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POVEZANOST ANTROPOMETRIJSKIH PARAMETARA SA VERTIKALNIM SKOKOM KADETSKE SELEKCIJE U ODBOJCI [1]

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Apstrakt: Odbojka je timska igra koju igraju dva tima na terenu koji je podeljen mrežom i intenzivan je sport koji kombinuje vertikalni i horizontalni pravac, koji uključuje anaerobni energetski sistem sa kratkim periodima oporavka. Antropometrijske karakteristike sportista predstavljaju važan preduslov za uspešno bavljenje određenim sportom, utiču na sportske performanse i neophodne su za postizanje vrhunskih sportskih veština. Cilj ove studije je da utvrdi odnos između antropometrijskih parametara i vertikalnog skoka kod kadetkinja u odbojci. Sprovedeno je istraživanje u kojem su procenjene motoričke sposobnosti i fizičke karakteristike 40 kadetkinja koje se bave odbojkom. Mereni su antropometrijski parametri, uključujući telesnu visinu, telesnu masu, procenat telesne masti, procenat mišićne mase i indeks telesne mase, kao i raspon ruku, koristeći odgovarajuće instrumente. Motoričke sposobnosti su procenjene putem testa vertikalnog skoka na OptoJump sistemu. Pearsonovi korelacioni koeficijenti pokazali su značajne pozitivne korelacije između skoka iz čučnja (CMJ) i procenta mišićne mase ($r=0.588$, $p<0.001$), raspona ruku ($r=0.515$, $p<0.001$), telesne visine ($r=0.502$, $p=0.001$) i telesne mase ($r=0.342$, $p=0.031$). Procenat mišićne mase se pokazao kao statistički značajan prediktor ($B=1.488$, $p=0.004$), dok je raspon ruku takođe imao značajnu pozitivnu povezanost sa CMJ ($B=0.095$, $p=0.002$). S druge strane, telesna masa ($B=0.233$, $p=0.146$) i telesna visina ($B=-0.238$, $p=0.447$) nisu se pokazali kao statistički značajni prediktori u ovom modelu. Rezultati analize višestruke regresije ukazuju na statističku značajnost modela ($F=6.667$, $p<0.001$), sa višestrukim korelacionim koeficijentom $R=0.660$. Rezultati ove studije naglašavaju potrebu za multidimenzionalnim pristupom u trenažnom procesu, koji ne uključuje samo fizičku pripremu, već i biomehaničke i tehničke faktore.

Ključne reči: *odbojka, vertikalni skok, antropometrija, antropometrijski parametri, pliometrijski trening, skokovi*

UVOD

Odbojka je timska igra koju igraju dva tima na igralištu podeljenom mrežom. To je intenzivan sport koji kombinuje vertikalne i horizontalne pravce, uključujući anaerobni energetski sistem sa kratkim periodima oporavka (Polglaze & Dawson, 1992; Gabbett & Georgieff, 2007; Sheppard et al., 2009). Većina trenera i istraživača slaže se da je pliometrijski trening (PT) metoda koja se koristi kada se želi poboljšati sposobnost vertikalnog skoka i snaga mišića nogu (Ebben & Blackard, 2001; Ebben et al., 2004; Markovic et al., 2007; Simenz et al., 2005).

Kada se brzina i agilnost kombinuju sa maksimalnom snagom, rezultat je snaga (Saeed, 2013). Za donji deo tela, PT uključuje izvođenje različitih vrsta skokova sa sopstvenom težinom, kao što su drop skokovi, saskoci, skokovi sa počučnjem (CMJ), naizmenični skokovi, skokovi i druge skakačke vežbe sa ciklusom istezanja i skraćivanja (Fleck & Kraemer, 2004). PT karakteriše korišćenje ciklusa istezanja i skraćivanja (SSC), koji se javlja tokom

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prelaska sa brze ekscentrične kontrakcije mišića (faza usporavanja) u brzu koncentričnu mišićnu kontrakciju (faza ubrzanja) (Sole et al., 2022). SSC pokreti koriste prednosti elastičnih svojstava vezivnog tkiva i mišićnih vlakana, omogućavajući mišićima da skladište elastičnu energiju tokom faze usporavanja i oslobađaju je tokom faze ubrzanja kako bi povećali mišićnu snagu i proizvodnju snage (Morio, 2011; Davies et al., 2015).

Štaviše, PT izaziva brojne povoljne adaptacije u mišićno-skeletnom i neuronskom sistemu, funkciji mišića i performansama zdravih osoba. U tom smislu, poboljšanjem SSC i srodnih neuromehaničkih mehanizama, PT može potencijalno poboljšati ljudske performanse. Vertikalni skok je osnovni deo napada, blokiranja i servisa. Na visokom nivou odbojke, skakanje se takođe koristi i pri podizanju lopte jer smanjuje vreme leta lopte, ubrzava napad i otežava prvoj liniji odbrane – bloku, da pročita mogućnosti napadačkog tima.

Procena vertikalnog skoka u odbojci neizbežan je deo treninga i testiranja (Ziv & Lidor, 2010). U odbojkaškoj utakmici koja se igra u pet setova, igrači na različitim pozicijama izvode različit broj skokova, od 65 do 136. U proseku, najveći broj skokova izvode tehničari, zatim srednji napadači, suprotnim napadači i spoljašnji napadači (Fontani et al., 2000). Naime, akcije za postizanje poena (npr. servis, smeč i blok) su zasnovane na skoku, sa tipičnim timom (n~12) odbojkaša koji izvode oko 120.000 skokova tokom sezone (Garcia-de-Alcaraz et al., 2020). Po principu specifičnosti treninga, odbojkašice treba sistematski da se bave programima vežbanja zasnovanim na skokovima.

