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KARLA ĐOLO

POUZDANOST I VALJANOST TESTOVA KOORDINACIJE U ODBOJCI

(DOKTORSKI RAD)

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RELIABILITY AND VALIDITY OF COORDINATION TESTS IN VOLLEYBALL

(DOCTORAL THESIS)

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PODACI O MENTORU

ZAHVALA

SAŽETAK

Doktorska disertacija usmjerena je na konstrukciju i validaciju općih i specifičnih testova koordinacije u odbojci te proizlazi iz uočene manjkavosti da u postojećoj znanstvenoj literaturi nedostaju mjerni instrumenti namijenjeni procjeni koordinacijskih sposobnosti kod mlađih dobnih skupina u populaciji odbojkašica. Koordinacijske sposobnosti predstavljaju jednu od temeljnih motoričkih sposobnosti, presudnih za dostizanje punog potencijala kod vrhunskih sportaša, no njihova se procjena često provodi nesustavno ili se zanemaruje. Poseban naglasak u disertaciji stavljen je na mlađe dobne skupine i žensku populaciju jer su dosadašnja istraživanja bila usmjerena na stariju dobnu skupinu.

Prvo istraživanje imalo je za cilj utvrditi metrijske karakteristike modificiranog testa brzine reakcije na uzorku mlađih odbojkašica. Nadalje, drugo istraživanje bilo je usmjereno na nadopunu postojećeg znanstvenog prostora kroz modifikaciju testa dinamičke ravnoteže kako bi preciznije simulirao specifične odbojkaške situacije. U oba istraživanja provedena je usporedba rezultata prvog mjerenja s prosječnim i najboljim rezultatom dobivenim iz više pokušaja radi utvrđivanja najveće stabilnosti mjerenja kod mladih igračica kao i njihove sposobnosti razlikovanja između različitih igračkih uloga. Treće istraživanje bilo je usmjereno na bateriju nespecifičnih testova koordinacije u odbojci. S ciljem utvrđivanja njihove pouzdanosti, kao temeljne pretpostavke valjane procjene, kao i diskriminativne sposobnosti u razlikovanju igračkih uloga. Završno istraživanje bilo je usmjereno na konstrukciju testova za procjenu kinestetičke diferencijacije te ispitivanje njihove pouzdanost i diskriminativne valjanosti.

Ova istraživanja obuhvaćala su mlade odbojkašice iz šest klubova u Bosni i Hercegovini. Ispitanice su činile prigodni uzorak mladih odbojkašica, sastavljen od ekipa koje su dobrovoljno pristale sudjelovati u postupku testiranja. Sve sudionice natjecale su se u regionalnom sustavu natjecanja Super lige i Prve lige, organiziranom prema modelu seniorske ženske lige. Nadalje, igračice su samostalno deklarirale svoje igračke uloge (dizač, srednji bloker, libero, primač i dijagonala). Za procjenu općih koordinacijskih sposobnosti (odbojkašica) primijenjeno je šest testova: Hodanje po klupi s tri okreta (BW3T), Zaustavljanje kotrljajuće lopte (SRB), Reaktivni test trčanja s promjenom smjera (SRrt), Nereaktivni test trčanja s promjenom smjera (SRnr), Ciljani test skoka u dalj s mjesta (TSBJ) i Ciljani test bacanja iz sjeda (TST). Za procjenu specifičnih

koordinacijskih sposobnosti primjenjeno je pet testova: Podlaktično odbijanje (FPT), Vršno odbijanje (OPT), Lelujavi servis s mrežom (FSTnet), Lelujavi servis bez mreže (FSTx) i Lelujavi servis 6 m od mreže (FST6m).

Rezultati prvog istraživanja pokazali su da test brzine reakcije (SRB) u prvom mjerenju ima nisku razinu pouzdanost (ICC = 0.21), dok je pouzdanost izračunata na temelju prosječne vrijednosti triju mjerenja (ICC = 0.84) i najboljeg pojedinačnog rezultata od tri mjerenja (ICC = 0.81) bila vrlo visoka. Analiza primjenjivosti testa potvrdila je da su višestruka mjerenja značajno pouzdanija od pojedinačnog pokušaja.

U drugom istraživanju, na testu dinamičke ravnoteže (BW3T), prvo mjerenje je također pokazalo slabu pouzdanost (ICC = 0.47), dok su prosječno (ICC = 0.68) i najbolje mjerenje (ICC = 0.73) pokazali dobru razinu pouzdanosti. Analiza primjenjivosti testa pokazala je da prosječna i najbolja mjerenja pružaju zadovoljavajuće dobru razinu primjenjivosti, dok pojedinačno prvo mjerenje ima ograničenu primjenjivost.

Rezultati trećeg istraživanja, koji je obuhvaćao opće koordinacijske testove, pokazali su visoku pouzdanost kod BW3T (ICC = 0.89), SRB (ICC = 0.82), SRrt (ICC = 0.76), SRnr (ICC = 0.80), TSBJ (ICC = 0.80), dok je TST test pokazao zadovoljavajuću razinu pouzdanost (ICC = 0.58). Primjena diskriminativnih sposobnosti ukazuje da međupozicijske razlike nisu značajne, a značajne razlike pronađene su između manje uspješnih i uspješnih odbojkašica.

Četvrto istraživanje, usmjereno na kinestetičku diferencijaciju, pokazalo je visoku razinu pouzdanost u većini primijenjenih testova. Testovi podlaktičnog odbijanja, vršnog odbijanja te lelujavi test bez mreže i s udaljenosti od 6 m ostvarili su ICC vrijednost između 0.77 i 0.87, dok je pouzdanosti lelujavog servisa s mrežom ocijenjena kao dobra (ICC = 0.66). Analiza diskriminativne sposobnosti pokazala je da međupozicijske razlike nisu statistički značajne kod svih pet testova, međutim, utvrđene su značajne razlike između manje uspješnih i uspješnih odbojkašica.

Nalazi ove disertacije potvrđuju važnost općih i specifičnih koordinacijskih sposobnosti u odbojci i potrebu za njihovim sustavnim i kontinuiranim razvojem kod mladih sportaša. Testovi se mogu koristiti u procesu identifikacije i selekcije sportskih talenata, kao i za longitudinalno praćenje napretka odbojkaša. Nadalje, predstavljaju valjan dijagnostički alat za procjenu razvoja sposobnosti u odnosu na specifične igračke uloge u odbojci.

Ključne riječi: diskriminativna sposobnost, igračke pozicije, kinestetička diferencijacija, metrijske karakteristike, odbojkaške tehnike.

ABSTRACT

This doctoral dissertation is focused on the construction and validation of general and specific coordination tests in volleyball, motivated by the fact that the existing scientific literature lacks measurement instruments intended for the assessment of coordination abilities in younger age groups, particularly among female volleyball players. Coordination abilities, as one of the fundamental motor abilities crucial for achieving full performance potential in elite athletes, are often assessed unsystematically or even neglected. Special emphasis in this dissertation is placed on younger age categories and the female population, as previous research has predominantly focused on older age groups.

The first study aimed to determine the metric characteristics of a modified reaction speed test in young female volleyball players. The second study sought to address an existing gap by modifying the dynamic balance test to better simulate situations specific to volleyball. In both studies, results from the first trial were compared with the average and best results from multiple trials in order to determine the most stable measurement approach for young athletes. The third study focused on constructing tests for the assessment of kinesthetic differentiation ability and examining their reliability and discriminative ability. The final study was directed at a battery of non-specific coordination tests in volleyball, with the aim of determining their reliability, essential for valid assessment, as well as their discriminative ability in distinguishing playing positions in volleyball.

The studies included young female volleyball players from six clubs in Bosnia and Herzegovina. The participants formed a convenience sample, consisting of teams that voluntarily agreed to participate in the testing. All participants competed in the regional Super League and First League, organized according to the structure of the senior women's league. Players also reported their playing positions (setter, middle blocker, libero, outside hitter, and opposite).

To assess general coordination abilities, six tests were applied: Bench Walking with Three Turns test (BW3T), Stopping the Rolling Ball test (SRB), Shuttle Run reactive test (SRrt), Shuttle Run non reactive test (SRnr), Target Standing Broad Jump test (TSBJ),

and Target Sitting Throw Test (TST). To assess specific coordination abilities, five tests were used: Forearm Passing Test (FPT), Overhead Passing Test (OPT), Float Service Test with Net (FSTnet), Float Service Test without a Net (FSTx), and Float Serivice Test 6 m from the net (FST6m).

Results of the first study showed that the reaction speed test (SRB) demonstrated poor reliability in the first trial (ICC = 0.21), whereas the average of three trials (ICC = 0.84) and the best of three trials (ICC = 0.81) exhibited very high reliability. The analysis of test usefulness confirmed that multiple trials are significantly more reliable than a single trial.

In the second study, the dynamic balance test (BW3T) also showed poor reliability in the first trial (ICC = 0.47), while the average (ICC = 0.68) and best trial (ICC = 0.73) demonstrated good reliability. The analysis of usefulness indicated that average and best scores provided satisfactory to good usefulness, whereas the single first trial showed limited usefulness.

The third study, focused on kinesthetic differentiation, demonstrated high reliability for most tests. The forearm passing test, overhead passing test, and floating serve tests without the net and from a 6 m distance showed ICC values ranging from 0.77 to 0.87, while the floating serve test with the net demonstrated good reliability (ICC = 0.66). Discriminative ability analysis indicated that differences between playing positions were not significant, whereas significant differences were found between less successful and more successful female volleyball players.

Results of the fourth study, which included general coordination tests, demonstrated high reliability for BW3T (ICC = 0.89), SRB (ICC = 0.82), SRrt (ICC = 0.76), SRnr (ICC = 0.80), and TSBJ (ICC = 0.80), while the TST test showed satisfactory reliability (ICC = 0.58). Discriminative analysis indicated that differences between playing positions were not significant, whereas significant differences were observed between less successful and more successful players.

The findings of this dissertation confirm the importance of general and specific coordination abilities in volleyball and emphasize the need for their systematic development in young athletes. The proposed tests can be applied in the talent

identification process by monitoring players' progress over time, as well as serving as a tool for evaluating performance development within specific playing positions in volleyball.

Key words: discriminative ability, kinesthetic differentiation, metric characteristics, playing positions, volleyball technique.

SADRŽAJ

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1. UVOD

1.1 Koordinacija

Promjenama pravila igre odbojka je postala jedan od najdinamičnijih sportova (D. Szade i B. Szade, 2005). Danas od igrača zahtijeva brzu prilagodbu na visoko intenzivna opterećenja pri čemu se kombiniraju motoričke, koordinacijske i kognitivne sposobnosti. Ključna značajka koju igrači moraju posjedovati jest visoka razina anticipacije u uvjetima kontinuiranih promjena u igri, zbog čega moraju predvidjeti namjeru suparnika prije nego što izvede određenu akciju te brzo reagirati u ograničenom vremenu. Za takve se sportaše često navodi da posjeduju sportsku inteligenciju ili da dobro "čitaju" igru (Günay, Ceylan, Çolakoğolu, i Saygın, 2019; Williams i Jackson, 2019). Navedene promjene u igri odnose se na uvježbane prijelaze, odnosno tranzicije, između različitih tehničko-taktičkih elemenata unutar napada i protunapada, kao što su prijelazi iz servisa u obranu polja, iz prijema servisa u dizanje za smeč u napadu, zatim u smečiranje u napadu te zaštitu smeča, kao i prijelazi u faze blokranja i obrane polja nakon protivničkog napada. Tranzicije se mogu odvijati unutar iste faze igre, primjerice kao brzi prijelazi iz početne u završnu poziciju u obrani polja. Time dolazi do preklapanja različitih tehničko-taktičkih elemenata. Stoga se može zaključiti da je odbojka specifična igra zbog kratkog kontakta pojedinog igrača s loptom, praćenja putanje lopte te praćenja položaja suigrača i protivnika na terenu (Zhang, Yan i Yangang, 2009).

Slijedom navedenog, koordinacijske sposobnosti imaju sve veću važnost za postizanje visoke razine izvedbe, ne samo u odbojci, već i u drugim sportovima (Zetou, Michalopoulou, Giazitzi i Kioumourtzoglou, 2007). Koordinacija je sposobnosti izvođenja kompleksnih kretnih struktura usklađivanjem središnjeg živčanog sustava i skeletnih mišića (Boichuk, Iermakov, Kovtsun, Pasichnyk, Melnyk i sur., 2018). Odnosno to je sposobnost da u pravo vrijeme, velikom brzinom i pod različitim uvjetima igrači preoblikuju kretne strukture aktivirajući odgovarajuću skupinu mišića koji su pod kontrolom malog mozga i osjetnih organa (Iorga, Jianu, Gheorghiu, Cret i Eremia, 2023).

Koordinacijske sposobnosti predstavljaju temelj za usvajanje i daljnje usavršavanje kretnih struktura u različitim sportovima, te za razvoj drugih motoričkih sposobnosti (Maj, Drabik, Adam i Smaruj, 2015). Kako bi igrači uspješno usvojili i unaprijedili tehničko-taktičke elemente odbojkaške igre, nužna je visoka razina koordinacijskih sposobnosti (Kozina, Goloborodko, Boichuk, Sobko, Repko I sur., 2018). Stoga je od iznimne važnosti da sportaši od samih početaka razviju dobru bazu koordinacijskih sposobnosti kako bi imali širok spektar sposobnosti što u vrhunskom sportu vodi do manje potrošnje energije prilikom izvođenja nekog pokreta (Bompa, 2000).

1.2. Podjela koordinacije

Svaki sport pa tako i odbojka, zahtijeva visoku razinu općih i specifičnih koordinacijskih sposobnosti. Opće koordinacijske sposobnosti odnose se na vještine koje se razvijaju u ranoj fazi sportskog razvoja te prethode specijalizaciji za pojedine igračke uloge, dok se specifične koordinacijske sposobnosti odnose na kretne strukture usko povezane uz specijalizaciju u određenome sportu, a koje se izvode u velikom broju ponavljanja tijekom treninga čime se postiže visoka razina izvedbene učinkovitosti (Bompa, 1999). Igrači s razvijenijim općim koordinacijskim sposobnostima brže usvajaju specifične koordinacijske sposobnosti (Boichuk i sur , 2018).

Zbog svoje kompleksnosti, ne postoji jedninstvena klasifikacija koordinacijskih sposobnosti u znanstvenoj literaturi. Prema Šimoneku (2014), najvažnije koordinacijske sposobnosti za odbojku su ravnoteža, ritam, brzina reakcije, prostorna orijentacija i kinestetička diferencijacija.

Brzina reakcije predstavlja sposobnost sportaša da u minimalnom vremenskom intervalu donese odluku i prikladno reagira na najbolji mogući način. Za nju se vežu dvije temeljne komponente: prva značajka je „vrijeme reakcije" odnosno vremenski interval između pojave akustičkog, vizualnog, taktilngm ili kinestetičkog podražaja i početka mišićne kontrakcije; druga značajka odnosi na „vrijeme kretanja" odnosno na trajanje kretanja nakon početne reakcije (Mroczek, 2007; Radak, 2018). Prema Mroczeku (2007) brzina reakcije u odbojci zauzima vodeće mjesto među koordinacijskim sposobnostima. Razlog tome proizlazi iz činjenice da se odbojka značajno promijenila posljednjih desetljeća, pri čemu je igra postala brža i dinamičnija. Iako je u ranijim razdobljima igra u napadu bila kompleksnija i raznovrsnija, suvremena odbojka obilježena je znatno većom brzinom lopte prilikom servisa i smeča, što je posljedica veće snage i eksplozivnosti igrača. Također, povećana prosječna visina igrača dovela je do promjene u visini dohvata u skoku. Zbog toga igrači danas imaju manje vremena za reakciju, što dodatno naglašava važnost brzine reakcije i anticipacije u uspješnom izvođenju igre (Zhou, 2018; Zetou, Michalopoulou, Giazitzi i Kioumourtzoglou, 2007). Važnost brzine reakcije posebno dolazi do izražaja unutar kompleksa napada i protunapada, koje se sastoje od strukturiranog niza faza igre. U kompleksu napada, brzina reakcije je ključna u fazi prijema servisa, dizanja za smeč u napadu, smečiranju u napadu te zaštiti smeča. U kompleksu protunapada, važnost brzine reakcije očituje se u bloku, obrani polja, dizanju u protunapadu, smečiranju u protunapadu te zaštiti smeča u protunapadu pri čemu dolazi do čestih promjena smjera kretanja.

Kinestetička diferencijacija predstavlja sposobnost finoga doziranja sile pri kontaktu s loptom u različitim fazama igre. Ona omogućuje precizno usmjeravanje lopte u fazama prijema servisa, dizanja za smeč, smečiranja i servisa pri čemu dolazi do izražaja kroz varijabilnost izvedbe (snažni i plasirani) udarci. Posebno je važna kod dizača, koji mora precizno distribuirati lopte različitih visina, brzina i putanja, kao i kod smečera i servera koji kombiniraju različite izvedbe udaraca.

Razvoj ove sposobnosti temelji se na velikom broju ponavljanja motoričkih zadataka, čime se postiže automatizacija pokreta i razvija osjećaj za loptu (Boichuk, Iermakov, Korop, Kovtsun, Vaskan i sur., 2020; Brodani i Šimonek, 2012; Bankosz i Stefaniak, 2021). Kinestetička diferencijacija izravno doprinosi povećanju preciznosti u svim fazama igre, uključujući prijem servisa, dizanje, smečiranje, servis te blok.

Ravnoteža predstavlja sposobnost održavanja tijela u stabilnom položaju. Postoji statička ravnoteža koja se odnosi na održavanje položaja tijela u mirovanju; te dinamička ravnoteža koja se očituje tijekom kretanja uz istodobno održavanje stabilnosti (Jo, CHoi, Cho, Yoon i Lee, 2022; Raymakers, Samson, Verhaar, 2005). Za svakog sportaša je važno da posjeduje visoku razinu ove sposobnosti, odnosno učinkovitu kontrolu pokreta tijela budući da svaki pokret narušava ravnotežu, a njezina adekvatna regulacija ima ulogu u prevenciji ozljeda.

Ritam predstavlja obradu kompleksnog motoričkog obrasca u zadanom vremenu i prostoru s rasporedom izvođenja pokreta (Mastrokalou i Hatziharistos, 2007). Svi koordinirani pokreti odvijaju se u određenom ritmu, stogaizvode se u nekom ritmu, stoga je ova sposobnost od velike važnosti u sportu. U odbojci primači-napadači kreću se određenom ritmu prilikom izvođenja smeča, ali kada dizač uputi neprecizno dizanje brže ili sporije od dogovorene brzine, primač-napadač mora prilagoditi ritam kretanja u odnosu na putanju lopte. Stoga je razvijen osjećaj za ritam veoma važan, kako uodbojci, tako i u drugim sportovima.

