KOMISIJA ZA OCENU NAUČNE ZASNOVANOSTI
TEME DOKTORSKE DISERTACIJA

NASTAVNO-NAUČNOM VEĆU FAKULTETA SPORTA I FIZIČKOG VASPITANJA

Predmet: Izveštaj o pregledu i oceni teme doktorske disertacije Vesne Vuković, studentkinje sa programa doktorskih studija.

Na 3. sednici Nastavno-naučnog veća Fakulteta sporta i fizičkog vaspitanja održanoj elektronski 15.12.2022. godine, u skladu sa čl. 42 i 43 Statuta Fakulteta, doneta je Odluka o formiranju Komisije za ocenu naučne zasnovanosti teme doktorske disertacije studentkinje doktorskih akadmeskih studija Vesne Vuković, pod naslovom: "KINEMATIC AND TEMPORAL PARAMETERS IN DIFFERENT MODALITIES OF THE REVERSE PUNCH MEASURED BY IMU SENSORS (KINEMATIČKI I VREMENSKI POKAZATELjI UDARCA ĐAKO ZUKI U RAZLIČITIM MODALITETIMA IZVOĐENjA MERENI IMU SENZORIMA)", (akt-02-br. 2761/22-3 16.12.2022.). Komisija je formirana u sastavu:

- Dr Aleksandar Nedeljković, redovni profesor, Univerzitet u Beogradu - Fakultet sporta i fizičkog vaspitanja, predsednik komisije;
- Dr Miloš Mudrić, PhD, vanredni profesor, Univerzitet u Beogradu - Fakultet sporta i fizičkog vaspitanja, član;
- Dr Nenad Koropanovski, redovni profesor, Kriminalističko-policijski univerzitet, Beograd, član;

Nakon pregleda dostavljenog materijala Komisija podnosi Nastavno-naučnom veću sledeći

I Z V E Š T A J:

Biografija

Vesna Vuković je rođena 25. aprila 1977. godine u Beogradu. Diplomirala je u III beogradskoj gimnaziji 1995. godine. Na osnovnim akademskim studijama Fakulteta za fizičku kulturu i menadžment u sportu iz Beograda diplomirala je 2016. godine. Na istom fakultetu stekla je zvanje magistra fizičkog vaspitanja i sporta 2017. godine. Iste godine upisala je doktorske studije na Fakultetu sporta i fizičkog vaspitanja Univerziteta u Beogradu.

Karateom se aktivno bavi od 1987. godine, kao takmičar, trener i sudija. Zaposlena je u OŠ „Mladost“ kao nastavnik fizičkog i zdravstvenog vaspitanja od 2019. godine.

Vesna Vuković govori engleski jezik.

Spisak objavljenih radova:

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3. Dopsaj, M., Marković, S., Jovanović, J., **Vuković, V.,** Maksimović, M., Miljuš, D., Tomanić, M., Aničić, Z., Tomić, L. D., & Stanković, A. (2018). BMI: Analysis of the Population Indicators in Working Population of the Republic of Serbia in Relation to Gender and Age. Fizička Kultura, 72(2), 148 160. https://doi.org/10.5937/fizkul1802148D
4. **Vuković, V.,** Koropanovski, N., Markovic, S., Umek, A. (2019). Descriptive profile of the reverse punch (gyako tsuki) kinematic characteristics measured by IMU sensor technology. XXII Scientific Conference „FIS COMMUNICATIONS 2019", October 17-19.2019. Nis. 40-44.
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6. **Вуковић, В.,** Марковић, С., Коропановски, Н., Миловановић, М., Допсај, М. (2019). Разлике простог и изборног времена реакција код младих каратиста оба пола различитог нивоа обучености. Физичка култура. 73(2): 238-248. https://doi.org/10.5937/fizkul1902238V
7. **Vuković, V.,** Marković, S., Koropanovski, N., Umek, T., & Dopsaj, M. (2019). Reaction Time in Young Karate Athletes in Relation to Gender and Level of Training [Abstract]. In T. Volmut & K. Koren (Eds.), The 10th International Scientific and Professional Conference “Child in Motion” Book of Abstract (p. 108). Science and Research Centre Koper.
8. Marković, S., **Vuković, V.,** Koropanovski, N., & Majstorović, N. (2021). Differences in Reaction Time Capabilities in Physically Active Subjects of Different Age. Serbian Journal of Sport Science, 12(1), 25-30.
9. **Vuković, V.,** Dopsaj, M., Koropanovski, N., Marković, S., Kos, A., Umek, A. (2021). Metrical characteristics and the reliability of kinematic sensor devices applied in different modalities of reverse punch in karate athletes. Measurement. 177: 309-315. https://doi.org/10.1016/j.measurement.2021.109315

