SVEUČILIŠTE U SPLITU

KINEZIOLOŠKI FAKULTET

DOKTORSKI STUDIJ KINEZIOLOGIJE

KREŠO ŠKUGOR

NATJECATELJSKA USPJEŠNOST MLADIH HRVAČA; ČIMBENICI UTJECAJA

DOKTORSKI RAD

Mentor:

Prof. dr. sc. Hrvoje Karninčić

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UNIVERSITY OF SPLIT

FACULTY OF KINESIOLOGY

DOCTORAL PROGRAMME IN KINESIOLOGY

KREŠO ŠKUGOR

COMPETITIVE SUCCESS OF YOUNG WRESTLERS; INFLUENCING FACTORS

DOCTORAL THESIS

Supervisor:

Full Professor Hrvoje Karninčić

Split, 2026.

Odluka o obrani

ZAHVALE

ŽIVOTOPIS MENTORA

Prof. dr. sc. Hrvoje Karninčić redoviti je profesor u znanstvenom području društvenih znanosti, polju kineziologije, grani kineziologije sporta. Diplomirao je na Kineziološkom fakultetu u Splitu 2001. godine, a akademski stupanj doktora znanosti stekao je 2011. godine na istom fakultetu. U zvanje redovitog profesora izabran je u srpnju 2022. godine.

Aktivno je uključen u nastavni proces na svim razinama studija. Na sveučilišnom prijediplomskom studiju nositelj je kolegija Povijest sporta, dok na sveučilišnom diplomskom studiju izvodi kolegije Teorija i metodika hrvanja i Razvoj snage u hrvanju. Na stručnom prijediplomskom studiju nositelj je kolegija Programiranje u sportu 1.

Osim nastavne i znanstvene djelatnosti, obnaša i funkciju predsjednika udruge ALUMNI KIFST.

SAŽETAK

Natjecateljska uspješnost u hrvanju rezultat je složenog međudjelovanja fizičkih, fizioloških i psiholoških čimbenika. Iako su dosadašnja istraživanja u borilačkim sportovima uglavnom bila usmjerena na pojedinačne odrednice uspješnosti, studije koje integriraju više dimenzija sportske izvedbe kod mladih hrvača i dalje su ograničene. Posebno su nedovoljno istraženi odnosi između generičke tjelesne pripremljenosti, sport-specifične izvedbe, sposobnosti izvedbe u uvjetima umora te motivacijskih obilježja. Stoga je cilj ove doktorske disertacije bio istražiti multidimenzionalne čimbenike povezane s natjecateljskom uspješnošću mladih hrvača.

Disertacija se sastoji od četiri izvorna znanstvena rada. Prvi rad bio je usmjeren na utvrđivanje razlika u generičkim i sport-specifičnim sposobnostima između hrvača različite natjecateljske kvalitete i težinskih kategorija. Drugi rad proširio je analizu ispitivanjem relativnog doprinosa antropometrijskih obilježja, generičke tjelesne pripremljenosti i sport-specifičnih pokazatelja u objašnjenju natjecateljske uspješnosti. Treći rad istraživao je ulogu ponavljanih i iscrpljujućih testnih protokola u diferencijaciji hrvača različitih razina uspješnosti, dok je četvrti rad bio usmjeren na analizu motivacijskog profila mladih hrvača i njegovu povezanost s natjecateljskom uspješnošću.

U istraživanjima uključenima u ovu doktorsku disertaciju sudjelovali su mladi hrvači grčko-rimskog stila različite natjecateljske razine. Ukupno su analizirani uzorci iz četiri studije koji su obuhvaćali između 23 i 49 ispitanika po studiji, u dobi približno od 16 do 19 godina. Ispitanici su bili aktivni natjecatelji s višegodišnjim trenažnim iskustvom te su, ovisno o cilju pojedine studije, bili podijeljeni prema natjecateljskoj uspješnosti (uspješniji-osvajači medalja ili članovi reprezentacije; manje uspješni -neosvajači medalja ili nečlanovi reprezentacije) te prema težinskim kategorijama (lakši i teži hrvači).

U svim studijama analiziran je skup varijabli koji je uključivao antropometrijske pokazatelje (tjelesna visina, tjelesna masa, indeks tjelesne mase i postotak masnog tkiva), generičke pokazatelje tjelesne pripremljenosti (eksplozivnost donjih ekstremiteta, jakost stiska šake, anaerobna sposobnost), kao i sport-specifične pokazatelje izvedbe dobivene primjenom Specifičnog hrvačkog fitness testa (SWFT). U pojedinim studijama dodatno su analizirani fiziološki odgovori na opterećenje (srčana frekvencija, metabolički i srčani indeksi) te sposobnost održavanja izvedbe u uvjetima ponavljanih visokointenzivnih

napora. U četvrtoj studiji uključene su i psihološke varijable, pri čemu je motivacija procijenjena validiranim upitnikom (Sport Motivation Scale, SMS-II), obuhvaćajući različite dimenzije motivacije (intrinzična, integrirana, identificirana regulacija, ekstrinzična motivacija i amotivacija). Podaci su obrađeni primjenom deskriptivne i inferencijalne statistike. Za utvrđivanje razlika između skupina korišteni su t-test za nezavisne uzorke i analiza varijance (ANOVA), dok su za procjenu povezanosti između varijabli primijenjene korelacijske analize. U pojedinim studijama korištene su i naprednije statističke metode, uključujući diskriminacijsku analizu i multivarijatnu analizu varijance (MANOVA), kao i analizu ponovljenih mjerenja za procjenu promjena u uvjetima ponavljanih opterećenja. Također su izračunavani pokazatelji veličine učinka (Cohenov d) i dijagnostičke točnosti (ROC analiza i AUC vrijednosti), s ciljem preciznijeg tumačenja dobivenih rezultata.

Rezultati prve studije, provedene na uzorku od 23 napredna mlada hrvača podijeljenih prema natjecateljskoj kvaliteti (članovi reprezentacije vs. ostali) i težinskim kategorijama (lakši vs. teži), pokazali su da je visina vertikalnog skoka jedini generički pokazatelj značajno povezan s rezultatom u SWFT-u ($r = 0.48$; $p < 0.05$). Članovi reprezentacije ostvarili su bolje rezultate u vertikalnom skoku u odnosu na hrvače koji nisu u reprezentaciji ($p = 0.02$, umjereni ES), dok su hrvači težih kategorija imali veću tjelesnu masu ($p = 0.001$, veliki ES) i visinu ($p = 0.01$, veliki ES). Nisu utvrđene razlike u SWFT-u između skupina niti povezanost s ostalim generičkim testovima, što upućuje na visoku specifičnost testa i homogenost uzorka. Rezultati druge studije koja je provedena na uzorku od 49 mladih hrvača podijeljenih prema natjecateljskoj uspješnosti (osvajači medalja vs. neosvajači) pokazali su da nema značajnih razlika između uspješnijih i manje uspješnih hrvača u antropometrijskim pokazateljima i iskustvu. Međutim, uspješniji hrvači ostvarili su bolje rezultate u skoku iz mjesta ($t = 2.55$; $p < 0.01$), snazi stiska šake ($t = 2.77$; $p < 0.01$) te u SWFT broju bacanja ($t = 2.29$; $p < 0.05$). Diskriminacijska analiza dodatno je potvrdila da generički i sport-specifični testovi značajno razlikuju skupine (Wilks $\lambda = 0.73$; $p < 0.05$). Treći rad se proveo na uzorku od 29 mladih hrvača podijeljenih prema natjecateljskoj uspješnosti (uspješni: osvajači medalja; $n = 13$ i manje uspješni: neosvajači; $n = 16$), pokazali su da nema značajnih razlika između skupina u prvom testiranju. Međutim, nakon ponavljanja SWFT protokola utvrđene su značajne razlike u ukupnom broju bacanja ($p < 0.01$; AUC = 0.82), srčanim indeksima ($p < 0.03$; AUC = 0.73) i metaboličkim indeksima ($p < 0.04$; AUC = 0.75), pri čemu su uspješniji hrvači

ostvarili bolje rezultate. Dobiveni rezultati ukazuju da se razlike između hrvača različite kvalitete jasnije očituju u uvjetima umora, odnosno nakon ponavljanog visokointenzivnog opterećenja. Rezultati četvrte studije koja je provedena na uzorku od 47 mladih hrvača podijeljenih prema natjecateljskoj uspješnosti (osvajači medalja vs. neosvajači) pokazali su da hrvači općenito imaju visoku razinu samoodređene motivacije, posebno intrinzične (5.97 ± 0.90), integrirane (5.99 ± 0.83) i identificirane regulacije (6.08 ± 0.82), uz nisku razinu amotivacije (2.53 ± 0.98). Uspješniji hrvači ostvarili su značajno višu razinu intrinzične motivacije u odnosu na manje uspješne (Cohenov d = 0.76; umjeren efekt veličine), dok u ostalim motivacijskim dimenzijama nisu utvrđene značajne razlike.

Zaključno, rezultati ove doktorske disertacije potvrđuju da je natjecateljska uspješnost u hrvanju rezultat složenog i međusobno povezanog djelovanja više dimenzija sportske izvedbe. Generičke tjelesne sposobnosti, poput eksplozivnosti i jakosti stiska šake, zajedno sa sport-specifičnim pokazateljima izvedbe, doprinose razlikovanju uspješnijih od manje uspješnih hrvača, pri čemu sport-specifični testovi pokazuju veću osjetljivost u procjeni natjecateljske spremnosti. Nadalje, rezultati ukazuju da se razlike između sportaša različite kvalitete jasnije očituju u uvjetima umora i ponavljanih visokointenzivnih opterećenja, čime se naglašava važnost procjene sposobnosti održavanja izvedbe. Uz to, motivacijska obilježja, osobito intrinzična motivacija, dodatno doprinose objašnjenju natjecateljske uspješnosti. Sveukupno, disertacija potvrđuje da je za razumijevanje i procjenu natjecateljske uspješnosti mladih hrvača nužan multidimenzionalni pristup koji integrira fizičke, fiziološke i psihološke čimbenike. Takav pristup omogućuje cjelovitije razumijevanje sportske izvedbe te predstavlja temelj za daljnji razvoj znanstveno utemeljenih modela procjene i praćenja sportaša u hrvanju.

Ključne riječi: borilački sportovi, mladi sportaši, natjecateljska uspješnost, tjelesna pripremljenost, sport-specifična izvedba, umor, motivacija

ABSTRACT

Competitive success in wrestling is determined by a complex interplay of physical, physiological, and psychological factors. Although previous research in combat sports has primarily focused on isolated performance determinants, studies integrating multiple dimensions of performance in youth wrestlers remain limited. In particular, the relationships between generic physical fitness, sport-specific performance, fatigue-related responses, and motivational characteristics have not been sufficiently explored. Therefore, the aim of this doctoral thesis was to investigate multidimensional factors associated with competitive success in youth wrestlers.

The thesis is based on four original scientific studies. The first study examined differences in generic and sport-specific fitness between wrestlers of varying competitive levels and weight categories. The second study expanded this analysis by exploring the relative contribution of anthropometric characteristics, generic fitness, and sport-specific performance in explaining competitive success. The third study investigated the role of repeated and exhaustive testing protocols in differentiating wrestlers of different performance levels, while the fourth study focused on the motivational profile of youth wrestlers and its association with competitive success.

Across the studies, samples consisted of young Greco-Roman wrestlers of different competitive levels, with sample sizes ranging from 23 to 49 participants per study, aged approximately 16–19 years. All participants were active competitors with several years of training experience. Depending on the study design, wrestlers were categorized based on competitive success (more successful: medalists or national team members; less successful: non-medalists or non-team members) and weight categories (lighter vs. heavier).

A comprehensive set of variables was assessed, including anthropometric measures (body height, body mass, body mass index, and body fat percentage), generic fitness indicators (lower-body explosive power, handgrip strength, and anaerobic capacity), and sport-specific performance measured by the Specific Wrestling Fitness Test (SWFT). In selected studies, physiological responses to exercise (heart rate, cardiac and metabolic indices) and performance under repeated high-intensity efforts were also evaluated. Additionally, the fourth study included psychological variables, with motivation assessed

using the validated Sport Motivation Scale (SMS-II), covering intrinsic motivation, integrated and identified regulation, external regulation, and amotivation. Data were analyzed using descriptive and inferential statistics, including independent samples t-tests, ANOVA, correlation analysis, discriminant analysis, MANOVA, and repeated measures analysis. Effect sizes (Cohen's d) and diagnostic accuracy indicators (ROC analysis and AUC values) were also calculated.

The results of the first study, conducted on 23 advanced youth wrestlers, indicated that vertical jump height was the only generic fitness variable significantly associated with SWFT performance ($r = 0.48$; $p < 0.05$). National team members achieved higher vertical jump results than non-team members ($p = 0.02$, moderate effect size), while heavier wrestlers had greater body mass ($p = 0.001$) and height ($p = 0.01$). No differences were observed in SWFT performance between groups, suggesting high test specificity and sample homogeneity. The second study ($N = 49$) showed no differences in anthropometric characteristics or experience between medalists and non-medalists; however, more successful wrestlers achieved better results in countermovement jump ($t = 2.55$; $p < 0.01$), handgrip strength ($t = 2.77$; $p < 0.01$), and SWFT throws ($t = 2.29$; $p < 0.05$). Discriminant analysis confirmed that both generic and sport-specific variables significantly differentiated performance groups (Wilks' $\lambda = 0.73$; $p < 0.05$). The third study ($N = 29$) demonstrated that no differences were evident under initial testing conditions, but significant differences emerged after repeated SWFT trials in total throws ($p < 0.01$; AUC = 0.82), cardiac indices ($p < 0.03$; AUC = 0.73), and metabolic indices ($p < 0.04$; AUC = 0.75), with more successful wrestlers achieving superior results. These findings highlight the importance of fatigue-related assessment. Finally, the fourth study ($N = 47$) revealed that wrestlers generally exhibited high levels of self-determined motivation, particularly intrinsic (5.97 ± 0.90), integrated (5.99 ± 0.83), and identified regulation (6.08 ± 0.82), alongside low amotivation (2.53 ± 0.98). More successful wrestlers demonstrated significantly higher intrinsic motivation (Cohen's $d = 0.76$), while no consistent differences were observed in other motivational dimensions.

In conclusion, the findings of this doctoral thesis demonstrate that competitive success in wrestling cannot be explained by isolated factors but rather emerges from the interaction of multiple performance domains. Generic physical capacities, particularly explosive power and handgrip strength, together with sport-specific performance indicators, contribute to differentiating more successful from less successful wrestlers,

with sport-specific tests showing greater sensitivity. Moreover, performance differences become more evident under conditions of fatigue and repeated high-intensity effort, emphasizing the importance of fatigue-based assessment. Psychological factors, especially intrinsic motivation, further contribute to explaining competitive success. Overall, this thesis supports a multidimensional approach that integrates physical, physiological, and psychological factors, providing a more comprehensive understanding of performance and a foundation for future research and athlete evaluation models in wrestling.

Keywords: combat sports, youth athletes, competitive success, physical fitness, sport-specific performance, fatigue, motivation

Sadržaj

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2 UVOD

2.1 Pozadina i kontekst

2.1.1 Hrvanje kao fiziološki zahtjevan borilački sport

Hrvanje je olimpijski sport koji se sastoji od ponavljajućih faza intenzivnog fizičkog nadmetanja. U hrvanju postoji stalna interakcija s protivnikom, pri čemu sportaši moraju generirati silu, kontrolirati položaj tijela te taktički reagirati u brzo i često promjenjivim situacijama (Demirkan et al., 2015). Borbe se sastoje od kratkih naleta eksplozivne aktivnosti isprekidanih kratkim pauzama ili aktivnostima nižeg intenziteta, tijekom kojih se sportaši pripremaju za sljedeću fazu i razmjenu napada (García-Pallarés et al., 2011). Tijekom tih sekvenci hrvači izvode tehnički zahtjevne radnje koje uključuju bacanja, podizanja, zahvate u klinču, potiske i obrambene protupokrete, pri čemu istovremeno nastoje spriječiti protivnika u ostvarivanju prednosti. Potreba za brzom produkcijom sile, održavanjem ravnoteže pod pritiskom te izvođenjem složenih motoričkih obrazaca postavlja značajne zahtjeve na neuromuskularnu koordinaciju, mišićnu snagu i jakost, anaerobnu snagu te sposobnost podnošenja i savladavanja umora (Chaabene et al., 2017; Horswill et al., 1989).

Budući da je hrvanje istodobno tehnički i fizički zahtjevan sport, ono uključuje međudjelovanje svih energetskih sustava (Chaabene et al., 2017; Karnincic et al., 2009). Iako aerobni metabolizam ima važnu ulogu jer omogućuje oporavak između pojedinih izmjena te održavanje ukupnog trajanja meča, odlučujući trenuci borbe najčešće se odvijaju tijekom radnji koje se izvode pri gotovo maksimalnom ili maksimalnom intenzitetu (npr. podizanja, bacanja) (Nikooie et al., 2017). Stoga uspješni hrvači moraju biti sposobni ne samo generirati visoke razine sile i snage, već i ponavljati takve napore više puta tijekom meča (Kafkas et al., 2016). Ova ponavljana produkcija eksplozivnog napora, često u uvjetima nepotpunog oporavka, naglašava središnju važnost anaerobnog kapaciteta, mišićne snage te otpornosti na umor za natjecateljsku uspješnost (García-Pallarés et al., 2011). Istodobno, izvedba se ne može u potpunosti razumjeti samo kroz izolirane fiziološke karakteristike. Tehnička vještina, taktičko donošenje odluka i sposobnost prilagodbe radnji u odnosu na ponašanje protivnika tijekom natjecanja neprestano su u međudjelovanju s fizičkim sposobnostima (Horswill, 1992; Kons et al., 2020). Ishod meča stoga odražava zajednički utjecaj fiziološke pripremljenosti,

neuromuskularne učinkovitosti i izvedbe sport-specifičnih vještina, što hrvanje čini iznimno zahtjevnim sportom. Zbog toga se hrvanje najbolje promatra kao sport u kojem uspjeh proizlazi iz međudjelovanja više sastavnica izvedbe, a ne iz jedne dominantne fizičke sposobnosti ili karakteristike.

2.1.2 Odrednice natjecateljske uspješnosti u hrvanju: perspektiva mlađih sportaša

Istraživanja u borilačkim sportovima dosljedno pokazuju da su ishodi izvedbe i natjecateljska uspješnost oblikovani kombinacijom antropometrijskih obilježja, sastava tijela, općih motoričkih sposobnosti, sport-specifičnih tehničkih vještina te fizioloških odgovora na napor (Cieśliński et al., 2021; García-Pallarés et al., 2011). Hrvači koji posjeduju veću mišićnu snagu, eksplozivnu snagu i anaerobni kapacitet obično pokazuju veću natjecateljsku učinkovitost, jer im te sposobnosti omogućuju izvođenje odlučujućih radnji, održavanje kontrole položaja te brzo reagiranje tijekom izmjena visokog intenziteta (Cieśliński et al., 2021). Istodobno, tehnička izvedba i taktika imaju važnu ulogu, jer učinkovito korištenje fizičkih sposobnosti sportaša ovisi o njegovoj sposobnosti odabira najprikladnijih tehnika te njihove učinkovite primjene u dinamičnoj situaciji meča (Demirkan et al., 2012). Nadalje, antropometrijske karakteristike poput tjelesne visine, tjelesne mase i raspona ruku mogu utjecati na natjecateljsku izvedbu sportaša, dok sastav tijela može doprinijeti razvoju relativne snage te sposobnosti izvođenja ponavljanih napora visokog intenziteta unutar pojedinih težinskih kategorija (Marques et al., 2019). Međutim, navedene strukturne i fiziološke karakteristike same po sebi ne mogu u potpunosti objasniti razlike u izvedbi hrvača, budući da je uspješnost u hrvanju rezultat dinamične interakcije fizičkih, tehničkih i taktičkih sposobnosti sportaša, pri čemu prednosti u jednoj od tih sposobnosti mogu biti neutralizirane slabostima u drugim sposobnostima (Chaabene et al., 2017).

Multidimenzionalna priroda izvedbe u hrvanju postaje osobito važna pri proučavanju mladih sportaša. Adolescencija predstavlja razdoblje izraženih bioloških i psiholoških promjena, tijekom kojeg se rast, sazrijevanje i prilagodba na trening odvijaju istodobno (Malina et al., 2004). Fizičke sposobnosti poput snage, eksplozivne snage i anaerobne izdržljivosti mogu se značajno povećati u relativno kratkom vremenskom razdoblju, djelomično zbog neuromuskularnog razvoja, a djelomično kao rezultat sustavne izloženosti treningu (Granacher et al., 2018). Međutim, ta poboljšanja nisu uvijek linearna niti jednaka kod svih pojedinaca. Razlike u biološkom sazrijevanju mogu

dovesti do privremenih prednosti u izvedbi koje ne moraju nužno odražavati dugoročni potencijal ili bolju prilagodbu na trening (Malina et al., 2015). Istodobno se tehnička vještina i taktičko donošenje odluka postupno razvijaju kroz sustavan trening i natjecateljsko iskustvo. Hrvanje, kao interaktivan i situacijski sport, zahtijeva od sportaša ne samo posjedovanje fizičkih sposobnosti, već i njihovu učinkovitu primjenu u uvjetima koji su stalno promjenjivi (Barbas et al., 2011). Usavršavanje motoričke koordinacije, osjećaja za pravovremenost izvedbe te perceptivno-kognitivnih sposobnosti stoga je usko povezano s akumuliranim trenažnim iskustvom i izloženošću natjecanjima (Vaeyens et al., 2008). Psihološke karakteristike također prolaze kroz značajan razvoj tijekom adolescencije. Motivacija, samoregulacija, ustrajnost i samopouzdanje utječu na to koliko se dosljedno mladi sportaši uključuju u trening te kako reagiraju na natjecateljske izazove (Deci & Ryan, 1985; Gould et al., 2002). Varijacije u tim psihološkim čimbenicima mogu djelomično objasniti zašto sportaši sa sličnim fizičkim profilima ostvaruju različite natjecateljske rezultate.