Antropometrijske osobine sportista predstavljaju važan preduslov za uspešno takmičenje u istom sportu, utiču na performanse sportista i neophodne su za postizanje izuzetnih veština u sportu. Fizičke karakteristike odbojkaša uglavnom se procenjuju merenjem antropometrijskih parametara kao što su visina, indeks telesne mase i drugi fizički faktori povezani sa performansama, kao što su sposobnost skakanja, agilnost, snaga i izdržljivost (Bayios et al., 2006; Ibrahim, 2010; Duncan et al., 2006). Kod sportistkinja, početak pubertetskog ubrzanja rasta je oko 10. godine, dok se odrasla visina dostiže oko 14-15. godine (Malina et al., 2004). Pubertetski rast kod devojčica prati povećanje telesne masti, što negativno utiče na sportske performanse (Rogol et al., 2002; Lidor & Ziv, 2010). Uspešne odbojkašice imaju manji procenat telesne masti, što se vidi po razlikama u adipozitetu između igračica prve i druge lige (Malousaris et al., 2008). Jedan oblik vežbanja koji se često zanemaruje je pliometrijski trening (PT), koji uključuje vežbe skoka koje koriste ciklus skraćivanja i istezanja (Chen et al., 2023). Pliometrijsko opterećenje je posebno efikasno i kod dece i kod adolescenata tokom perioda rasta kostiju. Dosadašnja istraživanja su pokazala da pliometrijski trening pozitivno utiče na rast i razvoj adolescenata (Kryeziu et al., 2023). Pliometrijski trening je vrsta treninga koji može značajno da poboljša skakačku sposobnost adolescenata (Coşkun et al., 2022), što je važno kako za atletski uspeh, tako i za opšte zdravlje.

Sila donjih ekstremiteta i vertikalni skokovi su značajni pokazatelji uspešnosti odbojkaša (Stec & Smulsky, 2007). Prosečna visina savremenog odbojkaša je viša u poređenju sa prethodnim periodima i iznosi između 195 i 200 cm (Ercolessi, 1999).

Cilj ovog istraživanja je da se utvrdi odnos između antropometrijskih parametara i vertikalnog skoka kod kadetkinja u odbojci. Ove informacije mogu pružiti značajan uvid i referentne vrednosti za identifikaciju talenta i procenu primenjenih trenažnih programa.

METOD

Učesnici

Izvršena je studija sa ciljem procene motoričkih veština i fizičkih karakteristika 40 odbojkašica uzrasta 12-15 godina, koje su trenirale četiri puta nedeljno sa prosečnim sportskim iskustvom od tri godine, u odbojkaškoj školi „DIF“. Standardni odbojkaški trening je trajao 90 minuta i uključivane su odbojkašice koje imaju trenažni staž u školi odbojke u proseku od tri godine (±6 meseci). Uključivani su tehnički elementi skoka, servisa, prijema i napada, kao i vežbe snage. Vežbe snage obuhvatale su vežbe za gornji i donji deo tela, koje su rađene u 3-4 seta po 10-15 ponavljanja, sa pauzama od po jedan minut. Fokus je bio na razvoju i učenju tehnike. U studiju su uključene samo one igračice koje nisu imale povrede koje bi mogle uticati na rezultate. Antropometrijske karakteristike poput visine tela, telesne mase, procenta telesne masti, procenta mišićne mase i indeksa telesne mase merene su odgovarajućim instrumentima – antropometar po Martinu i tanita vaga, dok je raspon ruku meren pomoću metra. Ovi antropometrijski parametri su izabrani kao prediktori performansi vertikalnog skoka jer imaju direktan ili indirektan uticaj na biomehaniku i energetsku efikasnost skoka, dok raspon ruku može imati prednost u fazi zaleta i zamaha rukama.

Sva testiranja su urađena u jednom danu. Antropometrijske dimenzije su merene na početku, pre merenja motoričke sposobnosti. To je izvršeno na sledeći način:

- Antropometar po Martinu je instrument koji smo koristili za merenje visine tela. Dužine je 2m i na njemu su iscrtani milimetri i centrimetri. Antropometar se stavlja iza leđa ispitanika, vertikalno, da bar u jednoj tački dodiruje telo. Ispitivač desnom rukom drži antropometar, tako da palcem i kažiprstom pomera klizni prsten, a levom rukom drži vrh horizontalne šipke tačno na sredini temena ispitanika.
- Tanita vaga - koristi revolucionarnu metodu analize bioelektričnog otpora. Automatski meri telesnu težinu i količinu ostalih telesnih masti i matematičkim modelom preračunava, na osnovu pola i starosti, odstupanje od idealne kilaže.
- Raspon ruku (RR) - izmeren je tako što su odbojkašice maksimalno raširile ruke (odručile) i uz pomoć metra smo izmerili raspon ruku s leđa.

Motorička veština je procenjena pomoću testova vertikalnog skoka na OptoJump sistemu.

Vertikalni skok (CMJ) (Slika 1): Skok je započet iz čučanj pozicije. Nisu date specifične instrukcije u vezi dubine ili brzine skoka. Intra-klasni koeficijent korelacije za pouzdanost testiranja i tipičnu grešku merenja za test vertikalnog skoka je bio 0,96 i 2,9%, redom.

