvedba zahtijeva odgovarajuće opće motoričke vještine i fiziološke odgovore koji pozitivno utječu na uspjeh u vaterpolskoj igri (Alcaraz i sur., 2012; F. Tan, Polglaze, & Dawson, 2009). Posljedično, razvojne godine mladih sportaša trebale bi poboljšati ukupne zahtjeve igre uključivanjem kombiniranih vježbi poput visokointenzivnog intervalnog treninga (engl. *high-intensity interval training*, HIIT) i treninga snage, istovremeno sa specifičnim vaterpolskim treningom za svaku igračku poziciju (Botonis, Toubekis, & Platanou, 2016; Lupo, Capranica, Cugliari, Gomez, & Tessitore, 2016). Treniranje specifičnih motoričkih sposobnosti ključno je zbog zahtjevnih, specijaliziranih vještina potrebnih za visokokvalitetnu izvedbu tijekom ranih faza razvoja (Canossa i sur., 2020; T. Platanou, 2005). Vaterpolisti stalno mijenjaju položaj tijela tijekom igre, a njihova sposobnost ovisi o specifičnoj razini kondicije (npr. izvlačenje tijela iz vode potrebno je tijekom svih specifičnih motoričkih sposobnosti igre) (Botonis, Toubekis, Terzis, i sur., 2016; Theodoros Platanou, 2004). Također, ne smije se zanemariti važnost specifičnih kretnji donjih i gornjih ekstremiteta, osobito vaterpolske bicikle (engl. *eggbeater kick*), koje su važne za učinkovitost propulzije u vaterpolu (De Jesus i sur., 2012; Kawai, Tsunokawa, & Takagi, 2018; Vilas-Boas i sur., 2015).

Antropometrijski profil vaterpolista relevantan je za njihovu individualnu izvedbu, ali i za ekipna postignuća u igri (T. Platanou, 2005). Poznato je da se izvedba specifičnih motoričkih sposobnosti pogoršava tijekom vaterpolske utakmice zbog fizičkog umora (Botonis, Toubekis, Terzis, i sur., 2016; Royal i sur., 2006), što naglašava važnost održavanja odgovarajuće razine kondicijske pripremljenosti igrača, kako bi se zadovoljili zahtjevi tehničkog treninga i natjecanja (Smith, 1998). Za izvođenje aktivnosti visokog intenziteta isprekidanih kratkim razdobljima oporavka izuzetno je važno imati odgovarajuću opskrbu energijom i iz aerobnog i iz anaerobnog metabolizma. Stoga se preporučuje individualizirani trening temeljen na rastu i razvoju mladih igrača (Botonis i sur., 2019; Lupo i sur., 2009; Noronha i sur., 2022). Osim navedenih čimenika koji utječu na uspješnost u vaterpolu, za razvoj i uspjeh mladih talentiranih igrača važno je i njihovo psihološko stanje i motivacija, kao i profil psihičkih osobina (Falk i sur., 2004; Noronha i sur., 2022; Theodoros Platanou, 2004; Williams & Reilly, 2000a).

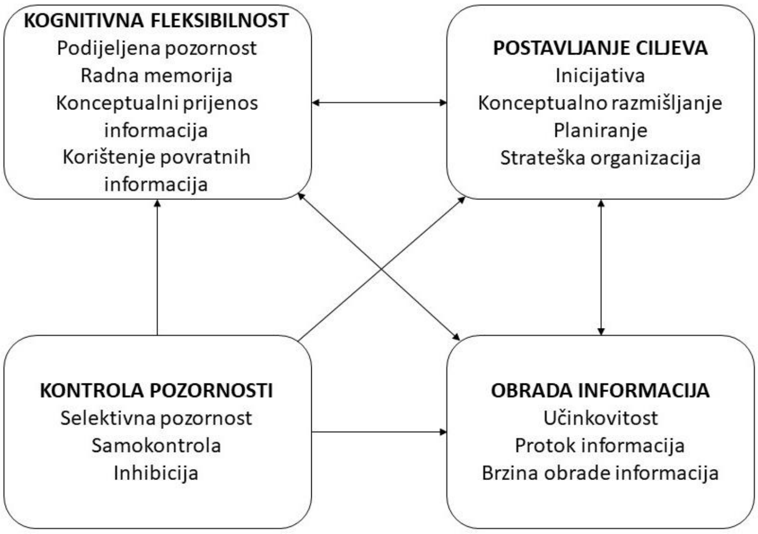
Tijekom jedne utakmice igrači su izloženi čestim izmjenama intenziteta, od niskih do umjerenih i visokih intenziteta plivačkih napora, uz veliki broj intenzivnih tjelesnih kontakata, osobito na poziciji središnjeg napadača i središnjeg braniča. Stoga je važno uskladiti trening koji maksimizira aerobnu izdržljivost i poboljšava aerobnu snagu uključujući intervale visokog intenziteta (Botonis i sur., 2019). Analizirajući plivačke sposobnosti u vaterpolu neki su autori primijetili da je bolji učinak u plivanju povezan s razinom izvedbe mladih vaterpolista (Kontic i sur., 2017; Melchiorri i sur., 2017). Kontić i Šajber (Kontić & Šajber, 2016) proveli su istraživanje među 82 mlada vaterpolista juniora i utvrdili su razlike u plivačkim sposobnostima među skupinama prema njihovim igračkim pozicijama. Krilni napadači pokazali su najbolje rezultate u sprintu dok su središnji napadači pokazali najbolju anaerobnu izdržljivost, što je u skladu s njihovom igračkom pozicijom, dužnostima u igri i vrlo intenzivnom radnom opterećenju tijekom igre. Također, u dosadašnjim istraživanjima dokazano je da su antropometrijska i morfološka obilježja vaterpolista povezana s funkcionalnim sposobnostima i plivačkim kapacitetima, a ujedno su to važni čimbenici za postizanje dobre tehničko-taktičke izvedbe, kako za mlade tako i za odrasle vaterpoliste (Kondrič i sur., 2012; Kontić & Šajber, 2016; Sekulic i sur., 2016; Viero i sur., 2020). Nekoliko autora pokazalo je da se navedene sposobnosti razlikuju po igračkim pozicijama pa su središnji napadači najteži i imaju najveći indeks tjelesne mase (engl. *body mass index*, BMI) od ostalih igračkih pozicija, zbog čestih kontakata tijekom igre. U dosadašnjim studijama najčešće je pronađena značajna razlika u tjelesnoj visini između središnjih i krilnih napadača, a u vaterpolistica su postojale i značajne razlike u tjelesnoj masi, kožnim naborima i relativnoj visini skoka {Ferragut, 2011 #308}{Martínez, 2015 #173}{Tan, 2009 #79}. To je također u skladu s prethodnim radom koji je uključivao španjolske vaterpolistice (Ferragut i sur., 2011), koji je pokazao značajne pozicijske razlike između središnjih i krilnih napadača u smislu tjelesne mase, duljine stopala, indeksa tjelesne mase, mišićne mase, opsega (struk, gluteus, gornji dio bedara i list) i kožnih nabora (subscapularni i aksilarni).

Melchiorri i sur. predložili su novu jednadžbu za predviđanje ukupne izvedbe igrača u koju su uz antropometrijske parametre uvrstili kondicijsku spremu mladih vaterpolista i funkcionalne plivačke sposobnosti. Također, su u jednadžbu uvrstili i subjektivnu procjenu dva trenera za vrijeme dvije prijateljske utakmice. Predložena jednadžba može se koristiti za predviđanje ukupne uspješnosti igrača i omogućuje procjenu koliko poboljšanje jedne od kvaliteta može utjecati na ukupnu uspješnost igrača. Trener tako može razumjeti koliko antropometrijske karakteristike, specifične plivačke sposobnosti i fizička izvedba utječu na njihovu ukupnu ocjenu igrača, dakle odvajajući ih od tehničkih. Takav pristup može pomoći treneru da identificira nedostatke za svakog pojedinog igrača i osmisli posebni program treninga za svakog od njih (plivačka izvedba, izvedba na suhom, tehničke sposobnosti), kao i lakšu identifikaciju talentiranih igrača (Melchiorri i sur., 2022).

1.3. Kognitivne funkcije vaterpolista

Iako nema istraživanja koja bi pokazala utjecaj kognitivnih funkcija na ukupnu uspješnot vaterpolista, rezultati studija u drugim sportovima kao što su nogomet, rukomet, odbojka, tenis, karate pokazali su da i taj aspekt razvoja mladih sportaša značajno utječe na njihov ukupan sportski uspjeh (Alesi i sur., 2014; Brigitta Kiss, 2019; Ishihara, Sugasawa, Matsuda, & Mizuno, 2017b; Kalen i sur., 2021; Sarmento i sur., 2018; H. E. Scharfen & Memmert, 2019; Trecroci i sur., 2021; Vestberg i sur., 2012).

Kognitivne funkcije obuhvaćaju: pamćenje, pozornost, vizualno-prostorne i izvršne funkcije, dok složeni kognitivni procesi uključuju: mišljenje (apstraktno, uzročno-posljedično, kreativno mišljenje i planiranje) te jezične funkcije (Bidzan-Bluma & Lipowska, 2018; Diamond, 2013). Temeljne izvršne funkcije obuhvaćaju (1) inhibitornu kontrolu, uključujući selektivnu pozornost: razmišljanje prije nego što djelujemo (tj. davanje promišljenih odgovora umjesto impulzivnih), odupiranje iskušenjima, odupiranje ometanjima i održavanje fokusa; (2) radno pamćenje: zadržavanje informacija i mentalni rad s njima, poput mentalnog istraživanja odnosa među idejama i činjenicama, ažuriranja razmišljanja ili planiranja, prevođenja uputa u akcijske planove ili mentalnog izvođenja matematičkog izračuna; i (3) kognitivnu fleksibilnost: „razmišljanje izvan okvira“, sposobnost prilagodbe promijenjenim zahtjevima ili prioritetima, iskorištavanje iznenadnih, neočekivanih prilika ili prevladavanje iznenadnih, neočekivanih problema (Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2013) (Slika 1).



Slika 1. Model izvršnih funkcija. Preuzeto i prilagođeno iz (Anderson, Anderson, & Garth, 2010).

Iz tih temeljnih izvršnih funkcija proizlaze i one višeg reda zaključivanja, planiranja i kreativnog rješavanja problema (Diamond, 2013; Logue & Gould, 2014). Mnoga su istraživanja dokumentirala ključnu ulogu izvršnih funkcija za mentalno i tjelesno zdravlje, kao i za bolju kvalitetu života. Tri su glavna procesa identificirana kao potencijalno važna: inhibicija, prebacivanje i radna memorija (Diamond, 2013.). Prvi se odnosi na sposobnost kontroliranja i potiskivanja prevladavajuće reakcije u korist druge reakcije ili bez reakcije. Drugi je sposobnost prebacivanja s jedne perspektive ili načina razmišljanja na drugu. Konačno, ažuriranje ili radna memorija odnosi se na sposobnost praćenja i manipuliranja mentalnim reprezentacijama u umu (van der Ven, Kroesbergen, Boom, & Leseman, 2013). Očekuje se da će strukturirane sportske aktivnosti biti učinkovite u poboljšanju izvršnih funkcija jer zahtijevaju fokusiranu pozornost (dio inhibicijske kontrole), pamćenje složenih sekvenci (dio radne memorije) i fleksibilno prilagođavanje u stvarnom vremenu (dio kognitivne fleksibilnosti), zato što poboljšavaju osjećaj društvene uključenosti i pripadnosti, samoodređenje i samopoštovanje, aerobnu kondiciju i motoričke vještine, ali i donose radost i ponos (Alesi i sur., 2014; Diamond, 2013, 2015).

1.3.1. *Razvoj kognitivnih funkcija*

Kognitivne funkcije počinju se razvijati u ranom djetinjstvu, između treće i pete godine života (Best & Miller, 2010), nastavljajući se kroz adolescenciju ili čak ranu odraslu dob, a njihov razvoj odgovara promjenama u frontalnom korteksu mozga (Davidson i sur., 2006). Odrasli su svjesniji grešaka i trenutno usporavaju svoj odgovor prilikom testiranja kognitivnih funkcija kako bi spriječili daljnju pogrešku, što sugerira doprinos metakognitivnog razvoja čak i nakon adolescencije (Davidson i sur., 2006; Gauvain & Richert, 2016). Drugi čimbenik koji može utjecati na dobni raspon sazrijevanja je pubertetski razvoj. Pubertetske promjene su značajne u adolescenciji i pokazalo se da imaju utjecaj na sazrijevanje korteksa i diferencijaciju spolova u kognitivnom razvoju (Roivainen, Suokas, & Saari, 2021). Čini se da procesi unutar domene kontrole pozornosti prolaze kroz značajan razvoj tijekom dojenačke dobi i ranog djetinjstva, a do srednjeg djetinjstva procesi samokontrole i samoregulacije su relativno zreli. Unatoč tome što slijede nešto drugačije razvojne putanje, obrada informacija, kognitivna fleksibilnost i postavljanje ciljeva su relativno zreli do 12. godine dobi, iako mnogi izvršni procesi nisu u potpunosti „uspostavljeni“ do sredine adolescencije ili rane odrasle dobi. Usporavanje razvoja zabilježeno je između 11 i 13 godina starosti, posebno u područjima samoregulacije i strateškog donošenja odluka (Anderson i sur., 1996., 2001.). To može biti povezano s prijelaznim razdobljem između pojedinih razvojnih faza. Produženi razvoj izvršnih funkcija vjerojatno je povezan s neurofiziološkim promjenama, posebno sinaptogenezom i mijelinizacijom u prefrontalnom korteksu. Osim toga, jasno je da se mijelinizacija prefrontalnih veza događa postupno tijekom ranog djetinjstva, srednjeg djetinjstva i adolescencije (Giedd i sur., 1996; Klingberg, Vaidya, Gabrieli, Moseley, & Hedehus, 1999). Progresivna mijelinizacija vjerojatno će rezultirati bržim i učinkovitijim prijenosom živčanih impulsa, poboljšanom obradom informacija, kao i poboljšanom integracijom kognitivnih procesa i poboljšanom izvršnom kontrolom (Anderson i sur., 2010).

Razlike u kognitivnim sposobnostima među spolovima široko su analizirane u psihološkoj i neuropsihološkoj literaturi (Benbow, 2010; Hyde, 2005; Roivainen i sur., 2021; Scheuringer, Wittig, & Pletzer, 2017). Hipoteza o rodnim sličnostima tvrdi da su muškarci i žene slični po većini, ali ne po svim, psihološkim varijablama, što znači da su muškarci i žene, kao i dječaci i djevojčice, sličniji nego različitiji (Benbow, 2010; Hyde, 2005). Razlike između muškaraca i žena, djevojčica i dječaka, u kognitivnim sposobnostima manje su nego što se nekad mislilo i vjerojatno se javljaju uglavnom zbog razlika u strategijama i/ili društvenih očekivanja (Roivainen i sur., 2021). Prema dostupnoj literaturi postoji mala razlika u korist muškaraca na podtestovima neverbalne, verbalne i radne memorije, dok žene nadmašuju muškarce na testovima brzine psihomotorne obrade (Benbow, 2010; Leahey & Guo, 2001; Scheuringer i sur., 2017).

1.3.2. Kognitivne funkcije po igračkim pozicijama

Kao što je već rečeno, vaterpolo je dinamičan i strateški sport koji ne samo da zahtijeva fizičku snagu i izdržljivost, već i niz dobro razvijenih kognitivnih funkcija (Melchiorri, Triossi, Bianchi, Tancredi, & Viero, 2022; Melchiorri, Viero, Tancredi, Bianco, & Bonifazi, 2020; Sekulic i sur., 2016; Viero, Triossi, Bianchi, Campagna, & Melchiorri, 2020). Kombinacija plivanja, manipulacije loptom i taktike u vaterpolskoj igri zahtijeva visoku razinu mentalnih sposobnosti, od donošenja odluka do komunikacije među suigračima (Botonis i sur., 2019; Canossa, Abraldes, Estriga, Fernandes, & Garganta, 2020; Escalante i sur., 2012). Igrači trebaju brzo donositi odluke u situacijama visokog pritiska. Na primjer, prilikom napada ili obrane, trebaju prepoznati prilike (npr. slobodne suigrače i priliku za šut) i prijetnje (npr. obrambeni pritisak ili potencijalne protunapade) te brzo reagirati. Vrijeme reakcije je ključno, posebno prilikom presretanja dodavanja, obrane šuteva ili reagiranja na pokrete protivničkih igrača (Napolitano, Tursi, Di Tore, & Raiola, 2013; Royal i sur., 2006).

Evidentno je da različite igračke pozicije u vaterpolu pokazuju različite zahtjeve igre. Vratari za vrijeme utakmice stalno rade nogama kako bi održali svoju poziciju i kako bi blokirali udarce prema golu. Budući da je vratar posljednja linija obrane i prva linija napada, od vratara se očekuje da bude hrabar, okretan, fleksibilan i psihički stabilan, s visokom razinom koncentracije, brzo reagirajući na promjenjive situacije. Treba imati brze reflekse, izvrsnu koordinaciju ruku i očiju te sposobnost čitanja protivničkih napadačkih akcija (Fritz i sur., 2022; Lozovina i sur., 2009; Napolitano i sur., 2013; Silva, 2006).

Središnji napadač igra između braniča protivničke ekipe, gdje se treba boriti za poziciju i stvoriti si priliku za šut. Od njega se očekuje fizička snaga i visoka tjelesna masa potrebna za sudjelovanje u čvrstim fizičkim kontaktima s protivnikom, a kako bi zadržao svoju poziciju u bazenu (Botonis, Toubekis, & Platanou, 2018; Lupo i sur., 2012; Napolitano i sur., 2013). Iz perspektive kognitivnih funkcija, od središnjeg napadača se očekuje širok raspon vanjske pozornosti, sposobnost višestrukog prebacivanja, pozicioniranja, čitanja obrane i donošenja odluka pod pritiskom te visoka razina radne memorije (Lozovina i sur., 2009; Lupo i sur., 2012; Melchiorri i sur., 2022). Sukladno novim izmjenama i dopunama pravila (Aquatics, 2025) vrijeme napada se skratilo, a kontakti središnjeg napadača sa središnjim braničem su češći, jači i intezvniji, što dovodi do još veće i zahtjevnije, ali i odgovornije uloge središnjeg napadača u napadu. Stoga se nameće potreba za još intezivnijim radom na poboljašanju kognitivnih funkcija odgovornih za igru središnjeg napadača na visokoj razini. Od trenera se traži da nađe originalna rješenja i izbor specifičnih vježbi koji će igračima na toj poziciji poboljšati kognitivne funkcije, osobito brzinu ispravnih zaključivanja i reakcija, anticipacije i inhibicije.

Od krilnih napadača se traži da puno plivaju kako bi stvorili prilike za postizanje golova za svoju ekipu i spriječili napadačke akcije protivnika. Glavni cilj pozicije krilnog napadača je plivati do linije od 2 m i otvoriti se za primanje lopte. Trebaju biti u poziciji za izvođenje ulaznih dodavanja u prostor, što često može rezultirati izbačajem protivničkog igrača. Dodavanjem lopte krilnim napadačima, cijeli napad se može približiti golu što stvara bolje prilike za postizanje pogotka. Krilni napadači u modernom vaterpolu trebaju biti polivalentni. Osim što su zaduženi za brzu tranziciju nakon osvojene lopte, trebaju anticipirati cijelu situaciju od početka do kraja tranzicije kod kontranapada ili brzog napada ili kada se formira pozicijski napad (Melchiorri i sur., 2022; Melchiorri i sur., 2020; Napolitano i sur., 2013). Vanjski napadači su obično brzi igrači koji otvaraju napad čime stvaraju prilike za postizanje golova. Oni su često strijelci, ali imaju i obrambenu ulogu, obavljaju više različitih zadataka istovremeno, što zahtijeva visoku razinu snage i kondicije, slično kao u rukometu (Michalsik, Madsen, & Aagaard, 2014; Napolitano i sur., 2013; Silva, 2006).

Središnji branič u napadu ima zadatak organizirati akcije i učinkovito dodavati loptu suigračima. Osim toga, treba imati jake obrambene instinkte i sposobnost predviđanja i blokiranja dodavanja i udaraca protivničkih igrača, uz stalne fizičke kontakte s protivničkim igračima, osobito središnjim napadačem. Očekuje se da donosi brze i točne odluke, predviđa poteze i brzo razmišlja (Michalsik i sur., 2014; Napolitano i sur., 2013; Silva, 2006).

Slično specifičnim sportskim zahtjevima za fizičku i tehničko-taktičku pripremu, kognitivne funkcije također se razlikuju za različite situacije unutar određenog sporta, kao i za različite igračke pozicije (Lupo i sur., 2012; Silva, 2006; Wagner, Finkenzeller, Würth, & von Duvillard, 2014). Stoga se može pretpostaviti da će u vaterpolu, za određene igračke pozicije, kognitivne funkcije poput koncentracije (omogućuje igraču da brže donosi ispravne odluke i da napravi manje pogrešaka); perifernog vida (omogućuje igraču da primijeti suigrače i protivnike sa strane); donošenja odluka, koje omogućuje odabir odgovarajućeg odgovora u specifičnom okruženju za igru; kratkoročnog pamćenja (omogućuje igraču da zapamti položaj suigrača i protivnika na terenu); i vremena reakcije (zbog visokog tempa igre, brzih bacanja itd.) igrati važnu ulogu u sportskoj izvedbi (Martínez i sur., 2015; Viero i sur., 2020; Vila, Manchado, Abraldes, & Ferragut, 2018; Wagner i sur., 2014).