Razlike u izvedbi među mladim hrvačima mogu odražavati ne samo razlike u treniranosti, već i varijacije u biološkoj zrelosti, trenažnom i tehničkom iskustvu te psihološkoj spremnosti, što dodatno otežava interpretaciju izoliranih pokazatelja izvedbe. Primjerice, bolji rezultat u pojedinačnom testu snage ili jakosti može biti posljedica čimbenika povezanih s biološkim sazrijevanjem, a ne nužno sport-specifične pripremljenosti. Stoga oslanjanje isključivo na pojedinačne fizičke mjere pruža samo ograničeno razumijevanje natjecateljske uspješnosti kod sportaša u razvoju. Sveobuhvatniji pristup zahtijeva razmatranje međudjelovanja različitih domena izvedbe. U tom smislu, integriranje pokazatelja generičke tjelesne pripremljenosti, sport-specifične izvedbene sposobnosti, fizioloških odgovora na ponavljane napore te psiholoških obilježja može omogućiti uravnoteženiju i razvojno osjetljiviju procjenu natjecateljske spremnosti (Demirkan et al., 2015). Takav integrirani pristup uvažava dinamičnu prirodu razvoja mladih sportaša te može unaprijediti prepoznavanje čimbenika koji doista razlikuju uspješnije od manje uspješnih hrvača tijekom adolescencije. U tom kontekstu, multidimenzionalno profiliranje sportske izvedbe čini se osobito prikladnim pristupom za razumijevanje natjecateljske uspješnosti u hrvanju kod mladih sportaša.

2.1.3 Opće i sport-specifično testiranje izvedbe u hrvanju

Procjena sportske izvedbe tradicionalno se temelji na općim testovima tjelesne pripremljenosti osmišljenima za procjenu temeljnih motoričkih sposobnosti i funkcionalnih sposobnosti organizma. U hrvanju takve procjene najčešće uključuju mjerenja maksimalne i eksplozivne snage (npr. snaga stiska šake, testovi jednog maksimalnog ponavljanja), snage donjih ekstremiteta (npr. testovi vertikalnog skoka), brzine, agilnosti i anaerobnog kapaciteta (npr., Wingate test) (Kraemer et al., 2004; Özbay & Ulupınar, 2022). Ovi testovi pružaju objektivne i pouzdane informacije o općoj tjelesnoj pripremljenosti te se široko koriste u praćenju sportaša, identifikaciji talenata i planiranju trenažnog procesa (Chaabene et al., 2018; Horswill et al., 1989). Hrvački mečevi obilježeni su ponavljanim eksplozivnim napadačkim i obrambenim radnjama koje omogućuju sportašima izvođenje bacanja, ostvarivanje „tuša“ ili izvlačenje iz nepovoljnih pozicija na strunjači. Uspješna izvedba tih manevara zahtijeva značajnu mišićnu snagu donjih ekstremiteta, budući da ovise o brzoj produkciji sile i učinkovitom prijenosu sile kroz kinetički lanac (Chaabene et al., 2018; García-Pallarés et al., 2011). Dokazi iz istraživanja provedenog na tuniskim hrvačima pokazali su značajnu povezanost između vršne snage donjih ekstremiteta, procijenjene Wingate testom, i uspješnosti u sport-specifičnom zadatku koji je uključivao ponavljana bacanja partnera (Melki et al., 2019). Slično tome, usporedbe između elitnih i amaterskih hrvača pokazale su da sportaši više natjecateljske razine ostvaruju veću visinu vertikalnog skoka i veći izlaz snage, što upućuje na to da eksplozivna snaga donjih ekstremiteta predstavlja važnu sastavnicu natjecateljske uspješnosti u hrvanju (García-Pallarés et al., 2011). Uz snagu donjih ekstremiteta, snaga gornjeg dijela tijela također ima temeljnu ulogu tijekom hrvačkih borbi. Pokreti poput povlačenja, potiskivanja, podizanja i kontrole protivnika zahtijevaju visoku razinu produkcije sile, osobito u muskulaturi podlaktice i šake. Snaga stiska šake (HGS) dosljedno se ističe kao važna sposobnost povezana sa sportskom izvedbom u hrvanju (Demirkan et al., 2015; Horswill, 1992). Zabilježene su snažne povezanosti između snage stiska šake (HGS) i natjecateljskog plasmana, što upućuje na to da snaga stiska značajno doprinosi uspješnim natjecateljskim ishodima (Cronin et al., 2017; Horswill et al., 1989). Ovi nalazi zajedno naglašavaju važnost sposobnosti snage donjih i gornjih ekstremiteta unutar multidimenzionalnog profila izvedbe hrvača.

Međutim, unatoč njihovoj korisnosti, opći testovi ne mogu u potpunosti reproducirati složenu i interaktivnu prirodu hrvačkog natjecanja. Izvedba u hrvanju ne očituje se kroz

izolirane zadatke poput vertikalnih skokova ili maksimalnih testova na cikloergometru, već kroz sposobnost dinamične primjene sile protiv protivnika, često u nestabilnim i nepredvidivim situacijama. Stoga prijenos rezultata izoliranih laboratorijskih mjerenja na stvarne natjecateljske uvjete nije uvijek jednoznačan. Primjerice, visoki rezultati u općem testu snage ili jakosti ne moraju nužno značiti učinkovitu izvedbu sport-specifičnih hrvačkih tehnika u uvjetima umora ili vremenskog pritiska (Chaabene et al., 2018). Kao odgovor na ta ograničenja, značajna pozornost posvećena je razvoju sport-specifičnih testnih postupaka koji vjernije oponašaju fiziološke i biomehaničke zahtjeve hrvačkih mečeva (Chaabene et al., 2018; Marković et al., 2022). Sport-specifični testovi osmišljeni su kako bi reproducirali ključne elemente natjecateljske izvedbe, poput ograničenih intervala oporavka, tehničke izvedbe i ponavljanih napora visokog intenziteta. Uključivanjem obrazaca kretanja koji nalikuju stvarnim hrvačkim tehnikama, takve procjene mogu pružiti relevantnije informacije o spremnosti sportaša za natjecanje.

Jedan primjer takvog pristupa je Specific Wrestling Fitness Test (SWFT), koji je osmišljen kako bi odražavao intervalnu strukturu i tehničke zahtjeve hrvanja uključivanjem ponavljanih bacanja u unaprijed definiranim vremenskim intervalima (Markovic, 2017; Markovic et al., 2021). SWFT kombinira mehaničke pokazatelje izvedbe (npr. broj izvedenih bacanja) s fiziološkim pokazateljima poput odgovora srčane frekvencije, čime se istodobno procjenjuju izvedbeni kapacitet i fiziološko opterećenje (Markovic et al., 2021). U usporedbi s izoliranim laboratorijskim testovima, sport-specifični protokoli poput SWFT-a mogu pružiti veću osjetljivost u razlikovanju razina izvedbe među hrvačima, osobito pri procjeni sportaša slične opće tjelesne pripremljenosti (Markovic et al., 2021; Marković et al., 2022). Međutim, sport-specifično testiranje također ima određena ograničenja. Različitost tehničke izvedbe, uključenost partnera u testiranje te varijabilnost kvalitete izvedbe mogu otežati postizanje potpune standardizacije takvih testova. Nadalje, odnos između opće tjelesne pripremljenosti i sport-specifične izvedbe još uvijek nije u potpunosti razjašnjen, osobito u populaciji mladih sportaša. Iako određene opće motoričke i funkcionalne sposobnosti mogu doprinositi uspješnoj sport-specifičnoj izvedbi, njihov relativni značaj može se mijenjati ovisno o trenažnom iskustvu, dobi sportaša i stupnju biološkog sazrijevanja (Lloyd & Oliver, 2012).

Osobito je važno naglasiti da pitanje valjanosti procjene postaje još relevantnije kada je riječ o mladim hrvačima. Tijekom adolescencije može doći do brzog povećanja snage i

jakosti kao posljedice biološkog sazrijevanja, što može rezultirati boljim rezultatima u općim testovima bez nužnog istovremenog poboljšanja tehničke učinkovitosti (Malina et al., 2015). S druge strane, tehnički vještiji sportaši, zahvaljujući boljoj koordinaciji i razvijenijoj taktičkoj svjesnosti, mogu ostvarivati dobru sport-specifičnu izvedbu iako postižu umjerene rezultate u općim testovima (Baker & Young, 2014). Ove razlike ukazuju na važnost sagledavanja međusobnog odnosa između općih i sport-specifičnih pokazatelja izvedbe, umjesto njihova promatranja kao odvojenih koncepata. Stoga se cjelovitija procjena izvedbe u hrvanju može postići primjenom uravnoteženog pristupa koji uključuje i opće testove tjelesne pripremljenosti i sport-specifične protokole. Dok sport-specifični testovi mogu vjernije odražavati funkcionalnu primjenjivost sposobnosti u natjecateljskom okruženju, opća testiranja pružaju vrijedan uvid u temeljne fizičke sposobnosti sportaša (Chaabene et al., 2018; Horswill, 1992). Razumijevanje odnosa između tih kategorija te načina na koji one utječu na natjecateljsku uspješnost mladih hrvača predstavlja važan prvi korak prema preciznijem profiliranju sportske izvedbe i razvoju sportaša utemeljenom na znanstvenim dokazima.

2.1.4 Izvedba u uvjetima umora

Potreba za održavanjem visoke razine izvedbe unatoč rastućem umoru predstavlja jedno od ključnih obilježja hrvačkog natjecanja. Za razliku od aktivnosti koje uključuju jednokratan napor, hrvački mečevi zahtijevaju od sportaša da u kratkom vremenu ponovno uspostave sposobnost produkcije sile, pritom zadržavajući tehničku preciznost. Takve izmjene aktivnosti isprekidane su kratkim razdobljima oporavka. Naizmjenična struktura aktivnosti u hrvanju snažno opterećuje i anaerobni i aerobni energetski sustav, a umor nastaje ne samo kao posljedica metaboličkog opterećenja, već i neuromuskularnog te perceptivnog naprezanja (Karnincic et al., 2009; Kraemer et al., 2001). Stoga se sposobnost ponavljanja napora visokog intenziteta više puta tijekom meča smatra jednim od ključnih čimbenika natjecateljske uspješnosti u hrvanju (Barbas et al., 2011). Sposobnost ponavljanja napora visokog intenziteta odražava sposobnost sportaša da održava razinu mehaničkog rada unatoč nepotpunom oporavku i sve većem fiziološkom opterećenju. Istraživanja u borilačkim sportovima pokazala su da uspješniji sportaši često pokazuju veću otpornost na umor te manji pad izvedbe tijekom ponavljanih napora (Kafkas et al., 2016; Kons et al., 2020). U hrvanju su padovi u izvedbi tijekom simuliranih protokola meča povezani sa smanjenom produkcijom sile i narušenom

tehničkom izvedbom, što upućuje na to da umor izravno utječe na natjecateljsku učinkovitost. Stoga se sposobnost podnošenja i savladavanja umora tijekom meča smatra jednom od najvažnijih sposobnosti za natjecateljsku uspješnost hrvača.

Važno je istaknuti da razlike u izvedbi između sportaša različitih natjecateljskih razina nisu uvijek jasno uočljive u uvjetima bez umora. Kada se testiranje provodi u odmornom stanju, sportaši sa sličnim profilima snage i jakosti mogu se činiti međusobno usporedivima. Međutim, kada se procjena provodi nakon iscrpljujućih ili ponavljanih protokola napora, razlike među pojedincima mogu postati izraženije (Özbay & Ulupınar, 2022). To upućuje na to da procjena izvedbe u uvjetima umora može pružiti dodatnu diskriminacijsku vrijednost u odnosu na tradicionalna maksimalna testiranja. Analiza promjena u izvedbi povezanih s umorom osobito je relevantna kod mladih hrvača. Tijekom adolescencije nastavljaju se razvijati anaerobni kapacitet, dinamika oporavka i neuromuskularna učinkovitost (Malina et al., 2015; Van Praagh, 2000). Posljedično, biološko sazrijevanje, trenažno iskustvo i razina tjelesne pripremljenosti mogu značajno utjecati na način na koji pojedinci reagiraju na umor. Stoga procjena sposobnosti održavanja izvedbe tijekom ponavljanih napora visokog intenziteta može pružiti ekološki relevantniju sliku natjecateljske spremnosti u odnosu na izolirane maksimalne procjene. Uzimajući sve navedeno u obzir, jasno je koliko je važno u procjenu hrvačke izvedbe uključiti protokole osjetljive na umor ili testiranja koja uključuju ponavljane napore. U okviru multidimenzionalnog pristupa procjeni izvedbe, takvi postupci mogu doprinijeti boljem prepoznavanju ključnih odrednica uspješnosti te jasnijem razlikovanju uspješnijih i manje uspješnih mladih hrvača.

2.1.5 Motivacija kao odrednica uspješnosti u hrvanju

Iako su fizičke i fiziološke sposobnosti ključne odrednice izvedbe u hrvanju, psihološke karakteristike također imaju važnu ulogu u razvoju sportaša i njihovoj natjecateljskoj uspješnosti. Među različitim psihološkim čimbenicima, motivacija se prepoznaje kao jedan od ključnih elemenata koji utječu na uključenost u trening, ustrajnost u zahtjevnim uvjetima vježbanja te natjecateljsku izvedbu. U literaturi sportske psihologije motivacija se najčešće opisuje kao skup unutarnjih i vanjskih procesa koji potiču, usmjeravaju i održavaju ponašanje usmjereno prema cilju (Deci & Ryan, 1985; Pelletier et al., 1995). Sportaši koji pokazuju višu razinu motivacije skloniji su ulagati veći trud u trening, održavati dugoročnu predanost bavljenju sportom te se uspješnije nositi s natjecateljskim

izazovima (Vallerand & Losier, 1994). U okviru teorije samoodređenja motivacija se najčešće dijeli na intrinzičnu i ekstrinzičnu (Ryan & Deci, 2020). Intrinzična motivacija odnosi se na sudjelovanje u sportu zbog unutarnjeg interesa, zadovoljstva ili osobne ispunjenosti, dok je ekstrinzična motivacija potaknuta vanjskim nagradama ili pritiscima (Standage & Ryan, 2020). Dosadašnja istraživanja upućuju na to da sportaši s izraženijom intrinzičnom motivacijom pokazuju veću ustrajnost, bolji razvoj vještina te povoljnije dugoročne rezultate u sportskoj izvedbi (Alkasasbeh & Akroush, 2025; Almagro et al., 2020). U borilačkim sportovima poput hrvanja, gdje su trenažni zahtjevi fizički i psihološki vrlo zahtjevni, motivacija može imati osobito važnu ulogu u održavanju redovitog sudjelovanja u treningu i poticanju kontinuiranog napretka (Fuentes et al., 2020; Turksoy et al., 2016).

Kod mladih sportaša motivacijske karakteristike mogu biti osobito važne. Tijekom adolescencije sportaši prolaze kroz brojne fizičke, psihološke i socijalne promjene koje mogu utjecati na njihovu predanost bavljenju sportom. U tom razdoblju motivacija može značajno utjecati na uključenost u trening i razvoj sport-specifičnih vještina, što u konačnici doprinosi natjecateljskoj uspješnosti. Prema dosadašnjim istraživanjima u području mladog sporta, sportaši s višom razinom intrinzične motivacije obično sudjeluju u treningu redovitije te pokazuju povoljnije razvojne putanje (Díaz-Rodríguez et al., 2025; Vallerand & Losier, 1994). Unatoč prepoznatoj važnosti psiholoških čimbenika u sportskoj izvedbi, relativno mali broj istraživanja bavio se motivacijskim obilježjima specifično kod mladih hrvača. Posljedično, potencijalni doprinos motivacijskih karakteristika natjecateljskoj uspješnosti u hrvanju kod mladih sportaša još uvijek nije dovoljno istražen. S obzirom na zahtjevnu prirodu hrvačkog treninga i natjecanja, razumijevanje uloge motivacije može pružiti vrijedan uvid u razvoj sportaša i optimizaciju sportske izvedbe (Turksoy et al., 2016). Stoga proučavanje motivacijskih obilježja zajedno s fizičkim i fiziološkim pokazateljima sportske izvedbe može doprinijeti cjelovitijem razumijevanju čimbenika koji utječu na natjecateljsku uspješnost mladih hrvača.

2.2 Ciljevi i hipoteze doktorskog rada

Natjecateljska uspješnost u hrvanju rezultat je složene interakcije fizioloških, motoričkih i psiholoških čimbenika. Dosadašnja istraživanja u borilačkim sportovima uglavnom su

se bavila pojedinačnim odrednicama uspješnosti, dok su istraživanja koja integriraju više dimenzija sportske izvedbe kod mladih hrvača i dalje relativno rijetka. Stoga je osnovni cilj ove doktorske disertacije bio istražiti multidimenzionalne čimbenike povezane s natjecateljskom uspješnošću mladih hrvača. Konkretno, disertacija je usmjerena na ispitivanje uloge generičke tjelesne pripremljenosti, sport-specifične izvedbe, sposobnosti izvedbe pri ponavljanim naporima visokog intenziteta te motivacijskih obilježja u natjecateljskoj uspješnosti mladih hrvača.

Specifični ciljevi ove doktorske disertacije bili su:

1. Utvrditi razlikuju li generička/opća tjelesna pripremljenost i sport-specifični pokazatelji izvedbe uspješnije od manje uspješnih mladih hrvača.
2. Ispitati valjanost i praktičnu primjenjivost Specifičnog hrvačkog fitness testa (Specific Wrestling Fitness Test) kao mjere sport-specifične izvedbe kod mladih hrvača.
3. Procijeniti dovode li protokoli ponavljanog i iscrpljujućeg testiranja do boljeg razlikovanja hrvača različite natjecateljske razine.
4. Utvrditi motivacijski profil mladih hrvača te ispitati njegovu povezanost s natjecateljskom uspješnošću.

Na temelju dosadašnjih znanstvenih spoznaja, teorijskih pretpostavki i postavljenih ciljeva istraživanja, formulirane su sljedeće hipoteze:

1. Uspješniji mladi hrvači ostvarit će bolje rezultate u generičkim i sport-specifičnim testovima izvedbe u usporedbi s manje uspješnim hrvačima.
2. Pokazatelji izvedbe dobiveni primjenom Specifičnog hrvačkog fitness testa bit će značajno povezani s natjecateljskom uspješnošću mladih hrvača te će biti valjan pokazatelj sport-specifične izvedbe.
3. Razlike u izvedbi između hrvača različitih natjecateljskih razina bit će izraženije kada se testiranje provodi u uvjetima umora ili ponavljanih napora.
4. Uspješniji hrvači imat će povoljniji motivacijski profil, posebno višu razinu intrinzične motivacije.

3 ORIGINALNI OBJAVLJENI RADOVI

3.1 **Studija 1:** *Skugor, K., Stajer, V., Zugaj, N., Gilic, B., & Karnincic, H. (2023). Generic and Specific Fitness Profile of Elite Youth Greco-Roman Wrestlers; Differences According to Quality and Weight Category. Sport Mont, 21(1), 23-30. doi: 10.26773/smj.230204*

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ORIGINAL SCIENTIFIC PAPER

Generic and Specific Fitness Profile of Elite Youth Greco-Roman Wrestlers; Differences According to Quality and Weight Category

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Abstract

This study aimed to investigate the validity of the Specific Wrestling Fitness Test (SWFT), correlating it with generic anaerobic tests in elite youth wrestlers and determining whether wrestlers differ according to quality and weight categories in all tests. The research included 23 advanced-level Greco-Roman wrestlers (aged 16-19 years) who were divided into two quality categories (National team members and Non-team members) and two weight categories (lighter and heavier). Variables included anthropometric characteristics, generic fitness tests, and SWFT. Results evidenced that only vertical jump height was associated with SWFT (Pearson's R=0.48, $p<0.05$). Team members had higher results in the vertical jump height ($p=0.02$, moderate ES), while wrestlers from the heavier category had higher body mass ($p=0.001$, large ES) and body height ($p=0.01$, large ES) than lighter wrestlers. Moreover, wrestlers did not differ in the SWFT according to quality and weight categories. SWFT was not associated with generic fitness tests, possibly because of its high specificity. Furthermore, team members and non-team members did not differ in the SWFT, which could be explained by the fact that only advanced-level wrestlers were included in this study. Thus, future studies should include lower-quality wrestlers and different testing protocols.

Keywords: *combat sports, physical capacities, selection, youth athletes*

3.1.1 Introduction

Two wrestling disciplines that are included in the Olympic games for men are Greco-Roman and freestyle wrestling. Greco-Roman wrestlers are allowed only to perform actions on the upper body and movements under the waist are forbid- den, while freestyle wrestlers are permitted to use the whole body for actions (Ulupınar et al., 2021). Both wrestling disciplines are characterized by intermittent actions, with periods of high-intensity activity interspersed with short recovery periods (Ulupınar et al., 2021). It has been reported that during the World Greco-Roman wrestling championship, the activity-to-rest ratio was approximately 2.5:1 (Nilsson et al., 2002). Namely, wrestling is characterized by constant and repeated shifts of sudden defense and offense movements in the sub- maximal and maximal physiological zones, which means that wrestling mainly relies on anaerobic energy systems (Horswill, 1992). Precisely, the activity during the match is 90% per- formed in anaerobic-alactate and anaerobic-glycolytic metabolic processes, while only 10% relies on the aerobic energy system (Kell, 1997).