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11. **Vuković, V.,** Koropanovski, N., Marković, S., Kos, A., Dopsaj, M., & Umek, A. (2022). Specific Test Design for the In-Depth Technique Analysis of Elite Karate Competitors with the Application of Kinematic Sensors. Applied Sciences, 12(16), 40-48.

Ocena važnijih radova kandidata koji su u vezi sa predloženom temom doktorske disertacije

1. Da bi se razumela složenost udaraca, neophodno je merenje u realnim uslovima. Ključni element za postizanje validnih rezultata je pouzdan instrument. Cilj studije pod nazivom „Metričke karakteristike i pouzdanost kinematičkih senzorskih uređaja primenjenih u različitim modalitetima reverznog udarca kod karatista“ bio je da se procene metričke karakteristike i pouzdanost kinematičkih senzora (KS) u specifičnom karate testiranju. U istraživanju je učestvovalo 14 takmičara, članova seniorske i kadetske reprezentacije Srbije u karateu. Segmentno ubrzanje u različitim modalitetima udarca Gjako Zuki (Giako tsuki) mereno je korišćenjem KS postavljenih na šaku i telo. U odnosu na kvalitativni kriterijum značajnosti intraklasnog koeficijenta korelacije (ICC), dobra pouzdanost (ICC = 0,75–0,90) uočena je za osam kinematičkih varijabli, dok je odlična pouzdanost (ICC > 0,90) potvrđena za deset kinematičkih varijabli. KS se mogu smatrati sofisticiranim mernim alatima koji pružaju pouzdanu bazu informacija za objektivizaciju procene.
2. Karatisti su pod stalnim pritiskom da pronađu adekvatna rešenja za bodovanje u uslovima borbe koji se stalno menjaju. Stoga, poboljšanje tehnike na visokim nivoima takmičenja zahteva novi pristup u prikupljanju ključnih podataka i njihovu dubinsku analizu. Rad pod nazivom „Specifičan dizajn testa za detaljnu analizu tehnike elitnih karate takmičara sa primenom kinematičkih senzora“ imao je za cilj da opiše kinematičku i vremensku strukturu reverznog udarca u fazi razvoja. U tu svrhu korišćena su dva bežična senzora za akviziciju odabranih parametara udarca. Rezultati pokazuju da vremenska linija kinematičkih parametara može biti pouzdan faktor u pogledu efikasnosti reverznog udarca. Dobijeni rezultati za parametre ruku pokazuju tendenciju ka održavanju većeg nivoa stabilnosti u odnosu na telo. Pored toga, uočene su razlike između parametara u odnosu na primenjene testove koji su replicirali uslove obuke i borbe. Najveće vrednosti ubrzanja su dobijene u kliznom kretanju koje prethodi RP, sa partnerom koji drži grudni koš, i statički (7,35 ± 0,47 g) i dinamički (6,99 ± 1,23 g) testovi. Isto važi i za brzinu (8,39 ± 0,14 i 7,30 ± 1,28 m/s). Dobijeni rezultati ukazuju na potrebu specifičnog testiranja i individualnog pristupa u analizi tehnika elitnih takmičara, uz korišćenje senzora u

akviziciji podataka. Takav pristup može pomoći u poboljšanju treninga i takmičarske prakse karatista.