Dosadašnje studije u vaterpolu utvrdile su razlike između specifičnih igračkih pozicija, uglavnom u antropometrijskim karakteristikama, funkcionalnim kapacitetima ili profilima fizičke spremnosti (Botonis i sur., 2019; Botonis, Toubekis, Terzis, Geladas, & Platanou, 2016; D'Auria & Gabbett, 2008; Escalante i sur., 2013; Ferragut i sur., 2011; Fritz i sur., 2022; Kondrič i sur., 2012; Kontic i sur., 2017; Martinez i sur., 2015; Noronha i sur., 2022; T. Platanou & Geladas, 2006; Sekulic i sur., 2016; F. H. Tan i sur., 2009). Prema dostupnoj literaturi, nijedna studija nije ispitivala kognitivne funkcije u vaterpolista prema njihovim igračkim pozicijama. Uzimajući u obzir prethodno opisane specifične zahtjeve svake igračke pozicije u vaterpolu, pretpostavka je da postoje razlike u kognitivnim funkcijama među igračkim pozicijama, kao što je dokazano u rukometu (Blecharz, Wrzesniewski, Siekanska, Ambrozy, & Spieszny, 2022; Brigitta Kiss, 2019; Silva, 2006), a vaterpolo bi se slikovito mogao opisati kao kombinacija rukometa i plivanja (Kondrič i sur., 2012). Blecharz i sur. (Blecharz i sur., 2022) pokazali su da rukometni vratari pokazuju najkraće vrijeme reakcije pri čitanju riječi (neutralna boja teksta), s najvećom sklonošću interferenciji pri čitanju (razlika između čitanja neutralnog teksta i teksta u boji), što ukazuje na njihovu visoku reaktivnost na vizualne podražaje. Osim toga, Kiss i Balogh (Brigitta Kiss, 2019) su otkrili da vratari, krilni i vanjski napadači imaju brže vrijeme reakcije u usporedbi s kružnim i središnjim napadačem. Također su primijetili da vratari čine manje pogrešaka od središnjih i vanjskih napadača pri brzom izvršavanju zadatka. Stoga se može pretpostaviti da manji raspon podražaja koje vratar treba obraditi olakšava bržu odluku o tome što sljedeće učiniti i kako to učiniti brzo i učinkovito (Brigitta Kiss, 2019; Silva, 2006), dok su ostale igračke pozicije u rukometu pokazale više međusobne sličnosti (Nuri, Shadmehr, Ghotbi, & Attarbashi Moghadam, 2013; Silva, 2006). Scharfen i sur. (H. E. Scharfen & Memmert, 2019) povezali su odnos između kognitivnih funkcija i sportski specifičnih motoričkih vještina u mladih nogometaša te su utvrdili da je kumulativni rezultat kognitivnih testova (mjerenje prozora pozornosti, perceptivnog opterećenja, praćenja više objekata i radne memorije) povezan s kumulativnim rezultatom motoričkih testova. Točnije, prozor pozornosti i radna memorija bili su pozitivno korelirani s driblingom, kontrolom lopte i žongliranjem loptom. Temeljem toga može se pretpostaviti da igrači koji imaju širi prozor pozornosti također imaju bolje vještine driblinga, što im može omogućiti učinkovitiju izvedbu. Na primjer, u situaciji u igri gdje igrač dribla i istovremeno prati loptu, svoje suigrače i protivnike, važno mu je da izbjegne kontakt s protivnicima i bude učinkovitiji u driblanju (H. E. Scharfen & Memmert, 2019). Takve aktivnosti događaju se i u vaterpolu, gdje igrači trebaju obraćati pozornost na loptu, suigrače i kretanje protivnika, uz neprekidno održavanje tijela u vodi, neprirodnom i složenom okruženju. Širi prozor pozornosti mogao bi im biti koristan kako bi lakše uočili svoje suigrače i pravovremeno im dodali loptu (Botonis i sur., 2019; Viero i sur., 2020). Nadalje, Kiss i Balogh (Brigitta Kiss, 2019) koji su proučavali rukometaše koristeći

Vienna Test System utvrdili su razlike u selektivnoj pozornosti i perifernoj percepciji kratkoročnog pamćenja, kao i u vremenu reakcije između rukometaša raspoređenih na različite igračke pozicije. Rukometaši na poziciji kružnog napadača bili su lošiji od igrača na drugim pozicijama u brzini reakcije, što je u skladu s njihovom ulogom u igri. Vratari, krilni igrači i razigravači (*playmakeri*) imali su brže vrijeme reakcije u usporedbi s kružnim napadačima (pivotima) i vanjskim napadačima (bekovima) te su vratari činili manje pogrešaka od napadača. To može biti povezano s činjenicom da vratar ima manji raspon podražaja što olakšava bržu odluku (ne nužno ispravnu) o tome što učiniti sljedeće (Brigitta Kiss, 2019). S druge strane, središnji vanjski napadač ima zadatak organizirati akcije i učinkovito dodavati loptu suigračima. Očekuje se da donosi brze, ali točne odluke jer je osoba koja najviše posjeduje loptu i od koje kreću napadačke akcije (Michalsik i sur., 2014). Vanjski napadači imaju ulogu strijelca u ekipi, ali često i ulogu braniča, što zahtijeva više zadataka istovremeno, visoku razinu snage i kondicije (Michalsik i sur., 2014). Krilni napadači su igrači s najvećom brzinom i agilnošću koji često šutiraju na gol u najizazovnijim situacijama (Silva, 2006). Iz kognitivne perspektive, tijekom pokušaja postizanja gola, vanjska pozornost igrača se sužava (samo na gol-prostor) (Blecharz i sur., 2022; Michalsik i sur., 2014; Silva, 2006). Od kružnih napadača očekuje se da imaju veliku fizičku snagu i tjelesnu masu, a istovremeno relativno nizak indeks tjelesne masti (Karcher & Buchheit, 2014), budući da igraju između braniča gdje se trebaju boriti za poziciju i stvorit si priliku za šut. Stoga se iz kognitivne perspektive očekuje da kružni napadač ima širok raspon vanjske pozornosti, sposobnost višestrukog prebacivanja i visoku razinu radne memorije (Brigitta Kiss, 2019).

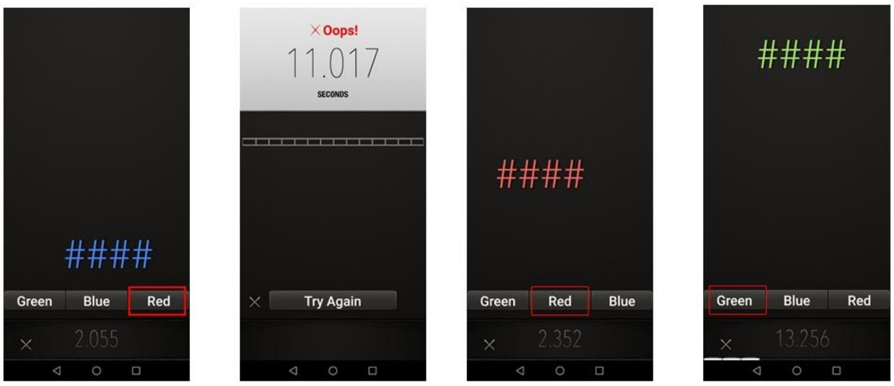
Kao što je ranije navedeno, igračke pozicije u vaterpolu mogu se izravno usporediti s rukometom. Dodavanje kognitivnih testova za procjenu izvedbe igrača podržavaju mnoge prethodne studije, koje izvještavaju o visokoj povezanosti i preklapanju između kognitivnih funkcija i važnih aspekata sportske izvedbe, poput situacijske igračke inteligencije, koja je ključna za uspjeh u ekipnim sportovima, iako je još uvijek teško mjerljiva (Simons i sur., 2016; Lot Verburgh, Scherder, van Lange, & Oosterlaan, 2014; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012). Takvi rezultati mogu trenerima pružiti opsežniju sliku profila igrača na višedimenzionalan način i mogu pomoći u određivanju njihove igračke poziciji unutar ekipe (Blecharz i sur., 2022; H.-E. Scharfen & Memmert, 2021; H. E. Scharfen & Memmert, 2019). Važno je istaknuti da se kognitivne funkcije u sportaša mogu poboljšati kognitivnim treningom. Kognitivni trening usmjeren na poboljšanje sportske izvedbe trebao bi se provoditi u situaciji usko povezanoj sa zadacima koji se obavljaju na terenu. U suprotnom će prijenos vještina biti ograničen (Conejero Suarez, Prado Serenini, Fernandez-Echeverria, Collado-Mateo, & Moreno Arroyo, 2020; Formenti i sur., 2019; Radic, 2020; Renshaw i sur., 2018).

Posljednjih godina interes za kognitivne procese u sportu je porastao (Walsh, 2014; Walton, Keegan, Martin, & Hallock, 2018; Yarrow, Brown, & Krakauer, 2009). Iako motoričke sposobnosti i vještine uglavnom određuju sportsku izvedbu i uspjeh, kognitivni procesi čine se ključnima za postignuća na vrhunskoj razini (H. E. Scharfen & Memmert, 2019; Trecroci i sur., 2021). Može se pretpostaviti da će u sportskim igrama kao što je rukomet ili vaterpolo, a posebno na pozicijama igrača u polju, kognitivne osobine poput koncentracije (koja omogućuje brže donošenje ispravnih odluka i manje pogrešaka), perifernog vida (koji omogućuje uočavanje igrača sa strane), kratkoročnog pamćenja (koje omogućuje pamćenje položaja igrača na terenu) i vremena reakcije (zbog visokog tempa igre, brzih bacanja itd.) igrati važnu ulogu u izvedbi.

1.3.3. Testovi za procjenu kognitivnih funkcija

Iako genetski čimbenici igraju ulogu u uspjehu u cijelom spektru sportova, doprinos treninga u razvoju igrača u današnje vrijeme je mjerljiv i smatra se značajnim (Williams & Reilly, 2000a). Također, prema Williamsu i Reillyju (Williams & Reilly, 2000a) psihološke odrednice i karakteristike ličnosti vrhunskih nogometaša povezane su s njihovom sportskom izvedbom i uspjehom, ali su te osobine izrazito varijabilne i teško mjerljive da bi se mogli izvući snažni zaključci o zahtjevima ličnosti za uspješnu karijeru u nogometu, ali i ostalim sportskim igrama. Stoga se naglasak stavlja na kognitivne mjere, a posebno na vještine predviđanja i donošenja odluka koje su obilježje nogometnog znanja (Williams & Reilly, 2000a). Dodavanje kognitivnih testova za procjenu sportske izvedbe podržavaju mnoge prethodne studije, koje izvještavaju o visokoj povezanosti i preklapanju između kognitivnih funkcija i važnih aspekata sportske izvedbe, poput situacijske igračke inteligencije, koja je ključna za uspjeh u vrhunskom sportu, a još uvijek je teško mjerljiva (Lot Verburgh i sur., 2014; Vestberg i sur., 2012). Brojni su psihološki testovi koji se koriste u znanstvenim istraživanjima za procjenu i mjerenje kognitivnih funkcija (Bajaj i sur., 2013; Brigitta Kiss, 2019; Kalen i sur., 2021; Ong, 2015; Sarmento i sur., 2018; Scarpina & Tagini, 2017; H. E. Scharfen & Memmert, 2019; Trecroci i sur., 2021).

Jedan od takvih testova je Stroopov zadatak ili Stroop test, neuropsihološki test koji se široko koristi u eksperimentalne i kliničke svrhe. Procjenjuje sposobnost inhibicije kognitivne interferencije, koja se javlja kada obrada jednog obilježja podražaja utječe na istovremenu obradu drugog atributa istog podražaja (Scarpina & Tagini, 2017; Stroop, 1935). U prvom dijelu testa koji predstavlja kongruentni (podudarni) uvjet sudionici trebaju pročitati nazive boja otisnute crnom tintom i imenovati različite boje. U drugom inkongruentnom (nepodudarnom) dijelu testa riječi u boji su otisnute u nekonzistentnoj boji tinte (na primjer, riječ „crvena“ je otisnuta zelenom tintom). Dakle, u tom nepodudarnom uvjetu, sudionici trebaju imenovati boju tinte umjesto da čitaju riječ. Drugim riječima, od sudionika se traži da izvrše manje automatizirani zadatak (tj. imenuju boju tinte) dok istovremeno inhibiraju interferenciju koja proizlazi iz automatiziranijeg zadatka (tj. čitanja riječi) (C. M. MacLeod & Dunbar, 1988). Takva poteškoća u inhibiranju automatiziranijeg procesa naziva se Stroopov efekt (Stroop, 1935). Iako se Stroop test široko koristi za mjerenje sposobnosti inhibicije kognitivne interferencije, u dostupnoj literatura također se navodi njegova primjena za mjerenje drugih kognitivnih funkcija kao što su pozornost, brzina obrade, kognitivna fleksibilnost i radna memorija (Kane & Engle, 2003). Stroop test, bez obzira je li riječ o kongruentnom ili inkongruentnom uvjetu, s gledišta vremena reakcije, zahtijeva od pojedinca da učinkovito raspodijeli pozornost i usredotoči se na vizualno predstavljeni podražaj, odredi njegovu boju i pruži motorički odgovor pritiskom na odgovarajući odabir na zaslonu (Bajaj i sur., 2013). Uvježbani smo čitati značenje i uglavnom ignorirati vizualne karakteristike riječi poput stila fonta ili boje tinte. Nekongruentni uvjet Stroop testa predstavlja riječi u boji (poput „zelene“) napisane bojom druge tinte („crvene“). Kada se od nas traži da ignoriramo značenje riječi (tj. inhibiramo naš automatizirani odgovor na riječi) i umjesto toga obratimo pozornost i odaberemo boju tinte, reakcija je sporija i čini se više pogrešaka (Colin M. MacLeod, 1991). Osim Stroop testa za koji se koriste boje i riječi u tablici na papiru ili na karticama, danas se koriste i aplikacije na zaslonima elektroničkih uređaja. EncephalApp Stroop je jedna od takvih aplikacija, koja se može preuzeti iz Apple ili Google Play trgovine aplikacijama, jednostavna je za korištenje, ispitanike je lako podučiti o načinu rješavanja testa, a rezultati su jednostavni za bodovanje i tumačenje. Zasloni elektroničkih uređaja mogu se koristiti za izvršavanje zadatka (Bajaj i sur., 2013). Kako je ranije navedeno, zadatak ima dvije komponente „Off“ i „On“, kongruentno i nekongruentno stanje, ovisno o podudarnosti ili nepodudarnosti podražaja. Obje komponente primijenjuju se nakon što se za svako stanje provedu dva pokušaja vježbanja. U lakšem „Off“ stanju, ispitanik vidi neutralni podražaj, znakove ### prikazane na ekranu u crvenoj, zelenoj ili plavoj boji, jedan po jedan i treba reagirati što je brže moguće dodirivanjem odgovarajuće podudarne boje na dnu zaslona. Boje na dnu zaslona pojavljuju se nasumično i nisu uvijek na istoj fiksiranoj poziciji (Slika 2).



Slika 2. Stroop Off – kongruentni dio Stroop testa.

Zadatci se nastavljaju sve do ukupno 10 prezentacija, što je jedan pokušaj i ukupno vrijeme potrebno za pokretanje, kao i pojedinačne odgovore. Ako ispitanik pogriješi, tj. pritisne pogrešnu boju, pokušaj se zaustavlja i treba se ponovno pokrenuti. Stoga broj pokušaja potreban za pet ispravnih zadataka također pokazuje broj pogrešaka. Test se nastavlja sve dok ispitanik nije postigao pet ispravnih zadataka. Stanje „On" je izazovnije s kognitivnog gledišta jer se u devet od deset prezentacija prikazuju nepodudarni podražaji. U tom dijelu testa, ispitanik treba točno dodirnuti boju prikazane riječi koja je zapravo naziv boje u neskladnom bojanju, tj. riječ „crveno" prikazana je plavom bojom i točan odgovor je plava, a ne crvena (Slika 3).

Slika 3. Stroop On – nekongruentni dio Stroop testa.

Slično „Off" stanju počinje se s dva pokušaja vježbanja i zatim se zadatak nastavlja dok nije postignuto pet točno rješenih zadataka (Bajaj i sur., 2013).

Specifične mjere ishoda na kraju Stroop testa su: ukupno vrijeme za pet točnih pokušaja u „Off" stanju (OffTime), mjera psihomotorne sposobnosti; broj pokušaja potreban za dovršetak pet točnih zadataka u „Off" stanju; ukupno vrijeme za pet točnih pokušaja u „On" stanju (OnTime), što je mjera inhibicije odgovora i motoričke brzine te broj pokušaja potreban za dovršetak pet točnih zadataka u „On“ stanju. Razlika između OnTime i OffTime je mjera kognitivne obrade koji kontrolira psihomotornu brzinu (Bajaj i sur., 2013).

1.4. Utjecaj sportskih aktivnosti na kognitivne funkcije

U svom istraživanju utjecaja sporta na kognitivne funkcije u djece, Bidzan-Bluma i Lipowska (Bidzan-Bluma & Lipowska, 2018) govore kako je u one djece koja se redovito bave organiziranim sportskim aktivnostima primijećeno poboljšanje koncentracije i pozornosti. Također je utvrđeno da su djeca koja su se bavila redovitom tjelesnom aktivnošću pokazala bolje izvršne funkcije u smislu inhibicije i bolje sposobnosti planiranja od djece koja se nisu bavila nikakvom tjelesnom aktivnošću, a i imala su bolji uspjeh u školskim ocjenama (Ahamed i sur., 2007; Carson i sur., 2016; Chomitz i sur., 2009; Trudeau & Shephard, 2008).

Brojna druga istraživanja su također pokazala da redovita fizička aktivnost poboljšava niz drugih kognitivnih funkcija i pridonosi boljem radnom pamćenju (Kamijo i sur., 2011), što su pokazala istraživanja među djecom koja su trenirala primjerice karate, tenis i nogomet (Alesi, Bianco, Luppina, Palma, & Pepi, 2016; Alesi i sur., 2014; Ishihara, Sugasawa, Matsuda, & Mizuno, 2017a; Ishihara i sur., 2017b; H. E. Scharfen & Memmert, 2019). Osim toga, utvrdili su kako redovita fizička aktivnost pospješuje cirkulaciju, što rezultira boljom dostavom kisika u mozak i opskrbom hranjivim tvarima. Alesi i sur. (Alesi i sur., 2014) proveli su značajno istraživanje fokusirano isključivo na utjecaj nogometa u kognitivnom i motoričkom razvoju. Istraživanje je provedeno na uzorku djece u dobi od 8 do 12 godina koja su sudjelovala u nogometnom trening programu tijekom 12 tjedana. Kognitivne funkcije su ocjenjivane putem standardiziranih testova pozornosti, pamćenja i izvršnih funkcija. Rezultati su i u ovom istraživanju bili pozitivni i pokazali su kako sudjelovanje u nogometnom treningu dovodi do poboljšanja kognitivnih funkcija, uključujući bolju pozornost, kratkoročno i dugoročno pamćenje te izvršne funkcije, kao što su planiranje i donošenje odluka. Djeca koja su sudjelovala u programu pokazala su veći napredak u kognitivnim testovima nego djeca iz kontrolne skupine (Alesi i sur., 2016).

Što se tiče funkcioniranja mozga, nedavne studije usredotočile su se na neurokognitivne funkcije sportaša kako bi se istražilo jesu li godine treninga ili urođene interindividualne razlike u neurokognitivnom funkcioniranju povezane s vrhunskom sportskom izvedbom (Yarrow i sur., 2009). Studije provedene s djecom u dobi od osam do devet godina potvrdile su da sport utječe na promjene u desnom prednjem prefrontalnom korteksu, koje su povezane s kognitivnom kontrolom (Chaddock-Heyman i sur., 2013). Na primjer, studije izvještavaju o superiornim sposobnostima vrhunskih sportaša u sportski specifičnim perceptivnim sposobnostima, vizualnim vještinama (Savelsbergh, Van der Kamp, Williams, & Ward, 2005) i pozornosti (Mann i sur., 2007). Međutim, kod nespecifičnih, osnovnih perceptivnih vještina, obrade vizualnih informacija i vremena reakcije, nisu pronađene razlike između sportaša više i niže razine uspješnosti (Helsen & Starkes, 1999; Kida, Oda, & Matsumura, 2005). Zanimljivo je da je pokazano da vrhunski sportaši nadmašuju manje uspješne sportaše u višim (složenijim) neurokognitivnim funkcijama (tj. izvršnim funkcijama) koje nisu specifične za sport, poput inhibicije (Alves i sur., 2013; Lot Verburgh i sur., 2014; Vestberg i sur., 2012). U studiji Vestberga i sur. (Vestberg i sur., 2012) pokazano je da izvršne funkcije čak predviđaju kasniju sportsku izvedbu u nogometu u smislu postizanja golova i asistencija. Rezultati meta-analize koju su proveli Kalen i sur. (Kalen i sur., 2021) pokazali su da su igrači na višoj razini natjecanja pokazali bolje kognitivne funkcije donošenja odluka od svojih vršnjaka u nižoj razini, što ukazuje na to da bi te vještine mogle biti važna značajka za sportsku izvedbu i uspjeh. Nadalje, pokazano je da vrhunski sportaši imaju povećanu debljinu korteksa u nekoliko područja mozga i da je taj povećani anatomski volumen povezan s razinom izvedbe (Wei, Zhang, Jiang, & Luo, 2011).