The anaerobic system provides quick energy for performing explosive actions such as lifts and throws and maximal intensity actions like pushing and pulling the opponent (Chaabene et al., 2017). As the beforementioned actions are the ones that determine the match outcome, it could be hypothesized that well-developed anaerobic capacity is the most important factor for success in wrestling. Thus, the main aim of the practitioners and scientists is to develop and determine the most appropriate test that tackles anaerobic metabolic pathways and determines the wrestler's level of preparedness. Sport-specific tests enable determining current levels of physical and physiological indices of their athletes (Chaabene et al., 2018).

As throwing wrestling manoeuvres are the most demanding ones as the wrestler has to lift and quickly throw the op- ponent, throwing actions employ an anaerobic energy system the most. Thus, several wrestling-specific tests that consist of consecutive wrestling throwing movements have been recently developed. Specific Wrestling Performance Test (SWPT) and Specific Wrestling Fitness Test (SWFT) both consist of throwing a dummy by a supplex technique, with SWPT consisting of two 3-minute segments and SWFT composed of three segments of 30 seconds (Markovic, 2017; Markovic et al., 2021). Thus, even though SWPT mimics actual combat duration, SWFT has better practical applicability as it is of a shorter duration, and a larger number of

athletes can be measured. Also, it is considered that SWFT sufficiently tackles the anaerobic capacities of wrestlers and can be used to determine their physiological capacities (Markovic et al., 2021). SWFT has previously been proven reliable (Markovic, 2017) and valid in predicting specific wrestling preparedness in wrestlers aged 20-24 years (Markovic et al., 2021).

Studies conducted on older wrestlers (20.3±2.7 years) displayed differences in SWFT according to quality categories. Precisely, Serbian first-league wrestlers had a higher number of throws of more than 30% compared to second-league wrestlers (Markovic et al., 2018). Moreover, national team wrestlers outperformed first-league wrestlers (32.40±1.8 vs. 28.30±1.7 throws), and first-league wrestlers exceeded second-league wrestlers (28.30±1.7 vs. 23.04±3.2 throws), indicating good discriminative validity of the SWFT (Marković et al., 2022). Further, wrestling is a sport where the weight of the athlete is extremely important (Karninčić et al., 2013). Therefore, it could be expected that wrestlers would differ in physiological and physical capacities according to their weight. However, few previous studies did not record differences according to weight in maximal muscle strength (bench press and squat exercise) and power tests (Izquierdo et al., 2002; García-Pallarés et al., 2011), but studies investigating weight differences in sport-specific tests are lacking.

From the brief overview of the previously conducted studies, it could be suggested that SWFT was not thoroughly checked for its metric characteristics and was mainly conducted on older wrestlers (older than 20 years) (Markovic et al., 2021). This research aimed to investigate the validity of the SWFT with protocol index calculation modification, correlating it with other generic anaerobic tests in elite youth wrestlers. Additionally, the aim was to determine whether wrestlers differ according to quality categories (national-team members vs. non-team members) and weight categories in all tests. The results of this study would enable coaches and scientists to determine whether some more simple anaerobic test could be used as a tool for determining wrestling performance apart from SWFT, which could potentially save time and enable coaches to identify a quality wrestler.

3.1.2 Methods

Participants

This research included 23 Greco-Roman wrestlers aged 16-19 years who were participating in a national team training camp in preparation for international competitions during the 2022 season. All wrestlers were medalists in national championships and had international experience. All wrestlers successfully completed the tests, and no injuries or illnesses were reported prior to and during the tests. Wrestlers were divided into two categories according to quality. The first category (n=12, age=17.92±0.9 years, body height=175.04±7.19 cm, body mass=74.07±9.85 kg) included wrestlers that were included in the national team (Team members), and the second category (n=11, age=17.5±1.18 years, body height=173.68±3.17 cm, body mass=70.33±8.61 kg) included wrestlers that were in the broader team selection but were not included in the final team (Non-team members). Also, wrestlers were divided into two weight categories: lighter (55-67 kg) and heavier (72-87 kg). Participants signed informed consent before the study began, and parents/legal guardians signed informed consent for participants under 18 years old. This study was approved by the Editorial Board Faculty of Kinesiology, University of Split (Ref.no 2181-205-02-05-22-0012; Date of approval: 11/03/2022).

Variables and procedures

Anthropometric variables, generic fitness tests, and specific fitness tests were included in the research.

Anthropometric variables consisted of body height, body mass, and percentage of body fat calculated as a sum of skinfolds measured on triceps and calf muscles by Harpenden skinfold caliper (British Indicators, Burgess Hill, England), using the Slaughter-Lohman formula.

Generic fitness tests included countermovement jump, consecutive jumps during 30 seconds, Wingate test on the rowing ergometer, and running 300 yards.

Countermovement jump (CMJ) and consecutive jumps during 30 seconds (CJ30) were measured using the Optogate system (Microgate, Bolzano, Italy). For the CMJ, Wrestlers

stood in a shoulder-width stance with hands on their hips. Wrestlers had to jump upwards maximally by first bending their knees and moving downwards, followed by a maximal jump upwards. They performed three jumping trials, and the best one (i.e., the highest jump) was taken into further analysis. For the CJ30, wrestlers stood in a shoulder-width stance and could freely move their hands during the jumps. They had to perform consecutive jumps during the 30 seconds. The parameters used for analysis were the highest jump, reactive strength index, and the number of jumps.

Wingate test on the rowing ergometer (WINGATEROW) was performed on the Concept 2 rowing machine, which was previously shown as valid and reliable (Mikulic et al., 2010). Variables from the WINGATEROW test included maximal power output and average power output.

A three hundred yards shuttle run test (300 yd) was performed in the school gymnasium. Two lines were placed 25 yards apart. Participants were instructed to take the high starting position behind the first line. They had to run to the 25-yards line, touch it with their foot, turn, and run back to the first line. They performed the same scenario six times. The test result was recorded as time for running the 300-yard distance. Specific-fitness test was the SWFT. All participants were given a dummy according to their weight category. Wrestlers in weight categories 55-67 kg performed the test with a 23 kg dummy, while wrestlers in 72-87 kg categories performed the test with a 25 kg dummy, and wrestlers over 90 kg performed the test with a 30 kg dummy. However, wrestlers with more than 97 kilograms were excluded from the analysis as they have to move higher absolute mass in throws which is more anaerobically demanding for producing relative to body weight. The weight of the dummy was determined according to instructions of the test's authors, with slight alliterations (Markovic, 2017). Wrestlers had to perform a maximum number of throws using the supplex technique in three periods of 30 seconds, with 20 seconds of rest between throwing periods. Wrestlers had visual and acoustic feedback on time, i.e., a large stopwatch was placed in their sight, and researchers were informing wrestlers about the time. The total number of throws was recorded. Each participant wore a POLAR H10 heart rate monitor (Polar, Inc., Lake Success, NY, USA). Heart rate was recorded immediately after each throwing period (i.e., when the test finished) and after the first and third minutes of rest and included following variables: Heart rate 1 – Sum of heart rate at test end and 1-minute rest, Heart rate 2 – Sum of heart rate at test end, at 1min rest and 3-minute rest.

The modification in the calculation of the SWFT index was made; the authors of this study propose that the simpler formula should be used as the original formula in calculating the SWFT index using blood lactates is time-consuming and expensive, and often coaches do not have certified equipment. The index of the SWFT was calculated similarly to the SJFT index (Drid et al., 2012), as a sum of heart rates at the end of the test and after one minute of rest divided by the total number of throws. Additionally, another index was calculated as the sum of heart rates at the end of the test, after one minute of rest, and after three minutes of rest divided by the total number of throws.

Testing protocol

Testing was conducted during two testing days.

The first day included anthropometric measurement, which was conducted before wrestlers performed warm-up. General warm-up lasted for 15 minutes and consisted of light running, followed by mobility exercises. After the warm-up, wrestlers first performed the CMJ test and, after a 10-minute break, performed the CJ30 test. After, WINGATEROW was conducted. Wrestlers firstly performed a familiarization trial of 5-minute light rowing, even though they had good rowing technique as rowing is included in their physical conditioning preparations. After 5-minute light rowing, they had 1-minute rest and performed a 30-second maximal test.

The second testing day included SWFT and 300 yd test. General warm-up lasted for 15 minutes and consisted of light running, mobility and stretching, and their regular warm-up on the wrestling mat. Afterward, wrestlers underwent a 20-minute familiarization process for the SWFT test that consisted of theoretical and practical explanation and practice. After a 10-minute rest, participants performed a maximal SWFT test. After a 30-minutes break, wrestlers performed a 300 yd running test once.

Statistical analyses

The normality of the variables was checked by the Kolmogorov-Smirnov test. Descriptive statistics included arithmetic means and standard deviations. Pearson's correlation coefficients were used to determine the correlation between SWFT and other

anthropometric and fitness variables. To determine the differences between quality categories and weight classes, a t-test for independent samples was used. Additionally, Cohen's d effect sizes (ES) were calculated for differences in quality and weight category in the studied variables, and were interpreted as: <0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large ES (Cohen, 2013). The p-level of 0.05 was applied for all analyses. A minimum level of significance of $p<0.05$ was established.

Statistical package Statistica ver.13 (Tibco, Palo Alto, California) was used for all analyses.

3.1.3 Results

Descriptive statistics and differences in anthropometric and fitness variables according to wrestlers' quality are displayed in Table 1. Team members had higher results in the maximal height during CJ30 (t-value=2.52, p=0.02). There were no significant differences in any other variable.

Table 1. Descriptive statistics and differences in anthropometric and fitness variables according to wrestlers' quality.

Variables	Team members (N=12)		Non-team members (N=11)		T-test	
	Mean	SD	Mean	SD	t-value	p-level
Body mass (kg)	74.07	9.85	70.33	8.61	0.97	0.35
Body height (cm)	175.04	7.19	173.68	3.17	0.58	0.57
Body fat percentage	11.95	1.75	11.35	2.75	0.62	0.54
30s maximal height (cm)	31.38	2.03	28.31	3.60	2.52	0.02
30s maximal power (W)	40.22	5.21	38.14	4.82	0.96	0.35

30s maximal RSI (index)	1.48	0.21	1.37	0.21	1.18	0.25
Broad jump (cm)	243.00	22.42	233.20	19.11	1.09	0.29
Countermovement jump (cm)	39.23	4.66	36.63	6.16	1.13	0.27
Push up jump (cm)	11.87	4.30	10.77	3.90	0.62	0.54
300 yards (sec)	63.60	3.76	63.20	2.07	0.28	0.78
Wingate average power (w/kg)	6.31	0.82	6.00	0.79	0.79	0.44
Wingate peak power (w/kg)	7.54	0.94	7.29	0.76	0.61	0.55
(SWFT repetitions total	28.42	2.39	26.33	3.43	1.64	0.12
Heart rate 1	334.00	15.14	336.56	10.24	-0.44	0.67
Heart rate 2	450.25	21.30	458.22	17.82	-0.91	0.38
SWFT index 1	11.85	1.33	12.97	1.71	-1.69	0.11
SWFT index 2	15.97	1.76	17.68	2.50	-1.84	0.08

Note: RSI - Reactive Strength Index, SWFT – Specific Wrestling Fitness Test, Heart rate 1 – Sum of heart rate at test end and 1-minute rest, Heart rate 2 – Sum of heart rate at test end, at 1min rest and 3-minute rest.

Figure 1 shows effect size differences between team members and non-team members in anthropometric variables, generic fitness tests, and Specific Wrestling Fitness Test parameters. The moderate effect size was found for the CJ30.

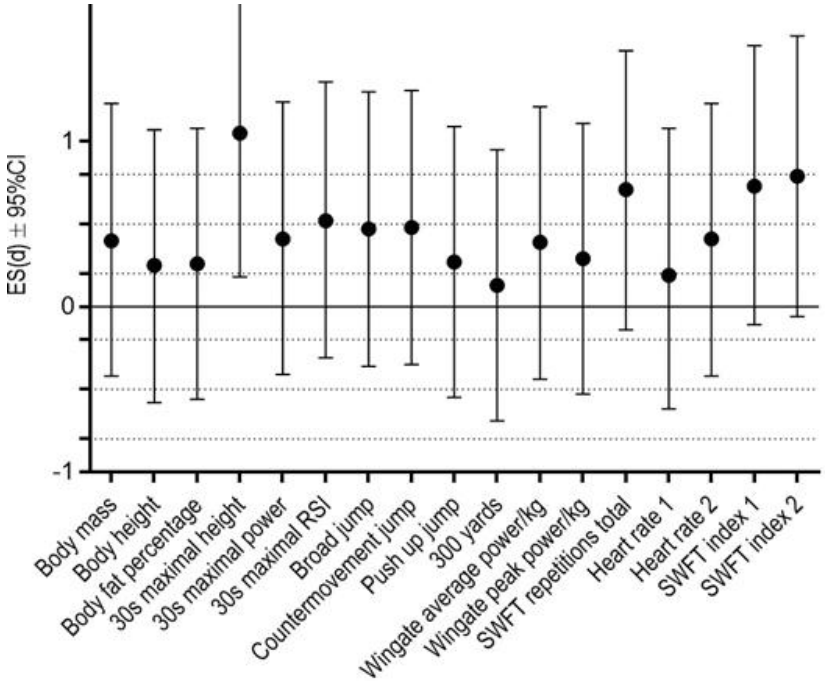

FIGURE 1. Effect size differences between team members and non-team members in anthropometric variables, generic fitness tests, and Specific Wrestling Fitness Test parameters. RSI - Reactive Strength Index; SWFT – Specific Wrestling Fitness Test; Heart rate 1 – Sum of heart rate at test end and 1-minute rest; Heart rate 2 – Sum of heart rate at test end, at 1min rest and 3-minute rest. Dashed lines present ES range (<0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large differences).

According to the weight category, wrestlers from the heavier category had higher body mass (t=4.33, p=0.001) and body height (t=2.99, p=0.01) than lighter wrestlers. They did not differ in any other variable (Table 2).

Table 2. Descriptive statistics and differences in anthropometric and fitness variables according to weight categories.

	Heavier category (N=15)		Lighter category (N=6)		T-test	
	Mean	SD	Mean	SD	t-value	p-level
Body mass (kg)	76.90	7.47	62.65	4.48	4.33	0.001
Body height (cm)	176.67	5.22	169.67	3.66	2.99	0.01
Body fat percentage	11.96	2.35	11.30	1.87	0.61	0.55

30s maximal height (cm)	29.72	3.38	30.38	2.74	-0.39	0.70
30s maximal power (W)	38.22	4.11	39.56	6.06	-0.55	0.59
30s maximal RSI (index)	1.36	0.19	1.50	0.20	-1.38	0.19
Broad jump (cm)	245.14	20.68	224.40	12.74	2.08	0.05
Countermovement jump (cm)	39.44	5.92	36.22	3.30	1.14	0.27
Push up jump (cm)	11.19	3.53	12.04	6.56	-0.37	0.72
300 yards (sec)	62.49	1.95	64.93	4.29	-1.66	0.12
Wingate average power (w/kg)	6.18	0.67	6.11	1.14	0.15	0.88
Wingate peak power (w/kg)	7.49	0.73	7.27	1.17	0.48	0.64
SWFT repetitions total	27.53	2.80	27.50	3.73	0.02	0.98
Heart rate 1	336.53	14.28	331.50	9.27	0.79	0.44
Heart rate 2	457.07	21.84	445.17	10.72	1.26	0.22
SWFT index 1	12.36	1.51	12.26	1.87	0.13	0.90
SWFT index 2	16.80	2.21	16.46	2.47	0.30	0.76

Note: RSI - Reactive Strength Index; SWFT – Specific Wrestling Fitness Test; Heart rate 1 – Sum of heart rate at test end and 1-minute rest; Heart rate 2 – Sum of heart rate at test end, at 1min rest and 3-minute rest.

Figure 2 shows effect size differences between team members and non-team members in anthropometric variables, generic fitness tests, and Specific Wrestling Fitness Test parameters. Large differences are noted for the body mass and height.

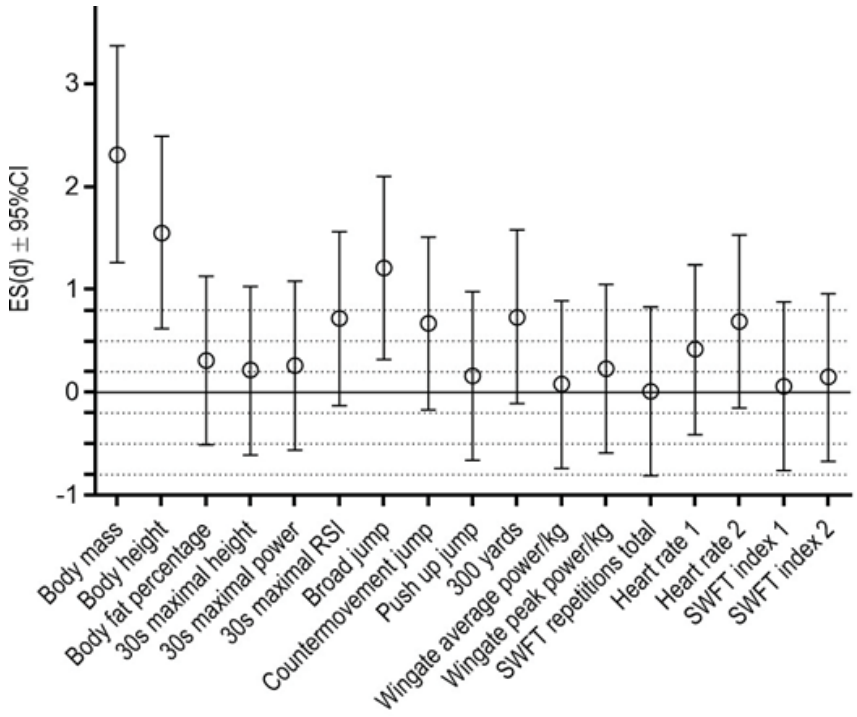

FIGURE 2. Effect size differences between lighter and heavier weight categories in anthropometric variables, generic fitness tests, and Specific Wrestling Fitness Test parameters. RSI – Reactive Strength Index; SWFT – Specific Wrestling Fitness Test; Heart rate 1 – Sum of heart rate at test end and 1-minute rest; Heart rate 2 – Sum of heart rate at test end, at 1min rest and 3-minute rest. Dashed lines present ES range (<0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large differences).

Pearson's correlation coefficients are shown in Table 3. Body fat percentage was positively associated with all SWFT parameters except for SWFT repetitions for the total sample. Moreover, maximal height during 30 seconds of consecutive jumps and the CMJ test was positively correlated with SWFT repetitions. The CMJ test was negatively correlated with SWFT index 1 and SWFT index 2, where the lower index represents the better result. When looking separately among team members, only body height was negatively correlated with SWFT parameter Heart rate 1. Among non-team members, body height and body fat percentage were positively correlated with Heart rates 1 and 2.

Table 3. Pearson's correlation coefficients between Specific Wrestling Fitness Test parameters and anthropometric and generic- fitness variables.

Variable	SWFT repetitions total	Heart rate 1	Heart rate 2	SWFT index 1	SWFT index 2
	Total sample				
Body mass	0.14	-0.02	0.08	-0.15	-0.11
Body height	0.23	-0.43	-0.35	-0.34	-0.31
Body fat percentage	-0.43	0.58*	0.61**	0.59*	0.60*
30s maximal height	0.48	-0.01	-0.06	-0.47	-0.48
30s maximal power	0.48*	0.11	0.11	-0.44	-0.42
30s maximal RSI	0.34	0.23	0.17	-0.26	-0.26
Broad jump	0.14	-0.31	-0.22	-0.26	-0.23
Push up jump	0.28	0.05	0.03	-0.25	-0.25
Countermovement jump	0.49*	-0.20	-0.15	-0.54*	-0.51*
300 yards	-0.26	-0.05	-0.17	0.24	0.18
Wingate average power/kg	0.26	0.17	0.17	-0.20	-0.18
Wingate peak power/kg	0.17	0.16	0.19	-0.12	-0.10
	Team members				
Body mass	0.27	-0.33	-0.29	-0.42	-0.41
Body height	0.36	-0.67*	-0.64	-0.60	-0.60
Body fat percentage	-0.49	0.56	0.55	0.61	0.63
30s maximal height	0.07	0.18	0.22	-0.01	0.00
30s maximal power	0.62	0.30	0.39	-0.42	-0.39
30s maximal RSI	0.31	0.48	0.50	-0.06	-0.05
Broad jump	0.22	-0.44	-0.39	-0.39	-0.38
Push up jump	0.26	0.16	0.17	-0.14	-0.14
Countermovement jump	0.27	-0.36	-0.31	-0.38	-0.37
300 yards	-0.60	-0.05	-0.20	0.54	0.48
Wingate average power/kg	0.42	0.15	0.11	-0.28	-0.30
Wingate peak power/kg	0.51	0.11	0.08	-0.38	-0.40
	Non-team members				
Body mass	-0.10	0.64	0.69	0.24	0.30

Body height	-0.19	0.75*	0.74*	0.37	0.41
Body fat percentage	-0.45	0.74*	0.73*	0.66	0.68
30s maximal height	0.54	-0.26	-0.18	-0.60	-0.57
30s maximal power	0.22	-0.51	-0.42	-0.38	-0.38
30s maximal RSI	0.18	-0.51	-0.42	-0.34	-0.34
Broad jump	-0.03	0.00	0.14	-0.06	-0.02
Push up jump	0.32	-0.18	-0.17	-0.38	-0.37
Countermovement jump	0.65	0.01	0.06	-0.67	-0.62
300 yards	0.04	-0.06	-0.03	-0.09	-0.08
Wingate average power/kg	-0.01	0.20	0.34	0.01	0.06
Wingate peak power/kg	-0.32	0.31	0.44	0.31	0.36

Note: RSI - Reactive Strength Index; SWFT – Specific Wrestling Fitness Test; Heart rate 1 – Sum of heart rate at test end and 1-minute rest; Heart rate 2 – Sum of heart rate at test end, at 1min rest and 3-minute rest; * $p<0.05$; ** $p<0.01$

3.1.4 Discussion

This study aimed to investigate the validity of the Specific Wrestling Fitness Test (SWFT), correlating it with other generic anaerobic tests in elite youth wrestlers and determining whether wrestlers differ according to quality and weight categories in all tests. According to the aims of the study, the most important findings are: (i) generic fitness tests are not associated with SWFT, (ii) wrestlers did not differ according to quality categories, and (iii) wrestlers did not differ according to weight categories.