Slika 1. *Grafički prikaz testa skok sa počučnjem (CMJ)*

Optojump (Microgate, Italija) je korišćen za procenu CMJ. OptoJump sistem se sastoji od dve prenosive ploče opremljene sa 33 optičke LED diode koje su postavljene na prenosnoj ploči u razmaku od 3,125 cm. LED diode na prenosnoj ploči komuniciraju kontinuirano sa onima na prijemnoj ploči. Sistem detektuje svako prekidanje komunikacije između ploča i izračunava njihovo trajanje. Ovo omogućava merenje vremena leta i kontakta tokom serije skokova sa tačnošću do 1/1.000 dela sekunde.

Dobijeni podaci su analizirani pomoću deskriptivne statistike, a sve merenja su opisivana prosekom, standardnom devijacijom, minimumom, maksimumom, koeficijentom korelacije i regresionom analizom. Excel, ANOVA i statistički programi su korišćeni za pripremu i obradu baze podataka. P-vrednost manja od 0,05 smatrana je statistički značajnom.

REZULTATI

Analiza deskriptivne statistike (Tabela 1) pruža pregled uzorka od 40 učesnica za odabrane varijable. Prosečna visina tela (TV) bila je 155,6 cm, sa standardnom devijacijom od 10,4 cm, dok su minimalne i maksimalne vrednosti iznosile 134,9 cm i 176,9 cm, redom. Raspon ruku (RR) imao je prosečnu vrednost od 156,4 cm (SD = 12,1 cm), u rasponu od 134,4 cm do 184,0 cm.

Prosečna telesna masa (TM) bila je 48 kg, sa standardnom devijacijom od 8 kg. Minimalne i maksimalne vrednosti bile su 30,5 kg i 72,3 kg. Indeks telesne mase (BMI) imao je prosečnu vrednost od 19,9 kg/m² (SD = 3,1), u rasponu od 14,2 do 25,7 kg/m².

Prosečan procenat telesne masti (PM) bio je 20,9%, sa standardnom devijacijom od 6,9%. Minimalne i maksimalne vrednosti iznosile su 7,7% i 33,9%. Procenat mišićne mase (%M) imao je prosečnu vrednost od 34,8% (SD = 2,5%), sa minimalnim procentom od 29% i maksimalnim od 39,4%.

Na kraju, visina skoka iz počučnja (CMJ) imala je prosečnu vrednost od 22,4 cm (SD = 5,7 cm), sa najnižom zabeleženom vrednošću od 9,8 cm i najvišom vrednošću od 34,0 cm.

Tabela 1. *Rezultati deskriptivne statistike*

	TV	*RR*	*TM*	*BMI*	*PM*	*%M*	CMJ
N	**40**	**40**	**40**	**40**	**40**	**40**	**40**
M	155.6	156.4	48.8	19.9	20.9	34.8	22.4
Max	176.9	184.0	72.3	25.7	33.9	39.4	34.0
Min	134.9	134.4	30.5	14.2	7.7	29.6	9.8
SD	10.4	12.1	11.8	3.1	6.9	2.5	5.7

TV - telesna visina; ***RR*** – raspon ruku; ***TM*** - telesna masa; ***BMI*** – indeks telesne mase; ***PM*** – procenat masti; ***%M*** – procenat mišića; ***CMJ*** - skok sa počučnjem; ***N*** – ukupan broj učesnika; ***M*** – srednja vrednost; ***SD*** –standardna devijacija; ***Min*** – minimum; ***Max*** – maksimum

Tabela 2. prikazuje Pearsonove koeficijente korelacije između visine skoka sa počučnjem (CMJ) i odabranih antropometrijskih varijabli, uključujući telesnu masu, procenat mišićne mase, raspon ruku i visinu tela. Uočene su značajne pozitivne korelacije između CMJ i procenta mišićne mase ($r = 0.588$, $p < 0.001$), raspona ruku ($r = 0.515$, $p < 0.001$), visine tela ($r = 0.502$, $p = 0.001$) i telesne mase ($r = 0.342$, $p = 0.031$). Ovi rezultati sugerišu da veći procenat mišićne mase, telesne dimenzije i masa tela imaju povezanost sa boljim performansama skoka.

Tabela 2. *Pearsonov koeficijent korelacije između visine skoka sa počučnjem (CMJ) i odabranih antropometrijskih varijabli*

Varijable	*Corelacija (r)*	*p-vrednost*
Telesna masa (kg)	0.342	**0.031**
Procenat mišića (%)	0.588	**<0.001**
Raspon ruku (cm)	0.515	**<0.001**
Telesna visina (cm)	0.502	**0.001**

Tabela 3. sumira rezultate višestruke regresione analize sprovedene kako bi se istražila veza između visine skoka sa počučnjem (CMJ) kao zavisne varijable, i telesne mase, procenta mišićne mase, raspona ruku i telesne visine kao prediktora. Rezultati iz ANOVA tabele ukazuju da je model statistički značajan ($p<0.001$).

Procenat mišićne mase bio je statistički značajan prediktor ($B=1.488$, $p=0.004$), što sugeriše da je viši procenat mišićne mase povezan sa većom visinom CMJ skoka.

Raspon ruku takođe je pokazao značajnu pozitivnu povezanost sa CMJ ($B=0.095$, $p=0.002$), što znači da pojedinci sa većim rasponom ruku imaju tendenciju da postignu veće skokove.

Telesna masa ($B=0.233$, $p=0.146$) i telesna visina ($B=-0.238$, $p=0.447$) nisu bili statistički značajni prediktori u ovom modelu, što sugeriše da njihov pojedinačni doprinos visini skoka postaje minimalan kada se kontrolišu druge varijable.