Prostorna orijentacija predstavlja sposobnost snalaženja u prostoru, koja uključuje prepoznavanje položaja vlastitog tijela u odnosu na okolinu (npr. teren, suigrače i protivnike) te prilagodbu kretanja i donošenje pravovremenih odluka u skladu s tim odnosima (Mitolo, Gardini, Caffarra, Ronconi, Venerii sur., 2015). Sportaši trebaju brzo i ispravno izvoditi promjene pravca kretanja koje određuje njihov sport na treninzima ili natjecanjima. Ova sposobnost usko je povezana s kognitivnim funkcijama i vizualnom percepcijom (Stoyanova, Ivantchev i Petrova, 2016). Dobra prostorna orijentacija omogućuje odbojkašima da se brzo orijentiraju na terenu u različitim situacijama tijekom igre.

1.3 Važnost koordinacije u sportskim igrama

Svaka od prethodno spomenutih koordinacijskih sposobnosti ima važnu ulogu u usavršavanju vještine potrebne za uspješnu izvedbu u pojedinim sportovima. Od iznimne je važnosti da djeca od najranije dobi u školskom programu kao i klubovima usvajaju različite opće koordinacijske sposobnosti kako bi što uspješnije i učinkovitije usvajala specifičnu kooordinaciju u kasnijoj životnoj dobi za izabrani sport (Platvoet, Elferink-Gemser, Baker i Visscher, 2015). Također, u posljednje vrijeme naglasak se stavlja na razvoj i validaciju testova opće koordinacije jer su oni pogodniji za primjenu na mlađim sportašima koji još nisu ušli u program specijalizacije igračkih uloga (Boichuk, Iermakov, Kovtsun, Levkiv i Karatnyk, 2019).

Slijedom navedenog, opće koordinacijske sposobnosti od velike su važnosti u usavršavanju tehnike te u riješavanja složenijih motoričkih zadataka karakterističnih za modernu odbojku kao što su prijem servisa, obrana polja, dizanje za smeč, smečiranje i zaštita smeča (Pion, Fransen, Deprez, Segerts, Vaeyens i sur., 2015).

Visoka razina razvijenosti koordinacijskih sposobnosti dovodi do učinkovitijeg usvajanja novih i kompleksnih tehničko-taktičkih elemenata igre te bržeg prilagođavanja promjenama koje donosi odbojkaška igra.

Prema Boichucku i sur. (2017) u kasnijoj životnoj dobi sportaša smanjuje se trening općih koordinacijskih sposobnosti, dok se povećava udio specifičnog koordinacijskog treninga, budući dasportaši već u dobi od 14 do 15 godina posjeduju relativno razvijenu tehniku, a dugotrajna primjena istih sadržaja tada pokazuje smanjeni transfer na specifičnu sportsku izvedbu.

1.4 Važnost koordinacije u identifikaciji i razvoju talenata u odbojci

Visoka razina koordinacijskih sposobnosti omogućuje brže i učinkovitije usvajanje kompleksnih tehničko-taktičkih elemenata u odbojci, što se izravno odražava na brži napredak igrača i kvalitetniju izvedbu na natjecanjima (Mostaert, Pion, Lenoir i Vansteenkiste, 2022; Georgiy, 2019). Odbojka je dinamična igra u kojoj se izmjenjuju različite situacije i obrasci kretanja, od jednostavnih do izrazito složenih, zbog čega je visoka razina koordinacije ključna za uspješnu prilagodbu zahtjevima igre. Dodatno, pravila koja reguliraju način kontakta s loptom (nošena i dupla lopta) povećavaju zahtjeve za preciznom i pravovremenom izvedbom pokreta, čime se dodatno naglašava važnost koordinacijskih sposobnosti u odbojci (Eider i Gieszczyk, 2004).

Prepoznavanje i razvoj talenata u odbojci ne predstavljaju jednokratne postupke, već dugotrajne i sustavne procese. Posebno je važno naglasiti da se identifikacija darovitosti ne može temeljiti na jednokratnom promatranju izvedbe, već zahtijeva kontinuirano praćenje djece kroz dulje vremensko razdoblje. U tom kontekstu značajnu ulogu imaju univerzalni sportski programi, poput sportskih vrtića i škola u kojima se djeca sustavno prate i razvijaju više godina.

Podaci dobiveni istraživanjima ukazuju da višedimenzionalne baterije testova mogu biti korisne u identifikaciji talenta kao što su antropometrijske, fiziološke, psihosocijalne, kognitivne i neuromotorne varijable (Rikberg i Raudsepp, 2011; Superlak, 2008). Unutar tih varijabli posebno mjesto zauzimaju opće i specifične koordinacijske sposobnosti koje omogućuju uočavanje djece s visokom početnom razinom koordinacije, ali i onih koji pokazuju brz tempo napretka (Pion i sur., 2015; Gabbett, Georgieff i Domeow, 2007; Tsoukos, Drikos, Brown, Sotiropoulos, Veligekas i sur., 2019).

Deprez, Fransen, Lenoir, Philippaerts i Vaeyens (2014) primijetili su da opća koordinacija nije uvjetovana biološkom zrelošću sportaša, što je od presudne važnosti za zadržavanje sportaša koji kasnije sazrijevaju unutar sportskog sustava. Na taj način koordinacijske sposobnosti omogućuju prepoznavanje sportskog potencijala neovisno o stupnju biološkog razvoja te smanjuju rizik od preranog odustajanja talentiranih sportaša. Nadalje, autori navode da specifična koordinacija jasno razlikuje vrhunske sportaše od onih koji su napustili sport tijekom faze specijalizacije.

Iako koordinacijske sposobnosti imaju ključnu ulogu u prepoznavanju i razvoju talenata, potrebno je naglasiti da one ne predstavljaju jedini čimbenik sportske uspješnosti u odbojci. Kod pojedinih igračkih pozicija, poput srednjeg blokera–napadača prvog tempa, značajnu ulogu imaju antropometrijske karakteristike, posebice tjelesna visina, kao i druge motoričke sposobnosti poput eksplozivne snage, brzine i agilnosti. Međutim, koordinacijske sposobnosti se mogu smatrati nužnim preduvjetom za uspješno izvođenje složenih tehničko-taktičkih elemenata te postizanje vrhunskih sportskih rezultata, zbog čega ih je potrebno pravovremeno prepoznati i sustavno razvijati.

1.5 Specijalizacija u odbojci

Zbog svoje kompleksnosti u rješavanju specifičnih igračkih zadataka, odbojka zahtijeva specijalizaciju igračkih uloga, pri čemu koordinacijske sposobnosti imaju važnu ulogu u diferencijaciji pojedinih uloga. Određivanje igračkih uloga u igri doprinosi poboljšanju kvalitete trenažnog procesa jer se igrači usmjeravaju na razvoj sposobnosti koje su ključne za uspješnu igru (Milić, Grgantov, Chamari, Ardigo, Bianco i Padulo, 2017). Postoji 5 igračkih uloga u odbojci: libero, dizač (tehničar), dijagonala (korektor), srednji bloker-napadač prvog tempa, primač-napadač, pri čemu svaka od njih imaspecifičnu funkcionalnu ulogu u igri. S obzirom na navedenu igračku raznolikost, neophodno je razvijati koordinacijske sposobnosti specifične za pojedine igračke uloge (Šimonek, 2014). Primjerice, kod dizača naglašena je sposobnost preciznog i pravovremenog usmjeravanja lopte na različite napadačke pozicije, pri čemu važnu ulogu ima kinestetička-diferencijacija. S druge strane, kod srednjih blokera posebno su važne sposobnosti brze prostorne orijentacije i pravovremenog reagiranja u bloku, dok se kod primača-napadača ističe koordinacija potrebna za usklađivanje kretanja, prijema lopte i pripreme za napad.

Nadalje, brzina reakcije predstavlja važnu koordinacijsku sposobnost koja dolazi do izražaja u različitim situacijama igre, poput obrane polja, reakcije blokera na dizanje lopte te prilagodbe dizača na neprecizan prijem. Zbog dinamičnosti i nepredvidivosti igre, ova sposobnost ima značajnu ulogu kod svih igrača, neovisno o njihovoj specifičnoj ulozi u ekipi.

Prema Vujmiloviću (2012) početak specijalizacije i podjela igračkih uloga u odbojci započinju u petnaestoj godini. Stoga je važno da treneri izbjegavaju poticanje rane specijalizacije, jer ona može dovesti do mišićno-koštanih ozljeda, sindroma pretreniranosti te preranog odustajanja od sporta (DiCesare, Montalvo, Foss, Thomas, Hewett i sur., 2019).

Iako rana specijalizacija može rezultirati brzim razvojem specifičnih koordinacijskih sposobnosti, takav napredak često je kratkotrajan, zbog prerane primjene specifičnih trenažnih sadržaja. Time se ograničava potencijal daljnjega razvoja u kasnijim fazama sportske karijere. Suprotno tome, produljeni naglasak na razvoju općih koordinacijskih sposobnosti omogućuje postupniji, ali dugoročniji napredak, pri čemu se uspostavljaju stabilniji temelji za kasniji razvoj specifičnih tehničko-taktičkih elemenata i ostvarivanje viših razina sportske uspješnosti. Početna faza sportske specijalizacije treba biti usmjerena na postupno usvajanje složenijih tehničko-taktičkih elemenata, uz izbjegavanje prerane i rigidne podjele na specifične igračke uloge. U ranoj fazi specijalizacije preporučuje se usmjeravanje igrača prema funkcionalnim zahtjevima igre, odnosno na skupine smečera i ne-smečera. Smečeri se usmjeravaju na razvoj primarno zadataka vezanih uz napadačke aktivnosti s različitih pozicija, dok se ne-smečeri usmjeravaju na usavršavanje zadataka vezanih uz organizaciju igre i obrambene aktivnosti. Navedeni pristup omogućuje razvoj šire motoričke baze i koordinacijskih sposobnosti te stvara kvalitetne preduvjete za kasniju, specifičniju i precizniju specijalizaciju u pojedinim igračkim ulogama.

1.6 Ciljevi istraživanja

Modernizacijom odbojke uspješna izvedba različitih faza igre, uključujući napadačke i obrambene akcije zahtijeva od igrača visoku razinu tehničkih i taktičkih vještina. Slijedom toga, koordinacijske sposobnosti sve se više integriraju u trenažni proces. Treneri su prepoznali da bez razvoja koordinacijskih sposobnosti od najranije dobi igrači ne mogu ostvariti svoj puni potencijal u vrhunskom sportu.

S obzirom na važnost koordinacijskih sposobnosti u razvoju i identifikaciji talenata u odbojci, kao i njihovu ključnu ulogu u uspješnoj izvedbi tehničko-taktičkih elemenata, potrebno je osigurati pouzdane i valjane metode njihova mjerenja. U tom kontekstu, posebno je važno razvijati i validirati testove koji će biti primjenjivi u mlađim dobnim skupinama odbojkašica.

Prva dva istraživanja usmjerena su na validaciju metrijskih karakteristika postojećih testova koordinacijskih sposobnosti na (specifičnom) uzorku mladih odbojkašica. U prvom istraživanju cilj je bio utvrditi metrijske karakteristike testa brzine reakcije sa specifičnim motoričkim zadatkom koji uključuje dinamičko okruženje i iščekivanje izvođenja zadatka kao što je „dohvati i dotakni“. U drugom istraživanju cilj je bio utvrditi metrijske karakteristike testa dinamičke ravnoteže prema Šimoneku, koji je modificiran kako bi bolje odražavao zahtjeve odbojkaške igre. U oba istraživanja pouzdanost testova procijenjena je usporedbom rezultata prvog mjerenja s prosječnim i najboljim rezultatom, u skladu s preporukama iz literature, s ciljem unaprjeđenja njihove primjene u trenažnoj praksi.

Treće istraživanje proširuje nevedeni pristup, zadržavajući fokus na općim koordinacijskim sposobnostima, ali uz dodatni cilj utvrđivanja njihove diskriminativnosti. Konkretno, cilj je bio ispitati mogu li odabrani testovi razlikovati igračice različitih igračkih uloga, kao i uspješnijeu odnosu na manje uspješne igračice unutar istih uloga. Time se dodatno naglašava praktična vrijednost testova u kontekstu identifikacije i usmjeravanja talenata.

Nadalje, s obzirom na ograničen broj istraživanja usmjerenih na specifične sposobnosti kod mlađih odbojkaša, javlja se potreba za razvojem specifičnih testiranja koja bi bila slična stvarnim uvjetima na sportskom terenu. Stoga, u četvrtom istraživanju naglasak je stavljen na konstrukciju i validaciju novih specifičnih testova koordinacijskih sposobnosti, usmjerenih na procjenu kinestetičke diferencijacije u uvjetima koji oponašaju zahtjeve odbojkaške igre. Za razliku od općih testova, koji su primjenjivi u ranim fazama razvoja i procesu usmjeravanja talenata, specifični testovi omogućuju precizniju procjenu igrača koji su već uključeni u odbojku te praćenje njihova napretka i procjenu maksimalnih razvojnih potencijala. Kao i u prethodnim istraživanjima, cilj je bio utvrditi mogu li testovi razlikovati igračice različitih igračkih uloga te uspješnije u odnosu na manje uspješne unutar istih uloga čime se može doprinjeti unaprjeđenju trenažnog procesa (Milić i sur., 2017).

Zaključno, istraživanja su koncipirana kroz jasnu gradaciju: od validacije postojećih testova koordinacijskih sposobnosti (prvo i drugo istraživanje), preko ispitivanja njihove diskriminativnosti u odnosu na igračku ulogu i razinu uspješnosti (treće istraživanje), do konstrukcije i validacije novih specifičnih testova (četvrto istraživanje). Takav pristup omogućuje cjelovit uvid u ulogu koordinacijskih sposobnosti u identifikaciji i razvoju talenata u odbojci te njihovu primjenu u praksi.

2. IZVORNI ZNANSTVENI RADOVI

2.1 Reliability and usefulness of the reaction speed test in young female volleyball players

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Original Article

Reliability and usefulness of the reaction speed test in young female volleyball players

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Abstract

Reaction speed represents a crucial ability to achieve a high-performance level in volleyball. A reliable computerized test for assessing reaction speed cannot simulate the dynamic environment of the volleyball game. Therefore, tests involving the activation of large muscle groups are needed. This study aimed to determine the reliability of young volleyball players' reaction speed ability using the Stopping the rolling ball test (SRB). Intraclass correlation coefficient (ICC), standard error of measurement (SEM) also expressed as a coefficient of variation (CV%), smallest worthwhile change (SWC), and minimal detectable change (MDC) were calculated. Paired t-test revealed no significant differences between test and re-test for first ($t = -0.09$, $p = 0.92$), mean of three ($t = -0.37$, $p = 0.71$), and best of three ($t = -0.02$, $p = 0.98$) trials. The ICC values showed poor relative reliability when the first trial was observed, while for the mean and best of three trials, reliability was consistently very high (excellent). The absolute reliability parameters (within-individual variation) showed large variations ranging from 5% to almost 10% and greater SEM (12.63 cm) for first trial when compared to other variables. The SEM was higher than SWC for all variables when the small differences (i.e., 0.2 multiplied by between-participants SD) were considered. This test showed a high level of absolute and relative reliability and usefulness, which means that the SRB test is an excellent indicator of reaction speed in young volleyball players.

Keywords: reaction speed, reliability, young volleyball players.

2.1.1 Introduction

Reaction speed is a player's ability to make decisions and act. It can be divided into two components. First is "*reaction tim*e" which is the time between exposure to a stimulus (acoustic, visual, tactile, kinesthetic) and the first muscular reaction. The second component is "*movement time"* that can be defined as a duration of a move [1,2]. Volleyball players train in a dynamic environment where they require in a short time great adaptation capacity and need to have an adequate level of cognitive skill, motor, and coordination capacities. For example, middle blockers task is to identify opponent's intention where the reaction speed comes to the high manifestation [3,4].

As one of five basic components of coordination [5], reaction speed has a positive impact on volleyball performance [5,6]. Modern volleyball has dramatically changed over the last decades. Coordination abilities become more important for a high-performance level because of skill complexity [7], and the players have limited time to react and respond [1,8]. In volleyball, according to Mroczek [1], reaction speed is ranked in the first place among all coordination abilities. A high level of reaction speed withdraws a better ability to read the game and anticipate what will happen before the opponent makes the action [6]. Skilled players are better in information extraction that is globally distributed across the body, rather than relying on a single isolated or local information cue or source [9]. Generally speaking, volleyball is a specific and complex game because of its short possession of a ball by one player, monitoring the ball's direction, and tracking the position of teammates and opponents on the court [10].

In several studies, reaction speed has been assessed with computerized tests, such as the Motor reaction test, Simple reaction time test, and Choice reaction time test [6,11–13]. Although they are reliable, they cannot replace sports activity situations [14]. Computerized tests put an accent on reaction time separating movement time component, which is not typical for sport-specific movements that require athletes to initiate large muscle groups [15,16]. Moreover, computerized tests require individuals to activate only small muscles without whole-body movement. Most reactive actions in sports are multi-joint movements that require the control of large muscles. Therefore, the precise response time of various simple and complex sport-specific actions can be achieved only by activating large muscle groups [15,17,18]. Additionally, large muscle groups activation can conceal deficiency in the components of reaction speed, such as the fact that the upper limbs are significantly faster than the lower limbs [19]. However, when recruiting large muscle groups, there is a possibility of unwanted inter-trial variability in movement. When a person repeats the same motor task over time, the movement produced is never the same. Inter-trial variability is greater in young children, and during motor development, movements gradually become more consistent. Consistent movement assumes that movement noise (unpredictable fluctuations) is kept under control [20]. Unwanted inter-trial variability can produce measurement error which inflates a participant's true score. Moreover, the participant's arousal, alertness, or motivation can account for greater trial-to-trial variation [21]. To adopt the optimal testing procedure, analysis of first, mean of three, or best of three trials can provide better insights on the reliability of reaction speed testing in athletes. Moreover, the testing procedure may differ between fully developed and youth athletes due to an immature nervous system and ability to focus on the task [22].

Therefore, this study aimed to determine test-retest reliability and usefulness of the Stopping the rolling ball test (SRB) in young female volleyball players. This previously constructed test for reaction speed ability assessment was chosen because of specific "reach and touch" motor tasks where players have constant anticipation in a dynamic environment [3,15]. Additionally, to determine the highest stability of SRB scores in young players, the first trial, mean of three trials, and the best of three trials reliability analysis was performed.