Generic fitness tests and specific wrestling fitness test

The finding that generic fitness tests were poorly or not associated with SWFT could be explained by the fact that SWFT is a highly sport-specific test that includes complex movements of the whole body, with constant changes in body positions (Markovic et al., 2021). Specifically, the throwing manoeuvre starts in an upright position and finishes in the lying position, after which wrestlers have to stand up quickly and repeat the throwing. Thus, this test relies on the synergistic functioning of the whole body in a very specific movement. To support our findings, anaerobic performance variables accounted for less than 60% of the variance in a somewhat similar test for Brazilian judo athletes - Special

Judo Fitness Test (SJFT) (Paulo Lopes-Silva et al., 2021). Supportively, SJFT was not correlated with upper-body Wingate test mean (R=-0.28) and peak power (R=-0.26) in Iranian judokas (Hesari et al., 2014). However, our results did evidence weak to a moderate association of SWFT with vertical jumping capacity. Indeed, probably the most powerful movement of the SWFT is when wrestlers have to explosively lift the dummy off the mat, which is mainly enabled by powerful movement from the lower extremities (Markovic, 2017). Similar to our study, a study on youth Tunisian wrestlers aged 16-17 years found an association between peak power of legs evaluated by the Wingate test and a specific wrestling test that consisted of throwing a partner, similar to SWFT (Melki et al., 2019). Thus, our results could lead to a hypothesis that lower-body power capacity determines performance in SWFT and potentially better performance in the wrestling match. Therefore, it could be proposed that wrestling coaches focus on developing muscle power in the lower extremities to enhance wrestling performance.

Differences according to quality groups and weight category

The SWFT did not differentiate team members and non-team members, implying that the test is not sensitive enough for this specific sample. Precisely, all participants in our study were advanced-level athletes; Besides selected team wrestlers, even non-team members were close to entering the team, meaning the differences between those quality groups are probably very small. Indeed, one potential reason could be the subjective evaluation of the team selector on the decision of which athlete to include in the team and which not to include, which can be based on the selector's self-perception of the wrestler. Opposite to the results of our study, a study conducted on Serbian wrestlers aged 20-21 years noted that wrestlers from different competitive levels (1st vs. 2nd Wrestling League of Serbia) differed in the wrestling-specific performance test, i.e., 1st league wrestlers outperformed 2nd league wrestlers (Markovic et al., 2018). However, the reason we recorded opposite results could be because we included only advanced-level wrestlers.

The research conducted on Croatian advanced wrestlers supports the results of our study. Specifically, top-level (national-team members) and high-level (non-selected for the national team) wrestlers did not differ in strength parameters (pull-ups and bench press) (Karnincic et al., 2015). Even though strength level is crucial for determining the fitness status of wrestlers, it can only discriminate lower-quality from high-quality wrestlers (García-Pallarés et al., 2011), while it does not efficiently differentiate advanced-level

wrestlers. This has also been proven in numerous studies (Horswill et al., 1989; García-Pallarés et al., 2011). Specifically, a study on elite and amateur wrestlers from five countries recorded that elite wrestlers reached significantly greater results in most physical performance variables, including maximal grip strength, upper-body Wingate test, jumping height, and maximum muscle strength, than amateur wrestlers (García-Pallarés et al., 2011). Moreover, a study on youth wrestlers aged 16-17 years recorded that elite wrestlers had better results than non-elite wrestlers in the upper-body and lower-body Wingate test (Horswill et al., 1989).

However, advanced-level wrestlers have similar strength levels because they must possess a high level of strength and power, or they will not be categorized as advanced wrestlers. Indeed, a study on Polish wrestlers noted that successful wrestlers had higher muscle power, strength, and endurance levels than unsuccessful wrestlers (Cieśliński et al., 2021). Thus, to determine whether SWFT is sensitive for discriminating performance and quality levels, future studies should include wrestlers of lower quality (e.g., club-level wrestlers) and not only elite wrestlers.

Finally, wrestlers did not differ according to the weight categories in the SWFT, which could be explained by the fact that the test was performed with a dummy with a specifically determined weight according to their weight category (Markovic et al., 2021). Thus, by matching the weight of the dummy to the weight of the wrestler, the impact of an athlete's lower or higher mass was somewhat diminished. Moreover, there is another additional explanation for the lack of differences between the weight categories. It is possible that the quality of wrestlers interfered in the results and that they were of similar physical capacities regardless of weight. Similar to the results of our study, a study on wrestlers aged 20-22 years noted that elite wrestlers from three weight categories did not differ in maximum muscle strength in the bench press and squat exercise (García-Pallarés et al., 2011). The authors explained such findings by hypothesizing that neural activation patterns and twitch tension per muscle mass during maximal concentric contractions are similar between elite wrestlers, irrespective of the weight category (Izquierdo et al., 2002; García-Pallarés et al., 2011). Therefore, matching the dummy to the wrestler's weight and probable similarity in the physical capacities between wrestlers most likely led to not finding differences between the weight categories in the studied wrestlers.

The study's main limitation is the cross-sectional character and the inability to conclude the relationship between success and physical capacities. Therefore, intervention studies that include exercises and training protocols that tackle capacities included in this study should be performed in the future. Further, we included a relatively small sample size. However, we have to mention that we included advanced-level wrestlers, and, as such, it was hard to collect more wrestlers of this level. Precisely, 170 wrestlers competed at cadet and junior championships (which corresponds to the age category of our participants). Thus, as we included wrestlers that were top performers in those competitions, this could also be the strength of this study. Indeed, including athletes at the top performance and testing their physical capacities could aid in creating more specific training programs for enabling less successful wrestlers to become more successful. To conclude, SWFT was not associated with generic-fitness tests, possibly because of its high specificity. Furthermore, team members and non-team members did not differ in the SWFT, which could be explained by the fact that only advanced-level wrestlers were included in this study. Thus, future studies should include wrestlers of lower quality. Also, the authors propose that future research/testing should consist of two consecutive SWFTs, with only a few minutes of rest between the trials. This way, wrestlers of greater quality will probably display better results and will be able to maintain higher performance levels during both testing trials compared with wrestlers of less quality.

Acknowledgments

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Conflict of Interest

The authors declare that there is no conflict of interest.

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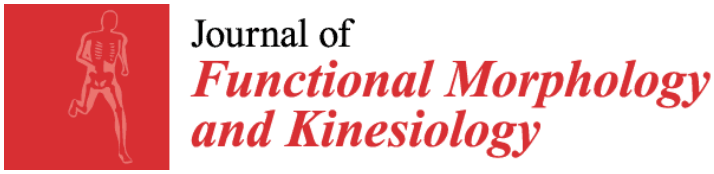

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What Determines the Competitive Success of Young Croatian Wrestlers: Anthropometric Indices, Generic or Specific Fitness Performance?

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Abstract: Identifying factors influencing wrestling performance is important for determining which capacities should be developed the most. This research aimed to investigate whether anthropometric indices, generic fitness, and specific fitness performance determine the competitive success of young wrestlers. This research included 49 Croatian Greco–Roman male wrestlers aged 17.75 ± 1.51 years. Variables included training and competing experience, anthropometric indices, generic fitness (countermovement jump and handgrip strength), and specific wrestling fitness test (SWFT). Wrestlers were separated into medallists and non-medallists (i.e., wrestlers who won a medal at the previous National Championship and wrestlers who did not win a medal, respectively). The t-test for independent samples was used to determine the differences between the two categories in all variables. Moreover, discriminant analysis was performed to identify differences in a multivariate manner. Medallists and non-medallists did not differ in anthropometric indices and wrestling experience. Medallists had better results in the countermovement jump ($t = 2.55$, $p < 0.01$), handgrip strength ($t = 2.77$, $p < 0.01$), and SWFT performance ($t = 2.29$, $p < 0.05$) than non-medallists. The discriminant analysis confirmed that performance categories differed in generic and specific fitness tests (Wilks' Lambda = 0.73, $p < 0.05$). It could be suggested that coaches should develop both the generic and specific fitness of their wrestlers to become more successful at competitions.

Keywords: combat; sports performance; sports success; talent identification; youth

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1. Introduction

The Olympic style of wrestling is an intermittent activity that, in its structure of fighting, requires highly developed physical capacities and technical and tactical abilities. The Olympic-style wrestling match consists of two 3-min rounds, with a 30 s break between the rounds [1]. The match is very dynamic, characterized by sudden attacks and counterattacks, and it is clear that aerobic and anaerobic metabolic energy systems are engaged during and after a wrestling match. During the match, the aerobic system supports continuous effort and recovery, while the metabolic system of anaerobic energy becomes critical in the movements that occur in the submaximal and maximal load zones [2]. It is well known that the anaerobic system provides a short and quick burst of maximum power. Having highly developed anaerobic capacities would lead to a better wrestling performance [3].

3.2.1 Introduction

The Olympic style of wrestling is an intermittent activity that, in its structure of fighting, requires highly developed physical capacities and technical and tactical abilities. The Olympic-style wrestling match consists of two three-minute rounds, with a 30-second break between the rounds [1]. The match is very dynamic, characterized by sudden attacks and counterattacks, and it is clear that aerobic and anaerobic metabolic energy systems are engaged during and after a wrestling match. During the match, the aerobic system supports continuous effort and recovery, while the metabolic system of anaerobic energy becomes critical in the movements that occur in the submaximal and maximal load zones [2]. It is well known that the anaerobic system provides a short and quick burst of maximum power. Having highly developed anaerobic capacities would lead to better wrestling performance [3]. Indeed, it was estimated that, during the wrestling match, 90% of energy needs come from anaerobic energy pathways, which means that anaerobic glycolysis prevails in a match [4,5]. Furthermore, anaerobic capacity has been suggested as a capacity that can differentiate successful from less successful wrestlers [6]; and, as such, is the focus of diagnostic testing of wrestlers.

As previously stated, a wrestling match includes explosive attacks and counterattacks that enable a wrestler to throw an opponent, pin him to the mat, or escape from critical bottom positions. All that effort requires a high level of muscular power in the lower limbs [6,7]. A study on Tunisian wrestlers showed the relationship between lower-body peak power evaluated by the Wingate test and performance on a specific wrestling test that included throwing a partner [8]. Moreover, elite wrestlers had higher vertical jump height and power compared to amateur wrestlers, indicating that vertical jump height (i.e., power of the lower extremities) is essential for wrestling success [9]. Furthermore, upper body strength, especially handgrip strength (HGS), is extremely important during the wrestling match for pulling, pushing, throwing maneuvers, and controlling the opponent [10]. HGS had a strong relationship with success in wrestling (ranking at the competition) and has been reported as an ability that differentiated successful from less successful junior and senior wrestlers [9,11].

In the wrestling community, coaches and scientists are interconnected with the common goal of developing and utilizing specific performance tests that will assess wrestlers' anaerobic and aerobic capacities [12]. One recently developed tests is the specific

wrestling fitness test (SWFT) which is constructed to imitate the demands of the wrestling match [13,14]. The SWFT consists of the maximal number of suplex throws (i.e., bridging and slamming the opponents/dummies on their backs) during three periods of 30 seconds with 20 seconds of rest between the throwing rounds [13]. This test can be a useful tool for directly evaluating a wrestler's physical and physiological readiness, specific level of fitness, and it has been proven to differentiate wrestlers of different qualities, with the assumption that it assesses the anaerobic energy system [15]. However, a study by Markovic et al. 2022, only evaluated differences according to specific tests. There was no attempt to compare the same group of tests with the tests that comprise the components of generic fitness. Moreover, a recent study on elite wrestlers did not record differences in SWFT performance between national team members and non-team members [16]. Authors believe that such findings were recorded because only elite athletes were included and suggested that future studies should also include lower-level wrestlers.

Generally, there is a low number of studies that investigated differences in fitness performances according to competitive success among young wrestlers, and such studies are especially lacking among Croatian wrestlers. Similarly, a few studies simultaneously investigated differences between quality groups in both generic and specific fitness tests in youth wrestlers. Thus, the aim of this study was to examine whether Croatian youth wrestlers differ in anthropometric indices and generic and specific fitness according to their performance (i.e., competitive) quality. We hypothesize that more successful wrestlers would have favourable body indices and better fitness test results than their less successful peers, which means that the selected tests and assessment tools would be able to differentiate wrestlers according to their performance quality. The results of this research would help clarify the factors that differentiate successful from less successful youth wrestlers and further determine which capacities are important for success in wrestling. Also, the study could be used as a guideline for selecting tests and assessment tools that are appropriate and able to differentiate the performance quality of youth wrestlers. Simply put, results could aid in creating training programs that help less successful wrestlers reach their full potential and become more successful.

3.2.2 Materials and Methods

Participants

This research included 49 Croatian Greco-Roman male wrestlers aged 17.75 ± 1.51 years, allocated to cadet and junior competitive categories. Wrestlers were selected from different clubs from four Croatian cities. To be included in the research, wrestlers had to have at least three years of wrestling experience to be able to perform all tests, with emphasis on the wrestling-specific test. Also, wrestlers with any illness or injury that might have prevented them from performing maximal tests were excluded from the study. The required sample size was 37 wrestlers, which was calculated according to the total sample of 170 wrestlers (69 cadets and 101 juniors) that competed at previous cadet and junior National Championship, meaning that a sufficient number of participants was included in this research. Wrestlers were divided into two quality/performance categories: medallists, wrestlers who won a medal at the National Championship (N=26), and non-medallists who did not win a medal at the National Championship (N=23). Wrestlers were informed about the aims and procedures of the research and signed an informed consent before the investigation began (legal guardians signed informed consents for participants under 18 years of age). The study was approved by the Ethical Board of the Faculty of Kinesiology, University of Split (Ref.no. 2181-205-02-05-22-0012).

Variables

This study included anthropometric indices, body composition, generic fitness tests, and a specific wrestling test.

Anthropometric indices included body mass (BM), body height (BH), body mass index (BMI), and body composition, i.e., body fat percentage. Body mass index was calculated using the following formula: BMI=BM(kg)/BH(m)2. Body fat percentage was calculated using the Slaughter-Lohman formula, which includes the sum of the triceps and calf skinfolds, measured by Harpenden skinfold calliper (British Indicators, Burgess Hill, England).

Generic fitness tests included HGS and the countermovement jump (CMJ). HGS was measured using the electronic hand dynamometer (Camry, Model EH101, Zhongshan Camry Electronic Co. Ltd. Kina). Wrestlers had three trials of maximum effort, with the

arm adducted and elbow flexed at 90º. The best result (i.e., the highest number) was taken for further analysis.

CMJ was measured by the Optojump system (Microgate, Bolzano, Italy). Athletes had to stand between the two photoelectric beams with their hands on their hips. They were instructed to assume the starting position and conduct a maximal vertical jump. Wrestlers had three jumping trials with a one-minute rest between the trials. The best result (i.e., the highest jump) was taken for further analysis.

A specific wrestling fitness test (SWFT) was used to determine sport-specific fitness. This test was recently developed by Markovic [13] and showed appropriate reliability and validity in wrestlers [14,15]. The participants throw a weighted dummy using the suplex technique, during three 30-second rounds performing a maximum possible number of throws, with 20 seconds of rest between the rounds. The weight of the dummy was adjusted according to weight categories: wrestlers who weight 55-67kg performed the test with a 23kg dummy, wrestlers in the 72-87kg category with a 25kg dummy, and wrestlers weighing over 90kg with a 30kg dummy. Athletes had heart rate monitors (POLAR H10, Polar Inc., Lake Success, USA) during the testing period and during the rest period after the test. Heart rate was observed immediately after the test ended and after one minute of rest. The test results included the total number of throws and the index, which was calculated as the sum of heart rate values divided by the total number of throws, as previously proposed [17].

Testing protocol

All testing procedures were conducted during the morning (to avoid diurnal variation) and by the same investigators. Testing was performed in a single day in the following order. Anthropometric indices were tested before initiating other physical testing procedures. After collecting anthropometric data, wrestlers completed a 15-minute warm-up session which consisted of running, jumping, mobility exercises, and wrestling-specific exercises that all athletes were familiar with and conducted at almost every training session. After the warm-up, wrestlers performed the CMJ and HGS tests. Finally, they performed 10-15 throws to familiarize themselves with the SFWT, after which they had a 5-minute break, followed by the SWFT.

Statistical analysis

The normality of the variables was checked using the Kolmogorov-Smirnov test. Descriptive statistics included means and standard deviations for all quantitative variables. As all variables were normally distributed, the t-test for independent samples was used to determine the differences between the two categories (medallists vs. non-medallists) in all variables. Also, discriminant analysis was performed to identify quality differences in a multivariate manner or, more precisely, to identify variables that predicted membership in the quality group. All analyses were conducted using Statistica 13.5 (TIBCO, Palo Alto, California) and applying a p-level of 0.05.

3.2.3 Results

Descriptive statistics and differences between medallists and non-medallists in all variables are shown in Table 1. It is evident that wrestlers do not differ in anthropometric indices or wrestling experience. However, they vary in performance variables in both generic and sport-specific tests.

Table 1. Descriptive statistics and differences between medallists and non-medallists in all variables.

	Medallists (n=26)		Non-medallists (n=23)		T-test	
Variable	Mean	SD	Mean	SD	t-value	p-level
Age (years)	18	1.36	17.46	1.64	1.29	0.20
Training experience (years)	7.28	2.64	6.20	2.80	1.33	0.19
Competing experience (years)	6.80	2.69	5.80	2.97	1.18	0.24
Body weight (kg)	79.01	16.2	76.59	12.37	0.59	0.55
Body height (cm)	177.27	7.31	177.61	7.66	-0.16	0.87
Body mass index	24.93	3.52	24.17	2.89	0.84	0.40

Body fat percentage (%)	14.6	7.10	15.83	6.18	-0.66	0.51
Countermovement jump (cm)	37.22	5.75	33.08	5.6	2.55*	0.01
Handgrip strength (kg)	51.55	7.22	45.87	7.06	2.77*	0.01
SWFT total throws	26.96	3.61	24.78	2.95	2.30*	0.03
SWFT total heart rate	347.11	19.93	342.5	18.16	0.60	0.55
SWFT index	12.92	2.19	13.98	1.83	-1.82	0.08

Note: n, number of subjects; SD, standard deviation; t, value of T-test; p, statistical significance; BMI, body mass index; kg, kilograms; cm, centimeters; %, percentage; SWFT, Specific Wrestling Fitness Test, * denotes statistically significant differences

Figure 1. shows differences in the variables that significantly distinguish quality groups of wrestlers, calculated by one-way ANOVA. It can be observed that medallists have better results than non-medalists in all tests, and the HGS (Figure 1B) is the variable that discriminates medalists from non-medallists the most, with medallists having better results.

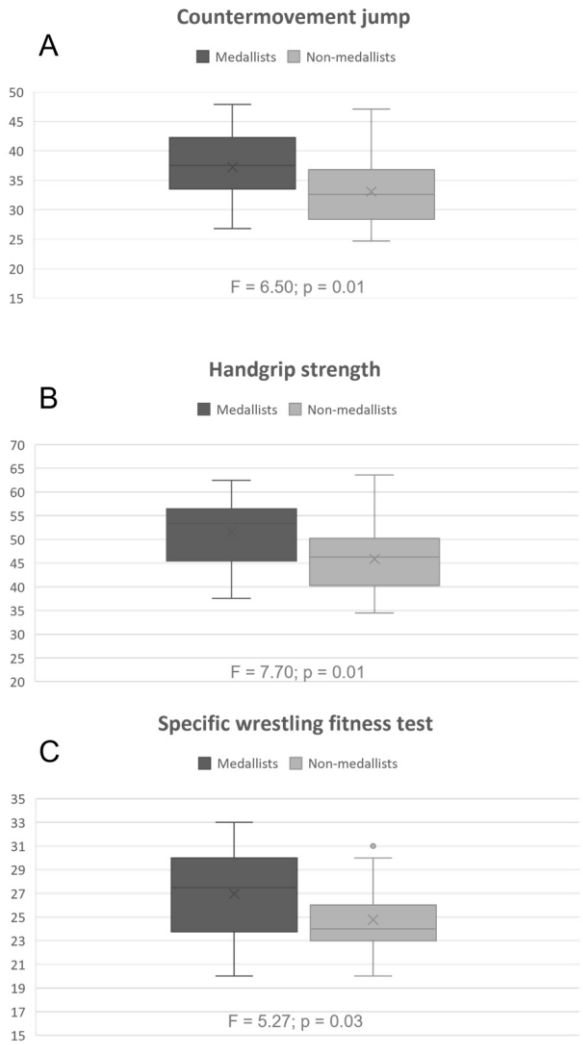

Figure 1. Graphical presentation of differences in the variables that significantly differentiate quality groups of wrestlers. A – Countermovement jump; B – Handgrip strength; C – Specific Wrestling Fitness Test total repetitions.