Osim uspjeha u sportskim igrama, tjelesna aktivnost, osobito tijekom djetinjstva značajno utječe na razvoj kognitivnih funkcija općenito. Međutim, manje je jasno koja vrsta tjelesne aktivnosti pokazuje najjaču povezanost s izvršnim funkcijama u djece (De Waelle, Laureys, Lenoir, Bennett, & Deconinck, 2021). Rezultati različitih istraživanja pokazuju da djeca koja sudjeluju u ekipnim sportovima pokazuju bolje izvršne funkcije u usporedbi s djecom koja sudjeluju u individualnim sportovima i djecom koja se ne bave organiziranim sportskim aktivnostima (Best & Miller, 2010; Bidzan-Bluma & Lipowska, 2018; De Waelle i sur., 2021). Ishihara i sur. (Ishihara i sur., 2017a) pokazali su da su djeca u dobi od 6 do 11 godina koja su godinu dana sudjelovala u satovima tenisa poboljšala svoje izvršne funkcije tijekom tog razdoblja. Nadalje, Formenti i sur. (Formenti i sur., 2019) otkrili su da su djeca koja su se bavila sportom otvorenih vještina (npr. nogomet ili odbojka) pokazala superiorniju inhibitornu kontrolu u usporedbi s djecom koja se bave sportovima zatvorenih vještina (npr. gimnastikom ili plivanjem) i djecom koja se ne bave sportskim aktivnostima. Iako su dokazi o vezi između sudjelovanja u sportu i izvršne funkcije u djece prilično ograničeni, ta je veza jasnije utvrđena u odraslih (H. E. Scharfen & Memmert, 2019; Voss i sur., 2010). Štoviše, čini se da sportaši ekipnih sportova (npr. odbojka, nogomet, hokej itd.) imaju bolje izvršne funkcije u usporedbi sa sportašima iz drugih sportova. Na primjer, studija koju su proveli Burris i sur. (Burris, Liu, & Appelbaum, 2020) pokazala je da sportaši ekipnih sportova ne samo da nadmašuju nesportaše, već i sportaše iz drugih sportova u zadacima radne memorije. Nadalje, Jacobson i sur. (Jacobson & Matthaeus, 2014) također su pokazali da igrači ekipnih sportova postižu najviše rezultate u rješavanju problema. Međutim, u njihovoj studiji, sportaši iz individualnih sportova (tj. sportova koji sportašu daju vremena da se pripremi za kritične radnje i izvodi ih vlastitim tempom) također su pokazali superiorno izvođenje zadataka inhibicije. Stoga se čini da je usklađenost s različitim zahtjevima određenih vrsta sportova povezana sa boljiom izvedbom različitih kognitivnih funkcija. Dakle, čini se da postoji jasna veza između sudjelovanja u različitim vrstama sportova i izvršnih funkcija u odrasloj dobi, dok postoji znatno manje dokaza za tu vezu u djetinjstvu. Studija Formentija i sur. (Formenti i sur., 2019) bila je prva koja je istražila navedenu povezanost na uzorku djece u dobi od 8 do 12 godina. Međutim, njihovo mjerenje izvršnih funkcija sastojalo se od samo jednog zadatka inhibicije, dok se izvršne funkcije obično definiraju kao široki konstrukt koji sadrži najmanje tri međusobno povezane podkomponente (tj. pomicanje, radno pamćenje i inhibicija) koje se sve mjere različitim zadacima (Brydges, Fox, Reid, & Anderson, 2014). U djece (mlađe od 12 godina), iako se mjeri nizom različitih zadataka, izvršne funkcije se najbolje mogu definirati kao unitarni konstrukt s jednim čimbenikom koji predstavlja višestruke podkomponente izvršnih funkcija (Laureys, De Waelle, Barendse, Lenoir, & Deconinck, 2022; Miyake i sur., 2000). Posljedično, potrebno je više od jednog testa kako bi se konstrukt izvršnih funkcija procijenio na sveobuhvatan način.

Nogomet kao sport otvorenih vještina, karakteriziran je aktivnostima koje se igraju u vanjskom okruženju bogatom distraktorima. Vjeruje se da nogomet istovremeno stimulira motoričke i kognitivne funkcije. Tijekom utakmice, igrači trebaju obraditi, manje-više u isto vrijeme, položaj i kretanje protivnika i suigrača te položaj i smjer kretanja lopte. Udaranje lopte je pokret visoke razine koji zahtijeva prospektivnu kontrolu, perceptivne vještine i motoričku koordinaciju (Chang, Tsai, Chen, & Hung, 2013). S druge strane, te perceptivne i kognitivne vještine igraju ključnu ulogu u nogometnoj izvedbi. Dakle, mladi nogometaši u dobi od 10 godina pokazuju razvijenije taktičke kognitivne sposobnosti i formalno razmišljanje, kao što su misao i kinetička memorija, od svojih vršnjaka s nižim nogometnim znanjem (Kun & Toth, 2012). Dakle, taj bi sport trebao djelovati kao snažan izazov sposobnosti sprječavanja ometanja i ostajanja usredotočenog na zadatak pomaganja vlastitoj ekipi da postigne pogodak i sprječavanja druge ekipe da postigne pogodak. U nogometu se okruženje stalno mijenja i pokreti se trebaju stalno prilagođavati. Tijekom utakmice svaki igrač treba planirati motoričke radnje, koristeći mentalne aktivnosti za reguliranje ponašanja. Štoviše, radnje se trebaju stalno ažurirati i mijenjati zbog radnji suigrača, kretanja lopte i protivnika na nogometnom terenu

(Alesi i sur., 2016; Kun & Toth, 2012). Igrač treba procijeniti situaciju, usporediti je s prošlim iskustvima, izraditi nove akcijske planove, donijeti odluke o akciji koju će poduzeti, a u isto vrijeme spriječiti iskušenja da pokuša postići pogodak umjesto dodavanja i fleksibilno mijenjati planove u stvarnom vremenu kao odgovor na akciju na terenu (Vestberg i sur., 2012). Malo je studija istraživalo kognitivno funkcioniranje djece koja treniraju nogomet. Većina istraživanja usmjerena je na vrhunske odrasle igrače (Voss i sur., 2010). Ukratko, nogomet može utjecati na razvoj izvršnih funkcija na više načina: kao uzbudljiva i ugodna zabava (povećanje užitka); stvaranjem „obogaćenog okruženja“ koje postavlja zahtjeve za višestruke izvršne funkcije, čime ih izaziva i poboljšava; stvaranjem prilika za društvenu interakciju, suradnju s drugima, razmjenu iskustava u slobodno vrijeme i primanje ohrabrenja vršnjaka, povećanje osjećaja pripadnosti i socijalne podrške; pomažući u razvoju osjećaja izvrsnosti i kompetencije; te poboljšanjem motoričkih sposobnosti i tjelesne kondicije (Alesi i sur., 2016; Voss i sur., 2010).

1.5. Identifikacija i selekcija talentiranih mladih igrača

Procesi identificiranja i ranog razvoja mladih talentiranih sportaša ključni su u svakom sportskom programu. Pri tome treba istovremeno uzeti u obzir fizičke i psihološke čimbenike te koristiti holistički pristup u kojem se motoričke vještine i psihološke karakteristike proučavaju i razvijaju istovremeno (Brigitta Kiss, 2019). Takav proces često uključuje tri aspekta mjerenja i evaluacije: fiziološki, psihološki i sociološki (Durand-Bush, 2001; van Rossum & Gagné, 2006). Međutim, ne zna se mnogo o odgovarajućim strategijama koje treba primijeniti tijekom tih procesa, a malo je znanstvenih istraživanja provedeno na tom području (Falk i sur., 2004; Reilly, Williams, Nevill, & Franks, 2000; Williams & Reilly, 2000a). Na primjer, u vaterpolu je predstavljeno mnogo testova, ali su slabo opisani ili im je relevantnost nejasna (Dimitric, Kontic, Versic, Scepanovic, & Zenic, 2022; Smith, 1998). Nadalje, provedeno je malo empirijskih istraživanja kako bi se istražile najpovoljnije metode, strategije i tehnike koje se mogu koristiti u identificiranju talentiranih sportaša u bilo kojem sportu (Reilly i sur., 2000). U sportskom okruženju treba promatrati niz čimbenika povezanih s kontekstom aktivnosti u koju su mladi sportaši uključeni, kao i njihova postignuća, vještine, stavove i osobne motive. Treneri vjeruju da su motoričke sposobnosti i tehničke vještine mladih igrača glavni čimbenici u predviđanju budućeg uspjeha (Lidor, 2000). Od posebnog su interesa za trenere tehnički aspekti igre, koji u osnovi odražavaju osnovne temelje motoričkih (npr. brzina, agilnost i eksplozivna snaga) i tehničkih (npr. dodavanje, dribling i šut) sposobnosti igrača. Međutim, treneri su također svjesni korištenja misaonih procesa tijekom natjecanja (Hardy, Jones, & Gould, 1996). Sposobnost igrača da predvidi, reagira, usmjeri pozornost i donese odgovarajuću odluku ključni je čimbenik u postizanju uspješne tehničko-taktičke izvedbe. Kao rezultat toga, testovi za identifikaciju i selekciju mladih talentiranih sportaša trebala bi uključivati i kognitivne funkcije, poput predviđanja i donošenja odluka. Zanimljivo pitanje u sportskim igrama s loptom je relativna težina koju treba dati motoričkim, tehničkim i kognitivnim funkcijama unutar procesa identifikacije talenata. Pronalaženje odgovarajuće kombinacije sposobnosti i testova trebalo bi pomoći trenerima da dobiju potrebne informacije za predviđanje budućih rezultata.

Od vaterpolista se ne traži samo izvođenje otvorenih i zatvorenih motoričkih vještina tijekom igre, poput plivanja s loptom i bez nje, bacanja na gol i čuvanja lopte od protivničkih igrača, već i obrada informacija, predviđanje, donošenje odluka i rješavanje problema koji se javljaju tijekom igre (Smith, 1998). Stoga, kako bi se procijenila učinkovitost i situacijska igračka inteligencija u igrama s loptom poput vaterpola, igrače treba procijeniti i motoričkim i kognitivnim testovima (Falk i sur., 2004; Williams & Reilly, 2000b). Ukupna slika dobivena iz rezultata motoričkih i fizioloških testova te procjena razumijevanja igre mogu treneru pružiti jasniju sliku o sposobnostima mladih igrača. Falk i sur. (Falk i sur., 2004) u procesu odabira mladih talentiranih vaterpolista predlažu korištenje manje specifičnih plivačkih i kondicijskih testova, a veći naglasak stavljaju na procjeni situacijske igračke inteligencije. U njihovoj studiji, mladi izraelski vaterpolisti praćeni su tijekom dvogodišnjeg programa selekcije za juniorsku nacionalnu reprezentaciju, a proveden je kontrolirani proces identifikacije i ranog razvoja talenata. Sudionici su proveli niz motoričkih testova vezanih uz vaterpolo. Svi testovi sadržavali su aktivnosti koje su igrači izvodili tijekom treninga i utakmica. Osim toga, treneri su procijenili situacijsku igračku inteligenciju. Pretpostavka je bila da su igrači koje je izbornik nacionalne selekcije na kraju odabrao za juniorsku nacionalnu vaterpolsku reprezentaciju bili superiorniji i u fizičkim i u kognitivnim aspektima igre, što je glavni rezultat studije proizašao iz dvogodišnjeg programa i potvrdio. Odabrani igrači, u prosjeku su već na početku programa bili superiorniji u raznim zadacima plivanja i motoričkih sposobnosti, kao i u situacijskoj igračkoj inteligenciji (Falk i sur., 2004).

Rezultati studije Dimitriča i sur. (Dimitric i sur., 2022) pokazali su da se antropometrijska obilježja i plivački kapaciteti mogu smatrati valjanim prediktorima sportskih postignuća vaterpolista. Posebno se tjelesna visina činila relevantnim čimbenikom i za središnje napadače i vanjske napadače, dok se niži postotak tjelesne masti pokazao ključnim za budući uspjeh vanjskih napadača. Plivački rezultati na juniorskoj razini također su se pokazali značajnim prediktivnim čimbenikom za budući uspjeh. Općenito, plivački kapaciteti igrali su značajnu ulogu u učinkovitosti i ukupnom postignuću igrača. Aerobna izdržljivost u plivanju bila je važnija za vanjske napadače, dok su anaerobni plivački kapaciteti igrali značajnu ulogu u budućim rezultatima za poziciju središnjeg napadača. U međuvremenu, sprint plivanje nije se pokazalo važnim čimbenikom uspjeha kada su igračke pozicije bile stratificirane. Stoga, iako su se testovi sprint plivanja više puta pokazali vrijednim kriterijima odabira u mlađoj dobi, kasniji uspjeh na seniorskoj razini bio je snažno povezan s energetskim kapacitetima specifičnim za poziciju (tj. anaerobno-laktatnim kapacitetom plivanja za središnje napadače i aerobnim kapacitetom plivanja za vanjske napadače) (Dimitric i sur., 2022).

1.6. Ciljevi i hipoteza istraživanja

Problem ovog istraživanja predstavlja nedostatak znanstvene literature (*research gap)* o procjeni kognitivnih funkcija i njihovoj povezanosti sa sportskim uspjehom u vaterpolu. Pretpostavlja se da će u budućnosti ekipe s boljom psihološkom pripremom i bolje razvijenim kognitivnim funkcijama, osobito brzinom reakcije, brzim donošenjem odluka i izraženom inhibicijom, biti u prilici nadigrati ostale ekipe.

Glavni ciljevi ovog istraživanja bili su:

1. utvrditi povezanost kronološke dobi s antropometrijskim karakteristikama i specifičnim funkcionalnim plivačkim sposobnostima kod mladih vaterpolista do 12 godina
2. usporediti kognitivne funkcije mladih vaterpolistica i vaterpolista i kontrolnih ispitanika – školske djece iste kronološke dobi koja nisu sudjelovala u organiziranim sportskim aktivnostima
3. usporediti kognitivne funkcije između mladih vaterpolistica i vaterpolistica iste kronološke dobi
4. procijeniti kognitivne funkcije i specifične funkcionalne plivačke sposobnosti mladih vaterpolista, te utvrditi povezanost kognitivnih funkcija i specifičnih funkcionalnih plivačkih sposobnosti s odabirom mladih vaterpolista u nacionalnu vaterpolsku reprezentaciju
5. usporediti kognitivne funkcije, antropometrijske karakteristike i specifične funkcionalne plivačke sposobnosti mladih vaterpolista koji igraju na različitim igračkim pozicijama

Hipoteze ovog istraživanja bile su:

1. Kronološka dobi značajno utječe na antropometrijske karakteristike i specifične funkcionalne plivačke sposobnosti mladih vaterpolista do 12 godina.
2. Djeca koja treniraju vaterpolo na visokoj razini pokazat će bolje kognitivne funkcije, posebno u pogledu kognitivne fleksibilnosti i inhibicije od njihovih vršnjaka koji se ne bave organiziranim sportskim aktivnostima.
3. Mlade vaterpolistice imaju bolje kognitivne funkcije od vaterpolista iste kronološke dobi.
4. Antropometrijske karakteristike, specifične funkcionalne plivačke sposobnosti i kognitivne funkcije značajno su povezane sa selekcijom mladih vaterpolista u nacionalnu vaterpolsku reprezentaciju.
5. Postoje značajne razlike u kognitivnim funkcijama među vaterpolistima na različitim igračkim pozicijama, pri čemu će krilni napadači nadmašiti igrače na drugim igračkim pozicijama.

2. IZVORNE STUDIJE

2.1. Anthropometric Characteristics and Specific Functional Swimming Capacities in Youth U12 Water Polo Players

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Anthropometric Characteristics and Specific Functional Swimming Capacities in Youth U12 Water Polo Players

Neven Kovačević[1,2], Frane Mihanović[3], Kristian Hrbić[2], Miodrag Mirović[4], Tea Galić[5,6]

Affiliations: [1]Faculty of Kinesiology, University of Split, Split, Croatia, [2]Croatian Water Polo Federation, Zagreb, Croatia, [3]University Department of Health Studies University of Split, Split, Croatia, [4]Water Polo and Swimming Federation of Montenegro, Kotor, Montenegro, [5]Department of Prosthodontics, Study of Dental Medicine, University of Split School of Medicine, Split, Croatia, [6]Department of Neuroscience, University of Split School of Medicine, Split, Croatia

Correspondence: Neven Kovačević. University of Split, Faculty of Kinesiology, Nikole Tesle 6, 21 000 Split, Croatia. E-mail: nevenkovacevic@hotmail.com

Abstract

Introduction: Water polo is a physically high-demanding team sport, therefore players' physical abilities and anthropometric characteristics are important factors to achieve a good level of quality in technical-tactical actions. The aim of this study was to determine the association of the chronological age with the anthropometric characteristics and specific functional swimming capacities in youth U12 male water polo players. Methods: There were 170 youth U12 water polo players who attended the Croatian Water Polo Federation training camps included in this cross-sectional study. Measurements included anthropometric characteristics and specific functional swimming capacities. Results: Players were divided according to their chronological age: Q1 (January-March) – 59 players (34.7%), Q2 (April-June) – 35 players (20.6%), Q3 (July-September) – 46 players (27.1%) and Q4 (October-December) – 30 players (17.6%). Older players born in Q1 presented higher values of body height and weight than their younger peers born in Q4 (Q1 165.96±7.88 cm vs. Q4 159.46±5.44 cm, $P=0.001$; Q1 60.14±13.99 kg vs. Q4 51.35±7.09 kg, $P=0.023$), while there were no statistically significant differences in specific functional swimming tests between different age groups. Discussion: Contrary to what was hypothesized, older water polo players presented only better anthropometric characteristics than their younger peers, probably due to the biological maturity influence on functional skills, as well as small range of chronological age differences. Conclusion: Such data might provide an understanding of the general and specific water polo player’s development process, which should be considered by coaches of youth players to improve their skills as a result of developing better training programs.

Keywords: *water polo, chronological age, development, swimming, performance*

2.1.1. Introduction

Water polo is a physically high-demanding team sport characterized by exchange of activities with different energy load while players constantly move through the field in the water. In such environment players use different swimming intensity, receiving, dribbling and passing the ball, as well as shooting accurately on the goal. Additionally, they use different techniques to accomplish many complex technical-tactical actions while wrestling with the opponents (Smith, 1998, Botonis i sur., 2015, Sekulić i sur., 2016). Several authors indicated physical abilities and anthropometric characteristics as important factors to achieve a good level of quality in technical-tactical actions, both for young and adult water polo players, especially considering constant physical contact during the game (Kondrič i sur., 2012, Uljević i sur., 2013, Sekulić i sur., 2016, Gardasevic i sur., 2017, Kontić i sur., 2017, Melchiorri i sur., 2017, Viero i sur., 2020). Greater body height and longer extremities also allow players to reach for the ball more easily, to shoot and to perform blocks more efficiently (Idrizović i sur., 2014, Dimitrić i sur., 2022). It is well known that water polo players' anthropometric characteristics are highly related with high performance levels, influencing intensive offensive and defensive actions in each playing position (Ferragut i sur., 2011, Kondrič i sur., 2012). Along with body size, swimming capacity is also related to the general performance level of youth water polo players in a game (Kontić i sur., 2017, Melchiorri i sur., 2017, Vasiljevic i sur., 2021). Since in recent years, water polo as a game has become more dynamic, the transition from offense to defense is faster increasing the frequency of situational parameters, player contacts are stronger and there are more frequent transitions from horizontal to vertical body position (Kovačević, 2012, Uljević i sur., 2021). Consequently, to reach higher level of general performance in the game, youth water polo players need to develop high swimming capacity (Kontić i sur., 2017, Melchiorri i sur., 2017).

Other than anthropometric characteristics and physical abilities, the complex process of growth and maturation must be considered for young athletes to ensure suitable training and competition routines. The players' initial development processes require deeper theoretical and practical knowledge, which might help to improve the training process and early identification of talented players (Escalante i sur., 2013, Chirico i sur., 2021). Chronological age is the traditional strategy to categorize young athletes appropriately for their level of development (Lloyd i sur., 2014, Giudicelli i sur., 2021). Growth is the process of increasing body size in whole or in parts, while biological maturation refers to physiological and cognitive development towards adulthood. Maturational events have an established order in which they happen but the moment when they occur and their duration have vast variability between individuals, even at the same age, affecting the physical, technical and psychological performance of young athletes (Malina i sur., 2004, Lloyd i sur., 2014, Giudicelli i sur., 2021). In sports where strength, power and speed are extremely important and physical contact is inevitable, more mature individuals who are usually taller and heavier show better results in motor, physical and functional evaluations compared with their peers in chronological age (Ford i sur., 2011, Till i sur., 2014, Luna-Villouta i sur., 2021). Such differences usually disappear when late-maturing athletes reach higher levels of maturation at the end of adolescence or in the beginning of adulthood (Malina i sur., 2004, Lloyd i sur., 2014).

Considering the importance of the chronological age and maturity, as well as functional development of youth water polo players, the aim of this study was to determine the association of the chronological age (see Methods section for details) with the anthropometric characteristics and specific functional swimming capacities in youth U12 male water polo players.

2.1.2. Methods

Subjects

This cross-sectional study included 170 youth water polo field players (goalkeepers were excluded due to the small number and different specific functional swimming tests conducted) who attended the Croatian Water Polo Federation (CWPF) training camp from the season 2015/2016 until 2020/2021 at the age of 12 (U12), representing the initial selection. The CWPF training camps are selective, developmental programs on-going for past 10 years, organized by the head coach-leader of the CWPF training camps, supported by 8-12 licensed water polo coaches who participated in all training activities assuring professional supervision of it. The training camps lasted for four days, with seven specific technical-tactical training sessions adjusted to the development level of youth players. All players who attended training camps had over two years of competitive practice. They trained regularly with their own teams with an average of 5 training sessions per week, lasting approximately for two hours and they participated in the highest league for their age group, playing between 20 and 30 games each season. The players were divided according to their chronological age in four groups: Q1 – those who were born in the first quarter of the year (January-March), Q2 – those who were born in the second quarter of the year (April-June), Q3 – those who were born in the third quarter of the year (July-September) and Q4 – those who were born in the fourth quarter of the year (October-December), respectively. Written informed consent was obtained from parents / legal guardians, with the study being approved by the Ethical Committee of the University of Split School of Medicine, Split, Croatia (N.: 2181-198-03-04-19-0053).