2.1.2 Material and Methods

Participants

A total of 28 female youth volleyball players (age 11.23±0.67 yrs, training experience 2.03±0.69 yrs) were included in the research from three volleyball clubs in Bosnia and Herzegovina. At the moment of testing, their training regime was two to three times per week. Parents of all participants were informed of the risks and benefits of the research and testing procedures. Written consent was received before participating in the study. They were also told that any of the participants (their child) could quit testing any time without any penalty. The inclusion criteria for participation in this research included: (1) at least one year of training experience, (2) being healthy (i.e., absence of cardiovascular disease, no history of chronic disease, illness, surgeries, hospitalizations, and musculoskeletal or joint injuries) and (3) having a valid sport medical certification. The investigation was conducted in accordance with the 1975 Declaration of Helsinki ethical principles for scientific investigations and approved by the Ethical Committee of the University of Split (number: 2181-205-02-05-20-025; 3 December 2020).

Experimental procedure

The test was performed on an indoor gym with a mean ambient temperature of ~25°C and ~65% relative humidity. To assess test-retest reliability, participants performed a test on two sessions with the 14-day interval in between [23]. All the participants had one initial attempt and three trials. A standard warm-up was conducted before the testing, which included 4 minutes of jogging and 6 minutes of head, shoulders, hips, and knee mobility exercises, all demonstrated by the measurer. Procedures were conducted by sport and exercise scientists, members of the Faculty of Kinesiology, University of Split. The principal investigator conducted both testing sessions (test-retest) in the same conditions, who initially demonstrated the SRB test, explained the procedures and monitored all trials. The second investigator recorded performance scores.

Stopping the rolling ball

Reaction speed was assessed by applying the Stopping the rolling ball test (SRB)[24]. The test was modified because every school in Bosnia and Herzegovina has a different standard for the size and quantity of benches. Participants stood behind two benches length 220 cm (5 cm distance between them), 150 cm from the lower edge of the benches with his back turned away in the opposite direction (cannot see the ball). Benches were leaned at the height of 120 cm so the volleyball ball could roll. The meter was attached to the surface of the bench. The principal investigator held a ball at the top of the benches (meter), and after the audio signal, he released the ball so that it rolls down between the benches. Participants' task was to turn around, run to the ball and stop the ball with both hands as fast as possible. The travelled distance of the ball was recorded after each attempt.

Statistical analysis

All data were analyzed with Statistica for Windows (Statsoft, version 14) and GraphPad Prism 9 (GraphPad Software, Inc.) and are presented as mean and standard deviation. The normality of the sample and homogeneity of variances was tested using Shapiro-'Wilk's test and 'Levene's test. The following important components of reliability were calculated:

(a) systematic bias, (b) within-individual variation, and (c) retest correlation (i.e. "relative" "measure of random error). Paired t-test was used to determine systematic bias/difference between two testing occasions (test/retest). Additionally, effect size was calculated using Cohen's d [25], with values of <0.2, >0.2 and <0.6, >0.6 and <1.2, >1.2 and <2.0, and ≥2.0 considered as trivial, small, medium, large, and very large effects, respectively [26]. Standard error of measurement (SEM) and standard error of measurement

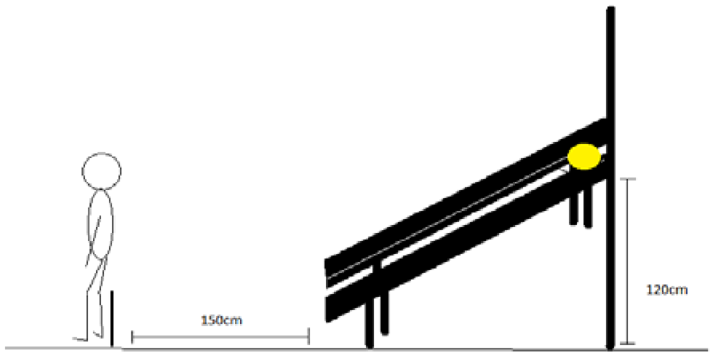

Figure 1. Visual representation of the SRB test

expressed as coefficient of variation (CV%) were calculated to determine within-individual variation, and the 95% confidence interval was also presented. The retest correlation was assessed with a two-way mixed model intraclass correlation coefficient (ICC) according to Koo and Li [27]. ICCs values of ≤0.4, >0.4 and <0.59, >0.6 and <0.74, and >0.75 are considered as poor, fair, good and excellent respectively [28]. The smallest worthwhile change (SWC) was also calculated for various effect sizes (0.2, 0.6, and 1.2 multiplied by the between-'participants' standard deviation, based on the 'Cohen's effect size principle, for small, medium, and large effect sizes, respectively). The usefulness of the test was determined by comparing the SWC score with the SEM [29]. If the SEM is lower than the SWC, then the test is rated as "good." If the SEM is higher than the SWC, then the test is rated as "marginal." If the SEM is about the same as the SWC, then the test may be useful or "satisfactory" [30]. Additionally, the minimal detectable change (MDC) was also calculated (SEM x 1.96 √2) for the interpretation of changes in scores which is outside an error and which is due to a real change in score and not due to the error in measurement and to complement the SEM [31]. Finally, repeated-measures ANOVA with effect sizes presented as partial eta-squared ($\eta 2$) was used to test statistical differences between the individual trials of each testing day (test, retest). The significance level was set at $p < 0.05$.

2.1.3 Results

All twenty-eight participants successfully completed SRB three trials without any complications. Figure 2 represents individual responses during the test and retest of the SRB. The analysis of variance revealed that there were no significant differences between trials on test ($F_{2,54}= 0.48$, $p = 0.62$, $\eta 2 = 0.02$) and retest ($F_{2,54}= 0.7$, $p = 0.5$, $\eta 2 = 0.03$).

Performance responses during the test and retest of the SRB are presented in table 1. Paired t-test revealed no significant differences in participant's performance outcomes (no systematic bias) between test and retest for SRBtrial1 ($t = -0.09$, $p = 0.92$), SRBmean ($t = -0.37$, $p = 0.71$), and SRBbest ($t = -0.02$, $p = 0.98$). High individual consistency in results between two testing occasions is observed for a mean of three trials and the best of three trials, while low consistency is found in the first trial of the SRB test (figures 3, 4, and 5).

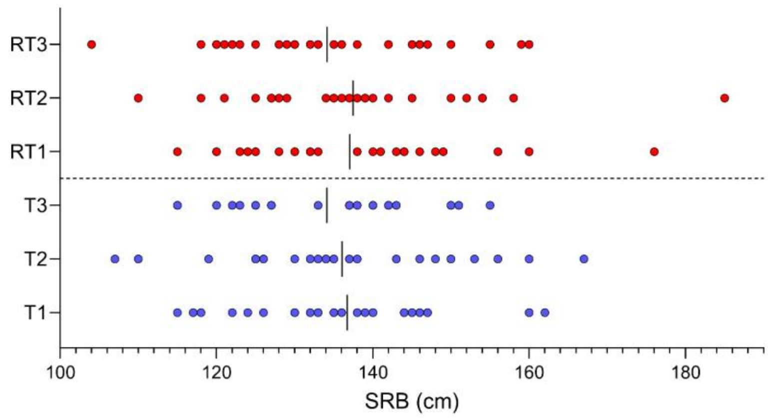

Figure 2. Individual performances during test and retest of the SRB, T – test; RT – retest.

Table 1. Performance responses during test and re-test of the SRB.

variable	Test	Retest	ES(95%CI)
SRB_{trial1}(cm)	136.71(12.35)	137.03(14.4)	-0.02(-0.55 – 0.5)
SRB_{mean}(cm)	135.63(10.62)	136.22(11.46)	-0.05(-0.58 – 0.47)
SRB_{best}(cm)	126.5(11.64)	126.53(11.99)	0.00(-0.53 – 0.52)

Legend: values are presented as mean and standard deviation; ES(95%CI) = effect size and 95% confidence interval; SRBtrial1 = first trial; SRBmean = mean of three trials; SRBbest = best of three trials

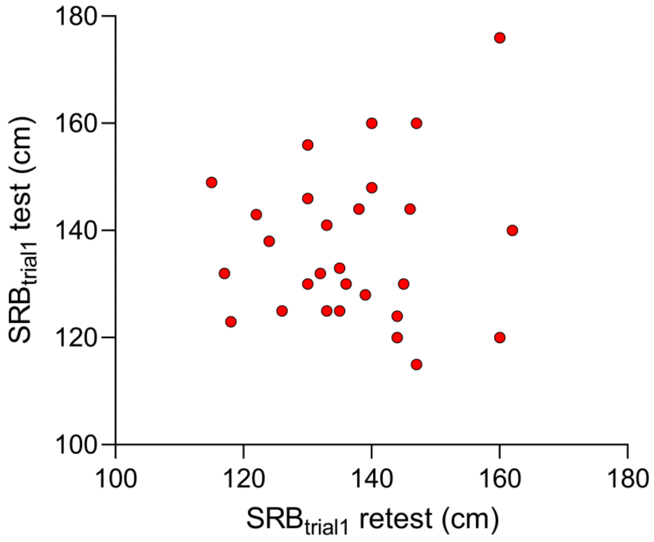

Figure 3. Scatterplot of the first trial obtained for the SRB at the test and retest.

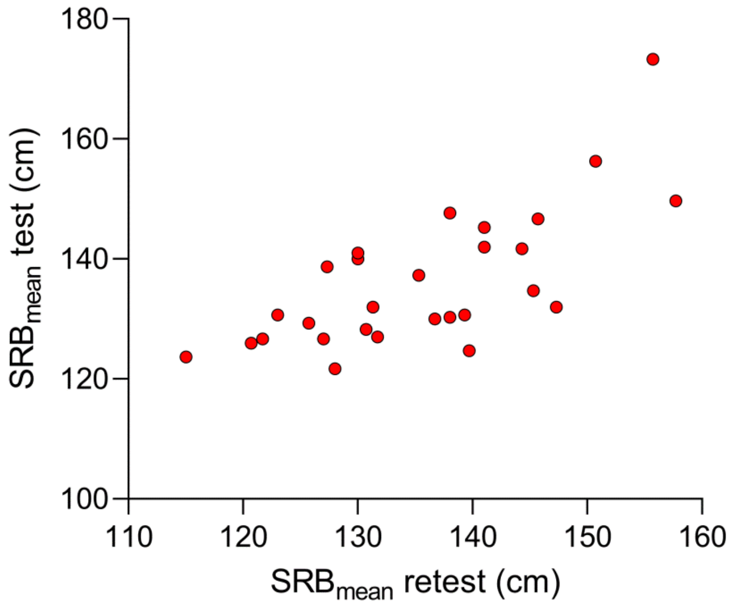

Figure 4. Scatterplot of the mean of three trials obtained for the SRB at the test and retest.

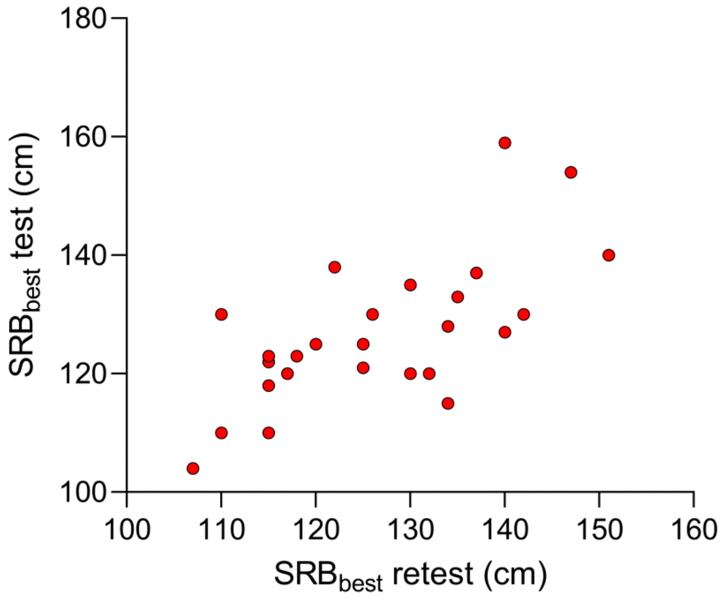

Figure 5. Scatterplot of the best of three trials obtained for the SRB at the test and retest

Table 2. Measures of reliability and usefulness of performance variables of the SRB test

variable	ICC(95%CI)	SEM(95%CI)	SWC(0.2, 0.6 and 1.2)	CV(%)	MDC
SRB_{trial1}(cm)	0.21(-0.71 – 0.64)	12.62(10.35 – 16.32)	0.91, 2.73, 5.46	9.67	34.98
SRB_{mean}(cm)	0.84(0.64 – 0.92)	5.92(4.68 – 8.06)	1.87, 5.6, 11.2	4.37	16.41
SRB_{best}(cm)	0.81(0.59 – 0.91)	6.71(5.31 – 9.14)	1.95, 5.84, 11.68	5.33	18.6

Legend: ICC(95%CI) = intraclass correlation coefficient and 95% confidence interval; SEM = standard error of measurement and 95% confidence interval; SWC = smallest worthwhile change; CV (%) = standard error of measurement expressed as cofficient of variation; MDC = minimal detectable change; SRB_{trial1} = first trial; SRB_{mean} = mean of three trials; SRB_{best} = best of three trials

Measures of reliability and usefulness of performance responses to the SRB test are presented in table 2. The ICC values showed poor relative reliability when the first trial was observed, while for the mean of three trials and the best of three, reliability between test occasions was consistently very high (excellent). The absolute reliability parameters (within-individual variation) showed large variations ranging from 5% to almost 10% and greater SEM (12.63 cm) for SRBtrial1 when compared to other variables. The SEM was higher than SWC for all variables when the small differences (i.e., 0.2 multiplied by between-participants SD) were considered.

2.1.4 Discussion

This study is the first investigation to evaluate the reliability and usefulness of SRB among young volleyball players. The SRB test scores on two testing occasions showed excellent absolute and relative reliability of SRBmean and SRBbest. This implicates that both approaches are equally useful when assessing reaction speed ability in young volleyball players. Although SRBmean and SRBbest showed excellent reliability (ICC=0.81 to 0.84), these results could be higher if participants were 13 years old and above when the complex motor reaction reaches its maximum [24,32]. However, ICC can be affected by the heterogeneity of the sample, and therefore, it is recommended to use SEM and CV as additional measures of absolute reliability [33].

The SEM is considered to be a parameter for the amount of measurement error present in a test [34]. Furthermore, SEM represents precision or the trial-to-trial noise of the test. The SEM values in this investigation are considered as small (below 10%), which suggests that the SRB test didn't differ in two testing occasions [35]. Furthermore, SEM value is useful to determine the minimal detectable change (true changes in performance) that athletes must show between two testing occasions to ensure that the observed change is real not just measurement error. This research revealed that the MDC was from 12 to 25% [36]. Despite the relative reliability being acceptable, the usefulness of the test must be taken into account. As shown above, the difference between SEM and SWC(0.2), which we can define as the ability to detect a meaningful change in tests, was large. The SWC(0.6) was satisfactory, and SWC(1.2) was higher than SEM, indicating "good" usefulness. In other words, the test can be utilized to detect changes that exceed 0.6 to 1.2 times the test standard deviation [30]. Within-individual variation values (lower than 6%) may be interpreted as good absolute reliability, meaning that typical variation from test to test will be around 6 cm for SRBmean and SRBbest. A similar coefficient of variation was found in reproducibility studies on the assessment of sport-specific reaction time [16,37]. Good reliability and usefulness indicate that the SRB test is a valid tool for assessment of the reaction speed ability in young volleyball players. The SRBtrial1 showed poor reliability (low and non-significant ICC) and low usefulness (rated as "marginal"; SWC [0.2, 0.6, and 1.2] considerably smaller than SEM). The reliability of a measure based on a single item can be compromised by a lack of variability across all participants [21]. This is important because If reproducibility between the first trial is high, practicians can consider saving time by having only one trial/attempt, which can be wrong. The poorest SRB scores occurred in the first trial, which can be attributed to the fact that young players may learn tasks over trials. Possible learning effects can exhibit in young athletes while performing complex tasks [38]. Moreover, younger participants might exhibit greater learning effects due to the novelty of the task and motor development processes [22,39].

The SRB uses distance instead of time as a measurement of reaction speed. A similar concept to record reaction was applied in RTclin test [40]. The authors used a thin, rigid cylinder to which a weighted disk is attached. The cylinder is released by the investigator and then caught as quickly as possible by the athlete. The distance of the falls before being grabbed by the hand is measured. However, researchers were able to convert the distance into the reaction time by using the formula for a free body falling under the influence of gravity. The same principle was not possible in the SRB test due to the angle of the benches and the distance between them.

Our results should be considered in light of few limitations. First, the reliability in physical performance is crucial when establishing whether a new test is valid and applicable, and construction of the new sport-specific tests is not an easy task [41]. Instead of constructing a new test, this investigation attempt to assess reproducibility and applicability of the previously constructed SRB test by determining absolute and relative reliability, which is a prerequisite to establishing the validity of a new test. Although this research did not deal with the validity of the SRB test, future research should conduct test validation analysis and compare obtained findings with previous well-established tests that assess reaction time in young athletes. Second, The SRB test does not simulate game-specific movements of opponents and ball, which can affect the pattern recognition in the stimulus-identification stage differently than simple reaction stimuli like audio signals [42]. Third, the sample size is small, and it is unknown whether a larger number of participants would produce the same or similar results. Moreover, the sample included only female participants. Although girls predominate at this age, future research should include boys to verify the generalizability of these findings. Forth, as this is the first investigation dealing with the reliability of the SRB test, comparison with the previous findings was not applicable.

2.1.5 Conclusion

In conclusion, the present investigation showed that the SRB test has good levels of reliability and usefulness in young volleyball athletes. Reaction speed impacts volleyball where the game is dynamic, and players must react quickly to the changing situation ("reading" the game), which requires a fast multi-joint movement response. Consequently, this research demonstrates that the SRB test is an excellent indicator of reaction speed in young volleyball players. A minimum of three test trials is recommended for future investigations due to the learning effect and possible lack of variability when only one trial is analyzed. Additionally, the discriminative and construct validity of the SRB test should be evaluated in future investigations. It would be interesting to establish how well the SRB test can differentiate athletes of different quality levels and the relationship with other tests assessing reaction speed.

Declaration of competing interest

The authors have no conflicts of interest to declare.

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2.2 Testing dynamic balance in youth female volleyball players: development, reliability and usefulness

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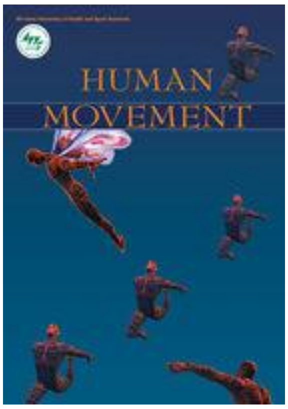

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Testing dynamic balance in youth female volleyball players: development, reliability and usefulness

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Abstract

Purpose. The aim of this research was to develop a dynamic balance test and examine its reliability by comparing first trial results with the average and best ones from multiple attempts.