Telesna masa i telesna visina nisu bili statistički značajni u regresionoj analizi, verovatno zbog snažne objašnjavajuće moći procenta mišićne mase, koji je mogao da prikrije njihov doprinos.

Tabela 3. *Multipla regresiona analiza*

Prediktor	*B*	*Std. greška*	*Beta*	*t*	*p-vrednost*
Telesna masa (kg)	0.233	0.157	0.182	1.487	0.146
Procenat mišića (%)	1.488	0.480	0.558	3.100	**0.004**
Raspon ruku (cm)	0.095	0.031	0.310	3.100	**0.002**
Telesna visina (cm)	-.238	0.435	-.076	-.769	0.447

B - regresioni koeficijent; ***Std. greška*** – standardna greška u proceni; ***Beta*** – standardizovani koeficijent; ***t*** – t-vrednost; ***p-vrednost*** – nivo značajnosti

R= .660 R^2= .436   F= 6.667

R – koeficijent multiple korelacije; $\mathbf{R^2}$ – koeficijent determinacije; **F** – F-test veze između zavisne promenljive i skupa nezavisnih promenljivih

DISKUSIJA

Studija je osmišljena sa ciljem utvrđivanja veze između odabranih antropometrijskih varijabli i vertikalnog skoka kod odbojkašica. Poznavanje razlika u odabranim antropometrijskim varijablama vrlo je važno za implementaciju treninga i performansi u odbojci. Rezultati studije takođe su korišćeni prilikom razmatranja faktora za izbor igrača uključujući trenažno iskustvo, kondiciju, itd. Prilikom odabira igrača za uključivanje u utakmice, ovi rezultati mogu se koristiti od strane trenera pri planiranju trening programa, imajući u vidu taktički plan za igrača. U savremenoj odbojci, svaka ekipa nastoji da skoči što više i da visoko skače kako bi akcije kao što su blok i napad učinilo kompleksnijim za protivnika, te se zbog toga mora posvetiti veća pažnja napadu, bloku i servisu tima jer su to ofanzivne akcije i većina poena ekipe postiže se kroz ove akcije. Takođe, verovatnoća pobede raste uz efikasan blok, čime se tim čini jačim u ovim akcijama.

U ovom istraživanju, cilj nam je bio da ispitamo uticaj različitih antropometrijskih varijabli – telesne mase, procenta mišićne mase, raspona ruku i telesne visine na visinu vertikalnog skoka. Rezultati Pearsonovog koeficijenta korelacije otkrili su značajne povezanosti između ovih varijabli i skoka.

Telesna masa (TM) pokazala je značajnu povezanost, pri čemu veća telesna masa može negativno uticati na performanse skoka. Međutim, naša analiza nije pokazala snažnu negativnu korelaciju, verovatno zbog visine učesnika i specifične telesne strukture. Korelacija između telesne mase i CMJ-a je niža, što ukazuje da viša telesna masa nije toliko kritična kao mišićna masa u objašnjavanju performansi skoka.

Procenat mišićne mase (%M) pokazao je značajnu pozitivnu korelaciju sa visinom skoka. Ovo se može objasniti činjenicom da veća mišićna masa doprinosi većoj snazi mišića, što je od suštinskog značaja za eksplozivne vertikalne aktivnosti poput skakanja (Bobbert & van Ingen Schenau, 1988). Veća mišićna masa omogućava brže kontrakcije mišića, poboljšavajući performanse skoka.

Telesna visina (TM) može se smatrati najvažnijim fizičkim atributom. Međutim, velika sposobnost skakanja može pomoći u kompenzaciji visinskog nedostatka pojedinca (Marques et al., 2009).

Raspon ruku (RR) takođe pokazuje značajnu pozitivnu korelaciju. Ovo može biti povezano sa biomehanikom pokreta, gde veći raspon ruku omogućava efikasniju upotrebu zamaha ruku tokom skoka. U drugom istraživanju (Reeves et al., 2008) postavljena je hipoteza da duža ruka stvara dodatno vertikalno ubrzanje kroz duži krak poluge generisan zamahom ruke. To je razlog značajne korelacije između raspona ruku i vertikalnog skoka u ovom istraživanju. Zamah ruku tokom CMJ-a može povećati brzinu odskoka za najmanje 6% u poređenju sa skokom bez zamaha i povećati visinu skoka za 15% ili više (Vaverka et al., 2016).

U istraživanju Pandeya i saradnika (Pandey et al., 2016) bilo je evidentno da je koeficijent korelacije između visine i sportskih performansi u odbojci bio značajan na nivou od 0.05, dok koeficijent korelacije između telesne mase i performansi u odbojci nije bio značajan. U našem istraživanju, rezultati multiple regresije ukazuju da telesna masa i visina nisu statistički značajni prediktori visine vertikalnog skoka kada se razmatraju zajedno sa drugim varijablama. Međutim, Pearsonov test pokazuje da telesna masa i visina imaju značajne individualne efekte. Ovo sugeriše da je njihov direktni doprinos ograničen kada se kontrolišu druge varijable. Ova promena sugeriše da odnos između telesne visine i vertikalnog skoka može biti posredovan ili zasenčen kombinovanim efektima telesne mase i mišićne mase. Moguće je da ovi faktori interaguju na način koji smanjuje izolovani doprinos telesne visine performansama vertikalnog skoka. Nedostatak značajnosti takođe može ukazivati na to da su telesna visina i mišićna masa međusobno povezani, pri čemu je mišićna masa direktniji određivač visine skoka, dok telesna visina može imati indirektnu ulogu.