Measurements and variables

In this study a battery of tests performed included anthropometric characteristics' measurements and specific functional swimming tests. Anthropometric variables included body height and weight which were measured using a stadiometer and a digital scale, respectively, while the subjects wore only swimming trunks. Body Mass Index (BMI) was calculated as body weight (kg) divided by height squared (m2). Water polo players' functional capacities were assessed by specific functional swimming tests including 25 m front crawl, 50 m front crawl, 100 m front crawl, 400 m front crawl, 25 m ball dribbling, 25 m eggbeater kicking, 25 m front crawl legs kicking. The players were timed with hand-held digital stopwatch (Longines, Saint-Imier, Switzerland) performing various distances and styles in 25-m swimming pool, starting at the sound signal from the water. They were allowed to push-off the wall at the start and after the turn, but a flip turn was not allowed. They were instructed to swim at maximum speed for each test. 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. Eggbeater kick is a cyclical movement and it consists of alternating the circular, asymmetric, continuous movements of the legs, an alternating circumduction of the hips accompanied by knee flexion/ extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position. Upper limbs are kept free, giving the opportunity to do technical movements with or without the ball (passing, throwing, tackling an opponent, wrestling, catching or intercepting passes, and blocking shots on goal) remaining vertical or moving in any direction while in a vertical position (Uljevic i sur., 2013). For testing 25 m eggbeater kicking players were instructed to swim in semi-horizontal body position with legs only, using eggbeater kick, while hands were neutralized with the ball, and head over the water surface.

Statistical analysis

Data analyses were performed using statistical software MedCalc for Windows (Microsoft Corp., Redmond, WA, USA), version 19.4. (MedCalc Software, Ostend, Belgium). Continuous data were presented as mean±standard deviation or whole number and percentage for categorical variables. The Kolmogorov-Smirnov test was used to assess normality of data distribution. Although data were not normally distributed according to the Kolmogorov-Smirnov test, it showed favorable distributionon Q-Q plots. Differences in anthropometric characteristics and specific functional swimming capacities of youth U12 water polo players according to the chronological age were tested using Kruskal-Wallis test with the post-hoc analysis. Additionally, Pearson's correlation coefficient analysis was performed to determine a relationship between chronological age, anthropometric characteristics and results of specific functional swimming tests, while multiple regression analysis was performed to determine the association between selected independent variables (anthropometric characteristics, specific swimming tests) with the chronological age of water polo players (dependent variable). The statistical significance was set at $P<0.05$.

2.1.3. Results

There were 170 youth U12 water polo players, divided according to their chronological age / the quarter of the year they were born in as follows: Q1 (January-March) – 59 players (34.7%), Q2 (April-June) – 35 players (20.6%), Q3 (July-September) – 46 players (27.1%) and Q4 (October-December) – 30 players (17.6%). Data about their baseline anthropometric characteristics and specific functional swimming capacities are presented in Table 1.

Table 1. Baseline characteristics of youth U12 water polo players

Chronological age (N=170)	N (%)
Age categories (quarter)	
Q1	59 (34.7)
Q2	35 (20.6)
Q3	46 (27.1)
Q4	30 (17.6)
Anthropometric characteristics (N=170)	**Mean ± SD**
Body height (cm)	163.27±7.51
Body mass (kg)	56.69±12.31
Body mass index (kg/m^2)	21.13±3.47
Specific functional swimming capacities	**Mean ± SD**
Front crawl, 25 m (s) N=143	16.45±1.14
Front crawl, 50 m (s) N=169	36.44±5.74
Front crawl, 100 m (s) N=140	79.91±5.29
Front crawl, 400 m (s) N=169	373.59±35.95
Front crawl leg kicks, 25 m (s) N=108	27.99±8.28
Eggbeater, 25 m (s) N=108	28.38±5.64
Dribbling, 25 m (s) N=170	17.73±1.48

Data are presented as mean±standard deviation or as whole numbers and percentage. Q1 – players born in the first quarter of the yeat (January-March); Q2 – players born in the second quarter of the year (April-June); Q3 – players born in the third quarter of the year (July-September); Q4 – players born in the fourth quarter of the year (October-December). Eggbeater - swimming in semi-horizontal body position with legs only, using eggbeater kick (cyclical movement consisting of alternating the circular and continuous movements of the legs, an alternating circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position), while hands were neutralized with the ball, and head over the water surface. Dribbling - dribbling the ball from wall to wall of the swimming pool, without throwing it and touching the
wall with one hand.

Older players born in Q1 presented higher values of body height and weight than their younger peers born in Q4 (Q1 165.96±7.88 cm vs. Q4 159.46±5.44 cm, P=0.001; Q1 60.14±13.99 kg vs. Q4 51.35±7.09 kg, P=0.023), while there were no statistically significant differences in specific functional swimming tests between different age groups (Table 2).

Table 2. Comparison of anthropometric characteristics and specific functional swimming capacities of youth U12 water polo players according to the chronological age

Chronological age	Q1 N=59	Q2 N=35	Q3 N=46	Q4 N=30	P
Anthropometric characteristics (N=170)					
Body height (cm)	165.96±7.88[c,d]	164.21±7.28[d]	161.47±7.04[a]	159.46±5.44[a,b]	0.001
Body mass (kg)	60.14±13.99[d]	57.13±13.53[a,d,e]	55.33±10.37	51.35±7.09[a]	0.027
Body mass index (kg/m^2)	21.61±3.53	21.12±4.23	21.13±3.14	20.21±2.74	0.299
Specific functional swimming tests					
Front crawl, 25 m (s) N=143	16.30±1.12	16.51±0.99	16.50±1.12	16.63±1.37	0.626
Front crawl, 50 m (s) N=169	36.31±2.61	36.59±2.37	36.51±1.68	36.42±2.96	0.643
Front crawl, 100 m (s) N=140	80.17±5.64	79.94±5.27	79.99±4.23	79.21±6.32	0.880
Front crawl, 400 m (s) N=169	374.13±30.59	381.18±59.25	370.65±18.79	368.20±29.51	0.778
Front crawl leg kicking, 25 m (s) N=108	27.63±2.98	27.50±2.26	28.58±2.60	28.37±3.50	0.404
Eggbeater kicking, 25 m (s) N=108	28.57±2.50	28.49±1.98	28.30±2.10	28.02±2.90	0.941
Dribbling, 25 m (s) N=170	17.55±1.53	17.97±1.45	17.60±1.40	17.98±1.55	0.474

Data are presented as mean±standard deviation. *Kruskal-Wallis test with the post-hoc analysis; $P < 0.05$. a comparison with Q1 ($P < 0.05$). b comparison with Q2 ($P < 0.05$). c comparison with Q3 ($P < 0.05$). d comparison with Q4 ($P < 0.05$). Eggbeater - swimming in semi-horizontal body position with legs only, using eggbeater kick (cyclical movement consisting of alternating the circular and continuous movements of the legs, an alternating circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position), while hands were neutralized with the ball, and head over the water surface. Dribbling - dribbling the ball from wall to wall of the swimming pool, without throwing it and touching the wall with one hand.

In Table 3, the Pearson's correlation coefficient between chronological age, anthropometric characteristics and specific functional swimming capacities of youth U12 water polo players can be seen.

Table 3. Pearson's correlation coefficient between chronological age, anthropometric characteristics and specific functional swimming capacities in youth U12 water polo players

	r	P	r	P	r	P	r	P
Age (Q)	-0.333	<0.001	-0.254	0.00	-0.131	0.119		
Front crawl, 25 m (s)	-0.388	<0.001	-0.107	0.203	0.078	0.353	0.102	0.224
Front crawl, 50 m (s)	-0.323	<0.001	-0.047	0.578	0.117	0.169	0.022	0.781
Front crawl, 100 m (s)	-0.226	0.016	0.081	0.397	0.218	0.021	-0.053	0.567
Front crawl, 400 m (s)	-0.113	0.184	0.011	0.897	0.070	0.406	-0.073	0.349
Dribbling, 25 m (s)	-0.356	<0.001	-0.013	0.122	0.036	0.674	0.070	0.362
Front crawl leg kicking, 25 m (s)	-0.139	0.152	0.055	0.575	0.149	0.122	0.130	0.179
Eggbeater kicking, 25 m (s)	-0.182	0.060	0.099	0.306	0.235	0.015	-0.084	0.385

*Significant correlation between variables, $P < 0.05$. BMI – body mass index; Q – quarter of the year players were born in. Eggbeater – swimming in semi-horizontal body position with legs only, using eggbeater kick (cyclical movement consisting of alternating the circular and continuous movements of the legs, an alternating circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation, producing an upward force and maintaining players afloat in a vertical position), while hands were neutralized with the ball, and head over the water surface. Dribbling - dribbling the ball from wall to wall of the swimming pool, without throwing it and touching the wall with one hand.

There were no strong correlations between tested variables. Although P was significant for the correlation between the age categories and body height (r=-0-333, P=0.001) and body weight (r=-0.254, P=0.002), as well as between body height and certain specific functional swimming tests (25 m crawl r=-0.388, P<0.001; 50 m crawl r=-0.323, P=0.001; 100 m crawl r=-0.226, P=0.016; 25 m dribbling r=-0.356, P=0.001), correlation coefficient r showed weak or low correlation (Table 3).

The statistical significance maybe was reached due to the large sample size (more than 100 subjects), and it has little practical importance (Taylor, 1990). Multiple regression analysis did not show any predictive value of chronological age as a dependent variable on anthropometric characteristics andspecific functional swimming capacities (independent variables) in youth U12 water polo players. The association between age-group water polo players' specific motor / swimming abilities and their anthropometric indices are provided in Table 4, showing no predicting value ofthe chronological age for the specific swimming abilities and anthropometric indices in youth U12 water polo players.

Table 4. Multiple regression analysis showing the predictive status of chronological age for the specific swimming abilities and anthropometric indices in youth U12 water polo players (N=170)

	β coefficient	SE	P*
Front crawl, 25 m (s)	0.103	0.179	0.564
Front crawl, 50 m (s)	-0.002	0.097	0.980
Front crawl, 100 m (s)	-0.313	0.037	0.530
	β coefficient	SE	P*
Front crawl, 400 m (s)	-0.023	0.003	0.554
Dribbling, 25 m (s)	-0.007	0.109	0.951
Body height (cm)	-0.267	0.085	0.247
Body weight (kg)	-0.132	0.113	0.595
Body mass index (kg/m^2)	0.352	0.111	0.263
Least squares multiple regression			
Coefficient of determination R^2	0.256		
R^2-adjusted	0.213		
Multiple correlation coefficient	0.391		
Residual standard deviation	1.089		

2.1.4. Discussion

With regard to the study aims, there are three most important findings. First, older youth players' born in Q1 chronological age category had significantly higher values of the body height and weight than their younger peers. Second, there were no significant differences between players in different chronological age categories in their specific functional swimming capacities, although we have hypothesized differently. Third, chronological age showed low correlation with the body height and weight, while there were no correlations between chronological age and specific functional swimming capacities. Other than moderate correlations between body height and 25 m front crawl and 25 m dribbling the ball, other specific functional swimming test showed low or no correlations with anthropometric variables.

Many previous studies showed tested swimming capacities as valid predictors of players' achievements, specifically between qualitatively different groups of players (for example national team players vs. lower performance level) (Falk i sur., 2004, Uljević i sur., 2021, Dimitrič i sur., 2022, Kovačević i sur., 2022). In this study the results did not discriminate older players over their younger peers in any conducted functional tests, but one should consider their chronological age as prepubescent, therefore differences between them were not prominent yet. We can only speculate that in older age of the puberty and intensive physical maturation differences in anthropometric characteristics and specific functional swimming capacities between older and younger players might be more distinguished. Still, one should be precautious in initial selection of youth water polo players based on showed results because besides functional and motor skills which are desirable to be well developed, many other skills such as general and specific endurance, agility, accuracy, coordination, reaction time, speed, cognitive skills, anticipation and decision-making time, game intelligence etc. contribute to the development of an elite water polo player. Youth water polo players with dominant anthropometric characteristics and well-developed specific functional swimming capacities have good predispositions to develop other important aspects of technical-tactical and situational demands of water polo game in order to become a successful elite water polo player, although in tested age group they hadnot yet reached the highest levels of motor skills and abilities on which decision-making abilities are based (Malina i sur., 2004).

The knowledge of youth specific functional swimming capacities and their chronological, as well as biological development in water polo, using a multivariate approach might improve developmental program processes in youth water polo and might assist in role assignments between different playing positions in water polo teams. Such approach might also help in selection of appropriate game strategy and tactics, according to the capabilities of the selected players. Contrary to what was hypothesized in this study, older water polo players presented only better anthropometric characteristics, while their specific functional swimming capacities were similar to their younger peers, probably due to the biological maturity influence on functional skills, as well as small range of chronological age differences (Lopez-Plaza i sur., 2021). Considering the observed anthropometric differences showed in the current study, an individualized training programs based on growth and development of young players is highly suggested.

Even if the current study included a multivariate approach to youth water polo performance, it has the limitation of presenting a different number of players per each age category, as well as small chronological age differences between groups, the players involved all belonged to the same age group, resulting with small or no differences in measured variables. Longitudinal studies on different age groups are therefore highly suggested for further analysis.

2.1.5. Conclusion

Data from the current study contribute to the specific knowledge about youth water polo players' anthropometric characteristics, as well as their performance of specific functional swimming capacities in pre-puberty developmental phase. Such data might provide an understanding of the general and specific water polo player's development process, which should be considered by coaches of youth players to improve their skills as a result of developing better training programs. Specific functional swimming capacities can be best trained because they are more modifiable, while the anthropometric characteristics should be sought in the process of identification and selection of talented players (height, arm span, extremities length). Still, those variables can only serve as possible prerequisites for the development of successfulwater polo player along with well-developed agility, speed, accuracy, coordination, game intelligence, cognitive skills and anticipation.

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2.2. Cognitive Functions of Youth Water Polo Players

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Cognitive Functions of Youth Water Polo Players

Neven Kovačević[1,2], Frane Mihanović[3], Linda Lušić Kalcina[4], Vladimir Pavlinović[1], Nikola Foretić[1], Tea Galić[4,5]

[1]University of Split, Faculty of Kinesiology, Split, Croatia, [2]Croatian Water Polo Federation, Zagreb, Croatia, [3]University of Split, Department of Health Sciences, Split, Croatia, [4]University of Split School of Medicine, Department of Neuroscience, Split, Croatia, [5]University of Split School of Medicine, Department of Prosthodontics, Split, Croatia

Abstract

Some previous studies suggested that children's engagement in sports has been associated with the improvement of cognitive functions, especially working memory, visual-spatial memory, motor coordination and cognitive flexibility. The aim of this study was to compare cognitive functions between female and male youth water polo players and the control subjects – school children of the same chronological age who did not participate in organized sports activity. There were 23 female (14.65±1.11 years old) and 23 male (14.52±0.51 years old) water polo players (WP), members of Croatian National team enrolled in this study for cognitive testing (Stroop test). The control group consisted of 8 female (14.75±0.89 years old) and 18 male (14.28±0.89 years old) school students who did not participate in organized sports activity. There were no significant differences in psychomotor speed (Stroop Off), while youth water polo players showed better response inhibition (Stroop On) (WP 65.33±9.09 s vs. control subjects 72.78±11.97 s, P=0.030) and psychomotor ability (OnTime minus OffTime) (WP 7.22±5.18 s vs. control subjects 14.13±9.22 s) (P<0.001) than control subjects. The findings of this study suggest that children who participate in high-level water polo develop better cognitive flexibility than school students who do not participate in organized sports activity.

Keywords: *team sport games, school children, psychomotor ability, inhibition*

2.2.1. Introduction

Regular physical activity is known to have numerous physical benefits including prevention of the most prevalent lifestyle chronic diseases: coronary heart disease, stroke, obesity, type II diabetes and specific types of cancer, as well as enhancing cognitive function (World Health Organization, 2010). Participating in physical activities and exercise can improve the physical, perceptual, and cognitive well-being (Mandolesi i sur., 2018). Moreover, superior performance of athletes with the result of the long-term practice has also been observed in some perceptual motor skills, like reaction time (Mann i sur., 2007; Best & Miller, 2010; De Waelle i sur., 2021). To date, the literature supports the causal link between regular physical activity and brain development particularly in the prefrontal cortical area (Best & Miller, 2010). It is well known that children's engagement in sports has been associated with the improvement of cognitive functions (De Waelle i sur., 2021). Also, it has been proven that playing high-level team sport games demands well-developed cognitive functions (Kamijo i sur., 2011; Bizdan-Bluma & Lipowska, 2018; De Waelle i sur., 2021).

Cognitive functions include memory, attention, visual-spatial and executive functions, while language and thinking (abstract, cause and effect, creative thinking and planning) represent complex cognitive processes. Executive functions (EF) include specific mental skills such as inhibition (inhibitory control, including self-control and interference control – selective attention and cognitive inhibition), working memory and cognitive flexibility (Halligan i sur., 2003; Bizdan-Bluma & Lipowska, 2018). They represent skills essential for mental and physical health; success in school and in life; and cognitive, social, and psychological development. Inhibitory control involves being able to control one's attention, behavior, thoughts, and/or emotions to override a strong internal predisposition or external stimulus, and instead do what is more appropriate or needed. Inhibitory control of attention (interference control at the level of perception) enables us to selectively attend, focusing on what we choose and suppressing attention to other stimuli, which might be useful in sports (Best & Miller, 2010; Diamond, 2013). Another EF is working memory, divided in verbal and non-verbal – visual-spatial working memory, also involved during sports activities (Diamond, 2013). And third component of EF is cognitive flexibility, meaning being able to change perspectives spatially or interpersonally. EF make it possible for us 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 sport games on high level (Diamond, 2013).

Interestingly, it has been shown that elite athletes outperform non-elite athletes on more complex nonsport-specific neurocognitive functions such as inhibition (Mann i sur., 2007; Vestberg i sur., 2012). In the study of Vestberg and colleagues (2012), it was reported that EF even predicted later performance in soccer in terms of scoring goals and providing assists. Also, it has been proven that team sport games players have better EF compared to players from other sports (Kamijo i sur., 2011).

One of the sports that requires a high level of perceptual and motor performance is water polo, as a highly demanding physical contact team sport taking place in water, not natural environment for human being, mainly including opened skills (Smith, 1998; Botonis i sur., 2015). Water polo players need to process real-time actions with regard to teammate positions and ball path while constantly updating that information in working memory. They need to be able to inhibit planned actions, for example passing the ball instead of scoring themselves and they need to have well developed cognitive flexibility for better and faster adaptation to the game dynamics of one specific high-level game (Botonis i sur., 2015; Diamond & Ling, 2016; De Waelle i sur., 2021).

Water polo as a game includes cognitive components such as anticipation, problem solving and decision making, similar as in other team sport games (Smith, 1998; Botonis i sur., 2015). In the study of Falk i sur. (2004) those cognitive functions were subjectively evaluated by the coaches during only 2-3 games each season, indicating better scores by the players selected to the youth national team. Also, Kovačević i sur. (2023) showed better cognitive functions of the selected players, objectively evaluated using the Stroop test. Still, both studies evaluated only cognitive functions of youth water polo players, without the comparison with the control subjects, presenting the research gap and the need for more studies about cognitive functions of youth water polo players.

Water polo has been chosen in this study because it challenges physical, perceptual and cognitive performance and the literature on the association of the cognitive performance and development in children practicing water polo is limited. Therefore, the aim of this study was to compare cognitive functions between female and male youth water polo players and the control subjects – school children of the same chronological age who did not participate in organized sports activity. It was hypothesized that children who play water polo at a high level would show better cognitive functions, especially concerning cognitive flexibility and inhibition.

2.2.2. Methods

Participants

There were 46 water polo players (23 female / 50%) between 12 and 16 years old (Mage=14.59±0.86) and 26 school children who did not participate in organized sports activity (8 female / 30.8%) between 13 and 16 years old (M_{age}=14.42±0.90) included in this study. Water polo players self-reported mean of 5 years of training experience with at least 5 training sessions per week, lasting approximately 2 hours, while control subjects self-reported no training experience in organized sports activity. The inclusion criteria for water polo group was selection to the national water polo team and for the control group no training experience in any sports. Measurements for this study were conducted from the season 2020/2021 until 2022/2023.

This 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.

Measurements and procedures

Anthropometric variables included body mass and height which were measured using a stadiometer and a digital scale, respectively, while the subjects wore only light clothes. Body mass index (BMI) was calculated as body mass (kg) divided by height squared (m^2).

The detail of the experimental setup was previously explained (Kovačević i sur., 2023). Cognitive functioning of the participants was measured using The EncephalApp_Stroop application (MacLeod, 1991; Homack & Riccio, 2004; Bajaj i sur., 2013) which was downloaded from the Google Play app store (EncephalApp Stroop) on the 7’’ HD C80 MeanIT tablets (MeanIT, China). The reliability and validity of the application has been well reported previously (Bajaj i sur., 2015; Luo i sur., 2020). In addition, the reliability of The EncephalApp_Stroop application has been confirmed in our previous study, in a sample of 24 water polo players and test-retest showed correlation coefficient for OffTime r=0.872 (95% CI 0.723-0.944) and OnTime r=0.890 (95% CI 0.760-0.952), respectively (Kovačević i sur., 2023).

The tablet screens were used to administer the task to all subjects. Tests were performed in the quiet, bright room with separate desks and it was performed in groups of 8 to 10 participants. Before the test, participants received a detailed explanation of the test battery. A trained researcher was present to ensure the test was executed correctly, without any noise, and to answer any additional questions. The participants did not report prior experiences in Stroop test.

The Stroop test comprises two components: “Off” state presenting congruent stimuli and “On” state presenting incongruent stimuli. Both components were administered after two training runs. In the easier “Off” state, the participants viewed a neutral stimulus, hashtag signs (###) presented in red, green or blue, one at a time and had to respond as quickly as possible by touching the matching color of the stimulus to the colors displayed at the bottom of the screen. The colors at the bottom of the screen were randomized and not fixed to their respective positions. In more challenging “On” state, nine of the ten presented stimuli were incongruent. The participants had to accurately touch the color of the word presented on the screen which was contradictory to the actual color, for example the word “blue” was displayed in green color and the correct response was “green”, not “blue”. Both parts of the test consisted of five runs with 10 different tasks in each run and if the participant made a mistake, pressed a wrong color, the run stopped and had to restart again until completing all five runs correctly (Bajaj i sur., 2013; Scarpina & Tagini, 2017).