Methods. Overall, 32 volleyball players (aged 11.3 ± 0.67 years) were investigated in 2 sessions (with a 14-day interval), each consisting of 3 trials of the modified bench walk with 3 turns (MBW3T) test. Three test methods were compared: first trial (MBW3Ttrial1), average result (MBW3Tmean), and best result (MBW3Tbest). A paired-sample *t*-test determined differences with an effect size. Test-retest reliability was assessed with an intraclass correlation coefficient.

Results. The paired-sample *t*-test revealed no significant difference in performance between test and retest for MBW3Ttrial1 ($t = 0.01$, $p = 0.99$), MBW3Tmean ($t = –0.46$, $p = 0.65$), and MBW3Tbest ($t = –1.05$, $p = 0.30$). Standard error of measurement (SEM) as the absolute reliability within-individual variation parameter showed that MBW3Ttrial1 had higher variation than MBW3Tmean and MBW3Tbest, in which the measurement error was minimal. To identify usefulness, we calculated the smallest worthwhile change and compared it with SEM for different effect sizes; the test was rated marginal to satisfactory. The study results indicated fair reliability when the first trial was observed and good reliability for the mean and best of 3 trials.

Conclusions. MBW3Tmean and MBW3Tbest are cheap, simple, reliable, and marginal to satisfactory useful measures for assessing dynamic balance in youth female volleyball players and can be used in scientific and practical settings.

Keywords: coordination, team sports, adolescent, athletic performance, movement

2.2.1 Introduction

Motor coordination appears to be crucial for success in different sports dominated by different movement structures, such as gymnastics [1], judo [2], or volleyball [3]. Although it is fundamental to performance development in sport, there is an evident lack of consensus between researchers on the theoretical structure of motor coordination abilities and reliable and valid procedures of testing them [3]. On the other hand, the majority of authors consider dynamic balance to be an important part of motor coordination and consequently involve it in testing protocols [1, 4]. Balance is the ability to maintain postural stability of the body without support throughout the somatosensory, vestibular, and visual systems as feedback from the central nervous system [5]. Furthermore, there is a classification into static balance ability, when the body is in a stationary position, not intended to move, and dynamic balance ability, when the body is in active movement, trying to maintain balance [6].

Balance is important for children who want to be engaged in sports activities because maintaining controlled body movement is essential for athletes during competitions and training [7, 8]. Elite players in team sports games are supposed to possess optimal balance control in static and, especially, dynamic conditions, as well as the ability to move in a controlled way over the limited playing surface [9]. Good balance reduces the risk of injury in every period in life [10, 11]. Therefore, incorporating balance training into the program has a positive impact on many aspects of sports performance [12]. In numerous studies one can find different protocols for testing static and dynamic balance in the athlete population, e.g. the Balance Error Scoring System (BESS). BESS was designed to easily assess postural stability in athletes who are at high risk of contusion, with an intraclass correlation coefficient (ICC) of 0.90. Despite a high reliability due to the BESS subcategories, the test is rated as inadequate for assessing postural stability [13]. The Star Excursion Balance Test and the Y Balance Test are also tools for assessing lower extremity balance and they are applied after the implementation of a rehabilitation program. Both tests have excellent inter-rater reliability (0.88–0.96) and therefore they can be applied in a healthy population [14]. Anothertest, the Motor Control Test, in most cases has been tested among older adults, with a high reliability of 0.85 [15]. All previously mentioned tests are utilized in computerized dynamic posturography [16], althoughvery reliable tests are not 'similar' to situational movement (lack of ecological validity). It is important to underline that movement structures in such tests arein general not dynamic enough owing to the lack of demands on the proprioceptive and the somatosensory systems, especially those which influence the reestablishment of posture after a perturbation [17, 18].

Consequently, for an ecologically valid estimationof dynamic balance among youth team sport athletes,tests with more pronounced dynamic componentsshould be developed and examined with reference to reliability and usefulness. For example, more dynamic tests should be used, such as the Backward BalanceTest, drawn from the Körperkoordinationstest für Kinder battery of tests, or bench walk with 3 turns [4].The Backward Balance Test has recently been researched for test-retest reliability (0.80–0.95) [19].There is, however, an evident lack of current investigations on the reliability and usefulness of bench walk with 3 turns. Furthermore, the performing complexity of this test clearly indicates a need for its modification; among others, it should be made more volleyball-specific and easier to apply in young players or children. In addition, the assessment of the first trial, the average result, and the best result of 3 trials have been used as outcome scores [20, 21]. Owing to lack of time or general resources, some coaches either do not conduct testing at all or implement tests in such a manner that only one item is performed for each test. Therefore, that single item would be the first one in our case; it was compared with the 2 methods recommended by scientists, i.e. the average result of multiple attempts and the best result of multiple attempts.

This testing procedure gives a more complete estimation of reliability and usefulness, especially respecting the fact that inter-trial variability is greater in children [22]. Following the previously stated facts, this study aimed to fill the existing gap – to modify the dynamic balance ability test in youth female volleyball players so that it more precisely simulated volleyball-specific situations. It was hypothesized that the test would present good reliability and potential usefulnessto assess balance in a sample of young volleyball players. Finally, the aim of this research was to develop a dynamic balance test and examine its reliability by comparing first trial results with the average and best ones from multiple attempts.

2.2.2 Material and methods

Study design

Owing to the issue of finding the most suitable balance test for youth female volleyball players, this research analysed the reliability and usefulness of the modified (i.e. ecologically more valid) dynamic balancetest by comparing the first, average, and best results.

Participants

A sample of 36 youth female volleyball players were recruited from 3 randomly chosen clubs in Herzegovina; they represented the same level of training andcompetition. During interviews with players, the participation criteria were verified: the inclusion criterion of at least 6 months of training experience and the exclusion criterion of any kind of injury that would prevent the athletes from testing. Two participants were excluded from the sample because of the recent injuries. Furthermore, the subjects were asked to identify their health status; then, another 2 participants were removed from the sample because of a musculoskeletal disorder and recent musculoskeletal injuries. Finally, a convenience sample of 32 participants (age: 11.3 ± 0.67 years, training experience: 6–48 months) completed both testing sessions. At the time of testing, they had 2–3 workouts per week. The parents of all participants were informed in detail on the goal of the research and testing procedures; they were notified that any player could withdraw from the testingat any time with no consequence.

Procedures

The test was performed on an indoor floor surface to control for the environmental conditions. The hall temperature was ca. 25°C and humidity equalled 65%. A dynamic warm-up was conducted before the testing and included 4 minutes of jogging and 6 minutes of head, shoulder, hip, and knee mobility exercises. One experienced measurer, the first author of the study,evaluated all participants. Before the testing, the procedure was precisely demonstrated to all subjects. After one preparatory attempt, the individuals performed the test 3 times, with a 30-second pause between the trials. The assessment was organized in 2 testing sessions, with a 14-day break between them. Each session was carried out in the afternoon, between 1:00 and 4:00 p.m. The participants were dressed in shorts and T-shirts.

Bench walk with 3 turns test

To evaluate the volleyball players' coordination, we used the modified bench walk with 3 turns (MBW3T) test (dynamic balance), in which the participant stands behind a 3-m long bench [23]. Before the signal is provided, child has right leg on the bench. At a signal, the child stands on the bench and tries to walk to the otherend, while making three 360° turns (Figure 1). If the examinee loses their balance, they can touch the ground up to 2 times; each touch represents one negative sec- ond added to the final measured time or, otherwise, becomes a reason for the test to be repeated. The final score is gathered as the time from the starting signal to the touch of the ground behind the bench. The modification of the test consisted in the fact that the bench was not turned upside down, and the movement was performed on the wide side (22 cm), which is 12 cm wider than the narrow one. Consequently, the test would not be too complicated and the movements with turns would be even faster and more dynamic, which is specific for volleyball.

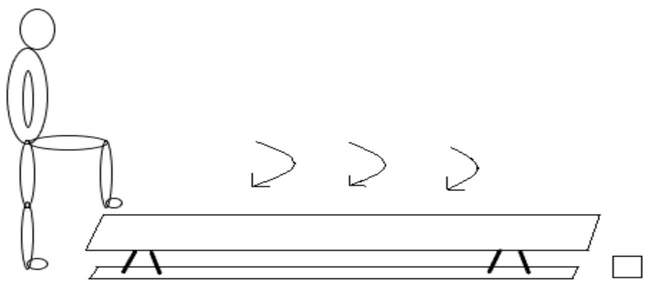

Figure 1. Visual representation of the modified benchwalk with 3 turns test

Statistical analysis

All data were analysed with the SPSS Statistics 27.0 for Windows and GraphPad Prism 9 (GraphPad Software, Inc.) software and are presented as mean and standard deviation. The Kolmogorov-Smirnov test was used to verify the normality of the data. Components of reliability such as systematic bias, within- individual variation, and retest correlation were calculated [24]. A paired-sample *t*-test was conducted to determine if there were the significant differences (systematic bias) between the 2 testing occasions (test-retest). In addition, the effect size was calculated in accordance with Cohen's *d*. The effect sizes were interpreted as follows: 0.0 to < 0.2, trivial; 0.2 to < 0.6, small; 0.6 to < 1.2, medium; 1.2 to < 2.0, large; 2.0 to < 4.0, very large; and ≥ 4.0, extremely large [25]. Test-retest reliability was assessed by using ICC model alpha witha 2-way mixed effect and a 95% confidence interval (CI) when analysing the first trial, the average result, and the best result [26]. ICCs are considered excellent if larger than 0.75, good from 0.60 to 0.74, fair from 0.40 to 0.59, and poor if ≤ 0.39 [27]. Furthermore, to identify within-individual variation and the 95% CI over the repeated trials, the standard error of measurement (SEM) was determined by using the following formula: $SEM = SD \cdot \sqrt{1-ICC}$.

Similarly, to identify the 95% CI of changes in scores which were generated by a real change in score and not by the error in measurement, minimal detectable change (MDC) was calculated with the following formula: $MDC = SEM \times 1.96\sqrt{2}$.

The coefficient of variation (CV) expressed as the percentage of the mean score and CV% below 10% were considered acceptable [28]. The smallest worthwhile change (SWC) was also calculated for various effect sizes (0.2, 0.6, and 1.2 multiplied by the between-participant standard deviation) to verify the usefulness of the test. The usefulness of the test was assessed by analysing SWC and SEM, where SEM below SWC indicated good usefulness, SEM similar to SWC was rated satisfactory, and SEM higher than SWC was considered as marginal [29].

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Research Ethics Committee of the Faculty of Kinesiology,University of Split, Croatia (approval No.: 2181-205- 02-05-18-002 as of January 8, 2018).

Informed consent

Informed consent has been obtained from all individuals included in this study and their parents.

2.2.3 Results

The sensitivity of the tests was monitored with the Kolmogorov-Smirnov test, which revealed no significant difference between the obtained distribution results and normal distribution (p > 0.20, skewness = 0.15, kurtosis = –0.11). The results of the paired-sample t-test demonstrated no significant difference in performance between test and retest for $MBW3T_{trial1}$ (t = 0.01, p = 0.99), $MBW3T_{mean}$ (t = –0.46, p = 0.65), and $MBW3T_{best}$ (t = –1.05, p = 0.30). High individualconsistency in results between the 2 testing sessions (Table 1) was observed for all 3 testing responses (Figures 2–4).

Table 1. Performance responses during test and re-test of the MBW3T

variable	Test	Re-test	*ES*(95%CI)
$MBW3T_{trial1}$(s)	7.30(1.57)	7.30(1.42)	0.00(-0.34 – 0.35)
$MBW3T_{mean}$(s)	7.21(1.20)	7.32(1.42)	-0.08(-0.43 – 0.27)
$MBW3T_{best}$(s)	6.39(1.00)	6.59(1.31)	-0.18(-0.53 – 0.17)

Legend: values are presented as mean and standard deviation; ES(95%CI) = effect size and 95% confidence interval; $MBW3T_{trial1}$ = first trial; $MBW3T_{mean}$ = mean of three trials; $MBW3T_{best}$ = best of three trials

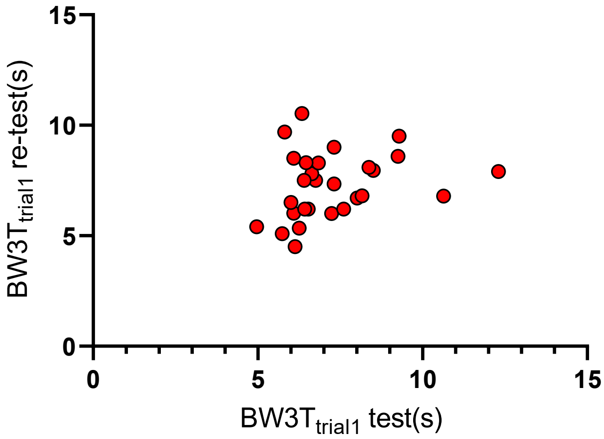

Figure 2. Scatterplot of the first trial obtained for the MBW3T at the test and re-test

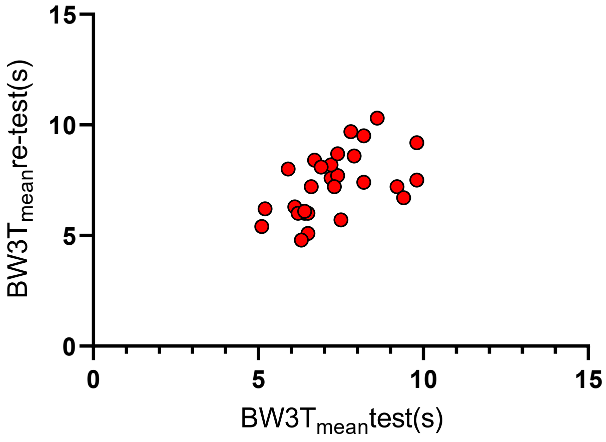

Figure 3. Scatterplot of the mean of three trials obtained for the MBW3T at the test and re-test

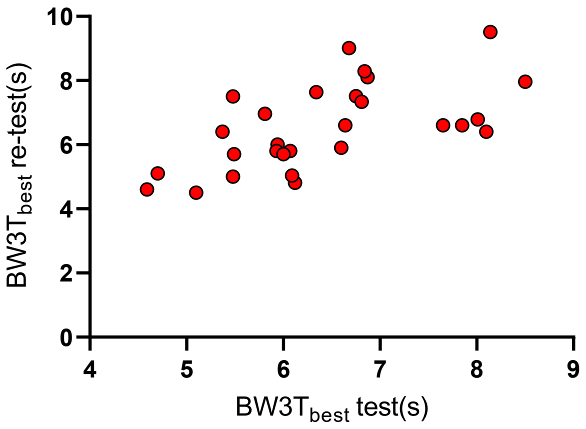

Figure 4. Scatterplot of the best of three trials obtained for the MBW3T at the test and re-test

Furthermore, the relative reliability assessment together with 95% CI and absolute reliability parameters of the MBW3T test are presented in Table 2. The test-retest reliability indicates a fair value at the first trial, while when it comes to mean and best results, the reliability was good. SEM was investigated as an absolute reliability within-individual variation parameter. It can be observed that $MBW3T_{trial1}$ exhibited higher variations compared with $MBW3T_{mean}$ and$MBW3T_{best}$.

In the first place, SEM was tested as the absolute reliability within-individual variation parameter and it was shown that $MBW3T_{trial1}$ presented higher variation (6.27%) than the $MBW3T_{mean}$ and $MBW3T_{best}$ results. To identify a meaningful change in performance, we calculated SWC by multiplying standard deviation by 0.2, 0.6, and 1.2, finding that SEM was higher than SWC for variables that were multiplied by 0.2 and 0.6.

Table 2. Measures of reliability and usefulness of performance variables of the MBW3T test

Variable	ICC(95%CI)	*p* (ICC)	SEM(95%CI)	SWC(0.2, 0.6 and 1.2)	CV(%)	MDC
$MBW3T_{trial1}$(s)	0.47(-0.12 – 0.74)	0.05	5.99(4.80 – 7.96)	1.7, 5.1, 10.2	6.27	16.55
$MBW3T_{mean}$(s)	0.68(0.38 – 0.84)	<0.01	2.38(1.88 – 3.24)	0.68, 2.04, 4.08	3.40	6.58
$MBW3T_{best}$(s)	0.73(0.45 – 0.87)	<0.01	0.77(0.62 – 1.03)	0.22, 0.66, 1.32	1.10	2.13

MBW3T – modified bench walk with 3 turns ($MBW3T_{trial1}$ – first trial, $MBW3T_{mean}$ – mean of 3 trials, $MBW3T_{best}$ – best of 3 trials), ICC – intraclass correlation coefficient, SEM – standard error of measurement, SWC – smallest worthwhile change, CV% – typical error expressed as coefficient of variation, MDC – minimal detectable change

2.2.4 Discussion

This study aimed to modify the bench walk with 3 turns test so that the ecological validity was even more emphasized, as well as to examine the reliability and usefulness of this test. In doing so, the existing testing procedure was modified in a way that the movement was performed on the wide side of a bench so the test performance was faster, more dynamic, and therefore more volleyball-specific. After all, it has to be underlined that a very limited number of studies deal with dynamic balance issues in volleyball so the resultsof this research are found to be hard to compare with previous outcomes. The test-retest reliability was observed through ICC and the results of $MBW3T_{mean}$ and $MBW3T_{best}$ showed good reliability. It can be concluded that both approaches are useful in the assessment of balance ability. The MBW3T test included reactions to postural disturbances evoked by abduction-adduction movements (i.e. turning around). Consequently, the application of more difficult tasks and posturokinetic activities leads to larger errors, which is an age-dependent process [30]. If MBW3T was im-implemented in a population of volleyball beginners (i.e. children), the number of turns should probably bereduced and reliability would increase. When dealing with younger age categories, one has to take into account that at the age of 12, dynamic balance, along with spatial orientation and rhythmic capacity, are the most frequently dominating abilities in volleyball [31].Furthermore, at the age of 15, volleyball players show the best results in dynamic balance. Considering the previously stated facts, one can conclude that there is a possibility to obtain higher reliability indexes in an observed sample. Also, in the context of junior and senior age categories and the interaction of their coordination capacities with long-term training processes, it would be of interest to examine

reliability indexesin that population [23, 32].
Moreover, the SEM values, as an estimate of the measurement error, indicate that the typical score in $MBW3T_{mean}$ and $MBW3T_{best}$ variables can deviate by 2.38 to 0.77 seconds. Additionally, SEM is used to calculate MDC [33]. When observing MDC, it is important to monitor progress, in this case, of volleyball players so that intra-trial variations do not inaccurately suggest a change [31]. In this research, random error was found to be low, which is reflected in good reliability.
The usefulness of the test was examined by comparing the results of $SWC_{(0.2, 0.6, \text{ and } 1.2)}$ with SEM. It can be concluded that the test can be utilized to detect changes that exceed 0.6–1.2 times the test standard deviation [29]. $SWC_{(0.2)}$ showed marginal usefulness and $SWC_{(0.6)}$ presented a satisfactory level of usefulnessof the test. It should be noticed that poorer results in $MBW3T_{trial1}$, with low reliability and usefulness, can be of great importance for practitioners. With this inmind, one should not conduct fewer than 3 testing trials so that conclusions can be drawn by using the meanor best result of 3 trials because they are equally reliable [34]. The modification of the test was introduced tomake the performance level adjustable for the childrenand it has shown to be a reliable measure. Also, the test modification is reflected in the dynamic aspect as volleyball is among the most dynamic sports [35]. The dynamic balance performance would have probably been even better if the participants had applied positive self-talk during the task as a motivation strategy [36]. It would have been more effective if the measurer had motivated the children with a precisely defined positive talk before their performance.
This research had some limitations. First of all, the study involved a relatively small sample size – it is unknown if a larger sample size would have brought about similar results. The second limitation is the fact that aspects of validity were not analysed. Moreover, in future research, the test would be even more dynamic if the number of turns is to be reduced. Most studies focus on the clinical application of balance and less on athletes, and the vast majority of them are based on computerized dynamic posturography. Consequently, another limitation refers to the impossibility of comparison with other, similar studies. Additionally, only female athletes were tested, which limits referring the results to male athletes.
In practice, balance tests are in most cases expensive to perform. This study indicates reliability of a dynamicbalance test that is simple and inexpensive and therefore can be applied in all sports, not only volleyball.