Rezultati višestruke regresije pokazuju da je model statistički značajan ($F=6.667$, $p<0.001$), sa koeficijentom višestruke korelacije $R=0.660$. Koeficijent determinacije ($R^2=0.436$) pokazuje da predloženi model objašnjava 43.6% varijabilnosti u visini CMJ skoka. Rezultati studije (Stojanović et al., 2020) sugerišu da ne postoji značajna povezanost između telesne mase i performansi vertikalnog skoka kod adolescenata. Naši nalazi su slični onima iz prethodnih istraživanja (Pérez-López et al., 2015; Davis et al., 2003), koji su takođe pokazali da telesna masa nema značajan uticaj na vertikalni skok. To podržavaju nalazi Markovića i Jarića (Davis et al., 2003), koji su istraživali vezu između visine vertikalnog skoka i telesne mase, pri čemu su rezultati pokazali da je telesna masa nezavisna od visine vertikalnog skoka. Naši rezultati ukazuju na to da ne postoji značajna povezanost između telesne visine i performansi vertikalnog skoka u CMJ testovima, u skladu sa istraživanjima (Stojanović et al., 2020; Aslan et al., 2011; Aragón-Vargas & Gross, 1997).

ZAKLJUČAK

Moderna odbojka, zbog kraćeg trajanja akcije u igri i povećane intenzivnosti vremena, zahteva sve veću upotrebu energije iz alaktatnog anaerobnog metabolizma. To znači da postoji rastuća potreba za sportistima sa poboljšanom kondicijom, koji su takođe brzi i sposobni da izvode visoke skokove. U ovoj studiji, cilj nam je bio da istražimo uticaj različitih antropometrijskih varijabli – telesne mase, procenta mišićne mase, raspona ruku i telesne visine na visinu vertikalnog skoka. Rezultati Pearsonovog koeficijenta korelacije otkrili su značajne veze između ovih varijabli i CMJ. Međutim, rezultati višestruke regresije pokazuju da telesna masa i visina nisu statistički značajni prediktori visine vertikalnog skoka kada se razmatraju zajedno sa drugim varijablama.

Pored nalaza predstavljenih u ovoj studiji, rezultati se mogu praktično primeniti u dizajnu specifičnih programa treninga usmerenih na poboljšanje performansi vertikalnog skoka kod odbojkaša. Ovi programi treba da se prioritetno fokusiraju na poboljšanje mišićne snage i eksplozivne moći, a ne samo na telesnu masu ili visinu, jer ove varijable nisu pokazale statistički značajnu ulogu kao prediktori.

Ova studija ima određena ograničenja, uključujući relativno mali broj uzoraka i drugih potencijalno uticajnih faktora, kao što su neuromišićna koordinacija i tehnika skoka. Buduća istraživanja trebala bi detaljnije istražiti ove aspekte i razmotriti širi opseg antropometrijskih i motoričkih varijabli kako bi se pružilo sveobuhvatnije razumevanje determinanti vertikalnog skoka.

Rezultati ove studije naglašavaju potrebu za multidimenzionalnim pristupom u treningu koji uključuje ne samo fizičku kondiciju, već i biomehaničke i tehničke faktore. Takav pristup može pomoći u optimizaciji performansi i smanjenju rizika od povreda u modernoj odbojci, gde se od igrača zahteva da izvode skokove sa sve većim intenzitetom i preciznošću.

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Original scientific paper

RELATIONSHIP BETWEEN ANTHROPOMETRIC PARAMETERS AND VERTICAL JUMP PERFORMANCE IN CADET VOLLEYBALL SELECTION [1]

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Abstract: Volleyball is a team sport played by two teams on a court divided by a net. It is an intense sport that combines vertical and horizontal movements, involving anaerobic energy systems with short recovery periods. The anthropometric characteristics of athletes are a significant prerequisite for successful engagement in a specific sport, influencing athletic performance and being essential for achieving elite sports skills. The aim of this study is to determine the relationship between anthropometric parameters and vertical jump performance in female volleyball cadets. A research study was conducted to assess motor abilities and physical characteristics of 40 female volleyball players. Anthropometric parameters, including body height, body mass, body fat percentage, muscle mass percentage, and body mass index, as well as arm span, were measured using appropriate instruments. Motor abilities were evaluated through a vertical jump test using the OptoJump system. Pearson correlation coefficients revealed significant positive correlations between countermovement jump (CMJ) and muscle mass percentage ($r=0.588$, $p<0.001$), arm span ($r=0.515$, $p<0.001$), body height ($r=0.502$, $p=0.001$), and body mass ($r=0.342$, $p=0.031$). Muscle mass percentage was identified as a statistically significant predictor ($B=1.488$, $p=0.004$), while arm span also showed a significant positive association with CMJ ($B=0.095$, $p=0.002$). Conversely, body mass ($B=0.233$, $p=0.146$) and body height ($B=-0.238$, $p=0.447$) were not statistically significant predictors in this model. The multiple regression analysis results indicate the statistical significance of the model ($F=6.667$, $p<0.001$), with a multiple correlation coefficient $R=0.660$. The findings of this study emphasize the need for a multidimensional approach in training processes, which should include not only physical conditioning but also biomechanical and technical factors.