Results from the discriminant function analysis are presented in Table 2. The factor structure revealed that fitness variables (CMJ, HGS, and SWFT) almost equally account for classifying wrestlers into their performance groups, which was not the case for the anthropometric variables.

Table 2. Discriminant function analysis with function structure matrix according to performance categories.

Chi-Square Tests with Successive Roots Removed				
Eigenvalue	Canonical R	Wilks' Lambda	Chi-Square	p-value

0.37	0.52	0.73	13.2	0.04
Factor Structure Matrix				
Body weight			-0.19	
Body height			0.01	
Body fat percentage			0.16	
Countermovement jump			-0,64	
Handgrip strength			-0.69	
SWFT total throws			-0.59	

*Note: SWFT, Specific Wrestling Fitness Test

3.2.4. Discussion

This study investigated whether Croatian youth wrestlers differ in anthropometric indices and generic and specific fitness according to their competition performance. The main findings of this research are: (i) wrestlers did not differ in anthropometric indices, (ii) medallists had better results in generic fitness tests than non-medallists, (iii) medallists had better results in SWFT than non-medallists, and (iv) wrestlers did not differ in competition and training experience.

No differences in anthropometric indices between medallists and non-medallists

Supportive to the results of our research, elite and amateur wrestlers from five different countries did not differ in body height, body mass, body mass index, and body fat percentage [9], and similar was noted among young Turkish wrestlers [7]. The main reason for these results could be found in the fact that wrestlers are competing in separate weight classes, which means that they are of a similar body type within the competitive category. Indeed, it was proven that body composition and body type depend on the wrestler's weight category. For example, the endomorph-mesomorph somatotype dominates in the heavy-weight categories, while the balanced mesomorph somatotype prevails in the lighter weight categories [18]. Therefore, as we included competitors from different categories, it is possible that both winners and defeated wrestlers from the same weight class would have similar anthropometric indices. Also, it can be assumed that

anthropometric indices are not that crucial for success in younger age categories, and some other factors are more important (e.g., technical, tactical skills, generic, and specific fitness performance). It should be noted here that also the static balance of the spine plays an important role in athletic performance [19].

Differences in generic and specific performance between medallists and non-medallists

Superior HGS is essential for the explosive execution of wrestling techniques and the initiation of at-tacks. It is important to note that HGS has been observed as one of the most important predictors of wrestling success [20]. Our results showed differences in HGS between medallists and non-medallists, which is in accordance with numerous previous studies. Specifically, it was recorded that in senior and junior Iranian Greco-Roman wrestlers, successful wrestlers had 8-18% greater HGS than less successful wrestlers [11]. Moreover, elite wrestlers produced up to 19% more strength in the handgrip compared to amateur wrestlers [9]. Similarly, Turkish junior national team members had higher HGS values than wrestlers not selected for the national team [21]. Özbay and Ulupınar [22] investigated whether the results in the HGS test, within a battery of strength-power tests, would be different when the tests are performed after exhaustive exercise in junior or under-23 athletes that belong to top-elite and elite wrestlers. The researchers showed that top-elite wrestlers presented higher relative results in all tests, except vertical and horizontal jump tests, when the tests were performed after exhaustive exercise. A note that top-elite wrestlers produced a higher output in both lower-body and upper-body Wingate average power (relative), comparing to elite wrestlers, when the tests were performed after full rest [22].

Vertical jump performance differentiated successful from less successful young wrestlers in Croatia. It has previously been noted that elite wrestlers had higher values in the vertical jump test (CMJ) compared to amateurs (35.0 ± 3.5 and 31.9 ± 3.8cm, respectively) [9]. Moreover, successful Iranian wrestlers had higher vertical jump values measured by the Sargent jump test than less successful wrestlers [11]. The observed differences in jumping capacities could be explained by better neuromuscular characteristics (i.e., neural activation patterns) among more successful wrestlers [9]. Explosive movements from the lower limbs are essential for performing successful lifting and throwing techniques that often decide the outcome of the match. Therefore, results

indicate that wrestlers should work on their jumping capacities to enhance their overall performance.

Young wrestlers who were more successful in competitions also performed better in the specific wrestling test (i.e., SWFT). This finding is in accordance with several studies on older wrestlers that were published by the authors of the SWFT. More precisely, a study performed on Serbian wrestlers, aged 20-21, observed differences between wrestlers included in the first and second Wrestling League of Serbia, with first-league wrestlers having better results [23]. Moreover, adult wrestlers from three different competitive levels (national team wrestlers, first league, and second league wrestlers) differed in the SWFT performance, whereby higher-level wrestlers had better results (i.e., the higher number of throws) than lower-level wrestlers [15]. Therefore, according to the results of our study, it can be suggested that SWFT can be used for evaluating the specific physical fitness of young wrestlers, as it is sensitive to differentiating successful from less successful ones. This shows that this test can be a good indicator of a young wrestler's fitness status and can follow their development of specific performance, which is crucial for success.

No differences in training and competing experience between medallists and non-medallists

The finding that there were no differences in training and competing experience between medallists and non-medallists could seem surprising at first, but we will try to explain why this might have happened. The main reason lies in the fact that we included young wrestlers, who mostly start training harder and competing at the age of 10 years [24]. As authors, we are actively involved in the coaching practices for youth wrestlers, we will briefly try to describe these coaching practices.

Coaches try to stimulate young athletes with early competitions that are mainly low-level and friendly. Precisely, coaches go to competitions with children that have been involved in wrestling training not for a long time, even after just a few months of training. This way, coaches try to “break the routine” and provide children with more interesting situations alongside building a competitive nature of the sports training. Moreover, young wrestlers usually compete at competitions that are organized within or between clubs from the same city and county. This means that wrestling clubs organize frequent competitions on the community level, which are actually training sessions organized to

look like a competition (i.e., low-level competition or simulation of the competition). Thus, the wrestlers we included in this study reported that they started to compete at a very early age and after a short training time (even after a couple of months of wrestling training), regardless of the level of the competition they participated in. Therefore, all wrestlers had similar (i.e., high) training and competing experience, as they were included in wrestling training and competitions at an early age, and that could be why we did not record differences in competition success and fitness performance.

Limitations and Strengths

The main limitation of this study is the cross-sectional type of research and the inability to make more precise conclusions. However, this study could serve as a guideline for future longitudinal and intervention studies. We can suggest that future studies conduct the same tests but on several testing points (e.g., at the beginning and after performing exhaustive exercise or after consecutive tests). Also, researchers could try to develop and apply specific training programs aimed to improve capacities that were identified as important in this study (i.e., CMJ, HGS, and SWFT; power, strength, anaerobic capacity) which would enable more accurate conclusions about whether those capacities are essential for becoming a successful wrestler (i.e., medallist). Further, the strength of this research is that it included a respectful number of athletes of top and advanced quality, which is usually hard to collect and test. Also, the study could have important implications for coaches as it provides good examples of testing athletes.

Practical implications

This research has important practical implications. All tests included in this research assess different areas of the body and relate to various fitness parameters (power, strength, anaerobic capacity) that are essential for wrestling performance and are, most importantly, very easy and fast to conduct. Therefore, it could be suggested that coaches and practitioners include those tests during training and competition cycles to determine the performance status of their wrestlers. This way, coaches would be able to create optimal training programs that enable less successful wrestlers to develop the capacities essential to achieving better results and winning competitions. Also, coaches can use those tests to identify higher-quality wrestlers and select them for the National team.

3.2.5 Conclusions

This study's results noted that more successful wrestlers in competitions have better generic and specific sports performance, which means that selected tests can be used for fast and easy evaluation of wrestler's quality. Precisely, medallists had better results in the CMJ, HGS, and SWFT performance than non-medallists. Thus, these tests can be observed as very useful for determining the actual performance capacity of youth wrestlers. It should also be emphasized once more that these tests (CMJ, HGS, and SWFT) are very easy and fast to conduct, with minimal equipment, which makes them very feasible and appropriate for coaches to directly assess wrestlers' performance capacities. Regarding the fact that coaches often have limited time to conduct the diagnostic testing of their athletes, identifying tests that are easy, fast, and sensitive for evaluating essential performance parameters is of great importance. Moreover, we propose that those tests become a part of the universal fitness screening tests that all coaches in Croatia (or broader) should use. This would enable better connectedness of the coaches and National team selectors and lead to more precise and faster identification of successful wrestlers. This study identified which tests are able to differentiate successful from less-successful Croatian youth wrestlers, which has not been known previously.

Wrestling coaches and scientists are constantly trying to learn what separates successful from less successful wrestlers to develop training plans that would allow all wrestlers to reach their full potential. The results from this study can help in creating optimal training plans, after conducting several tests as proposed in this study. Precisely, according to the results of this research, coaches should be oriented in creating the training regimens that develop and enhance upper and lower limb strength and power and wrestling-specific strength and endurance.

Supplementary Materials: Available upon reasonable request.

Author Contributions: Conceptualization, K.Š., B.G., H.K., M.J., V.Š. and P.D.; Methodology, R.R.; Software, K.Š., B.G. and G.B.; Validation, H.K., G.B., M.R. and V.Š.; Formal analysis, K.Š., B.G., M.J., G.B. and V.Š.; Investigation, M.J., M.R., R.R. and P.D.; Resources, K.Š.; Data curation, B.G., H.K., M.J., M.R., V.Š. and R.R.; Writing—original draft, K.Š. and M.R.; Writing—review & editing, B.G.; Visualization,

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

Data Availability Statement: Data for the current analysis are available upon request and can be obtained by contacting the corresponding author.

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Article

Repetition of the Exhaustive Wrestling-Specific Test Leads to More Effective Differentiation between Quality Categories of Youth Wrestlers

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Abstract: This study aimed to investigate whether wrestlers of different competitive qualities (i.e., medalists vs non-medallists) would differ in terms of specific test performance and cardiac and metabolic responses after a demanding testing protocol. The research included 29 wrestlers aged 17.62 ± 1.86 years divided into two performance categories: successful (medallists at the National Championships; n = 13) and less successful (non-medallists; n = 16). The variables included anthropometric indices and specific wrestling fitness test (SWFT) parameters, including the number of throws, heart rate, lactate concentration and calculated cardiac and metabolic indexes. To show differences between quality categories, Student's *t*-test and receiver operating characteristic curves (ROC) were calculated. Two-way ANOVA for repeated measurements was used to evaluate the differences in performance, cardiac, and metabolic characteristics between the test trials and quality categories. Wrestlers differed in the total number of throws ($p < 0.01$, AUC = 0.82), cardiac indices ($p < 0.03$, AUC = 0.73), and metabolic indices ($p < 0.04$, AUC = 0.75) after the second SWFT trial, with successful wrestlers reaching better results. There were no differences in the first testing trial. The findings of this study indicate that wrestlers exhibit differences in specific performance variables after undergoing an exhaustive testing protocol. Therefore, this study suggests that future research on sport-specific performance in wrestlers should include exhaustive exercise or testing protocols.

Keywords: physical performance; sport specific; testing; youth athletes; anaerobic capacities; combat

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1. Introduction

Wrestling is an Olympic sport characterized by intermittent activity requiring developed technical and tactical abilities and physical capacities. Olympic-style wrestling includes Greco-Roman and Freestyle wrestling, with the match consisting of two rounds lasting 3 min with a 30 s break between the rounds [1]. Wrestling matches are extremely dynamic and include sudden attacks and counterattacks interspersed with actions for controlling the opponent [2]. Thus, wrestling matches demand constant engagement, which means that aerobic and anaerobic metabolic energy systems are involved during the match [2,3]. Specifically, the aerobic metabolic energy system provides the energy for enduring continuous effort. It enhances recovery, while the anaerobic metabolic energy system is engaged during movements under submaximal and maximal loads [3–5]. Notably, 90% of the total energy generated during a wrestling match comes from the anaerobic energy system, meaning that anaerobic glycolysis is most prevalent during the match [6,7]. Moreover, the anaerobic system produces energy for quick bursts of maximum power, such as sudden lifts and

3.3.1 Introduction

Wrestling is an Olympic sport characterized by intermittent activity requiring developed technical and tactical abilities and physical capacities. Olympic-style wrestling includes Greco-Roman and Freestyle wrestling, with the match consisting of two rounds lasting 3 min with a 30 s break between the rounds [1]. Wrestling matches are extremely dynamic and include sudden attacks and counterattacks interspersed with actions for controlling the opponent [2]. Thus, wrestling matches demand constant engagement, which means that aerobic and anaerobic metabolic energy systems are involved during the match [2,3]. Specifically, the aerobic metabolic energy system provides the energy for enduring continuous effort. It enhances recovery, while the anaerobic metabolic energy system is engaged during movements under submaximal and maximal loads [3–5]. Notably, 90% of the total energy generated during a wrestling match comes from the anaerobic energy system, meaning that anaerobic glycolysis is most prevalent during the match [6,7]. Moreover, the anaerobic system produces energy for quick bursts of maximum power, such as sudden lifts and throws, which are crucial parts of the wrestling match [8]. Therefore, as crucial wrestling movements occur in the anaerobic metabolic pathway, wrestling performance in the anaerobic energetic system has been the focus of diagnostic work [9].

One of the recent sport-specific tests that was created to mimic the physical and metabolic loads of the wrestling match is the Specific Wrestling Fitness Test (SWFT). The SWFT simulates the time and load structure of the match. Specifically, SWFT is intermittent and consists of three rounds of 30 s maximum dummy throws with 20 s rest between the rounds [10]. Indeed, it has been reported that SWFT evoked cardiac and metabolic responses similar to ones after a wrestling match (i.e., maximal heart rate and blood lactate concentration of 10-20 mmol/L) and are associated with submaximal aerobic performance variables [11,12]. However, it predominantly evaluates the anaerobic glycolytic system, in which most of the actions are performed during the wrestling match [13]. Moreover, the SWFT is valid for differentiating successful from less successful adult wrestlers in Serbia and youth wrestlers in Croatia, which implies that the SWFT can be used for evaluating the specific physical performance of wrestlers [13–15].

A wrestling match can elevate blood lactate to high concentrations of nearly 20 mmol/L, which directly influences muscle contractile mechanisms by interrupting ac-tin-myosin

cross-bridge interactions [16]. Also, the wrestling match places high demands on the heart and can increase the heart rate to the maximum value [17]. Additionally, the high neuromuscular demand of the upper and lower limbs during a wrestling match may cause decrements in performance [18]. Indeed, a study on collegiate wrestlers re-ported a reduction in physical performance as a result of tournament wrestling [11]. Specifically, as a wrestling match includes isometric grasping for maintaining one's position, the handgrip strength was reduced in response to tournament wrestling. Furthermore, as the majority of actions are performed with powerful leg movements, the lower body power was reduced after one match [11]. Notably, a study on top-level junior and under-23 wrestlers indicated that strength and power tests performed after exhaustive exercise are better at discriminating between elite and top-elite wrestlers [19].

The capacity to endure as long as possible and maintain the highest level of muscular strength and power is crucial for winning in combat. This is especially important in combat sports, as strength–power interactions performed despite fatigue represent a determinative factor [18,20,21]. Thus, testing physical performance after exhaustive exercise or repeated tests should be more sensitive than testing at rest for differentiating successful from less successful athletes [19]. Therefore, this study aimed to investigate whether youth wrestlers of different competitive qualities (i.e., medallists vs. non medallists) would differ in the performance, cardiac, and metabolic parameters of SWFT after repeating tests, which created a physically demanding testing protocol that mimics real-life match situations. We hypothesized that successful wrestlers would have more favourable cardiac, metabolic, and performance responses after repeated tests than would less successful wrestlers.

3.3.2 Materials and Methods

Participants

The research included 29 Greco-Roman wrestlers from Croatia aged 17 ± 1 years with training experience of 6 ± 3 and competing experience of 6 ± 3 years who were competing in the cadet and junior categories. Wrestlers were divided into two performance categories: successful wrestlers were medallists, i.e., wrestlers who won a medal at the National Championship in 2022 (n = 13), and less successful wrestlers, non-medallists (n = 16). The main characteristics of the successful wrestlers were as follows: body height, 180 ± 7 cm; body mass, 83 ± 16 kg; body mass index, 25 ± 3; body fat percentage,

15 ± 5%; and competing experience, 7 ± 4 years. The main characteristics of the less successful wrestlers were as follows: body height, 177 ± 7 cm; body mass, 76 ± 14 kg; body mass index, 24 ± 3; body fat percentage, 17 ± 6%; and competing experience, 5 ± 2. years. The inclusion criteria were at least three years of wrestling experience and participation in the National Championships. This way, researchers wanted to be sure that wrestlers have appropriate knowledge of wrestling techniques and can execute the included tests correctly. The exclusion criterion was having any illness or medical condition that prevents wrestlers from maximally executing the tests included in the testing procedure. It is important to note that all the included wrestlers were competitors and not recreative individuals, which means that they all had highly developed physical capacities and wrestling skills. The sample size was computed through the statistical programme G*power using the data of the previous similar research with an effect size of 1.77 in the SWFT total number of throws variable, with the power of 0.95, resulting in a calculated 20 participants [22,23].

Participants were informed about the testing procedures and aims of the investigation and signed an informed consent (legal guardians signed an informed consent for participants under 18 years of age). The Ethical Board of the Faculty of Kinesiology, University of Split, approved this study (Ref. no. 2181-205-02-05-22-0012).

Variables

This research included anthropometric indices and specific wrestling fitness test parameters (heart rate, blood lactate, and performance indicators).

The SWFT is a relatively new specific wrestling test. The SWFT consists of 3 rounds of 30 s of maximal dummy throws followed by 20 s of rest after each throwing round (please see Figure 1 for details). Since the athlete's body mass plays a role in physical performance indicators, wrestlers perform the SWFT with a specific weight. Precisely, the weight of the dummy was allocated to each wrestler according to weight category as follows: the 55–67 kg category was tested with a 23 kg dummy, the 72–87 kg category was tested with a 25 kg dummy, and wrestlers weighing more than 90 kg were tested with a 30 kg dummy. The main result of the test was the total number of throws generated during all three throwing rounds [10].

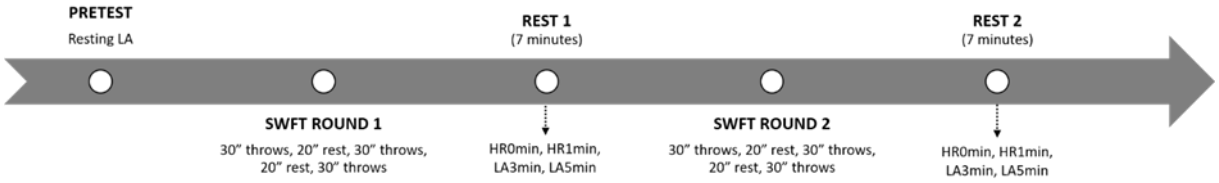

Figure 1. Testing procedure. Note: LA—blood lactate concentration, SWFT—Specific wrestling fitness test, HR0—heart rate directly after the test, HR1—heart rate after the first minute of recovery, LA3min—lactate concentration in the third minute of recovery, and LA5min—lactate concentration in the fifth minute of recovery.

In addition to the total number of throws, metabolic and cardiac indicators were included to provide insight into the physiological strain of the test. Specifically, the metabolic indicator was the lactate concentration in the capillary blood in the third (LA3min) and fifth minute (LA5min) of recovery, which represents achieved metabolic acidosis. The lactate concentration was measured by an experienced researcher using a portable lactate analyzer (Lactate Plus-NOVA Biomedical, MA, USA), and the results are expressed in mmol/L. All lactate samples were drawn from capillary blood drawn from the fingertip and from different fingers each time. The cardiac indicator was the frequency of the pulse, which represents the load on the cardiovascular system. Participants wore heart rate belts (POLAR H10, Polar, Inc., Lake Success, NY, USA) around the chest during the entire test. The heart rate was observed immediately after the test (HR0min) and after the first minute of recovery (HR1min), expressed in beats per minute.

The absolute performance measures (number of throws), metabolic (blood lactate concentrations), and cardiac (heart rate) response measures were integrated into performance-specific index measures of the SWFT. Specifically, the SWFT index 1 represents the cardiac response and was calculated in the same way as the judo fitness index: SWFT index 1= (HR0 + HR1)/total number of throws [34]. The SWFT index 2 represents the cardiometabolic response and was developed by Markovic et al. (2017), calculated as follows: SWFT index 2 = ((HR0min + HR1min)/(LA3min + LA5min)) ×* a total number of throws [10].

Testing Procedures

All testing procedures were conducted during the morning to avoid diurnal variations. First, body mass, body height, body fat percentage (skinfolds), and resting blood lactate concentrations were measured. After that, all the athletes underwent the same warm-up routine. Specifically, the warm-up consisted of 15 min of general warm-up, which included mobility exercises, running, and skipping for elevating heartbeats, and dynamic stretching exercises. Afterward, all participants practised throwing the dummy for 10 minutes of intermittent throwing, emphasizing the suplex throwing technique. Notably, we included experienced wrestlers who were proficient at throwing the dummy with the suplex technique.