2.2.5 Conclusions

Testing balance ability in children with the MBW3T test revealed a good level of test-retest reliability for 2 testing procedures (mean and best results). These findings indicate that there is a need to perform more than one trial for the test to be reliable. Nevertheless, the study proves that MBW3T can be considered as a cheap, reliable, and satisfying tool for dynamic balance estimation and can be used in scientific and practical settings, especially in coordination monitoringin longitudinal research designs.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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2.3 Non-specific coordination tests for female volleyball players: reliability, discriminative ability and usefulness

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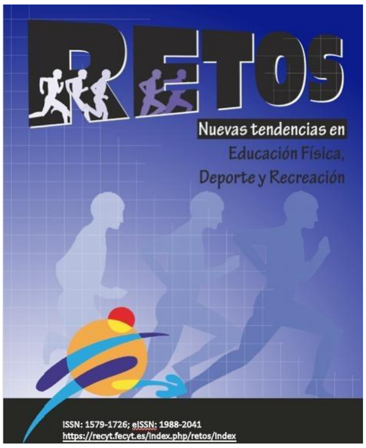

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Non-specific coordination tests for female volleyball players: reliability, discriminative ability and usefulness

Pruebas de coordinación no específica para jugadoras de voleibol femeninas: fiabilidad, capacidad discriminativa y aplicabilidad

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Abstract

Objective: This study aims to determine the reliability and discriminative ability of the non- specific coordination battery tests.

Methods: The sample in this study was 98 female volleyball players aged 15.20±1.00 years from six clubs in Bosnia and Herzegovina. Coordination abilities were assessed with six tests meas- uring balance (Bench walk with three turns), reaction speed (Stopping the rolling ball test), kinesthetic-differentiation of legs and arms (Target standing broad jump test and Target sitting throw test), and space-orientation abilities (Shuttle run reactive and non-reactive test). The first step was to determine the subgroup of 13 players' test-retest reliability using the test-re- test method. Discriminative ability was used to analyze the performance between different playing positions and situational performance.

Results: The relative reliability was excellent (ICC: 0.76 to 0.89) in all tests except for the Target sitting throw test, whose reliability was fair (ICC: 0.58). The absolute parameters of reliability: standard error of measurement (SEM) variations were low. The SEM was higher than the SWC (0.2) for all variables, indicating marginal usefulness for small changes, and lower than SWC (1.2) for most variables, suggesting good usefulness for larger changes. The minimal detectable change (MDC) varied, with smaller values for some tests (e.g., 0.50–0.72 s) and larger values for others (e.g., 23.73 cm for TST), reflecting differing precision levels. Afterward, one-way ANOVA detected no significant inter-positional differences in all tests. A significant difference was found between more successful and less successful players.

Conclusion: The obtained results reveal that this battery test is reliable and valid for estimating non-specific coordination abilities among female volleyball players.

Keywords: Technique, sport-specific skills, kinesthetic differentiation, and space-orientation ability.

2.3.1 Introduction

As in other sports, coordination, technique, and skills need to be well-developed in volleyball. Young athletes need to be challenged throughout training by learning a broad spectrum of motor skills. As a result, they can achieve high motor abilities, which will help them learn and improve sport-specific skills at a later age (Clark, 2007; Kirk & Gorely, 2000). Recently, a large number of researchers have been dealing with the problem of coordination in elementary school children. This is not only because coordination can be found in every movement structure, but also because coordination can be highly devel- oped during sensitive periods of child development (Boichuk et al., 2020; Ljach & Witkowski, 2010).

In volleyball, coordination is especially important for adapting to the unpredictable nature of the game. Players must respond quickly to complex stimuli such as changes in ball trajectory or opponent move- ment, which requires advanced spatial orientation, reaction time, and rhythm (Gjinovci et al., 2017). These demands become even more specialized depending on the playing positions, for example, setters require rhythm and fine motor control, while libero players rely on reaction speed and dynamic balance (Bobula et al., 2024; García-de-Alcaraz & Usero, 2019; Wang et al., 2025).

By understanding the process of young sports development, coaches in any sport, including volleyball, can avoid mistakes that may lead to reduced development of coordination abilities, which are most un- likely to be made up later (Boichuk et al., 2020; Đolo et al., 2022). Furthermore, improving the quality of training by including all coordination abilities in the early stage of sports development contributes to achieving high sports results (Šimonek, 2014). Therefore, general coordination abilities are vital in mastering techniques and solving complex motor tasks that are common in modern volleyball (Boichuk et al., 2023; Pion et al., 2015). Consequently, a high level of development of coordination abilities leads to easier mastering of new and complicated game techniques and tactical skills, and a faster adaptation towards the changes brought by the volleyball game (Bujang et al., 2019).

Even though there are several different divisions, most authors divide coordination into five basic abilities: kinesthetic differentiation, reaction ability, rhythmic ability, balance, and space-orientation ability (Šimonek, 2014; Starosta et al., 2003). Each of them plays an important role in mastering volleyball. In the last several decades, some studies have focused on researching tests for general coordination abilities since they are more suitable for application to young athletes before playing sports (Boichuk et al., 2018, 2019). In many ways, these investigations yield results by combining coordination with morphology, the nervous system, or other factors. Nonetheless, previous studies omitted more profound observations of coordination necessities for volleyball and provided more insight into the selection of volleyball players. These studies tend to omit key aspects of volleyball-specific coordination demands, such as the ability to perform precise and rapid movements due to unpredictable ball trajectories and the requirements of different playing positions. The focus has been shifted more towards players' selection criteria than a deeper understanding of general coordination abilities that underpin successful volleyball performance.

Coordination requirements of volleyball for improving general skills in these age groups are high due to the need for advanced attack preparation and court defense, which are part of the complex volleyball structure (Boichuk et al., 2017). Likewise, complex movement structures of opponents and teammates to get the finest out of the rally (competition) demand improvement in all the coordination abilities mentioned above.

Consequently, coordination is important for selecting female volleyball players (Mostaert et al., 2022; Pion et al., 2015). Equally important are the playing positions in volleyball with their specific tasks during matches. Initially, the playing positions were more universal, but by changing the rules and developing tactics, those positions evolved into more specialized ones. Moreover, apart from the anthropometric profile of players, coordination plays a crucial role in distinguishing between these positions (Cabarkapa et al., 2022). No information on differences in coordination abilities among playing positions has been found.

Therefore, the main purpose of this study was to determine the test-retest reliability and discriminative ability to assess non-specific coordination abilities. Reliable tests are essential for valid assessment, while discriminative ability is key to distinguishing between different performance profiles. Recent findings by Đolo, Grgantov, and Kuvačić (2023) have shown that coordination tests can demonstrate strong reliability and reveal differences between skill levels. By focusing on general coordination tests, this study provides valuable methods for coaches and researchers to assess coordination at early stages of development and to guide future studies into the development of position-specific coordination.

2.3.2 Methods

Study Design

In this study, the test-retest reliability and discriminative ability were assessed. A subsample of 13 female participants performed all tests in two testing sessions, separated by a seven-day break, to assess test-retest reliability. Furthermore, the discriminative ability was determined by analyzing the differences among players of different playing positions and situational performance. Players were instructed by their coaches to avoid factors that could affect their performance on the testing days, such as refraining from any physical activity before and during the testing days, and refraining from consuming caffeine-containing beverages and low-fiber diets. The testing was conducted in June 2021 with a temperature ranging from 21 to 24°C. All measurements were performed after the warm-up, which consisted of 10 minutes of jogging and mobility exercises. A demonstration was given by an experienced measurer who introduced them to all testing procedures with one preparatory attempt.

Participants

The study involved a group of 98 U-17 female volleyball players (age 15.2±1 years, body height 171.1±6.4 cm, sitting height 89.6±4.8 cm, body weight 62.2±8.35 kg, training experience 4.3±1.1 years) from six volleyball clubs in Bosnia and Herzegovina. These clubs were part of a convenience sample, consisting of teams that agreed to participate in the testing. All participating clubs compete in a two-tier regional youth competition system: Super League and First League, modeled after the senior women's league. Although not randomly selected, the sample includes players from competitive training groups within the relevant age category, providing valuable insights into this population. The players specified their playing positions (setter, middle blocker, libero, opposite hitter, and passer-hitter) and were asked for parental consent to conduct the testing. Coaches also agreed to participate and were given a clear explanation of the study. Players had been involved in a minimum of two years of training and trained 2 hours per session, four days per week.

Combining two criteria: (i) Placement of teams in the competition (Super League and 1st League) and(ii) Quality of individual players within their team, the situational performance of the players was assessed. In the second criterion, coaches categorize their team players into three groups: (1) leading team players; (2) the rest of the starting players and players entering the game, thus contributing to the team result; (3) players who rarely or never enter the game. Table 1 presents a combination of these criteria. Further details on this classification approach can be found in Grgantov, Katić, and Janković (2006). Coaches give each player a score from 1 to 5. Those players who scored 4 and 5 were more successful, and less successful players were the ones who scored 3, 2, and 1. Accordingly, the sample was divided into two subsamples: more successful (n = 39) and less successful (n = 59) players. During the analysis, eight players without an assigned playing position were excluded. No history of injuries or diseases that could affect test performance was observed.

Table 1. The situational performance of the players according to the two criteria.

Team Placement	Within Team Players' Quality Evaluated by the Coach		
	Group 1	Group 2	Group 3
Super League	5	4	3
1st League	3	2	1

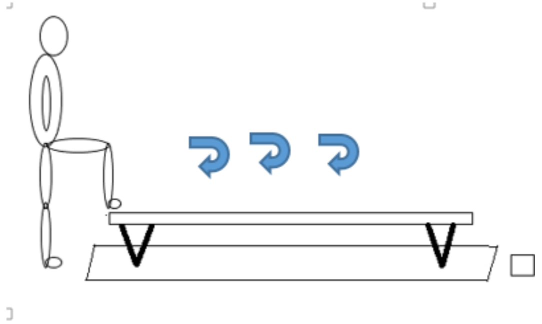
Measures

Coordination abilities were assessed with six tests measuring balance, reaction speed, kinesthetic differentiation, and space-orientation abilities. All tests were carried out under the same conditions by a team of trained researchers, all of whom hold PhDs in kinesiology. Before testing began, the team received detailed instructions to ensure consistency in how the tests were administered and scored. This standardization helped reduce potential differences between evaluators and improve the overall reliability of the assessments.

Bench walk with 3 turns test (BW3T)

To evaluate the volleyball players' balance ability, the Bench walk with 3 turns (BW3T) test was used, in which the participant stands behind a 3-m long bench (Broďáni & Šimonek, 2012). The bench was turned upside down, and the movement is performed on the narrower side, which is 10 cm wide. Before the signal was provided, the player had a stronger leg on the bench. At a signal, the child stands on the bench and attempts to walk to the other end, making three 360° turns. If the examinee loses their balance, they can touch the ground up to 2 times; each touch represents one negative second added to the final measured time, or, otherwise, becomes a reason for the test to be repeated. The final score was gathered from the time of the starting signal to the touch of the ground behind the bench.

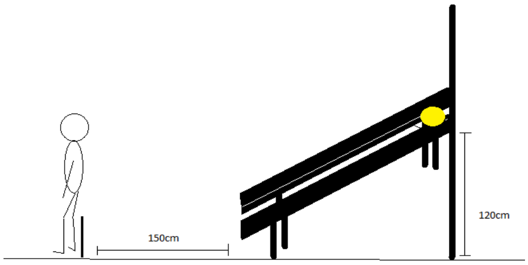
Figure 1. Visual representation of the BW3T test.



Stopping the rolling ball test (SRB)

Reaction speed was assessed by applying the Stopping the rolling ball test (SRB) (Šimonek, 2014). The player is standing behind two benches that have a 5 cm distance between them, 150 cm from the lower edge of the benches, with his back turned away in the opposite direction (without seeing the ball). Benches were placed at a height of 120 cm so the volleyball could roll. The meter was attached to the bench's surface, allowing the ball to roll down it. The measurer held a ball at the top of the benches (meters), and after the audio signal, he released the ball. The player's task was to turn around, run to the ball, and stop it with both hands as quickly as possible. The traveled distance of the ball was recorded after each attempt.

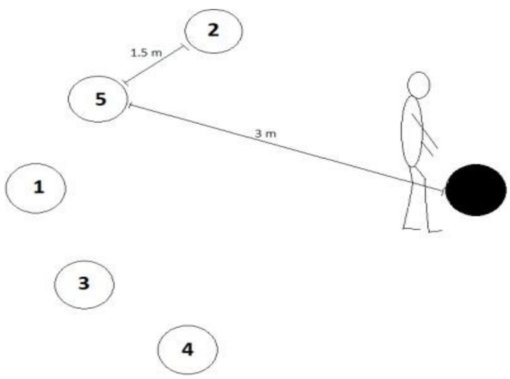
Figure 2. Visual representation of the SRB test.



Shuttle run reactive test (SRrt)

For assessing space orientation, the Shuttle run (reactive) test was used (Ljach & Witkowski, 2010). Six balls were arranged in the following way: one was in the center, and in front of it was the tested player standing. The others were arranged behind the tested person in a semicircle, and they all had a number on them (1-5). All balls are 3m away from the ball in the center (No. 0) and 1.5 m apart from each other. The tested player starts by standing with his back to the balls. The balls are randomly distributed at the moment the player takes their position, so they do not know which position corresponds to which number. Having called one number out of 5, the tested person runs to the ball with the called number, touches it, and returns to touch the ball No. 0. At the moment of touching the ball No. 0, the administrator calls another number of the balls (1 to 5). The same was repeated with the third number of a ball. The test finishes with touching the ball in the center after the return from the third ball. There was one preparatory attempt and three measured ones.

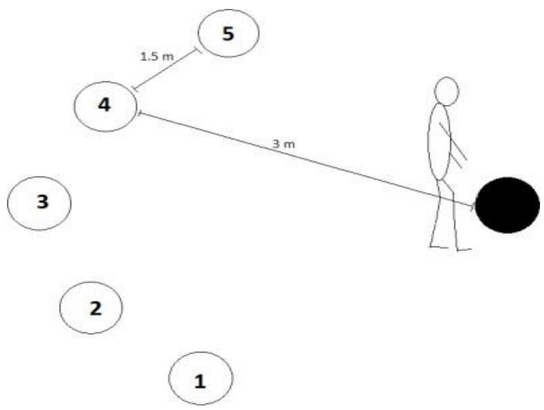
Figure 3. Visual representation of the SRrt test.



Shuttle run non-reactive test (SRnr)

The balls were arranged in the same way as in a reactive Shuttle run test. The tested person runs in order from the first ball, then returns to the center ball, and repeats this process for each of the five balls. The test finishes with the touching of the ball in the center after the return from the fifth ball. There was one preparatory attempt and three measured ones.

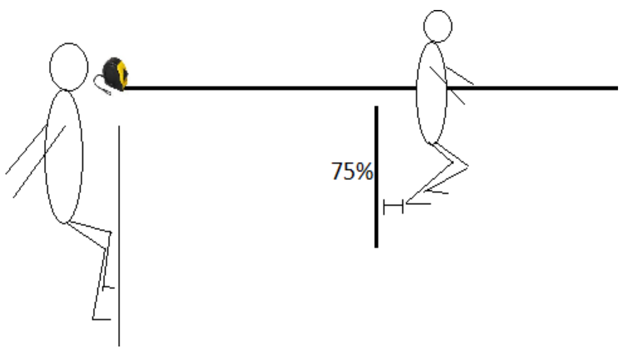
Figure 4. Visual representation of the SRnr test.



Target standing broad jump test (TSBJ)

In the TSBJ test (Broďáni & Šimnoek, 2010), the participant jumps to a maximum distance 3 times. After marking the 75% distance of his maximal performance, the tested person tries to jump three times with his heels as close as possible to the given mark. An average of the three measured results was recorded.

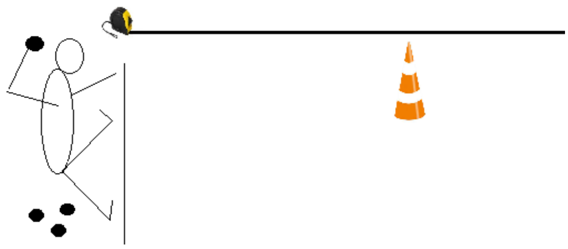
Figure 5. Visual representation of the TSBJ test.



Target sitting throw (TST)

In the Target sitting throw test (TST)(Broďáni & Šimnoek, 2010), a measurer stretches a measuring tape (approximately 50m long) on the floor surface. The player was sitting at the baseline with legs spread and threw a tennis ball 3 times to a maximum distance. The best result was recorded. In the second part of the test, 50% of the maximum result is marked with a cone on the floor. The tested person had ten attempts to throw at the target on the ground. A deviation from the 50% mark was recorded.

Figure 6. Visual representation of the TST test.