Keywords: *volleyball, vertical jump, anthropometry, anthropometric parameters, plyometric training, jumps*

INTRODUCTION

Volleyball is a team sport played by two teams on a court divided by a net. It is an intense sport that combines vertical and horizontal movements, involving anaerobic energy systems with short recovery periods (Polglaze & Dawson, 1992; Gabbett & Georgieff, 2007; Sheppard et al., 2009). Most coaches and researchers agree that plyometric training (PT) is a method used to improve vertical jump ability and leg muscle strength (Ebben & Blackard, 2001; Ebben et al., 2004; Markovic et al., 2007; Simenz, et al., 2005).

When speed and agility are combined with maximum strength, the result is power (Saeed, 2013). For the lower limbs, PT involves performing various types of jumps using body weight, such as drop jumps, squat jumps,

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countermovement jumps (CMJ), alternating jumps, and other plyometric exercises involving stretch-shortening cycles (Fleck & Kraemer, 2004). PT is characterized by the use of stretch-shortening cycles (SSC), which occur during the transition from rapid eccentric muscle contraction (deceleration phase) to rapid concentric muscle contraction (acceleration phase) (Sole et al., 2022). SSC movements harness the elastic properties of connective tissues and muscle fibers, allowing muscles to store elastic energy during the deceleration phase and release it during the acceleration phase to increase muscle strength and force production (Morio, 2011; Davies et al., 2015).

Furthermore, PT induces numerous beneficial adaptations in the musculoskeletal and nervous systems, muscle function, and overall performance in healthy individuals. By enhancing SSC and related neuromechanical mechanisms, PT can potentially improve human athletic performance. Vertical jump is a fundamental component of attacking, blocking, and serving in volleyball. In top-level volleyball, jumping is also utilized when setting the ball, as it reduces the time the ball spends in the air, speeds up attacks, and complicates the opponent's first line of defense – their block to predict the attacking opponent's options.

The assessment of vertical jump performance in volleyball is an essential part of training and testing (Ziv & Lidor, 2010). In a five-set volleyball match, players from different positions perform between 65 and 136 jumps. On average, setters perform the greatest number of jumps, followed by middle blockers, opposite hitters, and outside hitters (Fontani et al., 2000). Additionally, scoring actions (e.g., serves, spikes, and blocks) are jump-dependent, with a typical team (~12 players) executing around 120,000 jumps during a season (Garcia-de-Alcaraz, 2020). According to the principle of training specificity, female volleyball players should systematically incorporate jump-based training programs.

Anthropometric characteristics of athletes are important prerequisites for successful competition in the sport, affecting athletic performance and being necessary for achieving exceptional skills. The physical attributes of volleyball players are mainly assessed by measuring anthropometric parameters such as height, body mass index, and other physical factors related to performance, including jumping ability, agility, strength, and endurance (Bayios et al., 2006; Ibrahim, 2010; Duncan, et al., 2006). In female athletes, the onset of pubertal growth spurt occurs around the age of 10, with adult height generally reached by the age of 14–15 (Malina et al., 2004). Pubertal growth in girls is accompanied by increased body fat, which can negatively impact sports performance (Rogol et al., 2002; Lidor & Ziv, 2010). Successful female volleyball players tend to have lower body fat percentages, as evidenced by differences in adiposity between first and second league players (Malousaris et al., 2008).

A frequently overlooked form of exercise is plyometric training (PT), which involves jumping exercises utilizing stretch-shortening cycles (Chen et al., 2023). Plyometric loading is especially effective for children and adolescents during periods of bone growth. Previous research has shown that plyometric training positively influences growth and development in adolescents (Kryeziu et al., 2023). Plyometric training can significantly improve jump capacity in adolescents (Coşkun et al., 2022), which is crucial for athletic success and overall health.

Lower limb strength and vertical jumps are key indicators of volleyball players' success (Stec & Smulsky, 2007). The average height of today's volleyball players has increased compared to previous periods and ranges between 195 and 200 cm (Ercolessi, 1999).

The aim of this study is to examine the relationship between anthropometric parameters and vertical jump performance in female cadet volleyball players. This information may provide valuable insight and reference values for talent identification and the evaluation of applied training programs. Participants

METHOD

Participants

This study was conducted with the aim of assessing the motor skills and physical characteristics of 40 female volleyball players aged 12 to 15, who trained four times per week and had an average of three years of experience playing volleyball. All participants were enrolled in the volleyball school "DIF." Standard training sessions lasted 90 minutes and included athletes with an average training history of 3 years (±6 months) within the school. The sessions covered technical elements such as jumping, serving, receiving, and attacking, as well as strength training. Strength exercises targeted bot h the upper and lower body and were performed in 3–4 sets of 10–15 repetitions, with 1-minute resting intervals. The primary focus was on the development of and learning technique. Only athletes without any injuries that could affect performance were included in the study. Anthropometric characteristics such as body height, body weight, body fat percentage, muscle mass percentage, and body mass index were measured using appropriate instruments – the Martin anthropometer and the Tanita body composition scale. Arm span was measured using a tape measure. These anthropometric parameters were selected as predictors of vertical jump performance due to their direct or indirect influence on the biomechanics and energy efficiency of jumping, while arm span may offer an advantage during the run-up and arm swing phases.

The testing was completed in a single day. Anthropometric measurements were taken first, prior to the assessment of motor skills. The measurements were carried out as follows:

- The Martin Anthropometer: Used to measure body height. The anthropometer is 2 meters long and marked in millimeters and centimeters. It was placed vertically behind the participant's back, ensuring contact at minimum one point. The examiner held the anthropometer with the right hand, adjusting the sliding ring with the thumb and the index finger, while the left hand positioned the horizontal bar at the crown of the participant's head.
- The Tanita Scale: This device uses a revolutionary bioelectrical impedance analysis method. It automatically measures body weight and fat percentage and uses a mathematical model to estimate deviations from ideal weight based on gender and age.
- Arm Span (AS): Measured by asking participants to extend their arms horizontally to the sides at maximum reach. The measurement was taken from behind using a tape measure.