The specific outcomes of the Stroop test were OffTime – total time for five correct runs in the “Off” state, primarily assessing psychomotor ability; OnTime – total time for five correct runs in the “On” state which is a measure of response inhibition and motor speed. OnTime minus OffTime presented a measure of cognitive processing controlling for psychomotor speed and OffTime plus OnTime showed a composition measure of psychomotor speed and response inhibition (Bajaj i sur., 2013; Scarpina & Tagini, 2017).

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 cognitive performance between youth water polo players and school children who did not participate in organized sports activity were tested using Mann-Whitney *U* test. Additionally, a multiple regression analysis was used to determine a relationship between selected independent variables (participation in sports coded as 0-no participation and 1-currently participating in sports, age, gender, BMI) with the outcomes of the Stroop test as dependent variables (StroopOn time, StroopOff time, Ontime minus Offtime, Offtime plus Ontime). The statistical significance was set at $p<0.05$.

2.2.3. Results

There were 46 water polo players (WP), 23 females (50%) and 18 males (50%), with the mean age 14.59±0.74 years (median 14, 12-16 years) and 26 control subjects (C) – school children who did not participate in sports regularly, 8 females (30.8%) and 18 males (69.2%), with the mean age 14.37±0.93 years (median 15, 13-16 years) (p=0.567). Descriptive statistics of the whole study sample is presented in Table 1. Water polo players performed faster in StroopOn Time (65.33±9.09 s) than control subjects (72.78±11.97 s) (p=0.030), as well as in OnTime minus OffTime (WP 7.22±5.18 s vs. C 14.13±9.22 s) (p<0.001) (Table 1).

Table 1. Descriptive Statistics for Total Sample of Participants and Comparison of Results of Anthropometric Variables and Cognitive Performance between Youth Water Polo Players and Control Subjects

	Variables	**Total study sample N=72**	**WP N=46**	**Control subjects N=26**	**p**
Anthropometric characteristics	Age (years)	14.53±0.87	14.59±0.86	14.42±0.90	0.708
	Body height (cm)	172.13±8.88	174.33±8.60	167.40±7.68	0.003*
	Body mass (kg)	65.28±10.08	67.15±9.95	61.28±9.36	0.029*
	Body mass index (kg/m^2)	21.98±2.59	22.05±2.63	21.82±2.55	0.939
Cognitive functions	StroopOff time (s)	58.31±6.14	58.12±6.39	58.65±5.80	0.673
	StroopOn time (s)	68.02±11.16	65.33±9.09	72.78±11.97	0.030*
	StroopOff+StroopOn time (s)	126.33±16.33	123.45±14.84	131.42±17.84	0.098
	Ontime minus Offtime (s)	9.71±7.62	7.22±5.18	14.13±9.22	<0.001*

Note. Data are presented as mean±standard deviation. *Mann Whitney U test; p<0.05. WP - water polo players.

A multiple regression analysis showed that independent variables (participation in sports – water polo, gender, age and BMI significantly predicted StroopOn Time (F=3,3784, p=0.015, R^2=0.181) and OnTime minus OffTime (F=5,4258, p<0.001, R^2=0.262). Out of independent variables included in the model, only participation in sports (water polo) contributed significantly to the prediction of higher cognitive performance measured by StroopOnTime minus OffTime (p<0.001, R^2=0.262) (Table 2).

Table 2. Multiple Regression Analysis Showing the Predictive Status of Participation in Sports (Water Polo), Age, Gender and Body Mass Index on Cognitive Performance

	β coefficient	SE	t	p
StroopOff time				
Participation in sports	1.395	1.686	0.828	0.411
Gender	-0.476	1.633	-0.037	0.772
Age	-0.676	0.895	-0.755	0.453
Body mass index	0.222	0.304	0.093	0.468
R^2=0.030; R^2-adjusted=-0,033; F=0,474; p=0.755				
StroopOn time				
Participation in sports	10.047	2.886	3.482	<0.001*
Gender	-1.713	2.796	-0.613	0.543
Age	-1.130	1.533	-0.737	0.464
Body mass index	0.313	0.520	0.601	0.550
R^2=0.181; R^2-adjusted=0.128; F=3.378; p=0.015*				
StroopOff+StroopOn time				
Participation in sports	11.443	4.331	2.642	0.010*
Gender	-2.189	4.196	-0.522	0.604
Age	-1.806	2.300	-0.785	0.435
Body mass index	0.535	0.781	0.685	0.496
R^2=0.121; R^2-adjusted=0.064; F=2.107; p=0.091				
StroopOn minus StroopOff time				
Participation in sports	8.652	1.894	4.569	<0.001
Gender	-1.237	1.835	-0.674	0.503
Age	-0.454	1.006	-0.451	0.653
Body mass index	0.091	0.342	0.266	0.791
R^2=0.262; R^2-adjusted=0.214; F=5.426; P<0.001				

Note, β coefficient – multiple correlation 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.

2.2.4. Discussion

There are three main findings of this study. First, youth water polo players showed a better performance in psychomotor speed, response inhibition and motor speed than school children not participating in organized sports activity. Second, participation in water polo was found to be a significant predictor of cognitive functions in school children at the age of 12 to 16 years. And third, youth water polo players had higher values of body height and weight than their sedentary peers.

Cognitive functions

Coordinative activities, such as walking, running, jumping, kneeling, throwing, grasping, have been hypothesized to train and increase the activity in the cerebellum and prefrontal cortex and to improve such executive functions as working memory, focused attention and cognitive flexibility (Budde i sur., 2008). In such activities, children must quickly integrate available information to make split-second decisions, as well as to plan and perform a sequence of habitual or unfamiliar actions (Stratton i sur., 2004). Considering the nature of water polo, which stimulates components of visual-spatial attention, players need to be able to search and select targets from a spatial field requiring not only visual selective or focal attention, and peripheral visual acuity to move the attentive focus. In addition, water polo also requires more sophisticated metacognitive strategies (Stratton i sur., 2004). During a match, players have to process, more or less at the same time, cues including opponents' and teammates' positions and the ball's location and direction of movement. Water polo is categorized as mostly open skills sport, characterized by activities rich in distractors, played in water, an unusual environment for human being. So, this sport should act as a powerful challenge to the ability to inhibit distractionand to stay focused for better and faster adaptation to the game dynamics of one specific high-level game (Smith, 1998; Botonis i sur., 2015; Sekulić i sur., 2016). Current study reported faster OnTime of water polo players in comparison to control subjects. This is consistent with categorization of water polo among the "thinking games", where the environment constantly changes and movements have to be continuously adapted (Smith, 1998). Actions must be continually updated and changed due to teammates' actions, the ball's movement, the opponents in the swimming pool. These factors are relevant to adapting, planning, problem-solving, the use of cognitive control and inhibition of first inclinations (Diamond, 2013). Youth water polo players showed better performance in psychomotor speed and response inhibition compared to school children who did not participate in organized sports activities, which is consistent with other studies that have examined the difference between athletes and non-athletes in this age group (Alesi i sur., 2016; Ishihara i sur., 2016; Ishihara i sur., 2017). For example, Alesi i sur. (2016) showed improvement of executive functions (agility, visuo-spatial working memory, attention, planning and inhibition) by children practicing football compared to the sedentary group, although children in their study were evaluated before and after only 6 months of a Football Exercise Program compared to a control group of sedentary peers.

Ishihara i sur. (2016) provided evidence for the relationship between cognitively engaging exercise (i.e., game-based tennis training and coordinative exercise) and improved executive functions in 6 to 12 years old children. A longer duration of game-based exercise was positively correlated with inhibitory control and physical fitness. Coordination training was associated with improved working memory. Non-physical activity was inversely correlated with inhibitory control, working mem-ory, and physical fitness. The results suggest that game-based tennis lessons have beneficial effects on inhibitory control and physical fitness levels, and a longer duration of coordination training is associated with better working memory (Ishihara i sur., 2016). In another study of Ishihara i sur. (2017) findings suggest that tennis play is associated with the development of three foundational aspects of executive function – inhibitory control, working memory and cognitive flexibility, in children 6 to 15 years old. Especially, frequent participation in tennis play is related to better inhibitory control and working memory, while longer experience of tennis play is associated with better cognitive flexibility (Ishihara i sur., 2017). Although tennis belongs to self-paced sports including mostly closed skills, the results of the present study are in accordance to these findings, so additional research is needed to compare executive functions development among youth water polo players and children practicing other team sport games, as well as self-paced sports.

It has been suggested that water polo may affect the development of EF through multiple pathways: as an exciting and enjoyable activity (increasing enjoyment); by producing an "enriched environment" that places demands on multiple EF, thereby challenging and improving them; by creating opportunities for social interaction, cooperation with others, sharing leisure experiences, and receiving the encouragement of peers, increasing a sense of belonging and social support and a sense of ability and competence; and by improving motor skills and physical fitness (Alesi i sur., 2016).

To the best of our knowledge, there are only few studies investigating cognitive functioning in children practicing water polo, but those studies considered only influence of cognitive functions on the selection and identification of the talented players (Falk i sur., 2004; Kovačević i sur., 2023). Specifically, water polo as a complex team sport employs exercises in a cognitively-engaging context and implies sophisticated and complex moves which are regulated by the prefrontal neural network. It requires high cognitive engagement and impacts many of the same processing components as those implied in executive functioning tasks: involving in a relevant task, shifting the focus of processing activities, updating of information, monitoring mental representations and inhibiting irrelevant responses. Moreover, water polo stimulates strategic and goal-directed behaviours when faced to constantly changing situations and movements (Best & Miller, 2010). The impact of water polo on the cognitive development has been explained through multiple pathways: 1) neuro-physiological by inducing changes in the brain structure; 2) contextual by producing an "enriched environment"; 3) social by creating opportunities of social interaction, cooperation with teammates, respecting rules, sharing leisure experiences, receiving the encouragement of peers; 4) motivational by increasing self-concept and self-awareness (Barenberg i sur., 2011; Alesi & Pepi, 2013).

Many previous studies demonstrated the positive relationship of sports participation to multiple aspects of executive functions in children, suggesting that the frequency of participating in sports activity may be an important factor for development of inhibitory control and working memory (Ishihara i sur., 2017). Such results may also be supported by our findings showing better cognitive functions of high-level water polo players, members of youth national teams, in comparison to children of the same age with no training experience in organized sports activity. Sensorimotor learning in sports and cognitive engagement during exercise has been postulated as a key mechanism linking training and cognitive enhancement, and water polo requires both, cognitive engagement and sensorimotor learning (Best & Miller, 2010; Diamond, 2013).

Anthropometric characteristics

Concerning the anthropometric variables, water polo players showed higher values of body height and weight which might be explained by specificity of the game. It has been indicated in previous studies that physical abilities and anthropometric characteristics are important factors to achieve a good level of quality in technical-tactical actions, both for young and adult water polo players, especially considering constant physical contact during the game (Sekulić i sur., 2016, Vieiro i sur., 2020, Kovačević i sur., 2023, Kovačević i sur., 2023). Greater body height and longer extremities allow players to reach for the ball more easily, to shoot and to perform blocks more efficiently (Idrizović i sur., 2014, Dimitrić i sur., 2022). Similar results have been presented in different sports such as volleyball or football (Tatar & Cupic, 2011).

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, showing benefits of sports activities on cognitive development of children. The main limitation is the inclusion of unequal sample of participants (46 water polo players and 26 school children who did not participate in organized sports activity). Also, there is a need for use a larger battery of cognitive tests for assessment of different EF components as in the study of Alesi i sur. (2016) or Ishihara i sur. (2017). Future studies using longitudinal or interventional designs and more diverse measures (e.g. age and gender differences, socioeconomic status, different sports) should investigate the associations among EF, sports activity, and gender specificity of these relationships. Additionally, since it has been shown that more frequent tennis play is associated with better working memory, the importance of increasing the frequency of sports activity participation in the development of EF has been emphasized even in physically active children (Ishihara i sur., 2017). Therefore, future studies should assess the relevance of the full timeline of training experience in the investigated outcomes regarding water polo players. Finally, since a gender specificity of the relationships between certain sports training exposure and EF has also been suggested (Ishihara i sur., 2017), larger samples including both genders are necessary in order to assess this issue in water polo players.

2.2.5. Conclusion

The present study supported the hypothesis that a more frequent and longer experience of participating in sports activity is associated with better inhibitory control, working memory and cognitive flexibility. High-level youth water polo players showed better results in psychomotor speed, inhibitory control and motor speed than sedentary children, taking both age gender into account. Still, well-developed cognitive functions may serve only as one of the crucial factor along with other components of athlete’s development in order to become an elite water polo player. 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 andphysical 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 to participate in organized sports activities. Still, additional research is needed to compare executive skills development among youth water polo players and children practicing individual open skills sports (e.g., martial arts, dancing, tennis) where the teammates' support and shared responsibility are not present. Examination of the effects of exercise programs built on closed skills sports (e.g., swimming, running) would also be of interest, because the environment is relatively fixed and predictable.

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Conflict of interests:

The authors declare that there is no conflict of interests.

2.2.6. References

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2.3. Gender Differences in Cognitive Functions of Youth Water Polo Players

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ORIGINAL SCIENTIFIC PAPER

Gender Differences in Cognitive Functions of Youth Water Polo Players

Neven Kovačević[1,2], Frane Mihanović[3], Linda Lušić Kalcina[4], Tatjana Matijaš[3], Ivan Rukavina[2], Tea Galić[4,5]

[1]Faculty of Kinesiology University of Split, Split, Croatia, [2]Croatian Water Polo Federation, Zagreb, Croatia, [3]Department of Health Sciences University of Split, Split, Croatia, [4]Department of Neuroscience, University of Split School of Medicine, Split, Croatia, [5]Department of Prosthodontics, University of Split School of Medicine, Split, Croatia

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*

2.3.1. 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 i sur., 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 cognitive 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 i sur., 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 i sur., 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 i sur., 2006; Best & Miller, 2010; Roivainen i sur., 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 i sur., 2007; Best & Miller, 2010; De Waelle, Laureys, Lenoir, Bennett, & Deconinck, 2021). Moreover, playing high-level team sport games demands well-developed cognitive functions (Kamijo i sur., 2011; Bidzan-Bluma & Lipowska, 2018; De Waelle i sur., 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 i sur., 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 i sur., 2019; Melchiorri, Triossi, Bianchi, Tancredi, & Viero, 2022). Kovačević i sur. (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 i sur., 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 i sur. 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 i sur., 2004). Also, Kovačević i sur. showed better cognitive functions of the selected players, objectively evaluated using the Stroop test (Kovačević i sur., 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 i sur., 2004; Kovačević i sur., 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 i sur., 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.

2.3.2. 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 indeks (BMI) was calculated as body mass (kg) divided by height squared (m^2).

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 i sur. (Kovacevic i sur., 2023; Kovačević, Mihanović, Lušić Kalcina, i sur., 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 i sur., 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 stylesin 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 i sur. (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).

2.3.3. 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 comcompared 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 highercognitive performance measured by StroopOff Time ($p<0.001$, $R^2=0.107$), StroopOn Time ($p<0.001$, $R^2=0.123$), StroopOff plus StroopOn Time ($p<0.001$, $R^2=0.126$) and StroopOnTimeminus 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

2.3.4. 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 i sur., 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 i sur. (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 i sur., 2006; Roivainen i sur., 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 i sur., 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 whichis an ability primarily under the influence of the synergy and tonus regulation mechanisms (Holden, 2004; Hyde, 2005; Roivainen i sur., 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 i sur., 2006; Gauvain & Richert, 2016), Huizinga i sur. (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 i sur. (Davidson i sur., 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 i sur., 2006). Knowing that such functions can be improved by physical activity and participation in sports, specially playing high-level team sport games (De Waelle i sur., 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.

2.3.5. 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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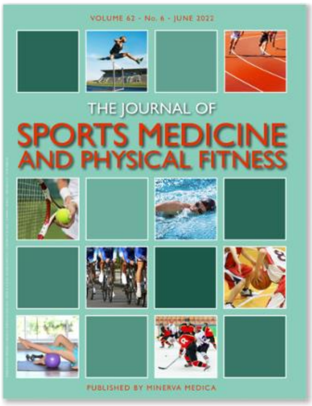

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Influence of cognitive performance and swimming capacities on selection of youth water polo players to national team

Neven KOVAČEVIĆ[1, 2], Frane MIHANOVIĆ[3], Linda LUŠIĆ KALCINA[4], Kristijan HRBIĆ[2], Tina POKLEPOVIĆ PERIČIĆ[5], Tatjana MATIJAŠ[3], Tea GALIC[4, 5 *]

[1]Faculty of Kinesiology, University of Split, Split, Croatia; [2]Croatian Water Polo Federation, Zagreb, Croatia; [3]Department of Health Sciences University of Split, Split, Croatia; [4]Department of Neuroscience, School of Medicine, University of Split, Split, Croatia; [5]Department of Prosthodontics, School of Medicine, Study of Dental Medicine, University of Split, Split, Croatia

ABSTRACT

BACKGROUND: Water-polo is an official competitive olympic sport with high energy and technical-tactical demands. The aim of this study was to evaluate the influence of cognitive performance and specific swimming capacities on the selection of youth water polo players to the national water polo team.

METHODS: There were 83 youth water polo players (mean age 13.61±0.67 years) who attended the Croatian Water Polo Foundation training camps included in this cross-sectional study. Testing included anthropometric measurements, specific swimming capacities and cognitive performance (Stroop test).

RESULTS: Among 83 youth water polo players included in this study there were 13 goalkeepers, 13 center-defenders, 13 centers, 31 perimeter players and 13 wings. Selected players (N.=40) performed faster in OffTime (selected 62.99±10.21 s vs. non-selected 69.98±8.93 s, P=0.002) and OnTime (selected 75.61±15.85 s vs. non-selected 86.01±15.40 s, P=0.004) of the Stroop test than non-selected players (N.=43). Logistic regression analysis showed significant association between selection of youth water polo players to the national team and swimming results in 400 m crawl and 100 m crawl, as well as OffTime, OnTime and OnTime minus OffTime on the Stroop test.

CONCLUSIONS: The results of this study showed that psychomotor ability, inhibition, motor speed and cognitive flexibility were found to be the most important predictors for the selection of youth water polo players to the national water polo team. Furthermore, selected water polo players demonstrated better psychomotor abilities, inhibition, and motor speed, as well as better results in all specific swimming tests in comparison to non-selected players.

Key words: Sports; Water sports; Swimming; Athletes

2.4.1. Introduction

Children's engagement in sports, independent of their age, has been associated with the improvement of cognitive functions, especially in regard to working memory, visual-spatial memory and cognitive flexibility, allowing for planning, inhibition or postponing of an action according to the given situation, as well as the improvement of motor coordination.[1-7] Cognitive functions include memory, attention, visual-spatial and executive functions, while thinking (abstract, cause and effect, creative thinking andplanning) and language functions represent complex cognitive processes.[8, 9] It has been reported that physical exercise lead to better oxygen supply to the brain with an increase in the level of oxyhemoglobin that facilitates the operation of executive functions.[5, 10-14] More specifically, physical activities stimulate the maturation of the motor areas in the brain, which in turn influences the motoric development and increases the speed of the conductance of nervous impulses.[13, 15, 16] Since sports performance involvesa combination of motor and perceptual-cognitive skills in order to select and execute appropriate actions, abilities such as to anticipate and make appropriate decisions occur to be important in sports.[17-19] Executive functions could be broken into more specific mental skills such as problem solving, planning, inhibition and decision making,[20] and they are highly utilized both in goal-oriented action under distraction and in novel response production when habitual dominant responses are apparent.[21] Team contact ball sports players seem to have an advantage in executive function compared to players from other sports,[21] because players need to process real-time actions with regard to teammate positions and ball path and constantly update this information in working memory. They also need to be able to inhibit planned actions when that might suddenly not be the best course of action, for example passing the ball instead of scoring themselves. It would be advantageous for them to have well developed cognitive flexibility for better and faster adaptation to the game dynamics and for adequate and efficient reaction on frequent situation changing of technical-tactical requirements of one specific high-level game.[22]

Water polo is a highly demanding team sport in which all players (goalkeeper, center-defender, center, perimeter players, wings) perform high-intensity activities separated by moderate-intensity and lower-intensity tasks in water. In such environment players constantly move through the field using different swimming intensity, receiving, dribbling and passing the ball, as well as shooting accurately on the goal using different techniques and completing many complex technical-tactical actions while wrestling with the opponents.[23-26] Water polo game re-quires efficacious specific skills and abilities which significantly depend on players' quality and capability to perform effectively in highly stressed situations during the game, with different roles and tactical demands according to their position in defensive or offensive actions.[27] However, regardless of the position, water-polo players are not only required to execute open and closed motor skills during the game, but also to process information, anticipate, make decisions and solve problems that occur during the game.[23] Considering that water polo players experience numerous rapidly changing unpredictable situations, expert performance in this field means to perceive the situation, process the stimuli, make the correct decision as fast as possible and carry out the action at the precise moment.[28, 29] Assessment of cognitive functions of young water polo players, along with functional and specific motoric abilities, may help coaches to identify talented players early and to lead, modify and develop their playing potentials and abilities.[30, 31] Team contact ball sports players seem to have an advantage in executive functions compared to players from other sports.[22] In team contact ball sports players need to process real-time actions with regard to teammate positions and ball path while constantly updating that information in working memory. They also need to be able to inhibit planned actions when that might suddenly not be the best course of action, for example passing the ball instead of scoring themselves. It would be advantageous for them to have well developed cognitive flexibility for better and faster adaptation to the game dynamics and for adequate and efficient reaction on frequent situation changing of technical-tactical requirements of one specific high-level game.[32] Despite a large number of professional and scientific publications on the technical and tactical aspects of team sports, literature on the association of the cognitive performance and early talent identification in team sports, particularly water polo, is limited. To the present, most publications focused on morphological, physiological, functional and motor characteristics of water polo players or technical-tactical on-court demands of the water polo game. To our knowledge, no previous studies have tested the hypotheses regarding cognitive functioning and specific skills development of youth water polo players. Accordingly, the aim of this study was to evaluate the cognitive and specific swimming tests of youth water polo players, and to determine the association of cognitive performance and specific swimming capacities with the selection of youth water polo players to the national water polo team.