3. Da bi postigli dobre performanse, sportisti treba da sinhronizuju niz pokreta na optimalan način. Jedan od indikatora koji se koristi je redosled pojavljivanja relevantnih događaja u vremenskoj liniji kretanja. Međutim, praćenje ove karakteristike brzog kretanja je praktično ograničeno na laboratorijske uslove, u kojima se sistemi za praćenje kretanja mogu koristiti za prikupljanje relevantnih podataka. Cilj rada pod nazivom „Upotreba IMU-a u diferencijalnoj analizi vremenske strukture reverznog udarca u odnosu na postignutu maksimalnu brzinu ruke“ je implementacija jednostavnog za upotrebu i robusnog IMU-baziranog rešenja pogodnog za svakodnevnu praksu. Na ovaj način može se stalno pratiti ponavljano izvođenje tehnike. Ovo pruža pojačanu povratnu informaciju trenerima i sportistima i relevantno je u kontekstu prevencije stabilizacije grešaka, kao i praćenja efekata umora. U ovom istraživanju, signal ubrzanja i brzine rotacije dobijen od IMU-a (Inertial Measurement Unit) se koristi za detekciju vremena nastanka događaja. Istraživanje je obuhvatilo 165 pojedinačnih udaraca 14 elitnih i nacionalnih karate takmičara. Svi udarci su klasifikovani kao spori, prosečni ili brzi na osnovu postignute maksimalne brzine ruke. Kruskal-Volisov test je otkrio značajne opšte razlike u redosledu pojavljivanja početka ubrzanja ruke, maksimalne brzine ruke, maksimalne brzine tela, maksimalnog ubrzanja ruke, maksimalnog ubrzanja tela i početka vertikalnog pokreta između grupa. Delimične razlike su određene korišćenjem Mann-Whitny testa. U ovom radu utvrđuju se razlike u vremenskoj strukturi reverznog udarca u odnosu na postignutu maksimalnu brzinu šake kao indikatora performansi. Detekcija vremena nastanka događaja pomoću IMU-a je nova metoda za merenje sinhronizacije pokreta koja pruža novi uvid u koordinaciju artikulisanih ljudskih pokreta. Ovakva primena IMU-a može pružiti dodatne informacije o proučavanoj strukturi brzih diskretnih pokreta u različitim sportskim aktivnostima koje su inače neprimetne ljudskim čulima.

Predlog teme doktorske disertacije

Vesna Vuković je za izradu doktorske disertacije predložila temu “KINEMATIČKI I VREMENSKI POKAZATELjI UDARCA ĐAKO ZUKI U RAZLIČITIM MODALITETIMA IZVOĐENjA MERENI IMU SENZORIMA (KINEMATIC AND TEMPORAL PARAMETERS IN DIFFERENT MODALITIES OF THE REVERSE PUNCH MEASURED BY IMU SENSORS)“. U skladu sa članom 31. stavom 2. Pravilnika o doktorskim akademskim studijama, 29.06.2021. godine je pred članovima Veća doktorskih akademskim studija održana javna

prezentacija predloga teme doktorske disertacije. Na osnovu prezentacije, predlog teme i projekat istraživanja za izradu doktorske disertacije pozitivno su ocenjeni.

Obrazloženje teme

U objašnjenju teme, autorka se na početku bavila problematikom istraživanja sa teorijskog aspekta, pozivajući se na činjenicu da je usavršavanje sportskih veština jedan od najvažnijih zahteva u karijeri sportiste, bez obzira na nivo konkurencije. Cilj treninga je ono što se menja. Pomeranje fokusa treninga u nekim borilačkim sportovima moguće je zbog osnovnih znanja o udarcima. Iz tog razloga, reverzni udarac (RU) usmeren u telo (na japanskom jeziku Giako Tsuki chudan) je možda najbolje proučavana tehnika karatea. Ipak, čini se da njegovi osnovni kinematički elementi i dalje izazivaju nesmanjeno istraživačko interesovanje.