Data analysis

The intraclass correlation coefficient (ICC) was used to test the relative reliability within sessions for the second group of the same age. The ICC scores are considered poor if less than 0.39, between 0.40 and 0.59 fair, between 0.60 and 0.75 good reliability, and excellent if larger than 0.75 (Ko & Li, 2016). Furthermore, to determine the usefulness of the non-specific coordination tests over repeated trials, the standard error of measurement (SEM) was assessed using the following formula: [$SEM = SD \times \sqrt{1 - ICC}$]. The smallest worthwhile change (SWC) was used to observe differences between SEM and SWC by various effect sizes (0.2, 0.6, and 1.2) multiplied by the between-participant standard deviation. If the SEM was higher for all variables than the SWC, the test was rated as marginal; when the SEM was similar to the SWC, the test was rated as satisfactory; and if the SEM was below the SWC, the SWC test indicated good usefulness (Hopkins, 2004). Moreover, the minimal detectable change was calculated with the following formula: [$MDC = SEM \times 1.96 \times \sqrt{2}$] to monitor progress so that intra-trial variations do not inaccurately suggest a change. The normality of the sample was tested using the Kolmogorov-Smirnov test ($p > 0.05$). After confirming the homogeneity of variances using Levene's test, which showed no significant violations ($p > 0.05$ for all variables), one-way ANOVA was used to assess the difference between players in different playing positions (setters vs. passer-hitters vs. opposite players vs. middle blockers vs. libero players) and situational performance in terms of discriminative ability. Compared to that, the Student's paired t-test was assessed to determine the difference between more successful and less successful players. Also, Cohen's d was used, with the magnitude of d qualitatively interpreted using the following thresholds: <0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, moderate; 1.2 to 2.0, large; and 2.0 to 4.0, very large (Hopkins, 2000). The statistical analysis was performed using SPSS Statistics 27.0 for Windows. The statistical significance for all tests was set at $p<0.05$.

2.3.3 Results

The within-session reliability results were presented in Table 2. In two-day sessions, the relative reliabil- ity was excellent in all tests except for the TST test, whose reliability was fair. The SEM exceeded the SWC at the smallest level for all variables, while SEM was below SWC values at moderate and large levels for most tests. The random error, represented by the MDC, ranged from small values to larger values for some tests, reflecting differing levels of reliability precision across the tests.

Table 2. Results of the reliability and usefulness of the non-specific coordination tests

Variable	Test	Re-Test	ICC	SEM	SWC(0.2, 0.6, 1.2)	MDC
BW3T (s)	14.27±3.54	15.38±5.10	0.89	1.35	0.82, 2.46, 4.92	3.73
SRB (cm)	135.02±15.62	163.53±20.70	0.82	7.52	3.58, 10.75, 21.49	20.78
SRrt (s)	8.37±0.39	8.07±0.43	0.76	0.26	0.1, 0.32, 0.64	0.72
SRnr (s)	11.77±0.65	11.39±0.48	0.80	0.18	0.08, 0.25, 0.50	0.50
TSBJ (cm)	3.26±2.40	3.52±2.67	0.80	0.94	0.43, 1.28, 2.57	2.60
TST (cm)	49.3±13.21	63.42±39.72	0.58	8.56	2.64, 7.93, 15.85	23.73

All values are presented as mean ± SD; ICC = intraclass correlation coefficient; SEM = standard error of measurement; SWC = smallest worthwhile change; MDC = minimal detectable change.

The Kolmogorov-Smirnov test showed that all data were normally distributed. After analyzing the sub- group for reliability and usefulness, Table 3 presents inter-positional differences by applying one-way ANOVA on the sample of female volleyball players. As shown in the table, there were no significant differences between all six non-specific tests.

Table 3. Inter-positional differences analyzed by one-way ANOVA for the non-specific coordination tests on the total sample of 98 young female volleyball players.

Variable	Setter (n = 17)	Passer-hitter (n = 35)	Opposite player (n = 16)	Middle blocker (n = 19)	Libero (n = 11)	F(p)
BW3T(s)	16.21±3.74	15.39±0.65	16.32±4.68	17.12±3.08	15.48±3.00	0.64(0.64)
SRB (cm)	137.53±14.04	136.53±19.75	136.69±12.07	134.52±20.35	133.11±19.87	0.12(0.97)
SRrt (s)	11.25±0.55	11.14±0.96	11.41±0.88	11.79±0.88	11.71±0.75	1.87(0.12)
SRnr (s)	8.49±0.56	8.42±0.68	8.47±0.55	9.01±0.65	8.59±0.58	2.43(0.06)
TSBJ (cm)	4.03±2.22	4.87±2.89	3.80±2.94	4.39±3.11	5.31±3.35	0.71(0.59)
TST (cm)	50.91±25.85	58.40±25.55	64.37±26.16	60.92±16.53	71.89±28.86	1.39(0.24)

All values are presented as mean ± SD. F – ratio of between-group to within-group variance; p – probability value.

Differences between more successful and less successful players were presented in Table 4, where more successful female volleyball players achieved better results than less successful ones in all tests. Moderate effect sizes were found in the SRB and SRrt tests, indicating better performance in more successful players. Small but significant differences were observed in the BW3T, SRnr, TSBJ, and TST tests.

Table 4. Differences were analyzed by independent t-test for non-specific coordination between less successful and more successful young female volleyball players.

Variable	Less successful (n = 59)	More successful (n = 39)	t(p)	d
BW3T(s)	16.91±3.38	14.92±3.68	2.55(<0.01)	0.56
SRB (cm)	141.04±17.63	128.03±14.05	3.38(<0.001)	0.81
SRrt (s)	11.68±0.87	11.01±0.70	3.72(<0.001)	0.85
SRnr (s)	8.71±0.64	8.38±0.59	2.30(0.02)	0.54
TSBJ (cm)	4.97±0.44	3.77±0.33	2.09(0.03)	0.46
TST (cm)	66.56±24.96	55.61±15.09	2.10(0.04)	0.53

All values were presented as mean ± SD; t – t-test value; p – probability value; d – effect size

2.3.4 Discussion

This study aimed to determine the reliability, discriminative ability, and usefulness of non-specific coordination battery tests. The main finding of this study is that almost all tests exhibit excellent test-retest reliability, except for the TST, which shows fair reliability. Following a study by Đolo, Grgantov, and Milić (2020), the reliability of this test was even higher (0.73). Consequently, the error in performing the test can be much more pronounced with fewer participants. Nevertheless, the two tests, TST and TSBJ, analyzing kinesthetic-differentiation ability, are mostly disturbed in puberty, which can also be related to these results (Šimonek, 2016). Space orientation (Shuttle run test) is in conjunction with reaction speed (Stopping the rolling ball test) (Hirtz & Starosta, 2002). In that way, high results from this research indicate its performance dependency not only in these two abilities but also in all coordination abilities that are associated with each other.

The results of usefulness show that the amount of measurement error and noise in the test range from 0.18 to 1.35 s and 0.94 to 8.56 cm (2% to 28%), with those tests that had SEM higher than 10% differ- entiated in two measurements. Therefore, TSBJ and TST tests were differentiated. These non-specific coordination battery tests yielded lower results for SWC (0.2) compared to SEM, whose usefulness was rated as "marginal," as SEM values for SWC (0.6 and 1.2) were lower and indicated "good" usefulness for all tests. Accordingly, coordination tests could detect a real change that exceeds 0.6 and 1.2 times the standard deviation. Furthermore, MDC was calculated to control measurement precision, specifically to reveal real changes in measured performance between test and re-test. In the present study, the MDC for the time variable tests varied from 0.50 to 0.72 s, and the BW3T test had 3.73 s, which may raise concerns for the precision of the measure, as well as the SRB test, with a variation of 20.78 cm, and the TST test had 23.73 cm. Therefore, different interactions can be found that lead to changes between these two testing occasions, such as pressure, fatigue, arousal, concentration, stress, and motivation (Struzik et al., 2014). The BW3T test has abduction-adduction (i.e., turning around) movements and may lead to postural disturbance, leading to larger errors and high MDC variations (Đolo, Grgantov, & Jelaska, 2023). Also, the reaction speed SRB test is a multi-joint movement requiring large muscle group activation, leading to higher inter-trial variability, which produces measurement error (Smits-Engelsman & Wilson, 2013).

This study highlighted the discriminative ability with two objectives: (i) to determine whether there are differences between playing positions (ii) to estimate the difference between less successful and more successful young female volleyball players in non-specific coordination battery tests. Although the mean results show differences between playing positions, there is a non-significant difference between playing positions in all coordination tests. This finding confirms that coordination tests are equally important for performance in all playing positions in volleyball.

When comparing the mean results of playing positions, it can be noticed that passer-hitters tend to achieve better results than other playing positions, which may be related to the greater emphasis on their play in attack in this age group. Because play in attack is mainly based on passer-hitters (Voigt & Vetter, 2003). Therefore, to be successful in all game segments, they must possess all coordination abil- ities at a high level. Moreover, middle blockers have lower values mainly due to their anthropometric characteristics (tallest and heaviest players) (Palao et al., 2014; Toselli & Campa, 2018).

Significant differences were found between the results of more successful and less successful volleyball players. According to Pion et al. (2015), high-level players had better motor coordination than average- level ones. Consequently, the successful performance of coordination abilities has an important role in future advancement in skill-based sports such as volleyball (Đolo, Grgantov, & Kuvačić, 2023). Observing players' performance of the space-orientation tests (Shuttle run reactive and non-reactive), it can be noticed that high results in more successful players were closely related to cognitive ability. This aligns with findings by Trecroci et al. (2021) on youth volleyball players, which demonstrated a significant relationship between cognitive functions and sport-specific physical performance. Their study suggests that athletes with higher cognitive abilities tend to perform better in a physically demanding task. Without being told the best way to perform the test, some of them found the easiest way to achieve good results by watching the other numbers while running. This observation is closely related to previous research (Vestberg et al., 2012; Walton et al., 2018). Also, the highest results of space-orientation ability have passer-hitters in both Shuttle run tests because they have similar movement structures during the game through field defense.

Regarding balance ability, during competition and training, maintaining controlled body movement is essential for players due to sport-specific situations in the game that contain postural disturbances (Fuchs et al., 2020). Equally, in the balance test, more successful players have the highest results. In reaction speed assessments where distance is used as the primary metric, middle blockers typically achieve the best results, likely due to their longer limb length. It is equally important to pay attention to the kinesthetic-differentiation ability, which controls movement in time, space, and dynamics. Kinesthetic memory helps players remember motor movements, such as jumping and throwing, to perform specific volleyball movements successfully. (Boichuk et al., 2020). In such a way, it can be noticed from the results of the TSBJ and TST tests that they have higher probability values, indicating the importance of higher mastery of non-specific kinesthetic-differentiation ability.

In the last few decades, researchers have become more involved in testing protocols to demonstrate the importance of coordination abilities in every sport. A high level of coordination abilities leads to a faster adaptation to complex motor tasks that are carried out in the volleyball game (Georgiy, 2019). Therefore, coaches need to implement all of them by age 7-12 when motor centers in the brain are intensively developing (90-95% of the maximum value) (Hudson et al., 2021). For that reason, children can perform complex motor tasks, which are characteristics of other team sports; coordination aims to learn and conduct these complex movements with increasing efficiency and control. In volleyball, as in other team sports, coordination involves learning and applying the techniques and tactics of the game, which are highly specialized and change with situations. In that way, the player with well-developed coordination abilities can make the best out of situations where the rule of three touches requires fine technique (Eider & Cieszczyk, 2004; Pion et al., 2015). Although variables such as training history and anthropometric characteristics were not included as covariates, no significant differences were found between groups in training experience, height, sitting height, or body weight, reducing the likelihood that these variables confounded the results.

This study has several limitations. It would have been valuable to analyze differences between more successful and less successful players within each position, rather than only across all positions. However, this was not feasible due to the small sample size. Second, success at a younger age does not guarantee success at the peak of a player's career. Therefore, while more successful players may differentiate from less successful ones in test results at a young age, this should not be interpreted as evidence that these tests can predict future success. Additionally, one of the main limitations of the reliability analysis is the small sample size (n = 13) used in the test-retest subgroup. While the results mainly showed high reliability coefficients, a small sample can inflate or deflate reliability estimates and reduce the generalizability of the findings. This may have particularly affected the TST test, which showed only fair reliability, as a larger sample might have yielded more stable estimates. Future research should consider replicating reliability analyses with larger and more representative subsamples to confirm these results. Finally, while the study assessed discriminative ability, future research should aim to establish convergent validity by comparing these results with other assessments considered gold standards.

2.3.5 Conclusions

The results of this study reveal that the battery test is reliable and useful for estimating non-specific coordination abilities among female volleyball players. This battery test can evaluate progress in playing position due to discriminative ability. Coaches need to be aware that non-specific coordination abilities have an essential role in preparing young players for specific situations that every sport requires. Further, more successful players had better coordination abilities than less successful players, which signifies how young volleyball players need to be challenged throughout training by learning a broad spectrum of motor skills. Based on the identified limitations, such as a small sample size and the need for additional analysis validity by comparing the results with other tests considered the gold standard, future studies should aim to include larger and more diverse samples. Solving these areas will strengthen the application of general coordination assessments and contribute to a deeper understanding of the role of players' development.

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2.4. New Specific Kinesthetic Differentiation Tests for Female Volleyball Players: Reliability, Discriminative Ability and Usefulness

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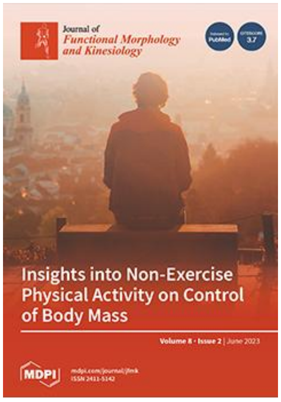

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MDPI

New Specific Kinesthetic Differentiation tests for Female Volleyball Players: Reliability, Discriminative Ability, and Usefulness

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Abstract

This study aimed to determine the test-retest reliability and discriminative ability of five sport-specific kinesthetic differentiation ability tests in female volleyball players. The sample of participants consisted of 98 female volleyball players aged 15.20 _ 1 years from six clubs in Bosnia and Herzegovina. Kinesthetic differentiation ability was determined by the overhead passing test, forearm passing test, float service with a net test, float service without a net test, and float service 6 m from the net test. To estimate test-retest reliability, a sub-sample of 13 players performed all tests on two testing occasions. Furthermore, the discriminative ability of the tests was determined by analyzing the performance between players of different playing positions and situational performances. Parameters of the intraclass correlation coefficient (ICC) were excellent (0.87–0.78) in all tests except for the float service with the net test, whose reliability was good (0.66). For the absolute reliability estimates, the SEM was higher than SWC (0.2) for all variables except the float service 6 m from the net test, and the SEM was lower than SWC (0.6, 1.2). One-way ANOVA detected no statistically significant inter-positional differences in all five tests ($p > 0.05$). A significant difference was found between less and more successful players ($p < 0.01$) for all applied tests. The results of this study show that a specific battery test is a reliable and valid measure and can be used to monitor kinesthetic differentiation ability in young female volleyball players.

Keywords: coordination abilities; inter-positional difference; volleyball techniques

2.4.1 Introduction

Modern volleyball is a dynamic sport that involves multidirectional accelerations from landing to jumping, sudden starts and stops, changes of direction, attack, and defensive actions that require high levels of technical and tactical skills [1–3]. To achieve all these skills at a young age, training must be based on coordination abilities to excel in all game segments [4]. Otherwise, it is unlikely for athletes to reach their full potential later in life. Most studies emphasize the importance of sensitive phases as critical periods of enhanced children's coordination development [5,6]. In contrast, others doubt the existence of these phases and conclude that motor learning capacity can also improve in adolescence and later [7–9]. Nowadays, all researchers must keep in mind that a high level of skills cannot be possible if a child has not reached neural maturity [10].

Previous research highlights the significance of improving technical and tactical skills by applying all five basic coordination abilities: kinesthetic differentiation, spatial orien- tation, rhythm, balance, and reaction abilities [11,12]. Moreover, supplementing general coordination abilities with specific coordination will facilitate the learning process [13–15]. A competitive sport such as volleyball is challenging to master due to many technical as- pects that require accuracy, such as serving, passing, and setting [16]. All of them represent the so-called ball feeling, partner feeling, and opponent feeling [17], which we can link with the most important coordination ability—kinesthetic differentiation. Researchers define it as a sense of upper and lower extremities and body movement where kinesthetic memory helps players to remember their motor movements, such as the skill needed for receiving service from different angles [7,18,19]. To successfully master this ability, players need to go through a large number of repetitions, monitored constantly until they no longer need to think about the movement; they just "do it" [20].

Until recently, many researchers have focused on constructing and developing tests to assess volleyball's general kinesthetic differentiation of lower and upper limbs [21–24]. General coordination tests, such as kinesthetic differentiation, are suitable for children before playing volleyball or for beginner volleyball players. They cannot perform specific tests because they have not yet perfected volleyball techniques. Therefore, it is common to apply general tests for jumping, throwing, and similar skills for players up to 14 years old. However, children aged 14 to 15 have already mastered volleyball techniques enough to be able to use specific coordination tests. Recent studies have noted the need for sport-specific tests, which have contributed to modern sports and are more appropriate than standard tests because they are similar to real sports situations [25]. Nevertheless, there are insufficient reports on specific kinesthetic differentiation ability, especially in volleyball [1,26,27]. In short, these researchers focused on measuring skills to identify talented volleyball players by applying specific tests.

Specific volleyball coordination tests can be used as a means of talent identification to monitor the progress of volleyball players over a certain period. We can assume that more talented players will adopt volleyball techniques more rapidly, progress faster over time, and reach a higher level of skill [28]. Another possibility is to use them as a tool to assess the current level of volleyball technique. Therefore, the study aimed to examine the test-retest reliability and discriminative ability of new sport-specific kinesthetic differentiation ability tests in female volleyball players.

2.4.2 Materials and Methods

Study design

This study had two stages: (1) test-retest reliability and (2) discriminative ability assessment. To assess the test-retest reliability, a subgroup of 13 participants underwent the same tests on two separate occasions, with a seven-day interval between them. The discriminative ability of the tests was determined by analyzing the group differences among players of different playing positions and situational performances. During the investigation days, the players were instructed to avoid any factors that could hinder their effort during testing. This included refraining from consuming caffeine- containing beverages and low-fiber diets 24 h before and during the investigation in order to minimize any interference with the testing. Additionally, the athletes were instructed to refrain from engaging in physical activity 48 h before and during the investigation. To prevent circadian variations, all tests were conducted in the morning, starting at 8 am [29].

The testing was conducted in June 2021 with an ambient temperature ranging from 21 to 24 °C. At the beginning of the testing session, a standardized warm-up consisting of 10 min of jogging and mobility exercises was conducted. Players performed three maximum trials, followed by six trials of each skill. All tests were demonstrated and conducted by professionals, members of the Faculty of Kinesiology, University of Split, who introduced them to all testing procedures. Participants were given a briefing on the testing procedures prior to beginning any of the tests.