Motor skill performance was evaluated using vertical jump tests on the OptoJump system.

Countermovement Jump (CMJ) (Figure 1): The jump was initiated from a squat position. No specific instructions were given regarding the depth or speed of the movement. The intra-class correlation coefficient (ICC) for test reliability and the typical measurement error for the vertical jump test were 0.96 and 2.9%, respectively.

Figure 1. *Graphical Representation of the Countermovement Jump (CMJ) Test*

The OptoJump system (Microgate, Italy) was used to assess the countermovement jump (CMJ). The OptoJump system consists of two portable bars equipped with 33 optical LED sensors spaced 3.125 cm apart along the transmitting bar. These LEDs continuously communicate with sensors on the receiving bar. The system detects any interruption in this communication and calculates its duration. This allows for precise measurement of flight and contact times during a series of jumps, with an accuracy of up to 1/1,000th of a second.

The collected data were analyzed using descriptive statistics. All measurements were presented using mean values, standard deviations, minimum and maximum values, correlation coefficients, and regression analysis. Microsoft Excel, ANOVA, and statistical software programs were used for data preparation and analysis. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Descriptive statistical analysis (Table 1) provides an overview of the sample of 40 participants for selected variables. The average body height (BH) was 155.6 cm, with a standard deviation of 10.4 cm, ranging from 134.9 cm to 176.9 cm. The average arm span (AS) was 156.4 cm (SD = 12.1 cm), with a range from 134.4 cm to 184.0 cm.

The average body mass (BM) was 48.8 kg, with a standard deviation of 11.8 kg. Minimum and maximum values were 30.5 kg and 72.3 kg, respectively. The average body mass index (BMI) was 19.9 kg/m² (SD = 3.1), with values ranging from 14.2 to 25.7 kg/m².

The average body fat percentage (BF%) was 20.9%, with a standard deviation of 6.9%, ranging from 7.7% to 33.9%. The average muscle mass percentage (MM%) was 34.8% (SD = 2.5%), with a minimum of 29.6% and a maximum of 39.4%.

Finally, the average countermovement jump height (CMJ) was 22.4 cm (SD = 5.7 cm), with the lowest recorded value at 9.8 cm and the highest at 34.0 cm.

Table 1. *Descriptive Statistics Results*

	BH	***AS***	***BM***	***BMI***	***BF***	***%M***	***CMJ***
N	**40**	**40**	**40**	**40**	**40**	**40**	**40**
M	155.6	156.4	48.8	19.9	20.9	34.8	22.4
Max	176.9	184.0	72.3	25.7	33.9	39.4	34.0
Min	134.9	134.4	30.5	14.2	7.7	29.6	9.8
SD	10.4	12.1	11.8	3.1	6.9	2.5	5.7

BH – body height; ***AS*** – arm span; ***BM*** – body mass; ***BMI*** – body mass index; ***BF*** – body fat percentage; ***MM*** – muscle mass percentage; ***CMJ*** – countermovement jump; ***N*** – number of participants; ***SD*** – standard deviation; ***Min*** – minimum; ***Max*** – maximum

Table 2 presents the Pearson correlation coefficients between the CMJ height and selected anthropometric variables, including body mass, muscle mass percentage, arm span, and body height. Significant positive correlations were observed between CMJ and muscle mass percentage ($r = 0.588$, $p < 0.001$), arm span ($r = 0.515$, $p < 0.001$), body height ($r = 0.502$, $p = 0.001$), and body mass ($r = 0.342$, $p = 0.031$). These results suggest that a higher muscle mass percentage, larger body dimensions, and greater body mass are associated with better jumping performance.

Table 2. *Pearson Correlation Between CMJ and Selected Anthropometric Variables*

Variables	***Correlation(r)***	***p-value***
Body mass (kg)	0.342	**0.031**
Muscle mass (%)	0.588	**<0.001**
Arm span (cm)	0.515	**<0.001**
Body height (cm)	0.502	**0.001**

Table 3 summarizes the results of the multiple regression analysis conducted to explore the relationship between the CMJ height (dependent variable) and body mass, muscle mass percentage, arm span, and body height (predictors).

The ANOVA results indicate that the model was statistically significant ($p < 0.001$). Muscle mass percentage was a statistically significant predictor ($B = 1.488$, $p = 0.004$), suggesting that a higher percentage of muscle mass is associated with greater CMJ height.

Arm span also showed a significant positive association with CMJ ($B = 0.095$, $p = 0.002$), indicating that individuals with greater arm span tend to achieve higher jumps.

Body mass (B = 0.233, p = 0.146) and body height (B = -0.238, p = 0.447) were not statistically significant predictors in this model, suggesting that their individual contributions become minimal when other variables are controlled.

The lack of statistical significance for body mass and body height in the regression model is likely due to the strong explanatory power of muscle mass percentage, which may have masked their effects.