Udarci su najprepoznatljivija tehnika rukom u raznim borilačkim sportovima. Da bi se razumela složenost udaraca, kinematička analiza bi mogla da pruži adekvatnu povratnu informaciju. O ovom pitanju se uglavnom raspravljalo u laboratorijskim uslovima, koristeći ili platformu sile ili elektromiografiju u kombinaciji sa reflektujućim markerima i kamerama. Zbog složenosti neuromišićnog i skeletnog sistema čoveka, ovaj pristup zahteva upotrebu skupe i obimne opreme, kao i stručnjaka koji će je adekvatno koristiti, čime se smanjuje obim primene. Neki autori, međutim, ističu važnost merenja u realnim uslovima. Ovo se može postići primenom nosivih senzora koji se brzo integrišu u široko polje istraživanja ljudskih pokreta i sporta, obezbeđujući praćenje van laboratorijskih uslova. Čak i tako, izgleda da nova tehnologija u borilačkim sportovima nije bila podvrgnuta širokoj primeni.

Sledeće poglavlje uključuje pregled prethodnih istraživanja relevantnih za problem koji je treba da se istraži. Autorka daje analizu dosadašnjih saznanja sa aspekta prepoznatog problema. Detaljno su razmotrene osnove tehnike karatea. Sa tradicionalnog stanovišta, trening karatea se odvija u nekoliko faza. Karakteriše ga postepeno savladavanje nastavnog plana i programa tehnike koji obuhvata: stavove, prelazne pokrete, udarce, udarce, blokove i tehniku prevlačenja. Iako se suština tradicionalne borilačke veštine održava u upornoj borbenoj orijentaciji, savremeni karate je evoluirao u kompleksan sport podeljen u dve istaknute discipline – kate i kumite. Iako svaka disciplina ima svoje zahteve, osnova izvođenja udaraca ostaje konstantna.

Za razliku od kata, koje se mogu smatrati zatvorenom veštinom koju karakteriše odsustvo protivnika, kumite je sport otvorenih veština, što znači da su modifikacije u borbenim postavkama konstantne. Sportisti moraju istovremeno da obrađuju veliku količinu informacija i da se shodno tome prilagođavaju kako bi bili efikasni. Varijabilnost se takođe ogleda u velikom intenzitetu i

brzini ofanzivnih, defanzivnih ili kontranapadnih akcija protiv protivnika na stalno promenljivoj udaljenosti. Bez obzira na vrstu akcije, udarci su daleko češći u poređenju sa tehnikama udaranja. Iako su brži za izvođenje, nisu manje zahtevni i njihova sekvencijalna struktura koja koordinira donje i gornje udove ukazuje na sledeći nivo varijabilnosti.

Reverzni udarac (RU) je najčešće korišćena tehnika izvođenja kod elitnih karate takmičara, sa preko 60% izvođenja. Takođe, RU ciljanje na torzo protivnika u poređenju sa RU ciljanjem u glavu protivnika je više nagrađena tehnika izvođenja na takmičenjima najvišeg nivoa. Ubrzanje i brzina su ključni elementi kinematičke šeme udaraca. Pored toga, blagovremeno uključivanje delova tela u sekvencijalnu strukturu pokreta utiče i na brzinu udaranja. Uzimajući u obzir doprinos donjeg dela tela u izvođenju udarca, treba uzeti u obzir i ugaonu brzinu karlice.

Različiti aspekti reverznog udarca su istraženi pod brojnim uslovima performansi i metodološkim pristupima. Analizirajući reverzni udarac četiri ispitanika sa različitim borbenim iskustvom, Stull i Barham otkrili su razlike u dobijenoj kinematici. Chiu i Shiang su istraživali vreme reakcije, brzinu napada i snagu udarca kod elitnih karatista i karatista, pod četiri različita uslova u pogledu stojećih položaja. Nisu otkrili sistematske razlike između ravnih i obrnutih udaraca. Pored studije o uticaju stava na vreme napada tokom karate pokreta, Vang i Liu su proučavali reverzni udarac pod dva uslova stava kod 24 elitna karate takmičara. Zaključili su da, osim male razlike u brzini udarca, ona nije značajna. Ali, što se tiče vremena napada, borbeni stav utiče na optimizaciju performansi.