Participants

The study was conducted on 98 young female volleyball players, aged 15.20 ± 1.00 years, from six clubs in Bosnia and Herzegovina. The players specified their playing positions, which included setter (n = 17), passer-hitter (n = 35), opposite hitter (n = 16), middle blocker (n = 19), and libero (n = 11). Coaches from six volleyball clubs agreed to participate and received a clear explanation of the study. All players had been involved in at least two years of training. Informed consent was obtained from parents before players were permitted to participate. The inclusion criteria for players were being at a stage of specialized basic training with no musculoskeletal or psychophysical disorder. A professional volleyball coach supervised and regulated young athletes' training programs, which mainly comprised technical and tactical volleyball training and some physical conditioning sessions. On average, athletes trained for approximately 2 h per session, four days per week.

The situational performance of the players was assessed by combining 2 criteria [1]: (1) Placement of teams in the competition (Super League and 1st League); (2) Quality of individual players within their team where the coaches categorize their team players into 3 groups: group 1 including leading team players; group 2 including the rest of starting players and players entering the game, thus contributing to team result; and group 3 including players who very rarely or never enter the game. As presented in Table 1, a combination of these assessment criteria, each player is scored 1–5. More successful players were those that scored 5 and 4, and less successful were the ones that scored 3, 2, and 1. Therefore, the sample was divided into two subsamples: less successful (n = 59) and more successful (n = 39) players.

Table 1. The situational performance of the players according to the two criteria.

Team Placement	Within Team Players' Quality Evaluated by the Coach		
	Group 1	Group 2	Group 3
Super League	5	4	3
1st League	3	2	1

During the experiment, eight players who did not have an assigned playing position were excluded. Additionally, three players were excluded because they could not perform the service tests.

Experimental Procedures

The kinesthetic differentiation ability was assessed using five different volleyball skill tests: forearm passing, overhead passing, and three different standing float service tests, all on an indoor floor surface.

Forearm Passing Test (FPT)

In the first task, the athlete stands in front of a line with a ball in their hands (Figure 1).Their task is to throw the ball in front of themselves and forearm pass the ball three timesas far as possible. A measuring scale is placed on the floor surface, and the ball bouncesalong that measuring scale. The measurer counts 50% of the athlete's maximum pass and marks that target with a cone. The kinesthetic differentiation during forearm passing is evaluated in the second part of the test, where athletes need to pass the ball as close to the cone as possible. The measurer records six attempts. Therefore, the test results represent the sum of deviations in centimeters in those six attempts (absolute values regardless of negative sign).

Overhead Pass Test (OPT)

The athlete begins by holding the ball and throwing it overhead to themselves (Figure 2). They then play the ball with an overhead pass as far as possible three times.The measuring scale is also placed on the floor surface, and the ball bounces along that measuring scale. After the athlete completes the three maximum passes, the measurer counts 50% of the maximum distance and marks that place with a cone. The kinesthetic differentiation during overhead passing is evaluated by asking athletes to overhead pass the ball as close to the cone as possible. The measurer records six attempts, and the test results represent the sum of deviations in centimeters in those six attempts (absolute values regardless of negative sign).

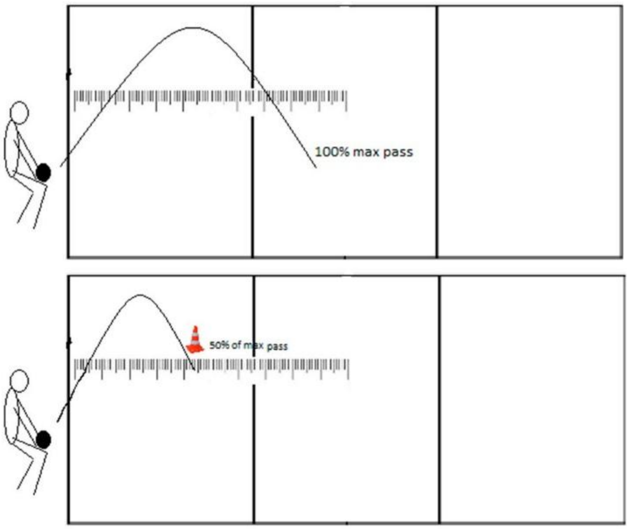

Figure 1. Visual representation of forearm passing test.

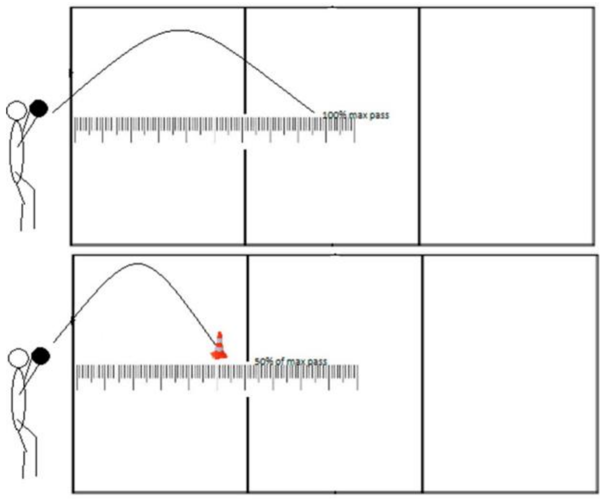

Figure 2. Visual representation of overhead passing test.

Float Service Tests (FST)

The standing float service accuracy was evaluated in three different tests: (1) float service with a net (FSTnet), (2) float service without a net (FSTx), and (3) float service 6 m from the net (FST6m). In all three tests, athletes first had to serve three maximum attempts on the court from a service position, followed by six attempts aiming at a target. Therefore, the test results represent the sum of deviations in centimeters in those six attempts (absolute values regardless of the negative sign).

In the FSTnet, athletes stand behind the baseline while serving (9 m from the net; Figure 3). After three maximum services over the net, the measurer counts 75% of the athlete's maximum serve and marks the target with a cone. Then, athletes have to serve the ball six times to that target. A measure of 75% was taken, unlike other tests, because the target would be farther from the net with this percentage. With 50%, the target for most participants would be near the net, and the test could not be performed since the net would interfere with hitting the target.

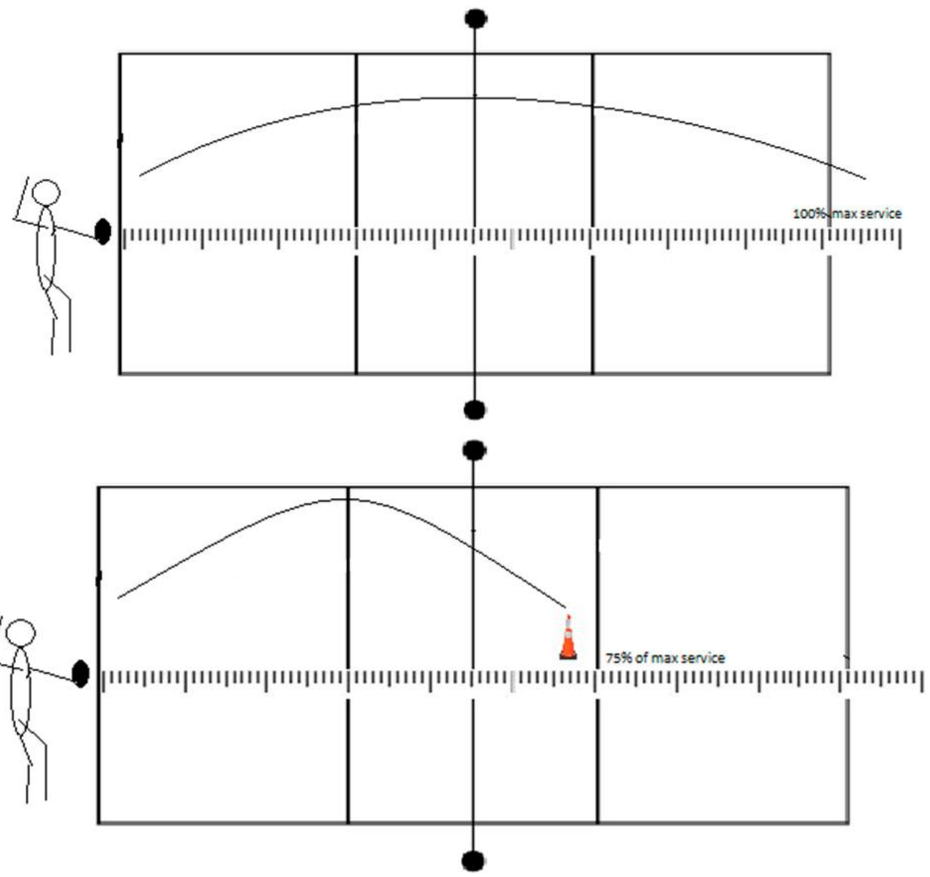

Figure 3. Visual representation of float service with a net test.

In the FSTx, the athlete serves in front of the baseline, imagining the net is on the court (Figure 4). The measurer counts 50% of the maximum serve and places the cone on that spot. Then, athletes have to serve the ball six times to that target.

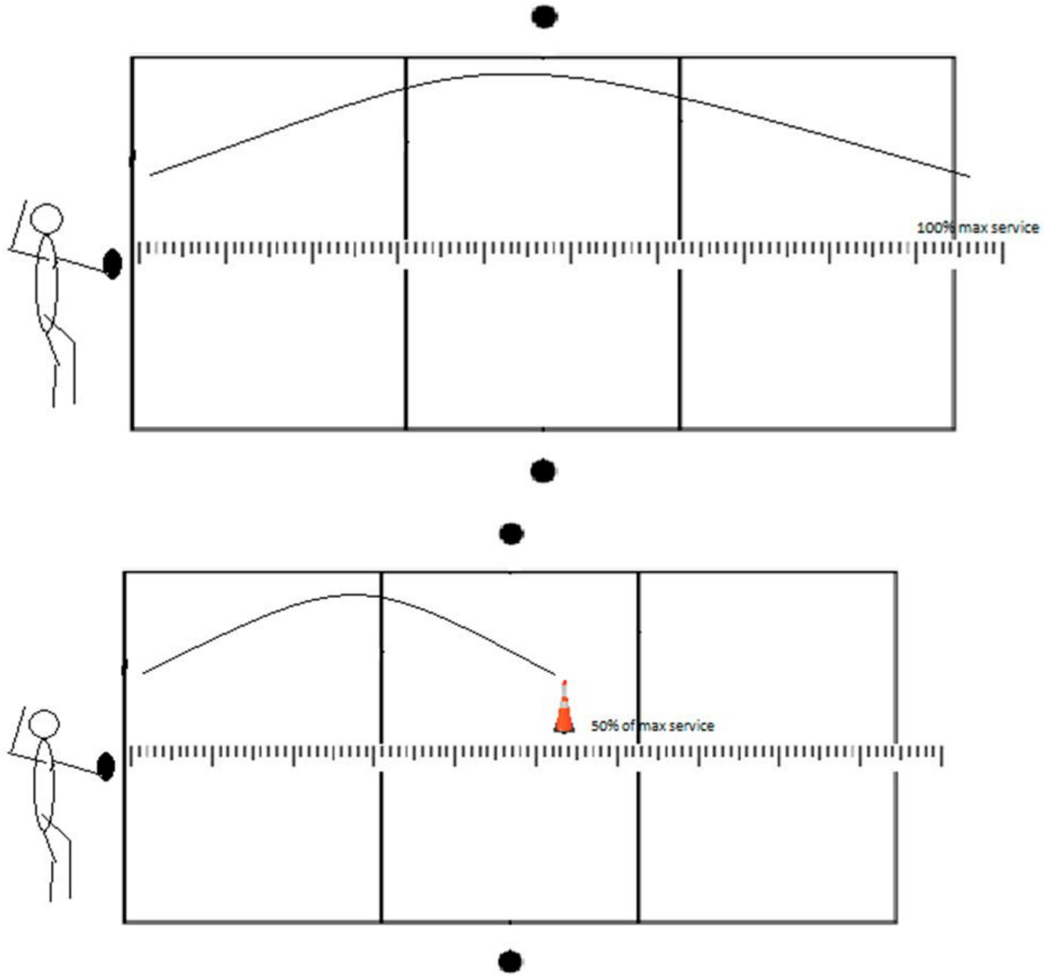

Figure 4. Visual representation of float service without a net test

The third version of the test (FST6m) differs by positioning the athlete in front of thenet after three maximum serves (Figure 5). The athlete serves three maximum serves from behind the baseline. Afterward, the athlete moves six meters from the net, from where they will serve the next six attempts. The measurer counts 50% of the maximum service and measures that distance, 6 m from the net. The athletes need to serve on the marked place over the net.Figure 5.

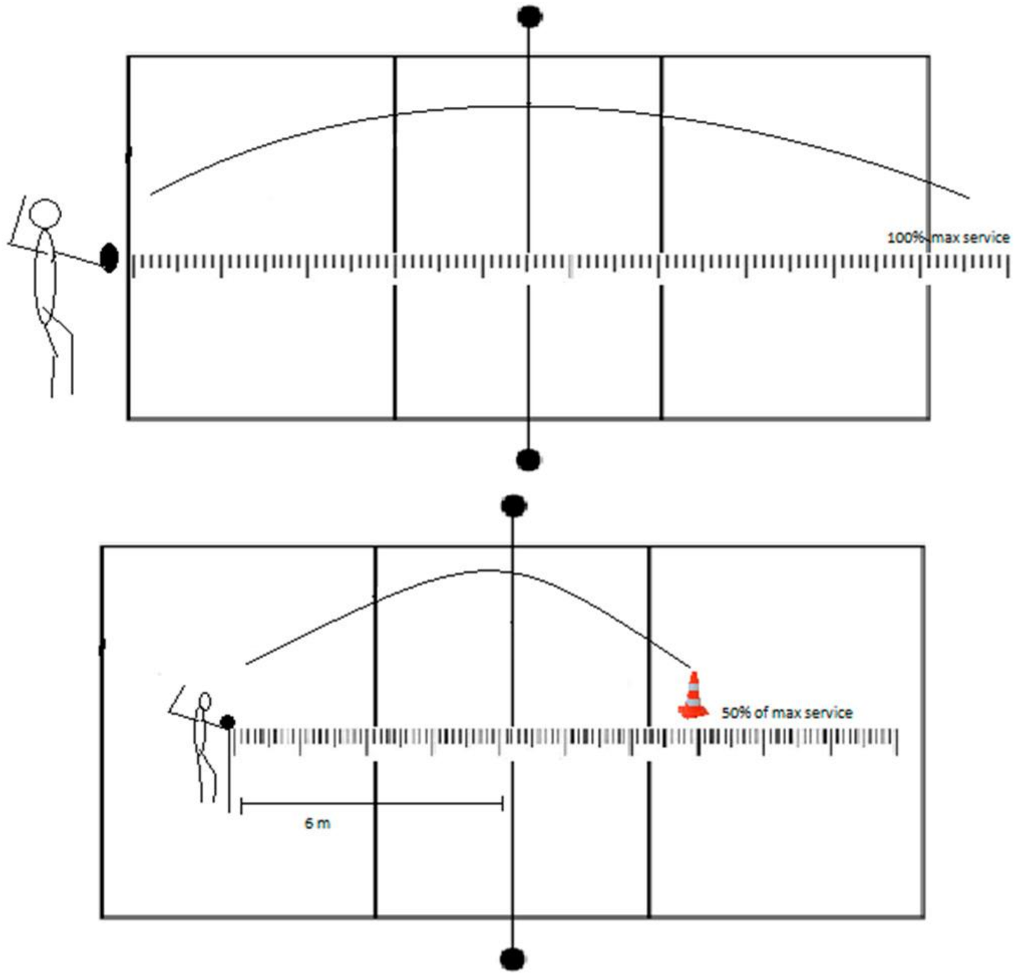

Figure 5. Visual representation of float service 6 m from the net test

Statistical analysis

The intraclass correlation coefficient (ICC) was used on the subsample group with the same age to measure test-retest reliability. According to Koo and Li [30], the ICC was considered poor if less than 0.39, between 0.40 and 0.59 was fair, from 0.60 to 0.75 was good reliability, and considered excellent if larger than 0.75. Absolute reliability was analyzed to determine the usefulness of the specific kinesthetic differentiation tests by calculating the standard error of measurement (SEM) using the formula: [$SEM = SD \times \sqrt{1 - ICC}$]. The smallest worthwhile change (SWC) was assumed by multiplying the between-participant standard deviation with different effect sizes (0.2, 0.6, and 1.2). The usefulness can be rated as "good", "marginal", and "satisfactory" when the SEM is below, similar, or higher than the SWC, respectively [31]. Furthermore, minimal detectable change (MDC) was analyzed with the following formula: [$MDC = SEM \times 1.96 \times 1.2$] to monitor progress so that intra-trial variations do not inaccurately suggest a change. The normality of the sample was tested using the Kolmogorov–Smirnov test ($p > 0.05$). The applied tests were assessed for their ability to distinguish differences between players in different playing positions and situational performance differences of young volleyball players in terms of discriminative ability. Therefore, one-way ANOVA was analyzed to determine differences in five positions (setter vs. passer-hitter vs. opposite player vs. middle blocker vs. libero), while the Student's paired t-test was used to determine if there is a difference between situational performance (successful vs. less successful). Additionally, Cohen's d was calculated with the magnitude of d was qualitatively interpreted using the following thresholds: <0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, moderate; 1.2 to 2.0, large; and 2.0 to 4.0, very large [32]. The statistical analysis was performed using SPSS Statistics 27.0 for Windows. The statistical significance for all tests was set at $p < 0.05$.

2.4.3 Results

The relative and absolute reliability of specific kinesthetic differentiation ability tests is presented in Table 2. The values of ICC range from 0.66 to 0.87, indicating excellent test-retest reliability in all tests except in the FSTnet, whose reliability was rated as good. The SEM values for almost all of the test measurements were low except in the FSTnet. Furthermore, SEM values were higher than SWC for all variables except for FST6m when the smallest level (0.2 multiplied by between-participants SD) was considered.

Table 2. Results of the reliability and usefulness of the coordination tests.

	Test	Re-Test	ICC	SEM	SWC (0.2, 0.6, 1.2)	MDC
FPT (cm)	62.6 ± 28.7	51.5 ± 16.8	0.84	0.06	0.03, 0.09, 0.19	0.16
OPT (cm)	24.2 ± 11.1	34.8 ± 21.1	0.78	0.07	0.03, 0.09, 0.18	0.19
FSTnet (cm)	111.8 ± 64.6	110.2 ± 46.7	0.66	0.15	0.08, 0.24, 0.48	0.41
FSTx (cm)	59.6 ± 14	54.2 ± 21.7	0.77	0.08	0.03, 0.09, 0.19	0.22
FST6m (cm)	61.4 ± 34.1	77.5 ± 21.6	0.87	0.01	0.04, 0.13, 0.27	0.03

Legend: All values are presented as mean SD; ICC = intraclass correlation coefficient; SEM = standard error of measurement; SWC = smallest worthwhile change; MDC = minimal detectable change.