After the warm-up, the first round of the SWFT was performed. Immediately after the first trial of SWFT, participants were resting for 7 min, and blood lactate concentrations were analyzed during the third and fifth minutes of rest. After the rest, participants again performed SWFT (the second round), after which they rested for 7 min, and all the testing procedures were the same as those used during the first resting phase. Typically, a 20 min rest is provided for wrestling/combat tests and competitions because this rest mimics the actual situation during the competition (i.e., a minimum of 20 min between two matches) [24]. However, the SWFT lasts for 3 min, which is one period of real wrestling match duration (a wrestling match consists of two rounds of minutes of fight); this is why we decided that wrestlers would have 7 min of rest, which corresponds to a work-to-rest ratio of 1:2.5. Additionally, we wanted to create a situation where the recovery ability of wrestlers would be evident, as differentiating the quality of wrestlers was the main aim of this investigation. The detailed testing procedure is shown in Figure 1.

Statistical Analysis

The Shapiro–Wilk W-test was used to determine the normality of the distributions of all the variables included. The means and standard deviations were included as the descriptive statistics.

Since all variables were normally distributed, the parametric tests were used to answer the research questions. To show differences between quality categories (i.e., successful vs. less successful wrestlers), the Student's t-test for independent sample analysis was used. Furthermore, to establish which variables are better at classifying wrestlers as successful or less successful, a receiver operating characteristic (ROC) curve was generated, with an area under the curve (AUC) greater than 0.70 indicating differences

in the selected variables [25]. Also, the ROC cut-point values of the SWFT parameters were calculated [26]. Furthermore, two-way analysis of variance (ANOVA) for repeated measurements (trials × group) was used to examine the variations in performance, cardiac, and metabolic characteristics between testing trials based on quality categories.

The statistical package Statistica ver. 14 (Tibco, Palo Alto, CA, USA) was utilized for all analyses.

3.3.3 Results

Descriptive statistics and differences between quality categories are presented in Table 1.

Table 1. Descriptive statistics and differences between quality categories.

	Successful (n = 13)		**Less Successful (n = 16)**		***t*-Test**		**ROC**	
Variables	Mean	SD	Mean	SD	*t*-value	*p*	AUC	95% CI
SWFT1 TT	26.08	3.99	23.87	2.42	1.79	0.09	0.63	0.38–0.89
SWFT1 INDEX HR	13.49	2.29	14.55	1.58	−1.42	0.17	0.64	0.42–0.86
SWFT1 INDEX LA	326.52	60.46	293.59	45.92	1.45	0.16	0.68	0.44–0.93
SWFT2 TT	24.5	2.43	21.6	2.47	3.05	0.01	0.82	0.63–1.00
SWFT2 INDEX HR	14.39	1.68	16.29	2.5	−2.25	0.03	0.73	0.53–0.92
SWFT2 INDEX LA	287.92	36.18	254.3	36.22	2.17	0.04	0.75	0.54–0.96

Note: SWFT—Specific wrestling fitness test, TT—total throws, SWFT1—The first trial of the Specific wrestling fitness test, SWFT2—The second trial of the Specific wrestling fitness test, INDEX 1—index calculated regarding heart rate and the total number of throws, INDEX 2—index calculated regarding heart rate, lactate concentration and total

number of throws, HR—Heart rate, LA—blood lactate concentration, ROC—Receiver operating characteristics, AUC—Area under the curve, and CI—confidence interval.

According to the results of the independent sample t-test, wrestlers differed in terms of the SWFT performance variables and cardiac and metabolic indices during the second testing trial (i.e., SWFT2 total throws, SWFT2 INDEX HR, and SWFT2 INDEX LA), while such differences were not observed in the first testing trial. These differences were additionally confirmed with ROC (area under the curve values), with SWFT2 total throws, SWFT2 INDEX HR, and SWFT2 INDEX LA reaching values greater than 0.70 (Table 1).

Figure 2 presents the ROC and AUC of the SWFT variables. It is evident that the SWFT total number of throws during the second testing trial had the greatest sensitivity for categorizing wrestlers as successful. Moreover, the ROC identified the cut points for the observed variables with an area under the curve (AUC) greater than 0.70. Specifically, the cut point value of 24.50 for SWFT2 total throws and, value of 261.26 for SWFT2 INDEX LA were identified, meaning that wrestlers who reach scores higher than those cut points are more likely to be categorized into a better performance quality group. Moreover, wrestlers who reach a value lower than 15.16 for SWFT2 INDEX HR are more likely to be categorized into better performance quality.

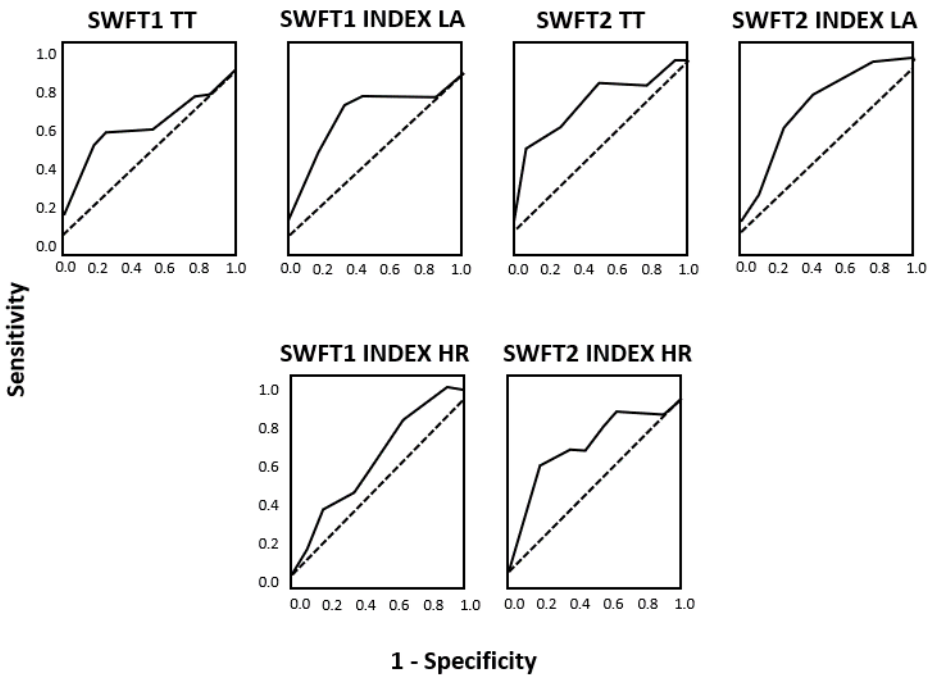

Figure 2. Receiver operating characteristics (ROC) curves for SWFT variables for differentiating quality categories. Note: SWFT1—The first trial of the specific wrestling fitness test, SWFT2—The second trial of the Specific wrestling fitness test, TT – total number of throws, LA—blood lactate, HR—heart rate, INDEX HR—index calculated regarding heart rate and a total number of throws, and INDEX LA—index calculated regarding heart rate, lactate concentration and a total number of throws. The dashed line represents reference line (AUC = 0.5).

Furthermore, to gain a detailed insight at which point of the testing procedure and in which parameters appear the most significant differences between performance categories, Figure 3 is presented. Figure 3 shows a graphical representation of the two-way ANOVA results for the SWFT parameters. As shown in Figure 3A, the most visible changes between quality categories occurred at the first throwing round during the second SWFT trial. Lactate concentrations (Figure 3B) and heart rate responses (Figure 3C) were similar among the quality categories across the testing procedure.

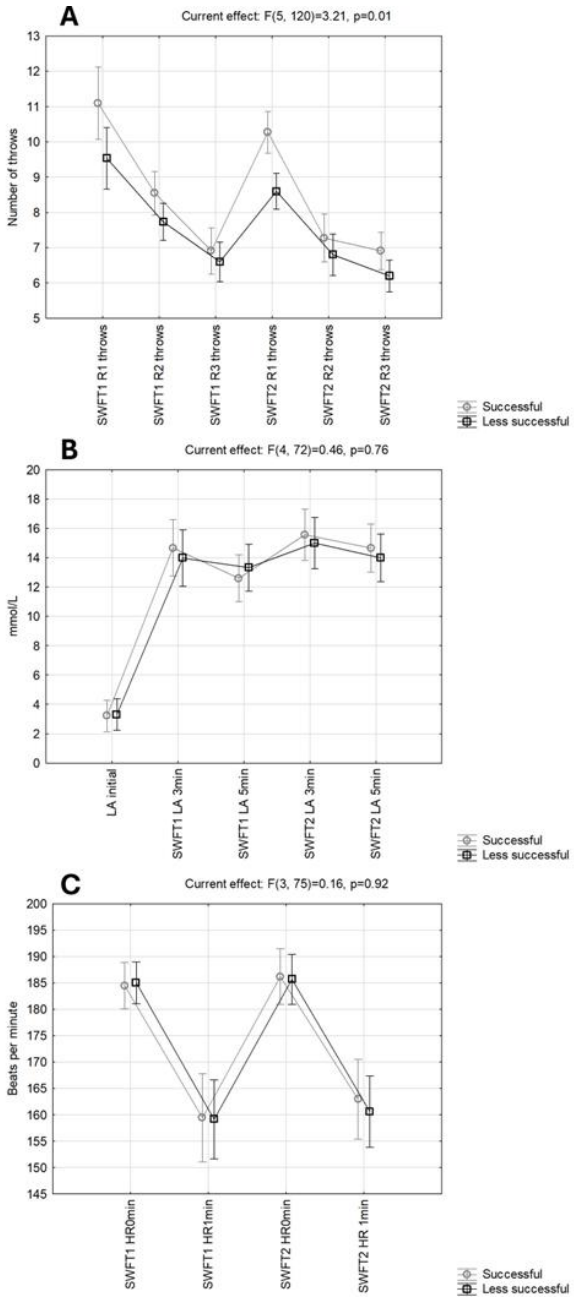

Figure 3. Two-way ANOVA for the SWFT throws cardiac and metabolic variables: (A) SWFT number of throws; (B) lactate concentrations; (C) heart rate. Note: SWFT1—The first trial of the specific wrestling fitness test, SWFT2—The second trial of the Specific wrestling fitness test, LA—blood lactate concentration, HR0—heart rate directly after the test, HR1—heart rate after the first minute of recovery, LA3min—lactate concentration in the third minute of recovery, and LA5min—lactate concentration in the fifth minute of recovery.

3.3.4 Discussion

The main objective of this study was to investigate whether wrestlers of different competitive qualities would differ in the performance, cardiac, and metabolic parameters in SWFT after repeating tests which created physically demanding testing protocols. According to the objectives, the main findings of this research are as follows: (i) Wrestlers of different competitive qualities did not differ in cardiac or metabolic variables in either of the SWFT trials; (ii) Wrestlers of different competitive qualities differed in terms of performance variables; successful wrestlers achieved a greater number of SWFT throws and had more favourable SWFT indexes in the second testing trial than did less successful wrestlers. Therefore, our study hypothesis can be partially accepted.

Differences in Cardiac and Metabolic Variables during Repeated Trials of Specific Wrestling Fitness Tests

The finding that cardiac and metabolic variables did not differ between wrestlers of different competitive qualities in either testing trial can be explained as follows. The noted results are supported by the results of previously published studies using a similar methodology. Specifically, a study on adult wrestlers from Serbia reported that the cardiac and metabolic responses of national, first, and second-league wrestlers did not differ according to the SWFT [13]. Moreover, a study on Croatian wrestlers revealed no significant differences in the La concentrations accumulated during a wrestling match between the national team and club-level wrestlers [7]. This could be explained by the fact that the SWFT and the biggest part of the wrestling match are predominantly anaerobic-glycolytic activities, which lead to high production and accumulation of blood La, placing high demands on aerobic metabolism (cardiovascular functions) to remove La from the blood during recovery [7,13]. Therefore, wrestling-specific performance corresponds to match requirements and leads to adaptations in cardiac and metabolic outputs [22].

To simplify, more successful wrestlers had advanced cardiac and metabolic adaptations, which allowed them to achieve better results and to resist fatigue during the testing trials, even though their absolute measures of physiological response were similar to those of less successful wrestlers. A similar explanation was provided by Marković, Toskić, Kukić, Zarić, and Dopsaj [13], who noted that wrestlers at higher levels could deliver larger amounts of oxygen to muscles included in the test for the same HR and execute a

greater number of throws for the same La concentrations, which was explained by the increased oxygen capacity and higher contraction intensity of the muscle resulting from peripheral adaptation [13,27]. A study on Croatian wrestlers aged 15-20 years that examined the dynamics of blood lactate production hypothesized that training-induced metabolic adaptations enable high-quality wrestlers to operate for longer periods and under greater loads, and they also create more blood lactate at greater intensities and remove it faster [28]. This might also be affected by increased buffering capacity, which enables well-trained athletes to generate ATP via glycolysis [29].

According to the results of our study and those of similar previous studies, the absolute values of cardiac and metabolic variables (i.e., HR and La) are not accurate representations of physiological response because they do not consider the efficacy of the work that the wrestler is performing [30]. Therefore, cardiac and metabolic responses to effort should be adjusted to real performance because wrestlers with greater performance and the same cardiac and metabolic responses have better specific training adaptations and overall physical performance. Thus, the creators of the SWFT have proposed using index values that take into account cardiac and metabolic responses calculated together with performance values (i.e., number of throws) [10]. Indeed, our study revealed that successful wrestlers had favourable SWFT index HR and index LA during the second test round of the SWFT, which represent cardiac and metabolic responses that accounted for the total number of throws performed. However, it must be emphasized that these differences were noted only in the second test round, which is the main novelty of this study and is described in the following paragraph.

Differences in Performance on Repeated Trials of Specific Wrestling Fitness Tests

The result that successful wrestlers performed more SWFT total throws and had better SWFT index HR and LA in the second testing trial than did less successful wrestlers is the most interesting result of this study. Indeed, this result supports the hypothesis that wrestlers of better performance quality can better endure the physical load which supports the statement that strength–power interactions performed despite fatigue represent a determinative factor in combat [31]. Also, the result that the second testing round was better for discriminating performance quality supported the results of a previous study which concluded that strength and power tests performed after exhaustive exercise are better at discriminating between elite and top-elite wrestlers [19]. Our results

can be compared to those of previous studies using the same test (i.e., the SWFT) for differentiating wrestlers according to performance and competitive quality. Specifically, a study on Serbian wrestlers evaluated the differences in performance among the national team, first-league, and second-league wrestlers and reported that higher-level wrestlers outperformed lower-level wrestlers in terms of the number of throws and the SWFT cardiac and metabolic indices [13]. However, we tested wrestlers on repeated trials of SWFTs and revealed that during the second testing trial, the most significant difference was observed between the performance qualities of the wrestlers.

The most decisive moments of wrestling combat appear when wrestlers are exhausted, tired, or unable to respond quickly to their opponent's actions [11]. Therefore, the finding that the second round of the SWFT was more sensitive than the first round of the SWFT supports this previous notion: successful wrestlers managed to perform a greater number of throws when fatigued. Additionally, it is important to mention from the results of this investigation that the most significant differences in SWFT performance appeared in the first round of throws during the second SWFT trial (please see results for details), which also indicates that more successful wrestlers were able to recover better and faster from the first SWFT trial. Notably, a study that investigated the acute physiological changes caused by wrestling tournaments reported that muscle damage markers (i.e., lactate dehydrogenase, creatine kinase, and interleukin) significantly increased during a one-day tournament, which indicates that wrestling matches place significant physiological demands on athletes and affect their performance [32]. Additionally, a study which evaluated psychological and performance changes during a one-day wrestling tournament reported a progressive rise in fatigue rating, muscle damage markers, and the inflammatory response which supported that performance is affected especially during the later rounds of the tournament [33]. Thus, better muscular capacity and physical performance of the wrestler can enable them to endure high physiological demands and stimulate recovery between matches or, in this case, between testing trials.

Limitations and Strengths

The main limitation of this study is that wrestlers were tested at the end of the competition season, and testing during different points of the season could lead to different results. Thus, a similar testing procedure should be conducted at several main points during the competition season (e.g., beginning, mid-season, and end of the season among the same

wrestlers). Additionally, we included only male participants, so the results and conclusions from this study cannot be generalized to female participants. Moreover, the relatively small sample size does not warrant generalizations of the results, which means that similar future studies should try to include a larger number of athletes. Also, more direct parameters such as muscle oxygenation, maximal oxygen uptake, mitochondrial respiration, liver function test for determining the lactate clearance, and pulmonary function test, which could improve the understanding of the observed issue, were not conducted in this research, but are suggested to be evaluated in future studies.

The main strength of this study is that cardiac, metabolic, and performance variables were recorded at several time points during the testing procedure, which helps to track the response of the athletes to the given effort. In this way, it was possible to determine in detail which parameters are decisive for optimal performance and which are the most important parameters for competitive success. Also, the strength of this research is that competitive-level wrestlers were included, as it is always challenging for researchers to include elite athletes.

Practical Implications

The development of tests and testing procedures that can predict wrestling performance has great usefulness for coaches and competitors. Regular monitoring of sport-specific performance is important for increasing the odds of success in competitions. The result that the competitive quality of the wrestlers was distinguished after the second testing trial implies that tests should be performed after a specific exhaustive exercise protocol and not at full rest to be more effective at determining the performance quality of wrestlers. In other words, the quality of the wrestler is determined during the decisive moments of the fight, which occur when the wrestlers are usually tired and exhausted, meaning that the one who can endure and overcome fatigue will be able to conduct actions that determine the match outcome (i.e., throwing the opponent). Thus, the practical implication of this study is that coaches and sports scientists should be advised to include more sport-specific tests and to conduct them after a standardized exhaustive protocol.

Moreover, the finding that cardiac and metabolic responses (HR and LA concentrations) did not distinguish the quality of the wrestlers, while the performance and index variables did, could lead to the suggestion that SWFT can be used with and without measuring HR

and LA concentrations. This is important to note because heart rate and lactate monitoring are expensive and usually unavailable for coaches, while performance variables (i.e., number of throws) during SWFTs are relatively easy for coaches to measure.

3.3.5 Conclusions

Wrestlers differed according to competitive quality in terms of the specific performance variables (i.e., SWFT total throws) after the exhaustive testing protocol, between the two testing trials. The findings of this study indicate that wrestlers exhibit differences in specific performance variables after undergoing an exhaustive testing protocol, and that wrestlers at higher levels could deliver larger amounts of oxygen to muscles included in the test for the same HR and execute a greater number of throws for the same La concentrations. This finding suggested that the performance of wrestlers in sport-specific actions is better assessed when they are tired, as the exhaustive protocol may reveal their true capabilities and distinguish between different performance levels. These findings have implications for the evaluation and training of wrestlers, highlighting the importance of incorporating sport-specific tests after exhaustive exercise, match or testing protocols to accurately assess their performance and tailor training programs accordingly. Therefore, future research on sport-specific performance in wrestlers in all age groups and weight categories should be conducted after exhaustive exercise or testing protocols.

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Motivation Profile of Youth Greco-Roman Wrestlers; Differences According to Performance Quality

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Abstract: Athletes have to possess high motivation levels to perform each training session and competition at the highest level. Thus, the motivation of the wrestler is essential to reach the highest performance quality. The research included 47 Greco-Roman wrestlers aged 17.71 ± 1.62 years. Variables included anthropometric indices, sports motivation assessed by the revised Sport Motivation Scale (SMS-II), and competitive success (medal winners and non-winners at the National Championship). The Cronbach's alpha coefficients checked the internal consistency of the SMS-II. Differences between performance quality were determined by Cohen's d effect sizes, and MANOVA for motivation and anthropometric variables/body build variables. In the total sample, wrestlers had high levels of intrinsic motivation (5.97 ± 0.90), integrated (5.99 ± 0.83), and identified (6.08 ± 0.82) regulation, while they had low amotivation (2.53 ± 0.98) and external regulation (3.26 ± 1.24). Successful wrestlers had significantly higher intrinsic motivation than less successful wrestlers (Cohen's d = 0.76, moderate effect size). Results evidenced that wrestlers have high self-determined motivation, which is vital for maximal performance and persisting in sports. Future research should investigate wrestlers from other age groups to ultimately determine the sport motivation profile of wrestlers and enable their optimal sports development.

Keywords: athletes; combat; competition; self-determination theory; sport psychology

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1. Introduction

Successful wrestlers have to possess high levels of physical and psychological readiness as wrestling is deemed to be an extremely demanding sport [1,2]. Indeed, a wrestling match consists of two rounds lasting three minutes with only a 30 s break between the rounds. During the match, wrestlers are constantly performing high-intensity attack and defense maneuvers in the submaximal and maximal physiological zones [3]. Thus, wrestlers must possess highly developed anaerobic capacities, and the ability to endure high energy demands during the entire match [4]. Numerous studies that investigated success factors of wrestlers identified that anaerobic power, strength endurance, upper and lower body strength, and technical skills, such as a throw over the hip and a supplex throw differentiate successful from less successful wrestlers [5].