2.4.2. Materials and methods

Participants and study design

This cross-sectional study initially included total of 85 youth water polo players, but two players were excluded from the final analyses because they did not fullfill the whole study protocol (one player left the training camp before all testings were performed due to the illness and one was not able to follow cognitive assessment due to the color blindness). Finally, 83 youth water polo players aged 13.61±0.67 years were included in this study. At the moment of testing all participants have been active in water polo for median of 5 years (4.64±1.89 years), with the median of 5 training sessions per week, lasting approximately for two hours. Out of 83 water polo players included in the study there were 13 goalkeepers, 13 center-defenders, 13 centers, 31 perimeter players and 13 wings. This study was conducted in full accordance with the ethical principles, including the World Medical Association Declaration ofHelsinki and it was approved by the Ethical Committee of the University of Split School of Medicine, Split, Croatia (N.: 2181-198-03-04-19-0053). Informed consent was obtained from parents or legal guardians after they were introduced to the background and the aim of the study. The inclusion criteria were participation in the Croatian Water Polo Fundation (CWPF) training camp at the age 13 or 14, their consent to participate and the signed informed consent of their parents or legal guardians. Participants who were not able to conduct the study protocol were excluded from the final analyses. The participants were selected in the CWPF selective, developmental programme training camps during the seasons 2018/2019 and 2019/2020 and their game positions were indicated for the purpose of the study by the head coach/leader of the CWPF training camps according to the players' positions in their teams. The CWPF training camps had been organized for past 10 years by the head coach-leader of the CWPF training camps, supported by 8-12 licenced water polo coaches who participated in all training activities assuring professional supervision of it. The training camps were usually organized during the school holidays or at the end of the school year, during the summer break, for three consecutive years, starting for players at the age of 12 who represent the initial selection continuing until the age of 14 as follows: players up to the age of 12 (U12), players up to the age of 13 (U13) and players up to the age of 14 (U14). The training camps lasted for four days, with seven training specific technical-tactical training sessions adjusted to the development level of youth players. The CWPF training camps had selective objecives and players were selected by their team coaches in collaboration and coordination with the head coach/leader of the CWPF training camps, mainly after the finals of the national water polo championships. At the end of the third year of participation and training in the CWPF training camps (U14 players), the water polo national team coach created a preliminary list of potential national team players. The selection was usually based on the personal impression of the national team coach, but it was also supported by the accomplished and analyzed results from the training camps. During the three years of organized training activities in the training camps, players trained regularly with their own teams, and they played the highest league for their age group, playing between 20 and 30 games each season.

Variables and measurements

In this study a battery of specific tests was assessed including anthropometric characteristics, specific swimming performance and cognitive functioning of youth water polo players. The main outcome of the study was the selection of players to the national water polo team (members *vs*. non-members of the national team). Anthropometric variables included body weight and height which were measured using a stadiometer and a digital scale, respectively, while the subjects wore only swimming trunks. Body Mass Index (BMI**)** was calculated as body weight (kg) divided by height squared (m^2). Specific swimming performance included sprint swimming (25 m front crawl), aerobic endurance (400 m front crawl for field players and 100 m butterfly for goalkeepers), anaerobic capacity (50 m front crawl), short distance swimming (100 m front crawl for field players and 100 m breaststroke for goalkeepers) and ball handling ability (25 m ball dribbling). Prior to the testing, the participants completed a 15-min convenient warm-up procedure, consisting of a dry land warm-up and 10-15 minutes of swimming, using different swimming techniques. Testings were carried out in groups of eight participants. The participants were timed with hand-held digital stopwatch (Longines, Saint-Imier, Switzerland) performing various distances and styles in 25-m swimming pool, starting at sound signal from the water. They were allowed to push-off the wall at the start and after a turn, but a flip turn was not allowed. They were instructed to swim at maximum speed for each test. Testing was carried out at four testing sessions. On the first day the participants were tested on aerobic endurance (400 m front crawl for field players and 100 m butterfly for goalkeepers), on the second day sprint swimming (25 m front crawl) and ball handling ability including 25 m ball dribbling. Participants 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. On the third day participants were tested on anaerobic capacity (50 m front crawl), while on the fourth day they were tested on short distance swimming (100 m front crawl for field players and 100 m breaststroke for goalkeepers). To avoid diurnal variations, all tests were performed in the morning from 9 a.m. to 11 a.m. Cognitive testing measured cognitive functioning of the participants, using The EncephalApp_ Stroop application.[33] The specific outcomes at the end of the Stroop app test were total time for five correct runs in the "Off" state (OffTime) primarily assessing psychomotor ability; number of runs needed to complete the five correct "Off" runs, total time for five correct runs in the "On" state (OnTime) which is a measure of response inhibition and motor speed, as well as number of runs needed to complete the five correct "On" runs. The test of cognitive processing controlling for psychomotor speed was subtracting the OffTime from the OnTime (OnTime minus OffTime).[33, 34] The Stroop test is widely used to measure the ability to inhibit cognitive interference, as well as multiple cognitive functions such as attention, processing speed, cognitive flexibility and working memory.[34, 35] The Stroop test is based on well-validated neuropsychological tasks that have been adapted to be suitable for computerized testing.[33-36] The Stroop (EncephalApp_Stroop) application[37] was downloaded from the Google Play app store (EncephalApp Stroop) and used on the 7" HD C80 MeanIT tablet (MeanIT, Zagreb, Croatia). The tablet screens were used to administer the task to all subjects. Tests were performed in the quiet, bright room with separate desks, and it was performed in groups of 10 participants. Before the test, participants received a general explanation of the test battery, as well as detailed explanations before each test. A trained researcher was present to ensure the test was executed correctly, without any noise, and to answer any additional questions. The participants had no prior experiences in Stroop test. The task had two components: "Off" and "On" state, depending on the congruence or incongruence of the stimuli. Both components were administered after two training runs were given for each state. In the easier "Off" state, the participants viewed a neutral stimulus, hashtag signs (###) presented in red, green, or blue, one at a time and had to respond as quickly as possible by touching the matching color of the stimulus to the colors displayed at the bottom of the screen. The colors at the bottom of the screen were randomized and not fixed to their respective positions. This continued until a total of 10 presentations which was one run and the total time taken for the run as well as the individual responses. If the participant made a mistake, pressed a wrong color, the run stopped and had to restart again. Therefore, the number of runs required to make five correct runs also indicated the number of mistakes. The "Off" state was continued until the participant had achieved five correct runs. The "On" state is more challenging from a cognitive standpoint in that incongruent stimuli were presented in nine of the ten stimuli. In this part of the test, the participants had to accurately touch the color of the word presented which was actually the name of the color in discordant coloring, for example the word "RED" was displayed in blue color and the correct response was blue, not red. Similar to the "Off" state, there were two training runs and then continued the task till five correct runs were achieved.[33, 34] Test-retest analysis using Pearson's correlation coefficient was performed for 24 participants and it showed correlation co-efficient for OffTime r=0.872 (95% CI 0.723-0.944) and OnTime r=0.890 (95% CI 0.760-0.952), respectively. All measurements were performed during the players' stay in the CWPF training camp and they consisted of three parts. On the first day of data collection anthropometric measurements were conducted. Swimming performance testing was conducted in the same order for each group of players (day 1-400 m front crawl/goalkeepers 100 m butterfly: day 2-25 m front crawl and 25 m ball driblling, day 3-50 m front crawl, day 4-100 m front crawl/goalkeepers 100 m breaststroke). Cognitive testing was conducted on day 3, in the morning right after the breakfast, between 8:00 a.m. and 9:00 a.m., in the quiet, bright room. All measurements were performed by the same coaches (anthropometric measurements, specific swimming tests) or trained researchers (cognitive testing).

Statistical analysis

Data analyses and sample size calculation were performed using statistical software MedCalc for Windows (Microsoft Corp., Redmond, WA, USA), version 19.4. (MedCalc Software, Ostend, Belgium). According to the calculations based on $\alpha=0.05$ and $1-\beta=0.8$ with respect to the results of Falk i sur.[31] (swimming 400 m, dribbling 50 m, game intelligence) the required sample size was 41 participants. Continuous data were presented as mean±standard deviation or median with the range. The Kolmogorov-Smirnov Test was used to assess normality of data distribution. Differences in cognitive performance and specific swimming capacities between selected and non-selected youth water polo players were tested using an independent samples t-test. Additionally, a logistic regression analysis was used to determine a relationship between selected independent variables (age, specific swimming tests, cognitive tests) with the selection to the national water polo team (dependent variable). The statistical significance was set at $P<0.05$.

2.4.3. Results

The mean age of 83 youth water polo players included for the final analyses was 13.61±0.67 years, with the mean body height 172.0±0.11 cm and weight 64.54±15.28 kg. The results of their specific swimming capacities and cognitive functioning are presented in Table I. The participants were divided in those who were selected to the national water polo team (N.=40) and non-selected players (N.=43). Selected players were significantly taller (175.63±10.56 cm vs. 168.45±9.93 cm, P=0.024) and significantly faster than non-selected players in all swimming tests, as seen in Table I. Regarding cognitive performance, selected players performed faster in OffTime (selected 62.99±10.21 s *vs.* non-selected 69.98±8.93 s, P=0.002) and OnTime (selected 75.61±15.85 s *vs.* non-selected 86.01±15.40 s, P=0.004) than non-selected players (Table I).

Table I. *Descriptive statistics for total sample of participants, selected and non-selected players with comparison of results between youth water polo players who were selected to the national water polo team and non-selected players.*

Variables	Total sample (N.=83)	Selected (N.=40)	Non-selected (N.=43)	P*
Age (years)	13.61±0.67	13.93±0.72	13.34±0.47	<0.001*
Body height (cm)	172.0±0.11	175.63±10.56	168.45±9.93	0.002*
Body mass (kg)	64.54±15.28	68.12±12.27	61.47±16.87	0.046*
Body Mass Index (kg/m2)	21.68±4.08	21.96±2.56	21.43±5.03	0.555
Front crawl, 25 m (s)	14.41±1.30	13.74±1.14	14.93±1.16	<0.001*
Front crawl, 50 m (s)	32.46±2.73	31.16±2.23	33.67±2.57	<0.001*
Front crawl, 100 m (s)	71.14±10.84	66.47±13.41	74.75±5.86	<0.001*
Front crawl, 400 m (s)	335.08±27.08	322.72±19.88	346.31±28.09	<0.001*
Breaststroke, 100 m (s)	99.97±4.99	99.37±4.93	101.95±4.55	NA
Butterfly, 100 m (s)	101.93±11.59	92.4±7.08	108.73±9.13	NA
Dribbling, 25 m (s)	15.48±1.44	14.84±1.15	16.06±1.44	0.017*
StroopOff time (s)	66.70±10.17	62.99±10.21	69.98±8.93	0.002*
StroopOn time (s)	81.12±16.45	75.61±15.85	86.01±15.40	0.004*
StroopOff+StroopOn time (s)	147.82±25.78	138.6±25.43	155.99±23.20	0.002*
Ontime minus Offtime (s)	14.43±9.15	12.62±8.02	16.03±9.77	0.092
Incorrect runs total time (StroopOff) (s)	6.60±8.14	6.34±7.96	6.84±8.29	0.781
Incorrect runs total time (StroopOn) (s)	10.35±11.90	10.34±11.97	10.35±11.84	0.996
Successful time (StroopOff) (s)	333.48±50.83	314.95±51.03	349.90±44.63	0.002*
Successful time (StroopOn) (s)	405.62±82.27	378.05±79.27	430.06±76.99	0.004*

Data are presented as mean±standard deviation.
*Independent samples *t*-test; P<0.05.

Logistic regression analysis showed significant association between selection of youth water polo players to the national team and 400 m front crawl (aerobic swimming test) and 100 m front crawl (anaerobic swimming test), as well as OffTime, OnTime and OnTime minus OffTime on the Stroop test (Figure 1; Table II). A better likelihood of being selected to the national team had players who performed faster in 100 m front crawl (OR=0.731, 95% CI: 0.535-0.998) and 400 m front crawl (OR=0.903, 95% CI: 0.825-0.988), as well as in StroopOff (OR=0.766, 95% CI: 0.766-0.766), StroopOn (OR=1.399, 95% CI: 1.399- 1.399), and OnTime minus OffTime (OR=0.697, 95% CI: 0.697-0.697), respectively.

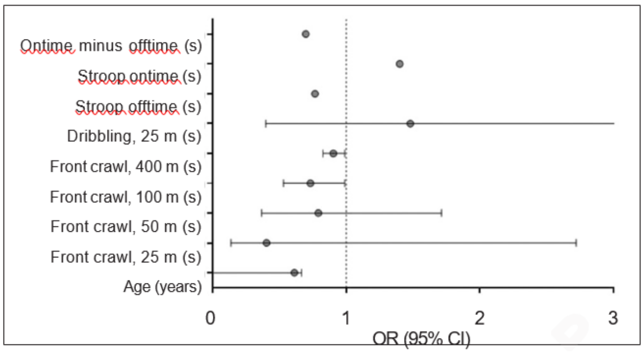

Figure 1. Logistic regression results (odds ratio) for determining a relationship between selected independent variables (age, specific swimming tests, cognitive tests) with the selection to the national water polo team (dependent variable). Ontime minus Offtime: a measure of cognitive processing controlling for psychomotor speed; StroopOn time: a measure of response inhibition and motor speed; StroopOff time: a measure of psychomotor ability.

Table II. *Logistic regression analysis performed in youth water polo players (N.=83) showing the predictive status of age, specific swimming abilities and cognitive performance with the selection to the national water polo team.*

Variables	ß coefficient	SE	P*
Age (years)	-3.241	1.446	0.025*
Front crawl, 25 m (s)	-0.492	0.761	0.518
Front crawl, 50 m (s)	-0.234	0.394	0.552
Front crawl, 100 m (s)	-0.313	0.159	0.049*
Front crawl, 400 m (s)	-0.102	0.046	0.026*
Dribbling, 25 m (s)	0.392	0.669	0.113
StroopOff time (s)	-0.267	0.001	<0.001*
StroopOn time (s)	0.336	0.001	<0.001*
Ontime minus Offtime (s)	-0.360	0.001	<0.001*
Overall model fit: ROC curve analysis			
Area under the ROC curve	0.862		
SE	0.045		
95% CI	0.752-0.936		

SE: standard error; ROC: receiver operating characteristic; 95% CI: 95% confidence interval.
*Significant difference between the groups, P<0.05.

2.4.4. Discussion

The main aim of this study was to investigate the association between cognitive and specific swimming performance of youth water polo players with the selection to the national water polo team. Psychomotor ability, inhibition, motor speed and cognitive flexibility, respectively, were found to be the most important predictors for selection of youth water polo players to the national water polo team. Specific swimming capacities, 400 m front crawl identifying aerobic endurance and 100 m front crawl, specific endurance swimming, identifying anaerobic capacity, also showed significant predicting values in selection of the youth water polo players.

Cognitive functioning

Cognitive functioning was found to be important factor in selection of youth water polo players to the national team. To successfully accomplish different technical-tactical demands of water polo game, besides speed-powerful and functional capacities, players should present well-developed cognitive inhibition and adaptation. Previously, in other sports such as soccer, the prognostic relevance of psychological talent predictors for young players was often reported and emphasized.[38] Additionally, findings have suggested that perceptual and cognitive skills also reliably discriminate elite from sub-elite soccer players between 9 and 17 years of age.[39] To the best of our knowledge, the current study is the first to report psychomotor ability, inhibition, motor speed and cognitive flexibility as important predictors for selection of youth water polo players. Accordingly, training processes in water polo should partly be oriented and modified to assess and develop cognitive functions of players. Such approach and development of cognitive flexibility, perception, concentration, and psychomotor speed should enable youth water polo players' high-level performance of previously adopted and automated specific technical-tactical elements of water polo game. Other than swimming abilities needed for successful transition from defense to offense, and vice-versa, during the water polo game, players with better psychomotor speed and cognitive flexibility might be in better condition while switching positions during the game. Earlier studies in soccer suggested that skilled defenders employed different visual search strategies, regardless of their actual playing position[40-42] and that different cognitive interventions are applied according to the playing position.[43] The link between cognitive performance and success has already been suggested in young soccer players, showing that reregarding working memory and cognitive flexibility correlate with the number of scored goals.[44] According to previous fidnings, high executive functions may predict athletic success in team sports like soccer.[44, 45] For early talent identification in water polo, it would be advantageous for coaches to assess cognitive functions of youth water polo players according to their specialized playing position in their team. Accordingly, it might be useful in training periodization and planning, as well as during the selection of talented players for specific playing positions. Falk *i sur.* suggested that future studies should place more attention on the assessment of various components of cognitive functions in young water polo players, following their reports of coaches' subjective evaluation of players' cognitive skills, such as decision making, anticipation and problem solving.[31]

Specific swimming performance

Specific swimming performance testing also showed significant predictive value in selection of youth water polo players to the national team. Swimming speed, efficient, fast, automated transition between defense and offense, along with the reaction speed are exceptionally important for attacking positions in water polo, but also for defensive roles, as well as for realization of extra players in transition – fast attack and counterattack.[35] Swimming movements from defensive to offensive role in the field, and vice-versa, require high physical endurance of water polo players. Players from the team which loses the ball and transits in defensive phase of the game, need to effectively stop the counterattack and to help the center who usually straggles in transition to the defense, because of high energy consumption during the intensive opposition and wrestling with the opponent center-defender during offensive actions. In such situation, the players who play offense need to react quickly and swim back to their defense positions. To achieve maximal sprinting, they must quickly change their position from facing the opponent's goal to facing their own goal while swimming, which is very difficult.[26] Therefore, water polo players should develop excellent speed-powerful swimming capacities, agility and endurance, as well as cognitive abilities which assure them fast reactions and adaptation on frequent, unpredictable technical-tactical situations during the game and capability for better adaptation to the demands of modern water polo.

Limitations of the study

There are some limitations of this study. Investigations with larger sample sizes for each position, primarily forgoalkeepers, are needed to determine the relationship between general perceptual cognitive abilities and position in the team. Future research should employ a longitudinal design with a follow-up and differentiation by playing positions, in order to better understand the cognitive performance development of youth water polo players, as well as comparison of such development between water polo players and children who do not participate in team sports.

2.4.5. Conclusions

Results of this study showed that youth water polo players who were selected to the national water polo team showed better results on the Stroop test, measuring psychomotor ability, inhibition, motor speed and cognitive flexibility, as well as better results in all specific swimming tests in comparison to non-selected players. Psychological assessment of water polo players might assist in role assignments between different playing positions in water polo teams, which could also help in selection of appropriate game strategy and tactics, according to capabilities of the selected players, contributing to the psychological balance within the team. Cognitive flexibility and psychomotor ability should be of interest to all ball game coaches and should be implemented in the process of early talent identification and selection to the national teams. In addition, psychological support could be of advantage to develop strategies for specific development training sessions. More theoretical and practical knowledge of these issues will enable coaches and physical educators to enhance the fundamental structures of talent detection and early development in sport, specifically water polo with intensive burst changes, high-intensity tasks separated by lower-intensity activities, including swimming, passing and shooting the ball to the goal accurately and completing complex individual and team technical-tactical tasks along with frequent contacts and oppositions with the opponents in all playing positions.

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Neven Kovačević, Linda Lušić Kalcina, Frane Mihanović and Tea Galic contirbuted to the data analysis; Frane Mihanović and Tea Galic contributed to the study supervision and to the manuscript draft. All authors read and approved the final version of the manuscript.

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2.5. Positional Differences in Youth Water Polo Players: Cognitive Functions, Specific Swimming Capacities and Anthropometric Characteristics

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Positional Differences in Youth Water Polo Players: Cognitive Functions, Specific Swimming Capacities and Anthropometric Characteristics

Neven Kovačević [1,2], Frane Mihanović [3], Linda Lušić Kalcina [4], Tatjana Matijaš [3] and Tea Galić [5,*]

[1] Faculty of Kinesiology, University of Split, 21000 Split, Croatia; nevenkovacevic@hotmail.com
[2] Croatian Water Polo Federation, 10000 Zagreb, Croatia
[3] University Department of Health Sciences, University of Split, 21000 Split, Croatia; frane.mihanovic@ozs.unist.hr (F.M.); tmatijas@ozs.unist.hr (T.M.)
[4] Department of Neuroscience, University of Split School of Medicine, 21000 Split, Croatia; linda.lusic.kalcina@mefst.hr
[5] Department of Prosthodontics, Study of Dental Medicine, University of Split School of Medicine, 21000 Split, Croatia
[*] Correspondence: tea.galic@mefst.hr; Tel.: +385-21-557-800

Abstract: Objectives: Water polo players ought to possess various physical capacities and well-developed cognitive functions that reflect the requirements of their specific playing position. Therefore, the objective of this study was to compare the cognitive performance, anthropometric characteristics and specific swimming capacities of youth water polo players in different playing positions. **Methods:** The present cross-sectional study involved 106 youth water polo players. The subjects were recruited as part of a project for talent identification and selection for the Croatian NationalWater Polo Team. Testing included anthropometric measurements, specific swimming capacities and cognitive performance (Stroop test). **Results:** Among the 106 youth water polo players, there were 15 goalkeepers (14.2%), 21 center-defenders (19.8%), 17 center-forwards (16.0%), 34 drivers (32.1%) and 19 wings (17.9%), with the mean age of 14.14 ± 0.38 years. The wings performed faster than center-forwards in both StroopOff time (wings: 57.14 ± 10.04 s vs. center-forwards: 67.03 ± 9.72 s, p = 0.016) and StroopOn time (wings: 66.18 ± 15.86 s vs. center-forwards: 80.24 ± 15.64 s, p = 0.019). **Conclusions:** In conclusion, this study demonstrated significant differences between different playing positions in youth water polo players, specifically between center-forwards and wings. They performed faster than center-forwards in all tested variables of the Stroop test, measures of psychomotor ability, response inhibition and motor speed, as well as in specific swimming capacities measured in the 50 m crawl and the 400 m crawl. The results of this study provide a valuable foundation for establishing developmental recommendations for different playing positions, aimed at improving player's performance. These recommendations should take into account anthropometric characteristics, specific functional swimming capacities and cognitive functions that influence players' game intelligence, which can be enhanced through properly designed training programs.