Table 3. *Multiple Regression Analysis*

Predictor	*B*	*Std. Error*	*Beta*	*t*	*p-value*
Body mass (kg)	0.233	0.157	0.182	1.487	0.146
Muscle mass (%)	1.488	0.480	0.558	3.100	**0.004**
Arm span (cm)	0.095	0.031	0.310	3.100	**0.002**
Body height (cm)	-.238	0.435	-.076	-.769	0.447

B – regression coefficient; ***Std. Error*** – standard error of estimate; ***Beta*** – standardized coefficient; ***t*** – t-value; ***p-value*** – level of significance

R=.660 R^2=.436 F=6.667

R – multiple correlation coefficient; $\mathbf{R^2}$ – coefficient of determination; **F** – F-test for the relationship between the dependent variable and the set of independent variables

DISCUSSION

This study was designed with the aim of determining the relationship between selected anthropometric variables and vertical jump performance in female volleyball players. Understanding the differences in selected anthropometric variables is crucial for implementing training strategies and enhancing performance in volleyball. The study's findings were also considered when evaluating factors for player selection, including training experience, fitness, and more. These results can be utilized by coaches when selecting players for matches and designing training programs, keeping in mind the tactical plan for each athlete.

In modern volleyball, every team strives to achieve higher jumps, as actions like blocking and attacking become more complex for opponents when executed at greater heights. Therefore, more attention must be given to offensive actions such as attack, block, and serve, since the majority of points are gained through these actions. Moreover, the probability of winning increases with effective blocking, strengthening the team in these key actions.

In this study, we aimed to examine the impact of various anthropometric variables – body mass, muscle mass percentage, arm span, and body height – on the height of vertical jump. The results of Pearson’s correlation coefficient revealed significant associations between these variables and jump height.

Body mass (BM) showed a significant correlation, where higher body mass may negatively affect jumping performance. However, our analysis did not reveal a strong negative correlation, likely due to the height and specific body structure of the participants. The correlation between body mass and CMJ was lower, indicating that body mass is not as critical as muscle mass in explaining jumping performance.

Muscle mass percentage (%M) showed a significant positive correlation with jump height. This can be explained by the fact that greater muscle mass contributes to increased muscle strength, which is essential for explosive vertical movements such as jumping (Bobbert & van Ingen Schenau, 1988). Greater muscle mass enables faster muscle contractions, thereby improving jumping performance.

Body height (BH) can be considered the most important physical attribute. However, a high jumping capacity can help compensate for a player's lack of height (Marques et al., 2009).

Arm span (AS) also showed a significant positive correlation. This can be linked to the biomechanics of movement, where a greater arm span allows for a more efficient use of arm swing during jumping. In another study (Reeves et al., 2008), it was hypothesized that a longer arm generates additional vertical acceleration due to a longer lever created by the arm swing. This explains the significant correlation between arm span and vertical jump observed in our research. The arm swing during a CMJ can increase take-off velocity by at least 6% compared to a jump without arm swing and increase jump height by 15% or more (Vaverka et al., 2016).

In a study by Pandey et al. (2016), the correlation coefficient between height and volleyball performance was significant at the 0.05 level, while the correlation between body mass and performance was not significant. In our study, the results of multiple regression indicate that body mass and height are not statistically significant predictors of vertical jump height when considered together with other variables. However, Pearson's test shows that body mass and height have significant individual effects. This suggests that their direct contribution is limited when other variables are controlled. This change implies that the relationship between height and vertical jump may be mediated or overshadowed by the combined effects of body mass and muscle mass. The lack of statistical significance may also indicate that body height and muscle mass are interrelated, where muscle mass is a more direct determinant of jump height, while height may play an indirect role.

The multiple regression results show that the model is statistically significant ($F=6.667$, $p<0.001$), with a multiple correlation coefficient $R=0.660$. The coefficient of determination ($R^2=0.436$) indicates that the proposed model explains 43.6% of the variability in CMJ height. The findings of this study are consistent with previous research (Stojanović et al., 2020), which also reported no significant association between body mass and vertical jump performance in adolescents. Our results align with those of earlier studies (Pérez-López et al., 2015; Davis et al., 2003), which also demonstrated that body mass does not have a significant impact on vertical jump. This is further supported by the findings of Marković and Jarić, who found that body mass is independent with vertical jump height.

Our results indicate that there is no significant association between body height and vertical jump performance in CMJ tests, in line with studies by Stojanović et al. (2020), Aslan et al. (2011) and Aragón-Vargas & Gross (1997).

CONCLUSION

Modern volleyball, due to the shorter duration of plays and increased game intensity, requires greater reliance on alactic anaerobic energy metabolism. This means there is a growing demand for athletes with improved fitness, who are also fast and capable of performing high jumps.

In this study, we aimed to explore the influence of different anthropometric variables – body mass, muscle mass percentage, arm span, and body height – on vertical jump height. Pearson's correlation coefficients revealed significant associations between these variables and vertical jump. However, the multiple regression results indicate that body mass and height are not statistically significant predictors of vertical jump height when considered alongside other variables.

Beyond the findings presented in this study, the results can be practically applied in the design of specific training programs aimed at improving vertical jump performance in volleyball players. These programs should primarily focus on increasing muscle strength and explosive power, rather than solely on body mass or height, as these variables did not demonstrate statistically significant roles as predictors.

This study has certain limitations, including a relatively small sample size and other potentially influential factors such as neuromuscular coordination and jumping technique. Future research should further investigate these aspects and consider a broader range of anthropometric and motor variables to provide a more comprehensive understanding of the determinants of vertical jump performance.

The results of this study highlight the need for a multidimensional training approach that includes not only physical conditioning but also biomechanical and technical factors. Such an approach can help optimize performance and reduce injury risk in modern volleyball, where athletes are expected to perform jumps with increasing intensity and precision.

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