When observing complete athletic performance and determinants that are important for identifying athletic talents, studies are contradictory as some consider that sports success is genetically predetermined, while others believe that highly motivated practice leads to sports success. A review study that aimed to collect studies regarding precursors and prerequisites of athletic talent and sports success noted that apart from appropriate body status and sport-specific abilities (i.e., strength, endurance, and explosiveness), psychological factors perform an essential role in becoming a top-performance athlete [6]. Specifically,

3.4.1 Introduction

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Researchers mainly strive to find out how to affect and predict performance. Hence, sports psychologists aim to determine performance predictors, with mood states being one of the leading research topics. Specifically, the relationship between the profile of mood states (POMS) and sports performance has been extensively examined over more than 50 years since it was shown that it could predict sports outcomes [9]. In that manner, it was noted that successful athletes had lower tension, depression, anger, confusion, and

fatigue, while they had higher vigor than less successful athletes [10]. Moreover, it is proposed that POMS subscales have greater predictive power for sports success in short-duration and individual sports [9]. For example, it was shown that anger could improve performance in short-duration sports, such as judo, karate, and wrestling [11]. All the aforementioned regarding POMS research could be related to explaining the psychological background that determines success in sports performance, which is described in more detail in further text.

Regarding the fact that wrestling is an extremely physically demanding sport, it is logical to assume that to endure high physical requirements, wrestlers must also have a highly developed psychological component. Additionally, psychological factors are essential as wrestling is a sport where two athletes perform in order to achieve a superior position using both body and intelligence [12]. What is essential is that wrestlers must possess high levels of motivation to perform each training session and competition at the highest level [13]. Additionally, competitors rely on themselves; therefore, their motivation to perform is responsible for reaching competitive success. Motivation is defined as "the direction and intensity of action" and includes factors influencing behavior [14]. Motivation enables an individual to be attracted to the targeted activity and depicts why people act the way they do in specific situations [14].

In a sports context, motivation relates to the presence of processes and factors which stimulate athletes to be active or inactive in different situations. The self-determination theory (SDT) is the most complete and stable framework regarding sport motivation in various contexts, as it emphasizes the necessity of the drive influenced by the need for autonomy and self-actualization [15]. SDT states that athletes are usually motivated by either external factors (e.g., rewards, pressure from opponents, and peoples' opinions) or internal factors (e.g., curiosity, desire to grow, and self-improvement) [16]. Additionally, it describes how different motives are associated with involvement in physical activity and sports in different ways [17]. SDT depicts motivation as a continuum ranging from amotivation (lack of motivation) through extrinsic (controlled) motivation to intrinsic motivation, which is the most self-determined and autonomous.

According to the SDT, a Sport Motivation Scale (SMS) has been constructed [18], and recently, a revised scale named SMS-II has been validated and gained increased research use in various sports [15,19]. SMS-II consists of six subscales, ranging from amotivation

(least self-determined type of motivation), external motivation, which includes external, introjected, identified, and integrated regulation, to the most self-determined type of motivation: intrinsic motivation [15]. The least self-determined type of behavior regulation is the amotivation, which relates to the state where an individual does not have any impetus to act. Furthermore, extrinsic motivation consists of four constructs: (i) external regulation; (ii) introjected regulation representing the con-trolling and least self-determined construct of extrinsic motivation because they rep-resent motivation to obtain external rewards (e.g., money, medals) and avoid punishments; (iii) identified regulation which is not entirely external, where behavior is commenced out of choice; and (iv) integrated regulation, the most self-determined type of extrinsic motivation, that describes personally endorsed behaviors becoming coherent, assimilated, and integrated within the self. Finally, the most self-determined and autonomous form of motivation is intrinsic motivation, which is based on the drives of satisfaction and joy [15]. Intrinsic motivation leads to voluntary participation in the sports activity with an absence of external pressures and rewards, which means that participation in the activity is for the satisfaction, fun, interest, and pleasure [18]. Therefore, it was hypothesized that athletes with higher intrinsic motivation would be more persistent and committed to sport, which leads to better sports performance.

SDT has been confirmed as an appropriate framework for understanding and promoting motivation in sports [20,21]. Therefore, SDT could also be interesting for observing the sport motivation profile of wrestlers. Indeed, it could be assumed that motivation is highly important for success in wrestling competitions. Therefore, the present study aimed to determine (i) the sport motivation profile of youth wrestlers and (ii) differences in motivation according to the quality of wrestlers (i.e., competitive success). The results of this study could help coaches and practitioners elucidate the motivation profile of their athletes, which could help develop the wrestler's optimal performance.

3.4.2 Materials and Methods

Participants

This study included 47 Croatian Greco-Roman wrestlers aged 17.71 ± 1.62 years with a training experience of 6.89 ± 2.75 years. The calculated required sample size was 37 wrestlers, as the overall population of young wrestlers that participated in National Championship was 170 (cadets and juniors). The inclusion criteria were at least two years

of structured wrestling training and participating in National competitions. This way, the authors wanted to make sure that included wrestlers have experience and developed a psychological profile that relates to this particular sport. The exclusion criteria were any illness or injury over the last two months, or any other condition and situation that could have prevented wrestlers from regular training and providing their maximum during the tests. Participants were informed about the study procedures before the initiation of the study, and participants or their legal guardians (for participants under the age of 18) signed informed consent. The study was approved by the Ethical Board Faculty of Kinesiology, University of Split (Ref.no. 2181-205-02-05-22-0012).

Variables and Procedures

Variables included demographic characteristics (age and gender), anthropometric indices, sports motivation, and competitive success.

Anthropometric variables included body mass, body height, and percentage of body fat. The percentage of body fat was determined by the Slaughter-Lohman formula calculated from a sum of triceps and calf skinfolds measured by Harpenden skinfold caliper (British Indicators, Burgess Hill).

Sports motivation was assessed by the revised sport motivation scale (SMS-II) which was translated into the Croatian language. SMS-II consists of 18 items, forming six subscales depicting low to a high level of autonomy (amotivation, external, introjected, identified and integrated regulation, and intrinsic motivation). The SMS-II was previously indicated as valid and reliable for assessing sports motivation [15]. The reliability and validity of the Croatian version of the SMS-II scale was assessed on athletes from different sports (unpublished material). The motivation was evaluated on the 7-point Likert scale, from 1, meaning “Does not correspond at all,” to 7, “Corresponds completely.”

Competitive success was determined based on the results (competition rankings) from the last National championship held in 2022. According to the competition rank, wrestlers were divided into two categories: (i) successful wrestlers (medal winners at the National Championship), and (ii) less successful wrestlers who did not win a medal at the National Championship.

Testing Protocol

All assessments were conducted prior to the training sessions when athletes were rested and relaxed. First, anthropometric indices have been measured. Then, investigators explained the aim of the questionnaire they were about to fulfill. Participants fulfilled the SMS-II on their mobile phones (or investigators gave the devices to athletes that did not have it). The SMS-II was fulfilled on the online platform SurveyMonkey, which enabled investigators to collect responses directly in a digital shape (i.e., excel sheet).

Statistical Analysis

The normality of the variables was checked by the Kolmogorov–Smirnov test. Descriptive statistics included means and standard deviations for all variables.

The internal consistency (reliability) of the six SMS-II subscales was checked by Cronbach's alpha coefficients. Cronbach's alpha coefficients indicate the correlation between items, meaning that appropriately high values justify categorizing items into a subscale. Values lower than 0.5 were considered unacceptable, 0.5–0.60 as poor, 0.60–0.70 as questionable, 0.70–0.80 as acceptable, 0.80–0.90 as good, and >0.90 as excellent [22]. Additionally, the Inter-item correlation coefficients were calculated to support the internal consistency of the SMS-II additionally.

The discriminative validity of the SMS-II was determined by comparing two performance levels (i.e., quality groups of wrestlers). The differences between performance levels were checked in several ways. First, differences between performance levels (successful vs. less successful wrestlers) were assessed by the magnitude-based Cohen's effect sizes with modified qualitative descriptors. The effect size was evaluated based on the following criteria: <0.02 represented trivial; 0.2–0.6 represented small; >0.6–1.2 rep-resented moderate; >1.2–2.0 represented large; and >2.0 represented very large differences. Moreover, differences in the motivation variables and anthropometric/body composition variables were calculated using the multivariate analysis of variance (MANOVA). Package Statistica 13.5 (Tibco Inc, Palo Alto, California, USA) was used for all statistical calculations, with an applied p-level of 0.05.

3.4.3 Results

SMS-II displayed appropriate internal consistency (Table 1). Cronbach's alpha coefficients ranged from unacceptable to good (0.33–0.79). Even though some subscales (Introjected regulation and amotivation) had unacceptable and poor Cronbach's alpha

values, they were retained for the analysis because these subscales had adequate reliability in previous research, in which it was also proved that the Cronbach's alpha coefficients would not increase if any of the items were deleted [15].

Table 1. Internal consistency of SMS-II subscales.

	Cronbach's Alpha	**Inter-Item Correlation**
Amotivation	0.58	0.32
External regulation	0.66	0.41
Introjected regulation	0.33	0.18
Identified regulation	0.72	0.47
Integrated regulation	0.75	0.51
Intrinsic motivation	0.79	0.57

Descriptive statistics and differences between successful and less successful wrestlers are shown in Table 2. Successful and less successful wrestlers did not differ in age, training, competing experience, or anthropometric variables. A very large effect size was noted for competition ranking, meaning that successful and less successful wrestlers had significant differences, and were not close in the ranking (i.e., there was a possibility that the difference is low, and that the non-medal winners were for example on the fourth place).

Table 2. Descriptive statistics and differences according to performance categories.

	Total Sample	**Successful (*n* = 27)**	**Less Successful (*n* = 20)**	**ES**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	
Age (years)	17.71 ± 1.62	17.96 ± 1.34	17.41 ± 1.89	0.34
Training experience (years)	6.89 ± 2.75	7.46 ± 2.69	6.19 ± 2.73	0.47
Competing experience (years)	6.45 ± 2.83	6.96 ± 2.73	5.81 ± 2.89	0.41
Competition ranking	4.07 ± 2.97	2.04 ±0.87	7.18 ± 2.24	3.22
Body weight (kg)	77.73 ± 14.31	79.31 ± 15.93	76.03 ± 12.43	0.23
Body height (cm)	177.45 ± 7.33	177.26 ± 7.30	177.64 ± 7.50	0.05
Body mass index	24.53 ± 3.23	25.03 ± 3.42	23.98 ± 2.97	0.32
Body fat percentage	15.43 ± 6.54	14.90 ± 6.99	16.00 ± 6.11	0.17

Note: SD-standard deviation, ES-Cohen's d effect size.

The graphical presentation of the sport motivation profile is displayed in Figure 1. It is visible that, on a motivation continuum, wrestlers have high levels of self-determined forms of motivation, and low levels of amotivation and external regulation. Additionally, successful wrestlers have significantly higher levels of intrinsic motivation compared to less successful wrestlers (6.25 ± 0.75 vs. 5.60 ± 0.96, moderate effect size).

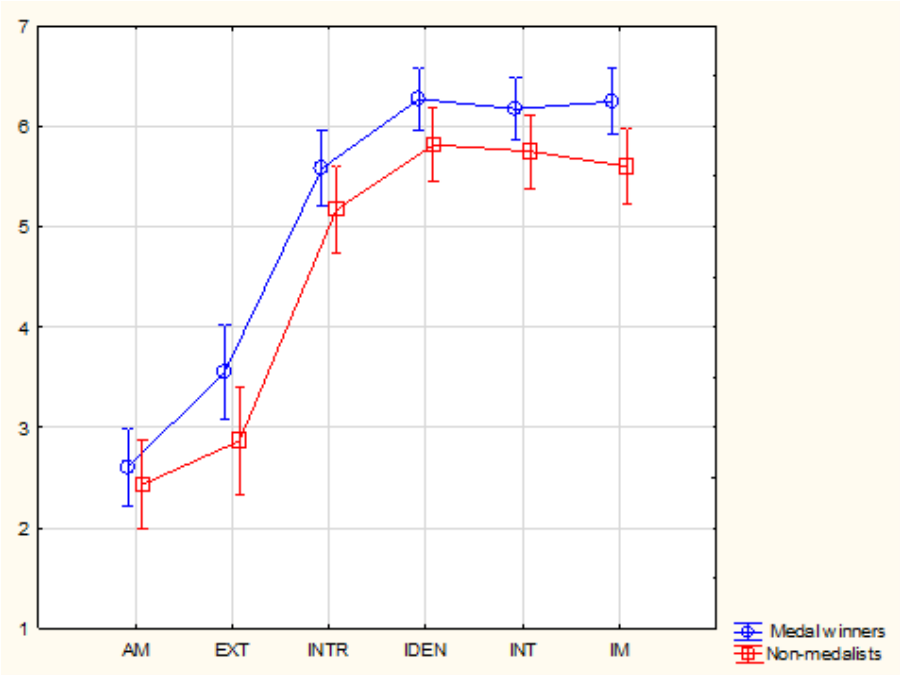

Figure 1. Motivation profile of successful and less successful wrestlers. (Note: AM—amotivation, EXT—external regulation, INTR—introjected regulation, IDEN—identified regulation, INT—integrated regulation, IM—intrinsic motivation).

Multivariate analysis of variance (MANOVA) did not reveal differences between medal winners and non-winners in motivation variables nor in anthropometric/body composition variables (Table 3).

Table 3. MANOVA for the motivation and anthropometric/body composition variables.

Factor	**Wilks' Lambda**	**F**	***p***
Motivation	0.77	2.01	0.09
Anthropometric/body composition	0.87	1.80	0.15

When further observing motivation variables on the subscales, there were differences in the intrinsic motivation between successful and less successful wrestlers (moderate effect size) (Figure 2).

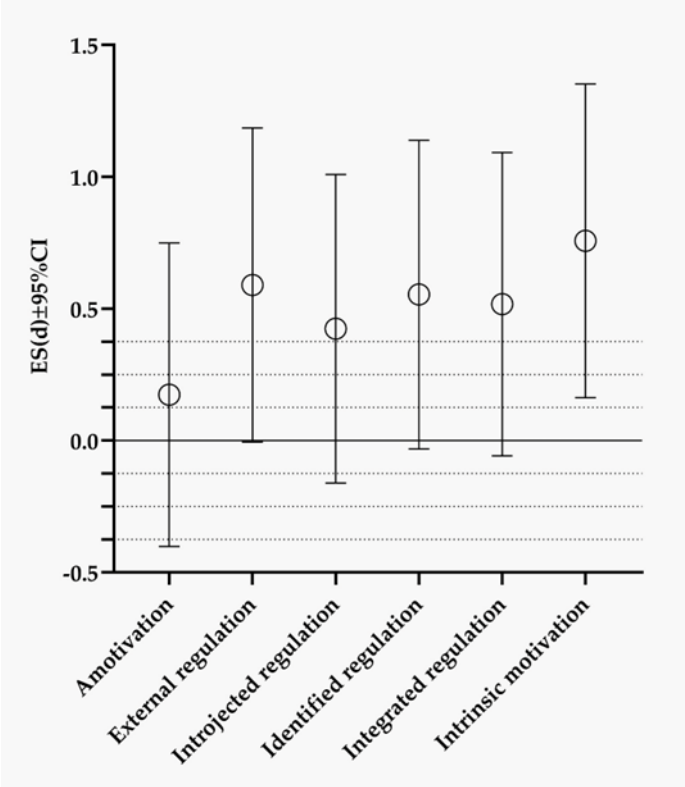

Figure 2. Differences between successful and less successful wrestlers in the motivation variables displayed through effect sizes.

3.4.4 Discussion

This study aimed to determine the motivation profile of youth wrestlers and investigate the differences between performance categories. The most important findings of this research are: (i) wrestlers have high levels of self-determined motivation and low amotivation, and (ii) successful wrestlers have higher intrinsic motivation compared to less successful wrestlers.

Motivation Profile of Greco-Roman Wrestlers

Results evidenced that wrestlers possess high levels of self-determined forms of motivation (i.e., intrinsic motivation and integrated regulation), while external regulation and amotivation were low. In sports, especially in competitive sports, the more self-determined and autonomous types of motivation have been linked to long-time

commitment and greater interest in sports participation at a high level [15]. Indeed, a predominance of autonomous and self-determined types of motivation in our wrestlers can be explained similarly. Wrestlers exclusively rely on themselves, and their goal is to perform constantly on the maximal level. Additionally, wrestlers have to put a lot of time and effort into their training sessions to become superior to their opponents and achieve their top performance. Thus, they have to possess a quality (i.e., motivation) that will allow them to execute extremely demanding training and competitions. Indeed, motivation has a direct impact on sports success as it regulates effort and time, which is necessary to overcome competitive challenges and obtain goals [23]. It is important to emphasize that more self-determined motivation leads to more positive consequences. Precisely, athletes with more self-determined motivation would have better objective performance, cope with challenges, put in more effort, decrease burnout, and have better mental health [24,25].

Additionally, individuals with more autonomous motivation will more likely continue practicing their sport and will have decreased chances of dropping out from sport. Indeed, a study on athlete students noted a positive relationship between the intention to continue participating in sports and autonomous motivation [26]. Similarly, a study on young athletes from different sports found that intrinsic motivation leads to adherence to sports practice [27]. Having that in mind, a recent study that investigated volleyball players noted a positive relationship between autonomous motivation and enjoyment, which most likely keeps athletes to continue practicing their sport [28]. Indeed, a study on Hungarian adolescent athletes that investigated commitment and motivation recorded a positive association between intrinsic motivation and sport commitment (i.e., enthusiastic commitment) [29]. Therefore, autonomous motivation not only leads to athletes being more committed and strive for better results due their personal satisfaction, but it also influences persistence in sports. We can theorize that persistence could be connected with autonomous motivation as athletes are actually enjoying, having fun and are satisfied with themselves while practicing sports.

Several studies supported our findings that wrestlers possess self-determined forms of motivation. A study on Bulgarian national team wrestlers aged 16–35 years recorded that wrestlers have higher intrinsic than extrinsic motivation [30]. Supportively, Spanish Olympic wrestlers reported that motivation is the construct that guides them to success. Specifically, wrestlers consider that their intrinsic motivation ensures overcoming several

daily training sessions (i.e., 2–3 training sessions a day), and is the catalyst for the sport's painful and challenging character [31]. Wrestlers reported that the most important reason for training and competing is to become the winner [31]. Indeed, it was shown that wrestlers have the motivation to achieve success and avoid failure, and are not motivated by external prizes [32].

Moreover, a study on Portuguese national Olympic team wrestlers investigated motivation (according to the SDT motivation continuum) related to recovery processes in wrestlers, as recovery is related to better results and sports performance [33]. They recorded a positive relationship between intrinsic motivation and recovery process dimensions of social and personal well-being, indicating that wrestlers practice in voluntary, satisfying, and pleasurable ways. Their findings indicate that intrinsically motivated athletes are more prone to commit, learn, and persist in their sports careers [33]. Therefore, more intrinsically motivated wrestlers would be more committed to recovery processes in an enjoyable, fun, and pleasurable way, which would consequently lead to better sports performance.

To further support our findings, the sports motivation profile of athletes involved in sports other than wrestling will be compared. Previously, an Irish study investigated sports motivation using the SMS-II in athletes aged 18–35 years from team sports, including basketball, soccer, hockey, hurling, and rugby [34]. They noted that their athletes had intrinsic motivation scores of 4.93 ± 1.4, which is significantly lower than our wrestlers, who had scores of 5.97 ± 0.90. Additionally, other self-determined forms of motivation were lower in the Irish team athletes than in our wrestlers: integrated regulation (4.81 ± 1.38 vs. 5.99 ± 0.83) and identified regulation (4.76 ± 1.48 vs. 6.08 ± 0.82) [34]. Moreover, a Finnish study on team sport adolescent athletes reported that elite athletes have higher intrinsic motivation and lower amotivation compared to non-elite athletes [35]. In a study of football players aged 13–20 years, more autonomous motivation was linked to positive results in a perceived effort that promoted task-involvement climate and basic psychological needs satisfaction of players [36]. Additionally, young handball players aged 16–17 years displayed high self-determined motivation coupled with a high task-involving climate, high basic psychological needs, and commitment [37]. Track and field athletes aged 13–18 displayed high levels of intrinsic motivation, with males and athletes from urban living environments having higher levels compared to females and rural athletes [38]. From this brief overview of motivation profiles in several sports, it

could be supported that self-determined forms of motivation are crucial for sports success. Additionally, according to the comparison between different types of sports (team vs. individual/combat), it can be stated that wrestlers indeed do possess a high level of self-determined motivation, which is proven to be related to better performance and persistence in practicing sports [24].

Somewhat opposite to our findings, a study on Hungarian national team wrestlers reported that younger wrestlers aged 10–19 years mainly relied on external regulation, but this trend was not present in the older age group (19–25 years) [39]. Additionally, amotivation was high in the youngest age group, while it had a descending pattern through older age groups [39]. However, we investigated athletes from the older age group, and we can assume that they already had their self-determined types of motivation formed on the higher levels. Moreover, a study on Croatian wrestlers aged 18.5 ± 3.58 years stated that younger wrestlers (cadets) most likely have lower positive intrinsic motivation (i.e., interest, enjoyment, and perceived competence), and higher negative intrinsic motivation (pressure) compared with older athletes (juniors and seniors) [40]. The authors of that study used different scale for assessing motivation (Intrinsic Motivation Inventory); thus, the results are hard to compare.

Differences in Motivation Profile between Successful and Less Successful Wrestlers

Our results showed that successful wrestlers had significantly higher intrinsic motivation than less successful wrestlers. Supportive to our findings, a study investigating Russian elite and intermediate wrestlers aged 18.4 ± 4.84 years evidenced that elite wrestlers are more intrinsically motivated than less successful wrestlers [41]. Therefore, the observed difference in the most self-determined form of motivation (i.e., intrinsic motivation) adds to the previous part of the discussion. This additionally proves that wrestlers are driven by internal factors, such as personal satisfaction and joy, and are not motivated by external prizes.