Keywords: water polo; cognitive functions; psychomotor ability; inhibition

2.5.1. Introduction

Cognitive Functions

Over the last two decades, there has been a growing interest in sports science, including perceptual–cognitive processes in sports, talent identification and performance success [1–8]. Nowadays, it has become widely accepted that for success in sports, an athlete should have a combination of extraordinary physiological capacities (aerobic and anaerobic capacity), specific technical and tactical skills and psychological and emotional characteristics (adaptation, emotional control and self-efficacy), as well as cognitive functions related to game strategy, such as perception, executive functions, attention, anticipation and decision-making [9–13]. The preparation program involves physical and cognitive components particular to a sport discipline, the level of performance, and the role of the player within a team [3,14–17]. Since all players obtain adequate physical and technical abilities, cognitive skills make a sharp distinction between players, positioning them in completely different athletic dimensions [18]. The ability to make prompt decisions is a substantial expectation in the majority of sports, especially in the case of fast and dynamic team sports like water polo. Such skills make a player capable to choose the most appropriate action for the given situation during the game

[13,18,19]. The results of the meta-analysis performed by Kalen i sur. [3] reported that high-level players demonstrated better cognitive decision-making skills than their low-level peers, indicating that these skills might be an important feature for athletic performance and success. Additionally, previous research by Kovačević i sur. [20] showed that youth water polo players selected in the national team outperformed their peers in the results of the Stroop test who did not reach that level of water polo performance. Similarly, Trecorci i sur. [21] showed a large positive correlation (r = 0.45, d-value = 1.01) of the cumulated score summarizing cognitive functions with the cumulated score summarizing sport-specific physical performance, suggesting that volleyball athletes with superior basic cognitive functions present better sport-specific physical performance. Vestberg i sur. [8] also showed that high division soccer players outperformed low division soccer players, in general, in terms of executive functions, which was also correlated with the numbers of goals and assists the players had scored two seasons later [3,8,20–23]. The results of previous research have also indicated that athletes perform better on selected cognitive tasks compared to the general population of the same age [18,19,24,25].

Similar to sport-specific requirements for physical and technical–tactical preparation, cognitive skills also vary for each type of sport, for different situations within a particular sport as well as for different playing positions [26–28]. Therefore, it can be assumed that in water polo, for particular positions of players on a field, cognitive features such as concentration (enabling the player to make the right decisions faster and to make fewer mistakes); peripheral vision (enabling the player to notice teammates and the opponents on the sides); decision-making, which enables the selection of the appropriate response in the specific playing environment; short-term memory (enabling the player to remember the position of teammates and the opponents on the field); and reaction time (due to the high pace of the game, quick throws, etc.) will play an essential role in athletic performance [17,26,29,30].

Water Polo

Among team sports, water polo is definitely a high-demanding one as it is characterized by organized physical contact among players. Water polo is a dynamic and strategic sport that not only requires physical strength and stamina but also engages a variety of cognitive functions to excel [17,31–33]. The combination of swimming, ball handling, and tactics in a water polo game demands a high level of mental processing, from decisionmaking to communication among teammates [34–36]. Anthropometric characteristics and swimming capacity play important roles related to the general performance level of a youth water polo player, as previously pointed out by various authors [17,20,31,37–41]. Although fewer studies have been published in the field of water polo compared to other sports, such as swimming, handball or soccer, position-specific differences in the anthropometric char acteristics of the players were reported [37,39–41]. These studies can provide a good basis for developing position-specific training programs by taking the anthropometric and body composition characteristics of the players into account. Accordingly, to develop positionspecific training programs, players' cognitive functions and mental strength should also be considered. Moreover, it has been proven that in addition to the physiological and biomechanical demands, technical, tactical and water polo-specific skills are important factors for successful participation at the elite level [20,33,42,43]. Players must make quick decisions in high-pressure situations. For example, when attacking or defending, they need to recognize opportunities (e.g., open teammates and a chance to shoot) and threats (e.g., defensive pressure or potential counterattacks) and respond swiftly. Reaction time is crucial, particularly when intercepting passes, defending shots, or responding to the movements of opposing players [44,45]. According to former studies, only a combination of performance characteristics can determine a player's performance level [17,28,36,46–48].

Playing Positions in Water Polo

A number of different playing positions in water polo show different game demands. Goalkeepers are required to constantly tread water between the goals and block shots made toward the goal. As the goalkeeper is the last line of defense and the first line of offense, a goalkeeper is expected to be courageous, agile, flexible and psychologically stable with a high level of concentration, reacting quickly to changing situations. They must have quick reflexes, excellent hand–eye coordination and the ability to read the opponent's offensive movements [27,38,44,49]. A center-forward plays between defenders, where he has to fight for the position and create a throw-in for himself. Therefore, he is expected to have the physical strength and high body mass required to engage in physical struggles with his opponent to hold key positions in the pool [28,34,50]. From a cognitive perspective, the center-forward is expected to have a wide range of external attention; the ability of multi-switching, positioning, reading the defense and decision-making under pressure; and a high level of working memory [28,33,38]. Wings are required to do large amounts of swimming up and down the sides of the pool to create scoring opportunities for their team and to prevent those of their opponents. The main objective of the wing position is to swim down to the 2 m line and be open to receive a pass. Wings are in a great position to make entry passes to the hole set, which can often result in an exclusion or kick out. By passing the ball to the wings, the entire offense is able to move closer to the goal for better scoring chances [32,33,37,40,44]. Therefore, wings need to have the greatest speed, agility and tactical awareness. Drivers are typically fast players that drive through the offense to create movement and goal scoring opportunities. The driver is usually the shooter in the team, playing the role of a defender as well, which requires multi-tasking and a high level of strength and fitness, similar as in handball [27,44,51]. The center-defender has the task of organizing actions and passing the ball effectively to teammates. This player needs strong defensive instincts and the ability to predict and block passes and shots. He is expected to make quick and accurate decisions, anticipate plays and demonstrate quick thinking [27,44,51].

Previous studies in water polo identified differences between specific playing positions, mostly in anthropometric characteristics, functional capacities or physical fitness profiles [37,40,52,53]. To optimize team performance, players in different positions along with different physical characteristics need to possess well-developed cognitive functions that reflect the requirements of their playing position [53–55]. The importance of cognitive functions in youth water polo players has been demonstrated in our previous study, where players selected to the youth national water polo team demonstrated better cognitive functions (psychomotor ability, inhibition, motor speed and cognitive flexibility) than non-selected players of the same age [20].

To the best of our knowledge, no studies have examined cognitive functions in water polo players according to their playing positions. Therefore, the objective of this study was to compare the cognitive performance of youth water polo players playing in different positions, along with the anthropometric characteristics and specific swimming capacities. Considering previously described specific demands of each playing position in water polo, the null hypothesis of our study was that wings will outperform players in other playing positions, specifically center-forwards, in cognitive functions. In addition, centerforwards will dominate through their anthropometric characteristics and show lower specific swimming capacities in comparison to other playing positions.

2.5.2. Materials and Methods

Participants

The present study involved 106 youth water polo players attending CroatianWater Polo Federation training camps for male water polo players under 14 years old (U14). The subjects recruited were part of a project for talent identification and selection to the Croatian National Water Polo Team. All participants had over two years of competitive water polo experience, with an average of five training sessions per week. At the time of data collection, their teams were playing at the top level of their respective age group (U14). Participants did not report any behavioral, learning or medical condition that might influence their cognitive function. Their physical fitness and educational level were comparable. There were 15 goalkeepers (14.2%), 21 center-defenders (19.8%), 17 center-forwards (16.0%), 34 drivers (32.1%) and 19 wings (17.9%), with an average age of 14.14 ± 0.38 years. This study was performed in accordance with the Declaration of Helsinki and approved by the Ethical Committee of the University of Split School of Medicine, Split, Croatia (No.: 2181-198-03-04-19-0053). All players and their parents/legal guardians received the detailed description of the study before providing their written informed consent.

Study Protocol

This study was performed from season 2019/2020 until 2023/2024 following the same protocol as in our previous studies [20,41]. The inclusion criteria were as follows: attendance in the CroatianWater Polo Federation camps, being active in water polo for at least 2 years, having at least 5 training sessions per week and played in the highest league for their age group. The exclusion criteria were color blindness and the inability to fulfill the study protocol. At the end of the season, when national championships for the U14 age category were finished, players from across the nation were invited to a 4-day training camp, specific for the U14 age category. On the first day, anthropometric measurements (body mass and body height) were collected, and subjects wore only swimming trunks. Swimming tests were performed in following order: first day: 400 m front crawls for field players and a 100 m butterfly test for goalkeepers; second day: 25 m front crawls and 25 m of ball dribbling; third day: 50 m front crawls and cognitive testing; and fourth day: 100 m front crawls for field players and a 100 m breaststroke test for goalkeepers. For cognitive evaluation focused on psychomotor ability, inhibition and motor speed the Stroop test with the following specification was conducted: early in the morning right after the breakfast, between 8:00 a.m. and 9:00 a.m. and in the quiet, bright room, while all swimming tests were performed in the morning from 9:00 a.m. and 11:00 a.m. in order to avoid diurnal variations.

Anthropometric Measurements

Anthropometric measurements were carried out according to conventional criteria and measurement procedures. Body mass was measured using a 100 g precision digital scale under standard conditions (wearing only swimming trunks). Height was measured with a 1 mm precision wall ruler. The body mass index (BMI) was calculated as body weight (kg) divided by height squared (m^2).

Specific Functional Swimming Tests

Specific functional swimming tests included a 25 m front crawl, a 50 m front crawl, a 100 m front crawl, a 400 m front crawl and 25 m of dribbling for field players and a 100 m butterfly test and a 100 m breaststroke test for goalkeepers. The testing was carried out in a 25 m pool; the start was at the signal sound from the water; the players were permitted to push off the wall, but in order for the test to be homogeneous, flip-turns were not allowed. Prior to the testing, the participants completed a 15 min convenient warm-up procedure, consisting of a dry land warm-up and 10–15 min of swimming, using different swimming techniques. The testing was carried out in groups of eight participants. The participants were timed with a hand-held digital stopwatch (Longines, Saint-Imier, Switzerland).

Cognitive Performance

For cognitive functions testing, a touchscreen version of the Stroop test (The EncephalApp_ Stroop application, version 15.6.1) was downloaded on tablets. Participants were tested under controlled environmental conditions in groups of 10 in an adequately prepared room for such research, i.e., proper lighting of the room, proper setting of the apparatus, and constant temperature; this ensured that none of the participants were disturbed. Players were asked to perform tasks according to the instructions presented on a computer screen. Throughout the test, two researchers (T.G. and F.M.) were present in the room and assisted participants as needed (e.g., when there were technical problems, interpretation of the task, etc.). During the testing procedure, participants sat at a table, with the dominant limb's hand open and placed at the table's edge. Participants were requested to respond as quickly and accurately as possible. The task included trials in two different conditions, i.e., congruent (StroopOff) and incongruent (StroopOn). At the beginning of the test, two training runs were given for each condition. In the easier StroopOff condition, the participants viewed a neutral stimulus, namely hashtag signs (###) that were presented in red, green, or blue, one at a time and had to respond as quickly as possible by touching the matching color of the stimulus to the color displayed at the bottom of the screen. The colors at the bottom of the screen were shown in a randomized order that was not fixed to their respective positions. If the participant made a mistake, such as pressing the wrong color, the run stopped, and he had to restart again. In the StroopOn condition, which is a more challenging part of the test, the participants were instructed to ignore the meaning of the words and to focus on the colors in which the words were printed on the screen. Both conditions were continued until five correct runs were achieved, therefore also indicating the number of mistakes. The specific outcomes of the Stroop test included the total time for five correct runs in the "Off" condition (OffTime), which primarily assessed their psychomotor ability; total time for five correct runs in the "On" condition (OnTime), which is a measure of response inhibition and motor speed; as well as the number of runs needed to complete the five correct "Off" and "On" runs. The test of cognitive processing controlling for psychomotor speed was subtracting the OffTime from the OnTime (OnTime minus OffTime), while OffTime + OnTime showed a composition measure of psychomotor speed and response inhibition [56–59]. The reliability of the Stroop test was tested using Pearson's correlation coefficient in test–retest analysis. It was performed in 24 participants, showing correlation coefficients for OffTime $r = 0.872$ (95% CI 0.723–0.944) and OnTime $r = 0.890$ (95% CI 0.760–0.952), respectively. A more detailed description of the test can be found in our previous study [20]. The mean response time was computed for each condition, considering only correct responses.

Statistical Analyses

Statistical analyses were performed using the MedCalc statistical software (Med- Calc Software forWindows, version 19.4, MedCalc Software Ltd., Ostend, Belgium). The assumption of homogeneity of the variance was tested using Levene's test, and the assumption of normality was checked using the Kolgomorov–Smirnov test. One-way ANOVA with the Scheffé post hoc test was used to determine the differences between the variables measured (anthropometric characteristics, specific functional swimming capacities and cognitive functions) in youth water polo players according to their playing position. Additionally, a one-way ANCOVA analysis with Bonferroni correction was used with the Stroop test outcomes as dependent variables, playing position as the independent variable (1 for a goalkeeper, 2 for a center-defender, 3 for a center-forward, 4 for a driver and 5 for a wing) and body mass and body height as covariates. Effect sizes (partial eta square) were reported [60], and the statistical significance level was set at $p < 0.05$.

2.5.3. Results

Baseline Characteristics of the Study Population

There were 106 players with a mean age of 14.14 ± 0.38 years (13–15 years) divided into five groups according to their playing position in the team: 15 goalkeepers (14.2%), 21 center-defenders (19.8%), 17 center-forwards (16.0%), 34 drivers (32.1%) and 19 wings (17.9%). The average body weight and height were 66.74 ± 11.21 kg and 176.65 ± 7.80 cm, respectively. Table 1 shows the data on the total sample (N = 106), reporting anthropometric characteristics, specific functional swimming capacities and cognitive functions.

Table 1. Anthropometric characteristics and performance tests for all tested players (N = 106).

Anthropometric Characteristics (N = 106)		
	Mean ± SD	**95% CI**
Age (years)	14.15 ± 0.36	14.082–14.219
Body height (cm)	176.65 ± 7.80	175.024–178.273
Body mass (kg)	66.74 ± 11.21	64.407–69.077
Body mass index (kg/m^2)	21.30 ± 2.78	20.724–21.882
Specific swimming capacities		
Crawl, 25 m (s) N = 91	13.70 ± 0.74	13.533–13.871
Crawl, 50 m (s) N = 91	30.10 ± 1.81	29.722–30.477
Crawl, 100 m (s) N = 91	96.41 ± 32.23	84.589–108.233
Crawl, 400 m (s) N = 91	314.62 ± 13.12	311.804–317.431
Breaststroke, 100 m (s) N = 15	96.90 ± 3.55	93.616–100.179
Butterfly, 100 m (s) N = 15	93.41 ± 10.84	83.390–103.433
Dribbling, 25 m (s) N = 91	14.65 ± 0.93	14.453–14.842
Cognitive performance via the Stroop test (N = 106)		
StroopOff time (s)	61.40 ± 9.40	59.589–63.210
StroopOn time (s)	72.52 ± 14.97	69.634–75.399
StroopOff + StroopOn time (s)	133.92 ± 23.66	129.358–138.473
Ontime minus Offtime (s)	11.12 ± 8.06	9.566–12.669
Incorrect runs total time (StroopOff) (s)	4.27 ± 6.39	3.042–5.504
Incorrect runs total time (StroopOn) (s)	6.307 ± 8.979	4.577–8.036
Successful times × attempts (Off) (s)	306.99 ± 47.01	297.94–316.05
Successful times × attempts (On) (s)	362.58 ± 74.83	348.17–376.99

Data are presented as the mean ± standard deviation and 95% CI. CI—confident interval.

One-Way ANOVA

We detected significant differences between different playing positions in anthropometric characteristics and specific functional swimming capacities, as shown in Table

2. Centerforwards had bigger body masses (77.99 ± 9.91 kg) and were taller (180.73 ± 5.98 cm) than drivers (63.18 ± 9.87 kg; 174.00 ± 6.34 cm) and wings (60.37 ± 8.16 kg; 171.83 ± 6.24 cm) (Table 2). Also, they were slower than drivers and wings in the 50 m crawl (center-forwards 31.27 ± 1.68 s vs. drivers 29.74 ± 1.28 s and wings 29.58 ± 2.09 s, p = 0.016) and the 400 m crawl (center-forwards 323.18 ± 14.67 s vs. drivers 311.53 ± 11.98 s, p = 0.020), as shown in Table 2. We found that players also differed in the results of the Stroop test. The wings performed faster than center-forwards in the StroopOff time (wings 57.14 ± 10.04 s vs. center-forwards 67.03 ± 9.72 s, p = 0.016), as well as in the StroopOn time (wings 66.18 ± 15.86 s vs. center-forwards 80.24 ± 15.64 s, p = 0.019), respectively.

Table 2. Comparison between playing positions.

Playing Positions	Goalkeepers N = 15	Center-Defenders N = 21	Center-Forwards N = 17	Drivers N = 34	Wings N = 19	p *
Anthropometric characteristics (N = 106)						
Age (years)	14.20 ± 0.41	14.14 ± 0.36	14.06 ± 0.24	14.15 ± 0.36	14.21 ± 0.42	0.756
Body height (cm)	180.93 ± 10.32 ^{d}	178.03 ± 6.64	180.73 ± 5.98 ^{d}	174.00 ± 6.34	171.83 ± 6.24 ^{a,b}	0.001 *
Body mass (kg)	66.82 ± 12.69	68.46 ± 8.29	77.99 ± 9.91 ^{c,d}	63.18 ± 9.87 ^{b}	60.37 ± 8.16 ^{b}	<0.001 *
Body mass index (kg/m^2)	20.24 ± 2.25 ^{b}	21.55 ± 1.92	23.92 ± 3.31 ^{a,c,d}	20.81 ± 2.60 ^{b}	20.42 ± 2.44 ^{b}	0.001 *
Specific swimming capacities						
Crawl, 25 m (s) N = 91		13.64 ± 0.99	14.04 ± 0.69	13.69 ± 0.58	13.44 ± 0.70	0.160
Crawl, 50 m (s) N = 91		30.20 ± 2.06	31.27 ± 1.68 ^{c,d}	29.74 ± 1.28 ^{b}	29.58 ± 2.09 ^{b}	0.016 *
Crawl, 100 m (s) N = 91		66.92 ± 4.29	69.05 ± 2.80	66.89 ± 2.83	66.13 ± 3.09	0.104
Crawl, 400 m (s) N = 175		312.25 ± 13.12	323.18 ± 14.67 ^{c}	311.53 ± 11.98 ^{b}	314.32 ± 10.84	0.020 *
Breaststroke, 100 m (s) N = 15	96.90 ± 3.55					NA
Butterfly, 100 m (s) N = 15	93.41 ± 10.84					NA
Dribbling, 25 m (s) N = 91		14.88 ± 1.13	14.76 ± 0.98	14.66 ± 0.74	14.28 ± 0.93	0.219
Cognitive performance via the Stroop test (N = 106)						
StroopOff time (s)	58.44 ± 6.99	62.68 ± 10.08	67.03 ± 9.72 ^{d}	61.48 ± 8.15	57.14 ± 10.04 ^{b}	0.016 *
StroopOn time (s)	66.81 ± 10.34 ^{b}	71.50 ± 12.29	80.24 ± 15.64 ^{a,d}	75.34 ± 15.57	66.18 ± 15.86 ^{b}	0.019 *
StroopOff + StroopOn time (s)	125.26 ± 16.88	134.18 ± 21.80	147.27 ± 24.3 ^{d}	136.81 ± 23.14	123.32 ± 25.38 ^{b}	0.017 *
Ontime minus Offtime (s)	8.37 ± 5.13 ^{b}	8.83 ± 5.47	13.21 ± 9.35 ^{a,d}	13.86 ± 9.08	9.03 ± 7.79 ^{b}	0.041 *
Incorrect runs total time (StroopOff) (s)	6.56 ± 8.43	4.97 ± 6.25	2.17 ± 6.90	5.05 ± 6.12	2.17 ± 3.72	0.159
Incorrect runs total time (StroopOn) (s)	5.46 ± 11.71	3.42 ± 6.09	6.68 ± 9.14	9.51 ± 9.46	4.09 ± 7.01	0.095
Successful times × attempts (Off) (s)	292.22 ± 34.93	313.38 ± 50.42	335.15 ± 48.59 ^{d}	307.38 ± 40.75	285.71 ± 50.18 ^{b}	0.016 *
Successful times × attempts (On) (s)	334.07 ± 51.69	357.52 ± 61.44	401.21 ± 78.22 ^{d}	376.68 ± 77.86	330.89 ± 79.30 ^{b}	0.019 *

Data are presented as the mean ± standard deviation. * ANOVA with the post hoc Scheffé test for all pairwise comparisons; $p < 0.05$. ^{a} comparison with goalkeepers ($p < 0.05$). ^{b} comparison with center-attackers ($p < 0.05$). ^{c} comparison with perimeter players ($p < 0.05$). ^{d} comparison with wings ($p < 0.05$).