In Table 3, inter-positional differences were presented by applying ANOVA on the whole sample of female volleyball players. The results showed that there were no significant differences in all five specific tests ($p > 0.05$).

Table 3. Inter-positional differences analyzed by one-way ANOVA for the specific kinesthetic differentiation tests on the total sample of 98 young female volleyball players.

Variables	Setter ($n = 17$)	Passer-Hitter ($n = 35$)	Opposite Player ($n = 16$)	Middle Blocker ($n = 19$)	Libero ($n = 11$)	F	p
FPT (cm)	72.3 ±32.9	57.6 ±29	53.5 ±25.6	59.4 ±31.6	48.2 ±25.3	0.51	0.76
OPT (cm)	40.1 ±12	38.7 ±16.8	44 ±14.2	45.1 ±18.4	36.5 ±16.6	0.72	0.6
FSTnet (cm)	124 ±97.2	109.6 ±60.4	91.7 ±37.9	154.3 ±80.4	109.6 ±21.6	2.27	0.06
FSTx (cm)	65 ±21.5	72.2 ±22.6	75.3 ±37.1	77.8 ±38.8	75.9 ±21.6	0.41	0.84
FST6m (cm)	125.1 ±67.8	119.6 ±83.3	106.4 ±63.4	175.8 ±87.1	110.2 ±64.2	1.51	0.2

Legend: All values are presented as mean ± SD; F—f test; *p*—probability value.

Table 4 shows the difference between less successful and more successful female volleyball players. Based on Table 4, successful young female volleyball players achieved better than less successful players in all five-specific kinesthetic-differentiation tests ($p < 0.01$).

Table 4. Differences analyzed by paired *t*-test for the specific kinesthetic differentiation between less successful and more successful young female volleyball players.

Variables	Less Successful ($n = 59$)	More Successful ($n = 39$)	*t-Value*	p	ES	
					d	95% CI
FPT (cm)	72 ±31.5	50 ±24.1	3.92	<0.01	0.76	0.34–1.18
OPT (cm)	51.5 ±18.6	35.4 ±11.4	4.80	<0.01	1	0.56–1.42
FSTnet (cm)	154.2 ±79.2	82.6 ±24.5	5.44	<0.01	1.13	0.69–1.55
FSTx (cm)	93.9 ±28.7	58.9 ±17.5	7.08	<0.01	1.41	0.95–1.84
FST6m (cm)	178.1 ±74.3	87.9 ±54.6	6.06	<0.01	1.34	0.89–1.78

Legend: All values are presented as mean SD; *t*—*t* test; *p*—probability value; ES—effect size; d—Cohen d; 95% CI—95% confidence interval.

2.4.4 Discussion

This study aimed to analyze the reliability, discriminative ability, and usefulness of new specific kinesthetic differentiation battery tests in young female volleyball players. Almost all tests had excellent test-retest reliability, except the FSTnet, whose reliability was good. These results agree with the findings of [33], who tested junior volleyball players in spiking, setting, serving, and passing techniques. Furthermore, performances of service change through different age groups and levels, as well as the accuracy of trajectory, which is critical for effectiveness in young age groups. In such a way, the intention for using three different service tests was to observe which were most suitable for use in this age group.

Observing the results of three service tests, it can be seen that the FSTnet has the lowest result in reliability (0.66). Primarily, the biomechanical process of serving must be on a higher level to achieve correct consecutive repetitions. For players to successfully perform the service from a long distance and to have an accuracy of performance, they should have developed coordination along the kinetic chain [34]. Therefore, the service movement starts with placing the foot on the floor during a step; thus, the reaction of the floor occurs, which passes through the entire body. Moreover, young players are limited with the strength of lower and upper muscles, which leads to greater oscillations in the trials of this test. Accordingly, FST6m is the most convenient for testing reliability in young female volleyball players. Neither does the long distance exists between the player and the net nor does strength come to such an extent. The net placed at a greater distance from the service point represents a psychological barrier that pushes players to apply greater force, which results in greater oscillations. Furthermore, when youth players are serving 9 m away from the net, the target is close to the net on the other side, requiring the ball to go over the net in a higher arc while also using considerable force. This is a challenging combination that could present a problem even for more experienced and technically skilled players.

Upon analyzing the usefulness of the tests, it can be observed that the amount of measurement error and noise in the tests ranges from 0.1 to 0.15 m (1% to 32%), indicating that below 10% only differentiate in FPT and FST6m. Other tests, apart from FST6m, whose usefulness was rated as "good," had small performance changes SWC (0.2) and showed "satisfactory" usefulness. Moreover, moderate variations could be detected as the SEM values were lower than SWC (0.6, 1.2) for all tests indicating "good" usefulness. Therefore, all kinesthetic differentiation tests could detect a real change that exceeds 0.6 and 1.2 times the standard test deviation [31]. Additionally, by observing the MDC (the real changes in measured performance from test and retest), values varied from 16, 19, 41, 22, and 0.03 cm.

High values of FSTnet (0.41) may raise concerns regarding the precision of the measure. Consequently, all these tests have small targets, which influence the accuracy and lead to higher performance variations [35]. Specifically, other interactions may also influence testing consistency every time players are tested, such as fatigue, stress, pressure, and concentration [36].

For this study, the intention was to establish how well-applied tests will discriminate against young athletes. Therefore, the present study analyzed the discriminative ability with two objectives: (i) to evaluate are differences between playing positions; (ii) to evaluate differences between more successful and less successful young volleyball players in specific kinesthetic-differentiation battery tests. No significant inter-positional differences were observed in all five tests. Volleyball is a late-specialization sport; therefore, individual player position specialization does not begin until the age of 14–15. The young volleyball players in this study have only begun the specialization process, so the position-specific training has not yet impacted the specific development of certain abilities and skills. It is important to master a high level of general coordination abilities afterward by entering the specialization of playing positions to master complex volleyball techniques later on [12,22,28,37]. In addition, volleyball is a skill-based sport where complex performance techniques, both with and without the ball, are characteristic of all player roles. Therefore, it can be assumed that a high level of kinesthetic differentiation is equally necessary for successful play in all player positions in volleyball. Consequently, a significant difference was observed between less successful and more successful volleyball players for all tests. The results are consistent with the conclusions drawn by Pion et al. [28], who highlighted that differences between elite and sub-elite levels of play in volleyball are influenced by motor coordination. Motor coordination could play a crucial role in differentiating those who reach an expert level in female volleyball from those who do not. As such, the results provide support for the notion that overall motor coordination may serve as a useful predictor of an athlete's potential for advancement in skill-based sports such as volleyball. Moreover, successful talent-identified junior volleyball players can be distinguished from unsuccessful ones based on their skill test results, specifically passing and serving technique evaluations by coaches, but not based on their physical characteristics [38]. These results highlight the significant importance of kinesthetic-differentiation ability in volleyball. This ability consists of three components: force (tension) as the strength of the movement, spatial (space) as the angle of joints, and temporal (time) through movement speed, which all contribute to more efficient volleyball techniques [36,39,40]. However, due to its complexity in defining learning methods and the relatively short contact time with the ball, it is essential to focus more on the development of specific kinesthetic-differentiation abilities in young volleyball players [20]. The accuracy of overhead and forearm passing is important for receiving serves, defending the court (especially for precisely playing balls that the opposing team did not hit with a strong spike but played lightly—which is common in younger age groups), as well as for setting up for a spike. The precision of serves enables serving into empty spaces that opposing serve receivers did not cover or targeting players who are known for poor serve reception.

This study has some limitations. Firstly, the sample only consisted of female athletes; future studies should include male athletes. Additionally, the reliability of the tests was established in a non-fatigued state, so further investigations are needed to assess their effectiveness when athletes are fatigued. Although the sample size was not small, it should be even larger when examining differences between playing positions. Lastly, only discriminant ability was analyzed in this study, and future investigations should establish convergent validity by comparing the results with other tests considered the gold standard.

2.4.5. Conclusions

The findings of this study confirm the importance of kinesthetic differentiation ability in volleyball and the need for its development in young athletes. The newly constructed tests of specific kinesthetic differentiation in this study are reliable. Due to their discriminative ability among performance levels, they can be used in the talent identification process and to assess progress in individual player positions in volleyball. Coaches should be aware of the importance of kinesthetic-differentiation ability in complex tasks such as service tests, overhead passing, and forearm passing and incorporate appropriate training methods from an early age. It can be assumed that the FSTx test is suitable for even younger volleyball players than those in this study group, while the FST6m test is best for this group, and it can be assumed that the FSTnet test will be the best option for a cadet, junior, and senior players (U17 and older age groups).

Author Contributions: Conceptualization, K.Đ. and Z.G.; methodology, K.Đ. and G.K.; formal analysis, K.Đ. and G.K.; investigation, K.Đ.; data curation, K.Đ. and Z.G.; writing original draft preparation, K.Đ.; writing—review and editing, Z.G. and G.K.; supervision, Z.G. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the 1975 Declaration of Helsinki, and ethical approval was given by the Ethical Committee of the University of Split (number: 2181-205- 02-05-20-025; 3 December 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data can be provided on reasonable request.

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Conflicts of Interest: The authors declare no conflict of interest.

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3. ZAKLJUČAK

Stavljajući naglasak na mlađe dobne skupine odbojkašica, koje su u dosadašnjim istraživanjima bile nedovoljno zastupljene, može se zaključiti da su konstruirani i modificirani testovi općih i specifičnih koordinacijskih sposobnosti u odbojci pouzdani i primjenjivi. Sva četiri istraživanja potvrđuju važnost koordinacijskih sposobnosti za procjenu uspješnosti u modernoj odbojkaškoj igri.

Rezultati prvog istraživanja ukazuju da je test (SRB) pouzdan pokazatelj brzine reakcije kod mlađih dobnih kategorija odbojkašica. Moderna odbojka, obilježena visokom dinamičnošću igre, zahtijeva od igračica brzu prilagodbu i pravovremenu reakciju na stalne promjene u igri. Zbog uočenog učinka učenja te potencijalnog smanjenja varijabilnosti rezultata preporučuje se provedba najmanje triju ponovljenih mjerenja.

U drugom istraživanju procjena ravnoteže primjenom testa (MBW3T) pokazalo je dobru razinu pouzdanosti u uvjetima ponovljenog mjerenja, kao i u prethodnom radu. MBW3T test predstavlja pristupačan i pouzdan instrument za procjenu dinamičke ravnoteže te je primjenjiv, kako u znanstveno-istraživačkom, tako i u praktičnom kineziološkom okruženju, osobito u longitudinalnim istraživačkim nacrtima.

Treće istraživanje ukazuje na visoku pouzdanost i uporabnu vrijednost testova za procjenu općih koordinacijskih sposobnosti kod odbojkašica te njihovu diskiriminativnu sposobnost u razlikovanju uspješnijih i manje uspješnih odbojkašica. Nisu utvrđene statistički značajnije razlike između pojedinih igračkih uloga, dok su unutar svake uloge uspješnije igračice postizale bolje rezultate u koordinacijskim testovima. Dobiveni rezultati sugeriraju da su opće koordinacijske sposobnosti u početnoj fazi specijalizacije podjednako važne za sve igračke uloge te potvrđuju potrebu za njihovim sustavnim i kontinuiranim razvojem.

Novokonstruirani specifični testovi kinestetičke diferencijacije, u četvrtom istraživanju, pokazali su vrlo dobru pouzdanost i dobru diskriminativnu sposobnost razlikovanja uspješnijih i manje uspješnih odbojkašica. Time se potvrđuje njihova primjenjivost u procesima identifikacije talenata i praćenja napretka s obzirom na specifične igračke uloge. Budući da je istraživanje provedeno na uzorku ispitanika u dobi od petnaest godina, dobiveni rezultati ukazuju na to da je test serviranja s udaljenosti od 6 m (FST6m) najprikladniji za ovu dobnu skupinu, jer omogućuje stabilniju i pouzdaniju izvedbu zadatka. Test serviranja bez mreže (FSTx) i test serviranja s mrežom (FSTnet) zahtijevaju višu razinu tehničke izvedbe, snage i koordinacije, zbog čega su primjereniji starijim i iskusnijim igračicama, dok kod mlađih mogu rezultirati poremećenom varijabilnošću rezultata. Ovi rezultati u skladu su s obilježjima faze rane specijalizacije, u kojoj se igračice nalaze oko petnaeste godine života, kada tehničko-taktičke i motoričke sposobnosti još nisu u potpunosti razvijene za izvedbu složenijih motoričkih zadataka. Navedeno opravdava primjenu jednostavnijih, metodološki i razvojno primjerenijih testova u procjeni koordinacijskih sposobnosti.

3.1 Ograničenja istraživanja

Unatoč značajnim znanstvenim i praktičnim doprinosima, ova disertacija ima nekoliko ograničenja koja je potrebno uzeti u obzir pri interpretaciji dobivenih rezultata. Prije svega, veličina uzorka, osobito u podskupinama za analizu pouzdanosti i razlika prema igračkim ulogama ograničava mogućnost provedbe detaljnijih statističkih analiza i smanjuje razinu generalizacije rezultata. Iako je ukupan uzorak iznosio 98 ispitanika, što bi bilo zadovoljavajuće za opću analizu, njegova podjela na poduzorke prema igračkim ulogama i situacijskoj uspješnosti smanjuje statističku snagu analize. Veći i heterogeniji uzorci omogućili bi stabilniju procjenu pouzdanosti, osobito kod testova koji su pokazali tek zadovoljavajuće vrijednosti. Dodatno ograničenje odnosi se na činjenicu da su u istraživanju sudjelovale isključivo odbojkašice, što onemogućuje izravnu generalizaciju zaključaka na mušku populaciju.

Važno je istaknuti da je pouzdanost testova procijenjena u uvjetima odmora, što je u skladu s preporukama za procjenu koordinacijskih sposobnosti i učenja novih motoričkih zadataka. U stvarnim uvjetima, koordinacijske sposobnosti i tehnička izvedba mogu biti pod utjecajem zamora, no takvi uvjeti primjereniji su za usavršavanje već usvojenih tehnika. Stoga se testiranje u uvjetima zamora može razmatrati kao dodatni pristup, ali isključivo u kontekstu procjene stabilnosti već naučenih motoričkih obrazaca.

Nadalje, analizirana je isključivo diskriminativna sposobnost. Iako su uočene razlike između uspješnijih i manje uspješnih odbojkašica u mlađoj dobi, dobiveni rezultati ne mogu se interpretirati kao pouzdani prediktori buduće sportske uspješnosti. Unatoč navedenim ograničenjima, dobiveni rezultati pružaju vrijednu osnovu za daljnji razvoj i validaciju koordinacijskih testova u odbojci. U ovoj disertaciji naglasak je stavljen na diskriminativne sposobnosti testova, dok drugi aspekti valjanosti poput konvergentne valjanosti nisu bili obuhvaćeni analizom.

Nadalje, s obzirom na to da su pojedini testovi u ovome istraživanju prvi put primijenjeni ili metodološki modificirani, izostaje mogućnost njihove izravne usporedbe s rezultatima prethodnih istraživanja što dodatno naglašava potrebu za daljnjim istraživanjima.

Unatoč navedenim ograničenjima, dobiveni rezultati predstavljaju relevantnu znanstvenu i metodološku osnovu za daljnji razvoj, unapređenje i validaciju koordinacijskih testova u odbojci.

3.2 Smjernice za buduća istraživanja

Buduća istraživanja trebala bi biti usmjerena na uključivanje većeg i metodološki reprezentativnijeg uzorka ispitanika, čime bi se omogućile pouzdanije statističke procjene te daljnija analiza razlika s obzirom na igračke uloge i razinu sportske uspješnosti odbojkaša.

Nužno je provesti istraživanja koja uključuju mušku populaciju odbojkaša kako bi se ispitala spolna specifičnost koordinacijskih sposobnosti te utvrdila primjenjivost predloženih testova u različitim populacijama sportaša.

Poseban naglasak u budućim istraživanjima trebao bi biti stavljen na longitudinalni pristup koji bi omogućio praćenje razvoja koordinacijskih sposobnosti kroz različite faze sportskog razvoja kao i precizniju procjenu njihove povezanosti s budućom sportskom uspješnošću.

Zbog analiziranja isključivo diskriminativne valjanosti testova, u budućim istraživanjima potrebno je ispitati i konvergentnu valjano tzv. „zlatnim standardom“ čime bi se dodatno potvrdila opravdanost i znanstvena utemeljenost predloženih testova.

Također, u budućim istraživanjima preporučuje se ispitivanje primjenjivosti testova u uvjetima zamora, ali isključivo u kontekstu procjene stabilnosti već usvojenih tehničkih obrazaca, čime bi se dodatno mogla procijeniti njihova praktična vrijednost u realnim trenažnim i natjecateljskim uvjetima.

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ŽIVOTOPIS

Karla Đolo (djevojački Barać) rođena je 7. travnja 1989. u Mostaru. Nakon završetka Gimnazije fra Dominika Mandića u Širokom Brijegu (opći smjer), upisala je Fakultet prirodoslovno-matematičkih i odgojnih znanosti Sveučilišta u Mostaru, gdje je u srpnju 2012. godine diplomirala Fizičku kulturu.

Tijekom studija radila je kao demonstrator na kolegijima *Kvantitativne metode 1 i 2* te na kolegiju *Tjelesna i zdravstvena kultura* i *Metodika treninga izbornog usmjerenja Kineziološka rekreacija*.

Po završetku studija zapošljava se kao asistentica, a potom i viša asistentica u razdoblju od 2012. do 2023. godine. Tijekom tog razdoblja sudjelovala je u izvođenju nastave na kolegijima: *Kvantitativne metode 1 i 2, Odbojka, Aerobika, Fitnes, Tjelesna i zdravstvena kultura*, *Metodika treninga izbornog usmjerenja Kineziološka rekreacija*, *Osnovne kineziološke transformacije 2, Metodika kondicijske pripreme 2* te *Planiranje i programiranje kondicijske pripreme sportaša*. Također je bila asistentica na kolegiju *Osnovne motoričke transformacije* na sveučilišnom studiju fizioterapije pri Fakultetu zdravstvenih studija.

Radila je kao nastavnica tjelesne i zdravstvene kulture u Osnovnoj školi Biograci.

Obavljala je poslove instruktora aerobika, zumbe i pilatesa, kondicijskog trenera u Tenis akademiji Set te trener u odbojkaškom klubu Smeč u Širokom Brijegu.

Trenutno obavlja posao trenerice u Hrvatskom ženskom odbojkaškom klubu Blato u Širokom Brijegu.

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