Observing from the aspect of the country that wrestlers are from, the predominance of self-determined motivation can indeed be explained by personal enjoyment and success, and not being motivated by the prize (e.g., money). In Croatia, wrestling is not a mainstream sport and is not highly financially supported by the governing bodies. Additionally, the salary of a competitive wrestler is substantially lower than in other sports (e.g., football, basketball, and handball). For example, the best wrestlers who

participated in the highest level of competitive wrestling (i.e., Olympic games) have a very low salary and are usually forced to work while they compete, which makes their sports path even harder. However, they have the honor to, for example, hand out medals at national competitions and promote wrestling on mass media (i.e., television). Collectively, according to our results and from our personal knowledge of the situation, wrestlers in Croatia are mainly training and competing to fulfill their satisfaction and joy, and are not motivated by external prizes.

Findings from previous studies that coaches' behavior influences athletes' motivation should be considered as an important guideline for coaches. Previously, a study on Turkish elite freestyle and Greco-Roman wrestlers recorded a positive relationship between intrinsic motivation and wrestlers' perception of instruction and the training behavior of their coaches [42]. Supportively, a study on Croatian athletes noted that coaches can increase athletes' intrinsic motivation by demonstrating training and instruction behavior, social support, and positive feedback behavior [43]. Additionally, a study on college athletes involved in various sports (i.e., football, tennis, gymnastics, volleyball, basketball, and track and field) investigated the relationship between coaching behaviors and athletes' intrinsic motivation [44]. Study revealed that all coaching behaviors, including autocratic and democratic behavior, positive feedback, training, and instruction, predicted the perceived competence, autonomy, and intrinsic motivation of their athletes [44]. Therefore, the results of this research emphasize that coaches could additionally try to develop a more self-determined motivation of their wrestlers. This way, they could influence changing attitudes, behavior, persistence in sports, and overall sports performance of youth wrestlers.

Limitations and Strengths

This research has several limitations. The main limitation comes from the cross-sectional type of the study. This means that the causality could not be determined, and the results should be interpreted with caution. For example, it is possible that performance predicted motivation, meaning that successful wrestlers were more motivated, as winning is motivational. However, this research emphasizes the importance of creating a positive and self-determined motivational climate among wrestlers, regardless of the bidirectional possibility of interpreting the results. Thus, the main strength of this study is that it investigated one really important psychological construct that forms the wrestler's

actions and enables optimal sports performance. Another important thing is that we included youth wrestlers, who can still be guided, and the coach greatly influences their development. Therefore, this research can be used as a guideline for coaches to create and nurture motivation among their youth athletes.

3.4.5 Conclusions

Youth Greco-Roman wrestlers possess high levels of self-determined motivation, which allows them to endure the suffering in combat and the high psycho-physiological demands of both training and competitions. Moreover, successful wrestlers have higher levels of intrinsic motivation than less successful wrestlers, which points out that wrestlers should be intrinsically motivated to achieve good competitive success. Investigating and determining sport motivation is very helpful for practitioners and coaches that strive to optimize their athletes' performance and well-being. It enables coaches to engage and connect with their athletes' motivation, which consequently leads to better performance and well-being. Future research should investigate wrestlers from other age groups (both younger and older) to completely determine the sport motivation profile of wrestlers and enable their optimal sports development.

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

Data Availability Statement: Not applicable.

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4 ZAKLJUČAK

4.1 Opći zaključak

Ova doktorska disertacija temeljila se na četiri međusobno povezana istraživanja koja su sustavno ispitivala višedimenzionalne odrednice natjecateljske uspješnosti mladih hrvača. U odnosu na postavljene ciljeve istraživanja, rezultati u velikoj mjeri potvrđuju postavljene hipoteze. Ukratko, rezultati prvog istraživanja ukazali su na ograničenu povezanost između generičkih testova i sport-specifične izvedbe, naglašavajući potrebu za primjenom specifičnih protokola. Drugo istraživanje pokazalo je da su generičke i sport-specifične sposobnosti ključni čimbenici koji razlikuju uspješnije od manje uspješnih mladih hrvača. Treće istraživanje dodatno je istaknulo važnost izvedbe u uvjetima umora, pri čemu su razlike između kategorija uspješnosti sportaša izraženije tijekom ponavljanih visokointenzivnih opterećenja. Konačno, četvrto istraživanje potvrdilo je značaj motivacije, osobito intrinzične, kao važnog psihološkog čimbenika povezanog s natjecateljskom uspješnošću. Zajedno, ovi nalazi potvrđuju da je uspješnost u hrvanju rezultat kompleksne interakcije fizičkih, fizioloških i psiholoških čimbenika. Zaključci pojedinih istraživanja detaljno su prikazani u priloženim radovima, a kako bi se izbjeglo ponavljanje, u nastavku su sažeto prikazani njihovi ključni nalazi.

Prvo istraživanje provedeno je na relativno malom i homogenom uzorku elitnih mladih hrvača, što je omogućilo detaljan uvid u odnose između generičkih i sport-specifičnih pokazatelja unutar visoko trenirane populacije. Rezultati su pokazali da generički testovi imaju ograničenu povezanost sa sport-specifičnom izvedbom procijenjenom putem SWFT-a, što upućuje na visoku specifičnost hrvačke izvedbe. Također, nisu utvrđene značajne razlike između hrvača različite natjecateljske kvalitete niti između težinskih kategorija, što se može objasniti homogenosti uzorka i visokoj razini treniranosti svih ispitanika. Ovi nalazi ukazali su na potrebu za proširenjem istraživanja na heterogeniji uzorak i primjenu dodatnih metodoloških pristupa.

U skladu s tim, drugo istraživanje obuhvatilo je veći i heterogeniji uzorak mladih hrvača različite natjecateljske razine, čime je omogućeno preciznije ispitivanje čimbenika uspješnosti. Rezultati su pokazali da uspješniji hrvači (osvajači medalja) ostvaruju značajno bolje rezultate u testovima eksplozivne snage (vertikalni skok - CMJ), maksimalne snage (stisak šake - HGS) i sport-specifične izvedbe (SWFT), dok

antropometrijske karakteristike nisu značajno razlikovale skupine. Rezultati su pokazali da su upravo funkcionalne sposobnosti, poput eksplozivne snage, maksimalne snage i sport-specifične izvedbe, ključne za natjecateljski uspjeh, dok antropometrijske karakteristike nisu imale značajnu diskriminacijsku vrijednost. Ovim istraživanjem potvrđena je važnost kombinirane primjene generičkih i sport-specifičnih testova u procjeni sportaša.

Treće istraživanje proširilo je analizu uključivanjem procjene izvedbe u uvjetima umora i ponavljanog visokointenzivnog opterećenja. Rezultati su pokazali da se razlike između hrvača različite natjecateljske razine jasnije očituju upravo u takvim uvjetima, dok su u stanju odmora te razlike manje izražene. Ovi nalazi naglašavaju važnost sposobnosti održavanja visoke razine izvedbe unatoč akumuliranom umoru kao ključnog čimbenika uspješnosti u hrvanju. Time se dodatno potvrđuje potreba za primjenom testova koji uključuju ponavljani napor i simuliraju stvarne uvjete natjecanja.

Četvrto istraživanje usmjereno je na psihološke čimbenike, s posebnim naglaskom na motivaciju. Rezultati su pokazali da motivacijske karakteristike, osobito intrinzična motivacija, imaju značajnu ulogu u objašnjenju natjecateljske uspješnosti mladih hrvača. Sportaši s višom razinom intrinzične motivacije pokazuju veću uključenost u trenažni proces, veću ustrajnost i povoljnije razvojne putanje. Ovi nalazi potvrđuju da psihološki čimbenici predstavljaju važnu komponentu ukupnog sportskog uspjeha te ih je potrebno uključiti u procjenu i razvoj sportaša.

Zaključno, rezultati ove disertacije potvrđuju da je natjecateljska uspješnost u hrvanju rezultat međudjelovanja generičkih i sport-specifičnih tjelesnih sposobnosti, sposobnosti održavanja izvedbe u uvjetima umora te motivacijskih karakteristika. Integrirani, multidimenzionalni pristup procjeni sportaša pokazuje se kao najprimjereniji za razumijevanje i unapređenje sportskih rezultata.

Znanstvena važnost ove disertacije ogleda se u sustavnom i cjelovitom pristupu proučavanju natjecateljske uspješnosti u hrvanju, pri čemu su istovremeno obuhvaćene fizičke, fiziološke i psihološke komponente izvedbe. Za razliku od prethodnih istraživanja koja su se najčešće usmjeravala na pojedinačne čimbenike, ova disertacija integrira više dimenzija izvedbe i time doprinosi dubljem razumijevanju kompleksne prirode sportskog uspjeha, osobito u populaciji mladih hrvača. Posebna znanstvena novost ove disertacije očituje se u nekoliko ključnih aspekata. Prvo, utvrđeno je da

generički pokazatelji tjelesne spremnosti imaju ograničenu sposobnost objašnjenja sport-specifične izvedbe, čime se naglašava važnost primjene specifičnih dijagnostičkih protokola u hrvanju. Drugo, pokazano je da se razlike između sportaša različite natjecateljske razine jasnije očituju u uvjetima ponavljanog visokointenzivnog opterećenja i umora, što predstavlja važan metodološki doprinos u području procjene sportske izvedbe. Treće, uključivanjem motivacijskih karakteristika kao relevantnog čimbenika, disertacija proširuje postojeće modele objašnjenja uspješnosti i potvrđuje važnost psiholoških varijabli u kontekstu sportskih rezultata. Dodatna vrijednost rada očituje se u progresivnom istraživačkom pristupu, gdje su početni nalazi dobiveni na manjem i homogenijem uzorku poslužili kao temelj za daljnja istraživanja na većim i heterogenijim uzorcima. Takav pristup omogućio je postupno produbljivanje analize i povećanje valjanosti zaključaka, čime je osiguran logičan kontinuitet istraživanja unutar disertacije. Sveukupno, ova disertacija predstavlja doprinos znanstvenom području kineziologije i sportskih znanosti kroz razvoj i potvrdu multidimenzionalnog pristupa razumijevanju natjecateljske uspješnosti u hrvanju te postavlja temelje za buduća istraživanja usmjerena na integrirano proučavanje sportskih performansi.

4.2 Ograničenja istraživanja

Unatoč značajnim doprinosima ove disertacije, potrebno je uzeti u obzir određena ograničenja koja mogu utjecati na interpretaciju dobivenih rezultata. Prije svega, dio istraživanja proveden je na relativno malim i homogenim uzorcima elitnih mladih hrvača, što može ograničiti mogućnost generalizacije nalaza na širu populaciju sportaša različitih dobnih i natjecateljskih razina. Nadalje, većina istraživanja temelji se na presječnom istraživačkom dizajnu, koji ne omogućuje utvrđivanje uzročno-posljedičnih odnosa između analiziranih varijabli i natjecateljske uspješnosti. Iako dobiveni rezultati pružaju vrijedan uvid u povezanosti među varijablama, za dublje razumijevanje mehanizama sportskog uspjeha nužna su longitudinalna istraživanja. Dodatno ograničenje odnosi se na primjenu sport-specifičnih testova, kod kojih standardizacija može biti otežana zbog složenosti izvedbe i tehničkih zahtjeva. Varijacije u izvedbi pokreta, kao i interakcija s opremom, mogu utjecati na rezultate testiranja i time ograničiti njihovu potpunu usporedivost. Također, iako su u istraživanje uključeni psihološki čimbenici kroz procjenu motivacije, širi spektar psiholoških varijabli nije bio obuhvaćen. Time je

djelomično ograničeno cjelovito razumijevanje psiholoških aspekata koji mogu utjecati na natjecateljsku uspješnost. Unatoč navedenim ograničenjima, ova disertacija pruža vrijedan doprinos razumijevanju složene prirode sportskog uspjeha u hrvanju te predstavlja temelj za daljnja istraživanja u ovom području.

4.3 Praktična primjena i smjernice za buduća istraživanja

Rezultati ove disertacije imaju značajne implikacije za trenažnu praksu, dijagnostiku i selekciju mladih hrvača, ali i za daljnji razvoj znanstvenih istraživanja u području sportskih znanosti. Dobiveni nalazi jasno ukazuju da procjena natjecateljske uspješnosti ne bi trebala biti temeljena na izoliranim pokazateljima, već na integriranom pristupu koji uključuje generičke i sport-specifične sposobnosti, izvedbu u uvjetima umora te psihološke karakteristike sportaša. U praktičnom smislu, posebnu vrijednost imaju testovi koji su se pokazali osjetljivima u razlikovanju uspješnijih i manje uspješnih hrvača, a istovremeno su jednostavni i primjenjivi u svakodnevnom radu. To uključuje procjenu eksplozivne snage donjih ekstremiteta (npr. vertikalni skok), maksimalne snage (osobito snage stiska šake) te sport-specifične izvedbe putem Specifičnog hrvačkog fitness testa. Dodatno je zanimljivo i korisno za praktičnu primjenu nalaz da je i sam broj bacanja u SWFT testu dostatan za određivanje izvedbe hrvača, bez uporabe srčanih monitora i laktatomjera. Nadalje, rezultati naglašavaju važnost procjene izvedbe u uvjetima umora i ponavljanog visokointenzivnog opterećenja. Budući da se razlike između sportaša različite razine uspješnosti jasnije očituju upravo u takvim uvjetima, preporučuje se uključivanje testnih protokola koji simuliraju stvarne natjecateljske zahtjeve. Time se omogućuje realnija procjena natjecateljske spremnosti i sposobnosti održavanja izvedbe tijekom meča. Posebnu pozornost potrebno je posvetiti i psihološkim čimbenicima, pri čemu motivacija ima važnu ulogu u dugoročnom razvoju i natjecateljskoj uspješnosti sportaša. Uključivanje procjene motivacijskih karakteristika može doprinijeti boljem razumijevanju angažmana sportaša u treningu te omogućiti dodatnu individualizaciju trenažnog procesa.

S aspekta budućih istraživanja, preporučuje se primjena longitudinalnih studija kako bi se omogućilo praćenje razvoja sportaša kroz vrijeme i utvrdile uzročno-posljedične veze između analiziranih čimbenika i natjecateljske uspješnosti. Također, potrebno je

uključivati veće i heterogenije uzorke sportaša različitih dobnih i natjecateljskih razina, s posebnim naglaskom na mlađe dobne skupine kod kojih biološko sazrijevanje može značajno utjecati na rezultate. Dodatno, buduća istraživanja trebala bi razvijati i primjenjivati ekološki validnije testne protokole koji uključuju ponavljana mjerenja i simulaciju natjecateljskih uvjeta, čime bi se dodatno unaprijedila osjetljivost u razlikovanju sportaša različite razine uspješnosti i odredili čimbenici uspješnosti. Konačno, preporučuje se daljnja integracija psiholoških varijabli s fizičkim i fiziološkim pokazateljima kako bi se razvili sveobuhvatniji modeli razumijevanja i predikcije natjecateljske uspješnosti u hrvanju.

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6 ŽIVOTOPIS DOKTORANDA

Krešo Škugor rođen je 28. veljače 1995. godine u Šibeniku. Nakon završetka Srednje prometno-tehničke škole u Šibeniku (smjer tehničar cestovnog prometa, 2012.), upisuje Kineziološki fakultet u Splitu, gdje 2016. godine stječe akademski naziv prvostupnika kineziologije. Diplomski studij kineziologije završava 2019. godine, a iste godine stječe zvanje magistra kineziologije. Doktorski studij na Kineziološkom fakultetu u Splitu upisuje 2022. godine.

Profesionalno iskustvo započinje već tijekom studija, radeći kao kondicijski i osobni trener u fitness centrima. Paralelno razvija stručni interes za borilačke sportove, osobito hrvanje, te djeluje kao trener i demonstrator na kolegiju Teorija i metodika hrvanja. Nakon završetka studija nastavlja suradnju s Kineziološkim fakultetom u Splitu kao vanjski suradnik na više kolegija iz područja borilačkih sportova i kondicijske pripreme, uključujući: Teoriju i metodiku hrvanja, Razvoj snage u hrvanju, Programiranje i kontrolu treninga u borilačkim sportovima, Kineziološku i antropološku analizu u borilačkim sportovima te Metodiku treninga u borilačkim sportovima.

Od 2016. godine zaposlen je u Hrvačkom klubu Split, gdje djeluje kao trener svih uzrasnih kategorija, sudjelujući u razvoju sportaša od početničke do natjecateljske razine. Poduzetničku aktivnost razvija osnivanjem obrta *GIZMO TRENING* 2024. godine, kroz koji provodi individualne i grupne programe treninga za sportaše i rekreativce. Daljnji doprinos razvoju hrvanja ostvaruje osnivanjem Hrvačkog kluba Gizmo 2025. godine, u kojem obnaša funkciju predsjednika i glavnog trenera. Godine 2022. obnašao je dužnost trenera hrvatske reprezentacije u hrvanju slobodnim stilom za uzrast U15, sudjelujući u pripremi i vođenju sportaša na Europskom prvenstvu.

Kao sportaš, tijekom kadetskog i juniorskog razdoblja ostvario je zapažene rezultate osvojivši brojne državne i međunarodne medalje u brojnim borilačkim sportovima (MMA, karate, jiu-jitsu, grappling, kickboxing i tajlandski boks). U seniorskoj konkurenciji specijalizira se za hrvanje slobodnim stilom, u kojem osvaja šest državnih medalja te jednu međunarodnu. Najznačajniji rezultat ostvaruje 2024. godine osvajanjem naslova prvaka Hrvatske u hrvanju slobodnim stilom. Također je bio član reprezentacije te nastupao na Europskom prvenstvu 2023. godine te Svjetskom prvenstvu 2025. godine.

Trenutno ima status kategoriziranog sportaša III. kategorije Hrvatskog olimpijskog odbora.

Tijekom doktorskog studija je objavio brojne znanstvene radove u znanstvenim časopisima i zbornicima sa konferencija. U nastavku je popis svih njegovih radova.

Radovi objavljeni u publikacijama koje citiraju WoS i/ili Scopus:

1. **Škugor, K.,** Štajer, V., Žugaj, N., Gilić, B., & Karninčić, H. (2023). Generic and Specific Fitness Profile of Elite Youth Greco-Roman Wrestlers; Differences According to Quality and Weight Category. *Sport Mont, 21*(1), 23-30. doi: 10.26773/smj.230204

2. **Škugor, K.,** Gilić, B., Mladenović, M., Štajer, V., Roklicer, R., Slačanac, K., Bagarić, D., Karninčić, H. (2023). Motivation Profile of Youth Greco-Roman Wrestlers; Differences According to Performance Quality. *Sports 11*(43). https://doi.org/10.3390/sports11020043

3. **Škugor, K.,** Gilić, B., Karninčić, H., Jokai, M., Babszky, G., Ranisavljev, M., Štajer, V., Roklicer, R., & Drid, P. (2023). What Determines the Competitive Success of Young Croatian Wrestlers: Anthropometric Indices, Generic or Specific Fitness Performance? *Journal of Functional Morphology and Kinesiology*, *8*(3), 90. https://doi.org/10.3390/jfmk8030090

4. **Škugor, K.,** Karnincic, H., Zugaj, N., Stajer, V., & Gilic, B.. (2024). Repetition of the Exhaustive Wrestling-Specific Test Leads to More Effective Differentiation between Quality Categories of Youth Wrestlers. *Applied Sciences*, 14(9), 3677. https://doi.org/10.3390/app14093677

5. Gilic, B., **Škugor, K.,** & Sunda, M. (2024). Psychometric evaluation of the Croatian version of the revised sports motivation scale in youth athletes. *Journal of physical education and sport*, 24(7), 1699-1706

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7. **Škugor, K.,** Gilic, B., & Kvesić, I. (2025). Physical and Performance Differences Between More and Less Experienced Wrestlers. *Sport Mont*, 23(2), doi: 10.26773/smj.250606

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1. Karninčić, H., López Gullon, J.M., **Škugor, K.** (2022). Regulation of body weight in wrestling – A review. *30th Summer School of Kinesiologists of the Republic of Croatia, Zadar, Croatia: Satellite Symposium-Wrestling,* 1702-1715.
2. **Škugor, K.,** Žugaj, N., Gilić, B., Štajer, V., Roklicer, R. (2022). Power and strength of the upper body of top junior wrestlers: differences according to the quality of athletes. *30th Summer School of Kinesiologists of the Republic of Croatia, Zadar, Croatia: Satellite Symposium-Wrestling,* 1729-1734.
3. Manojlović, M., Roklicer, R., **Škugor, K.**, Maksimović, N., Rossi, C., Drid, P. (2022). Rapid weight loss alters handgrip strength in Greco-Roman wrestlers. *30th Summer School of Kinesiologists of the Republic of Croatia, Zadar, Croatia: Satellite Symposium-Wrestling,* 1741-1747.
4. **Škugor, K.,** Žugaj, N., Gilić, B. (2022). Biological age-related differences in fitness status of young wrestlers. 12. Međunarodna konferencija ‘’Sportske nauke i zdravlje’’. Banja Luka: Panevropski univerzitet “Apeiron”.
5. Žugaj, N., **Škugor, K.,** Kontić, D. (2022). Fitness profil vrhunskih hrvača Grčko-Rimskog stila. 12. Međunarodna konferencija “Sportske nauke i zdravlje’’. Banja Luka: Panevropski univerzitet “Apeiron”.
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