ANCOVA

Table 3 reports differences in the cognitive functions of youth water polo players in different playing positions assessed with the Stroop test when controlled for covariates, body mass and body height. The ANCOVA analysis revealed no significant differences, with the exception of one significant difference in the StroopOn minus StroopOff time, where the ANCOVA model was significant.

Table 3. ANCOVA analysis showing differences in cognitive functions between different playing positions.

		Mean	SE	95% CI	F	*p*
StroopOff time	**R^2 = 0.102 R^2 adjusted = 0.038**				1.587	0.161
	Goalkeeper (N= 15)	58.61	2.32	54.010–63.202		
	Center-backward (N = 21)	62.68	1.95	58.800–66.554		
	Center-forward (N = 17)	66.63	2.20	62.263–70.994		
	Perimeter (N = 34)	61.24	1.55	58.165–64.314		
	Wings (N = 18)	58.59	2.19	54.229–62.944		
StroopOn time	**R^2 = 0.127 R^2 adjusted = 0.065**				2.035	0.070
	Goalkeeper (N = 15)	67.005	3.730	59.603–74.406		
	Center-backward (N = 21)	71.503	3.147	65.260–77.747		
	Center-forward (N = 17)	79.768	3.543	72.738–86.798		
	Perimeter (N = 34)	75.058	2.495	70.107–80.009		
	Wings (N = 18)	67.822	3.537	60.804–74.840		
StroopOff + StroopOn time	**R^2 = 0.115 R^2 adjusted = 0.065**				1.818	0.105
	Goalkeeper (N = 15)	125.610	5.864	113.976–137.245		
	Center-backward (N = 21)	134.180	4.946	124.366–143.995		
	Center-forward (N = 17)	146.396	5.570	135.345–157.448		
	Perimeter (N = 34)	136.298	3.923	128.514–144.081		
	Wings (N = 18)	126.408	5.560	115.376–137.441		
StroopOn minus StroopOff time	**R^2 = 0.160 R^2 adjusted = 0.100**				2.674	0.020
	Goalkeeper (N = 15)	8.399	2.043	4.346–12.452		
	Center-backward (N = 21)	8.827	1.723	5.408–12.246		
	Center-forward (N = 17)	13.139	1.940	9.290–16.990		
	Perimeter (N = 34)	13.818	1.367	11.107–16.530		
	Wings (N = 18)	9.236	1.937	5.393–13.079		

ANCOVA, including body mass and body height as covariates in the model comparing the cognitive functions of youth water polo players in different playing position; Bonferroni correction; $p < 0.05$.

The partial eta squared as a measure of the effect size showed a medium effect for all Stroop test variables (StroopOff $\eta^2 = 0.102$, StroopOn $\eta^2 = 0.127$; StroopOff + StroopOn $\eta^2 = 0.115$, and StroopOn minus StroopOff $\eta^2 = 0.160$). This indicates that, when controlling for the effect of body mass and body height, the different playing positions differ in their executive function performance, with a moderate effect size.

2.5.4. Discussion

To the best of our knowledge, this is the first study to report the association of cognitive functions and playing positions in youth water polo players. The aim of this study was to evaluate the level of selected cognitive features in youth water polo players while considering their assigned position on the field, as well as their anthropometric characteristics and specific swimming capacities. The results of this study indicated significant differences in psychomotor ability, response inhibition and motor speed between players in different playing positions, showing that wings performed faster in all measures of the Stroop test than players in the center-forward position. Additionally, center-forwards had a bigger body mass index than other playing positions, and they were slower in the 50 m crawl and the 400 m crawl than perimeter players and wings. This result can be explained by the fact that the playing position of wings requires more dynamism, explosiveness and agility than center-forwards. Unlike wings, center-forwards have to fight for the position with the defenders through constant physical contact and create a throw-in for themselves, which requires superior anthropometric characteristics [37,49]. To accomplish such a demanding role during the game, the center-forward is expected to have a wide range of external attention, the ability of multi-switching and a high level of working memory.

The importance of cognitive functions in sports has been widely demonstrated in previous studies [21,61–63]. Formenti i sur. showed that the combination of cognitive functions (executive control and perceptual speed) and volleyball-specific skills was found to be useful for discriminating players of different competitive levels [61], similar as in soccer [63] or handball [2,12]. Another importance of cognitive functions in numerous sports shown in the previous literature (soccer, handball, volleyball, water polo, tennis and karate) mostly presented differences in cognitive functions and sport-specific physical performance for discriminating players of different competitive levels [2,3,8,13,20,43,64–67] and for talent identification [20,43,64,68]. Kalen i sur. [3] reported that higher-skilled athletes performed better on cognitive function tests than lower-skilled athlete. Similar results were obtained by Krawczyk i sur. [69] regarding handball goalkeepers playing in the champions league and super league when comparing simple and choice reaction times.

Recent studies highlight the need for a position-specific approach to the study of water polo, but the literature about the importance of cognitive functions in water polo is scarce [30,37,38,46,53,55]. Figuratively, water polo could be described as a combination of handball and swimming [37]; therefore, our results, which consider cognitive functions in different playing positions, can be partially compared with some previous research in handball. Blecharz i sur. [2] presented that goalkeepers showed the shortest reaction time in reading words (neutral text color), with the highest tendency to read interference (difference between reading a neutral text and a colored text), indicating their high reactivity to visual stimuli. Additionally, Kiss and Balogh [12] found that goalkeepers, wingers, and playmakers had faster reaction times compared to pivot and back players, similar as in our study, which presented that center-forwards showed the slowest psychomotor speed. They also observed that goalkeepers committed fewer errors than pivot and back players when performing the task quickly.

Therefore, it can be hypothesized that a smaller range of stimuli that a goalkeeper must process facilitates a quicker decision on what to do next and how to do so quickly and effectively [12]. In our study, wings showed the shortest reactiontime and psychomotor speed, while goalkeepers followed them in comparison to centerforwards. These results are congruent with Silva's approach in handball, suggesting that there is a similarity of cognitive demands for players assigned to different positions [27,70]. The exception comprises goalkeepers whose role on the court is different compared to the other players [27,38,44,70].

Trecroci i sur. [21] suggested that volleyball players with superior basic cognitive functions (expressed by cumulated cognitive score) presented better sport-specific physical performance (expressed by the cumulated motor score). This finding is in line with a recent study that investigated the relationship between cognitive functions and sportspecific motor skills in young soccer players [13]. In that study, the cumulated score of cognitive tests (measuring attention window, perceptual load, multiple object tracking and working memory) was found to be associated with the cumulated score of motor tests [13]. Specifically, attention window and working memory were positively correlated with dribbling, ball control and ball juggling [13]. Based on those results, it could be speculated that well-developed cognitive functions may contribute to enhance players' sport-specific skills within a game in unpredictable situations. In water polo, players play in water, an unnatural and complex environment, where they have to pay attention to the ball, teammates, and opponents' movements. This dynamic environment stimulates their cognitive demands, encouraging players to find the best solution with the increasing complexity of the game [21,71,72]. Scharfen i sur. [13] showed that the diagonal attention window (AW) was positively correlated with dribbling performance. This may suggest that athletes who have a wider AWalso have advanced dribbling skills, which may enable them to execute early reactions in their sensorimotor system to make their performance more efficient. For example, in a game situation where the athlete is dribbling and simultaneously keeping an eye on the ball, his teammates and his opponents, helping him avoid contact with opponents and be more efficient in dribbling is important. Such activities also happen in water polo, which is in a different environment, namely water, and a broader AW could be beneficial for water polo players to spot their teammates easier and pass them the ball. Furthermore, Kiss and Balogh [12] demonstrated that handball players in pivot positions were outperformed by players in other positions in reaction when selecting adequate figures. Additionally, playmakers reacted with faster reaction time and decision-making than players in other positions. Pivots reacted slower, but that is in line with their role in the game, while they have fewer stimuli and less incorrect answers. Playing positions in water polo can be directly compared to handball, where center-forwards play a similar role as pivots; therefore, our results are in line with Kiss and Balogh's in handball.

The positive association between cognitive and sport-specific performance domains is in line with the large body of the literature [3,5], which reports a substantial relationship between general motor and cognitive skills in children [9,73], adolescents [13,21,48,74] and adults [2,75].

Adding cognitive tests to assess players' performance is supported by many previous studies, reporting a high association and overlap between cognitive functions and important aspects of sports performance, such as game intelligence, which is crucial for success in high-performance sports and still hardly measurable [8,76,77]. Therefore, it would be advantageous to include more participants in each playing position in future studies, which could help to clarify the reported model and possibly explain in which playing positions are cognitive differences consistently different. Such results may provide coaches with a more extensive picture of the players' profiles in a multidimensional way and may help to assign them to the specific playing position within the team [2,13,63].

It is important to highlight that cognitive functions in athletes can be improved with cognitive training. Therefore, our results can be helpful for discriminating players for different playing positions and preparing cognitive training for each of them. Cognitive training aiming at improving athletic performance should be performed in a situation closely related to tasks performed on the field. Otherwise, skill transfer will be limited [61,62,78–80].

In the present work, we also analyzed the anthropometric characteristics and specific functional swimming capacities of youth water polo players playing in different playing positions, showing that center-forwards had bigger body weight and height than drivers and wings. Also, they were significantly slower in the 50 m crawl and the 400 m crawl than drivers and wings, which is in accordance with the demands of their playing position during the game. The center-forward position implements demanding technical and tactical elements, requiring more strength and power, as well as highly consistent athletic performance, than drivers or wings, who need to be faster and show better agility in the water.

In a former study, Kondrič i sur. [37] examined the anthropometric and body composition characteristics and physical fitness of 110 junior water polo players with different playing positions. Based on their results, center-forwards had significantly higher body weight, BMIs, and larger subscapular skinfolds compared to other players. Concerning the physical condition measured by swimming tests, they found that the drivers achieved the best test results in 25 m and 400 m sprints, but without significant differences [37]. However, swimming tests are not suitable to describe the performance status of players during the training sessions and games, which both consist of technical and tactical components requiring further skills as well. Unfortunately, the accurate monitoring of players during training and games is still unresolved, making it difficult to collect performance data [37]. Therefore, analyzing cognitive functions, mental strength and game intelligence may contribute to developing adequate training programs for each playing position in water polo.

As water polo experienced recent rule changes [35,81], in order to make the game more attractive, actions during the game became faster, while the reaction time and decision-making time for players in specific playing positions became shorter. It could be speculated that a shorter water polo field of play will require different roles for players. For example, goalkeepers will participate more during the transition and defense actions, requiring welldeveloped anticipation and a fast reaction time. Players who can reach the 2 m-line first will play the center-forward position, which could change the definition and requirements for that specific position. Therefore, implementing cognitive training based on the demands of each playing position would be advantageous in the improvement of the training process in water polo.

Limitations

The main limitation of this study is that it was conducted in laboratory settings, although the tasks players performed involved the functions needed when playing on the court. It would be advantageous to use sport-specific stimuli as suggested by Kalen i sur. [3] who found that tests using sport-specific stimuli were considerably more successful in differentiating higher- and lower-skilled athletes than tests with non-sport-specific stimuli. However, it still remains unclear which cognitive tests should be used for these purposes. Also, in the present study, the number of athletes stratified by playing positions is limited, and we tested only male water polo players. Cognitive functions are influenced by many variables, such as age [82,83] and sex [84,85]. For these reasons, any form of generalization should be avoided, and results should be interpreted with caution. Therefore, we suggest using a consistent sample per playing position, increasing the number of participants, analyzing female water polo players as well and, if possible, conducting a longitudinal data analysis, in future studies.

2.5.5. Conclusions

In conclusion, this study demonstrated significant differences between different playing positions in youth water polo players, specifically between center-forwards and wings. They performed faster than center-forwards in all tested variables of the Stroop test, measures of psychomotor ability, response inhibition and motor speed, as well as in specific swimming capacities measured in the 50 m crawl and the 400 m crawl. On the contrary, center-forwards had a bigger body mass index than players in other playing positions, with the exception of center-defenders. However, caution should be used when interpreting these findings because differences in cognitive functions were not significant when controlling for body mass and body height. Thus, more studies with more participants should be conducted to confirm our results and possibly explain in which playing positions are cognitive differences consistently different.

Considering that cognitive functions may contribute to the development of game intelligence and play important role in successful long-term athlete development, this study can be an important basis for establishing developmental recommendations for players with distinct playing positions to improve their performance, taking into account their cognitive functions, anthropometric characteristics and specific functional swimming capacities. Additionally, this knowledge could be used by coaches to test athletes not only physically but also on the cognitive domain. Developing novel individualized training strategies and adding mentally demanding technical and tactical elements to their everyday training might advance players' athletic development and ensure successful field efficiency.

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Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

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3. ZAKLJUČAK

Struktura vaterpolske igre na različitim igračkim pozicijama zahtjeva i različite antropometrijske karakteristike, fizičku spremnost, funkcionalne i motoričke kapacitete. Ova doktorska disertacija upotpunila je dosadašnje znanstvene spoznaje o utjecaju navedenih čimbenika na uspješnost izvedbe mladih vaterpolista, ali i proširila spoznaje o kognitivnim funkcijama i njihovom utjecaju na selekciju i uspjeh u vaterpolu. Rezultati su pokazali nekoliko važnih zaključaka:

1. Prva studija pokazala je da su mladi vaterpolisti 12-godišnjaci rođeni u prvom kvartalu godine imali značajno veću tjelesnu visinu i težinu od svojih mlađih vršnjaka, dok nije bilo razlike u specifičnim funkcionalnim plivačkim sposobnostima.
2. U drugoj studiji utvrđeno je da su mlade vaterpolistice i vaterpolisti pokazali bolje rezultate u psihomotornoj brzini, inhibiciji reakcije i motoričkoj brzini od školske djece istog spola i kronološke dobi koja ne sudjeluju u organiziranim sportskim aktivnostima. Sudjelovanje u vaterpolu pokazalo se kao značajan prediktor kognitivnih funkcija u školske djece dobi od 12 do 16 godina.
3. Rezultati treće studije pokazali su da su mlade vaterpolistice imale bolje psihomotorne sposobnosti, inhibiciju reakcije i motoričku brzinu, mjereno Stroop testom, u usporedbi s mladim vaterpolistima iste kronološke dobi.
4. U četvrtoj studiji psihomotorne sposobnosti, inhibicija, motorna brzina i kognitivna fleksibilnost pokazale su se kao značajni prediktori selekcije mladih vaterpolista u nacionalnu vaterpolsku reprezentaciju. Specifični plivački kapaciteti, 400 m kraul i 100 m kraul, također su pokazali značajne prediktivne vrijednosti u odabiru mladih talentiranih vaterpolista.
5. Rezultati pete studije pokazali su značajne razlike u psihomotornim sposobnostima, inhibiciji reakcije i motoričkoj brzini između igrača na različitim igračkim pozicijama, pokazujući da su krilni napadači postigli brže rezultate u svim mjerama Stroop testa od igrača na poziciji središnjeg napadača. Osim toga, središnji napadači imali su veći indeks tjelesne mase od igrača na ostalim igračkim pozicijama, a bili su sporiji u specifičnim plivačkim testovima na 50 m kraul i 400 m kraul od vanjskih i krilnih napadača.

Rezultati ove disertacije doprinose specifičnim znanjima o antropometrijskim karakteristikama mladih vaterpolista, specifičnim funkcionalnim plivačkim sposobnostima, kao i o njihovim kognitivnim funkcijama. S obzirom da je vaterpolo doživio nedavne promjene pravila kako bi igra bila atraktivnija (Aquatics, 2025; Canossa et al., 2022), akcije tijekom igre postale su brže, dok je vrijeme reakcije i donošenja odluka za igrače na određenim igračkim pozicijama postalo kraće. Moglo bi se nagađati da će kraće igralište za vaterpolo zahtijevati drugačije uloge za igrače. Na primjer, vratari će više sudjelovati tijekom tranzicije i obrambenih akcija, što zahtijeva dobro razvijenu anticipaciju i brzo vrijeme reakcije. Igrači koji prvi mogu doći do linije od 2 m igrat će na poziciji središnjeg napadača, što bi moglo promijeniti definiciju i zahtjeve za tu specifičnu poziciju, osobito antropometrijske karakteristike tih igrača. Stoga bi provedba kognitivnog treninga temeljenog na zahtjevima svake igračke pozicije bila prednost u poboljšanju trenažnog procesa u vaterpolu. Kognitivni trening, često nedovoljno iskorišten alat u svijetu sportskog treninga, može značajno poboljšati situacijsku izvedbu igrača, izoštravanjem uma baš kao što fizički trening poboljšava tijelo. Cilj je poticati oštriji i brži um sposoban za prilagodbu i reagiranje na brze zahtjeve natjecateljskih sportova, uključujući vaterpolo. Zaključno, dobro razvijene kognitivne funkcije mogu poslužiti kao jedan od ključnih čimbenika, uz ostale komponente razvoja sportaša, poput antropometrijskih i funkcionalnih sposobnosti, kao i situacijske igračke inteligencije i samopouzdanja, kako bi mladi igrač postao vrhunski vaterpolist.

4. SNAGA I OGRANIČENJA ISTRAŽIVANJA

Koliko je autoru poznato, nema ranijih istraživanja koja su se bavila procjenom kognitivnih funkcija u vaterpolu, osobito u svrhu selekcije mladih talentiranih igrača i razlika između igrača na različitim igračkim pozicijama. Rezultati ove disertacije doprinose specifičnim znanjima o kognitivnim funkcijama, antropometrijskim karakteristikama, kao i o specifičnim funkcionalnim plivačkim sposobnostima mladih vaterpolista u predpubertetskoj i pubertetskoj razvojnoj fazi, pružajući bolje razumijevanje općeg i specifičnog procesa razvoja vaterpolista. Poznavanje specifičnih funkcionalnih plivačkih sposobnosti mladih vaterpolista i njihovog kronološkog, kao i biološkog razvoja, korištenjem multivarijantnog pristupa moglo bi poboljšati razvojne programe u vaterpolu i pomoći u raspodjeli uloga između različitih igračkih pozicija u vaterpolskim ekipama. Međutim, važno je istaknuti da te varijable mogu poslužiti samo kao moguća predispozicija za razvoj uspješnog vaterpolista uz dobro razvijenu agilnost, brzinu, točnost, koordinaciju, situacijsku igračku inteligenciju, kognitivne funkcije i anticipaciju. Temeljem procjene kognitivnih funkcija, uz uobičajene sportske testove, moguće je osmisliti individualizirane treninge za svaku igračku poziciju, kao i za svakog mladog talentiranog igrača pojedinačno.

Postoje i neka ograničenja ove disertacije. Prije svega, istraživanje je provedeno u izoliranim uvjetima u kojima su kognitivne funkcije procijenjene samo jednim testnim instrumentom, Stroopovim testom, iako su zadaci koje su ispitanici obavljali uključivali funkcije potrebne pri igri na vaterpolskom terenu. Ne može se isključiti mogućnost da neki od rezultata mogu biti donekle specifični za test. Bilo bi korisno koristiti sportske podražaje, kako sugeriraju Kalen i sur. (Kalen i sur., 2021) koji su pokazali da su testovi koji koriste sportske podražaje znatno uspješniji u razlikovanju sportaša s višim i nižim kognitivnim funkcijama od testova s podražajima koji nisu specifični za sport. Također, postoji potreba za korištenjem veće baterije kognitivnih testova za procjenu različitih komponenti kognitivnih funkcija. Međutim, još uvijek nije jasno koji bi se kognitivni testovi trebali koristiti u te svrhe.

U ovoj studiji broj sportaša stratificiranih po igračkim pozicijama je ograničen. Općenito, uzorak je bio prilično malen i imao je nejednak broj ispitanika u različitim skupinama, mladih vaterpolista na različitim igračkim pozicijama, djevojčica i dječaka, ili mladih vaterpolista i školske djece koja se ne bave organiziranim sportskim aktivnostima. Također, u ovoj disertaciji nije procijenjen pubertetski status ispitanika, što bi moglo utjecati na rezultate, kako testiranja kognitivnih funkcija, tako i ostalih mjerenih varijabli. Iz tih razloga, svaki oblik generalizacije treba izbjegavati, a rezultate treba tumačiti s oprezom.

S obzirom na to da su proučavane varijable pod snažnim utjecajem dobi ispitanika, s obzirom na postojeće razvojne razlike u funkcioniranju kognitivno-motoričkih područja, jedinstvena dobna raspodjela u obje proučavane skupine jedna je od glavnih snaga ove studije, iako bi za generaliziranje rezultata bilo potrebno proširiti uzorak ispitanika na više dobnih skupina, uključujući i odrasle vaterpoliste.

5. SMJERNICE ZA BUDUĆA ISTRAŽIVANJA

U budućim istraživanjima trebalo bi proširiti uzorak ispitanika na više dobnih skupina, uključujući i odrasle vaterpoliste. Osim toga, trebalo bi koristiti longitudinalni dizajn s praćenjem i diferencijacijom po igračkim pozicijama, kako bi se bolje razumio razvoj kognitivnih funkcija mladih vaterpolista, kao i usporedba takvog razvoja između vaterpolista i djece koja se bave drugim sportovima ili ne sudjeluju u organiziranim sportskim aktivnostima. Takvi rezultati mogli bi pružiti trenerima opsežniju sliku profila igrača na višedimenzionalan način i pomoći u dodjeljivanju određene igračke pozicije unutar ekipe sukladno igračevim psiho-fizičkim sposobnostima. Nadalje, važno je istaknuti da se kognitivne funkcije u sportaša mogu poboljšati kognitivnim treningom. Kognitivni trening s ciljem poboljšanja sportske izvedbe trebao bi se provoditi u situacijama usko povezanim sa zadacima koji se obavljaju na terenu. Bilo bi korisno procijeniti uspješnost prijenosa vještina s takvog treninga u igru i vaterpolsku utakmicu u budućim longitudinalnim istraživanjima.

6. POPIS LITERATURE

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