Dworak et al. su proučavali parametre brzine i kinetike u udarcima rukama i nogama koje su izvodili Shotokan takmičari u laboratorijskim uslovima. Glavni nalazi su bili: udarci šakom su otprilike dva puta slabiji od udaraca nogom. Analizirajući pet karatista sa različitim nivoima performansi Emmermacher et al. zaključili su da je ubrzanje u fazi izvođenja udarca pod uticajem individualnih karakteristika. Girodet et al. koristili su 12-segmentni model markera u kinematičkoj i dinamičkoj analizi pravog udarca. Otkrili su da je vršna sila (1745 N) dostignuta 5 ms nakon početnog kontakta sa makivarom. Gulledge i Dapena uporedili su mehaničke faktore u reverznom i snažnom udarcu od tri inča koji su izvedeni u podstavljenoj meti. Manje brzine neposredno pre udara zabeležene su za snažni udarac (0,14 m/s) nego za reverzni udarac (0,31 m/s). Cesari i Bertucco su testirali različite načine izvođenja udaraca upoređujući performanse eksperata i početnika. Pokazalo se da karate eksperti imaju tendenciju da: koriste specifičnu strategiju za održavanje stabilnosti tela; dostižu veću brzinu gornjih ekstremiteta, udarni impuls i veće pomeranje kutije. Ionete et al. su potvrdili sekvencijalnu struktura reverznog udarca.

Venses Brito et al. uporedili su kinematičke i elektromiografske obrasce udarca Čoku Cuki između grupe iskusnih karatista i učesnika bez karate iskustva. Otkrili su da se aktivnost udarca: javlja unutar 400 ms; ima skoro distalni kraj; intenzitet aktivacije je veći sa mišićima ruke u odnosu na podlakticu. Iskustvo ima veliku ulogu u tehničkoj veštini, što znači da karatisti izvode udarac sa manjom amplitudom (ruka – fleksija i unutrašnja rotacija; podlaktica – ekstenzija i pronacija). U opsežnom istraživanju Koropanovski je uporedio karakteristike neuromišićne funkcije kod seniorskih muških reprezentativaca u karateu, kata i kumite takmičara. Kinematske i dinamičke karakteristike udarca Giako Tsuki izvedenog u različitim modalitetima (u vazduhu ili platformi; sa ili bez povlačenja udarne pesnice u početni položaj; sa ili bez izduženja stava) otkrile su razlike u performansama između sportista različitih specijalizacija.

Loturco et al. proučavali su odnos između ubrzanja udarca i varijabli snage. Glavni nalazi su bili: muškarci u poređenju sa ženama postižu veće vrednosti ubrzanja; različiti uslovi i ciljna orijentacija utiču na ubrzanje udarca (izvođenje udarca sa udaljenosti koju sami birate sa ciljem maksimalnog udara proizvodi veća ubrzanja u poređenju sa brzinskim ciljem i fiksnom distancom); niže vrednosti ubrzanja se dobijaju u cilju maksimalne brzine sa fiksne udaljenosti nego sa udaljenosti koju sami biramo; maksimalna snaga i snaga gornjeg i donjeg dela tela je u pozitivnoj korelaciji sa ubrzanjem udarca u različitim uslovima. Martinez de Kuel i Benett su uporedili grupu karatista sa grupom bez karate iskustva kako bi utvrdili da li stručno znanje i praksa utiču na vreme izvođenja pokreta koji se izvodi pod dva uslova: 1) kao reakcija i 2) samoinicijativno. Na osnovu kinematičke analize istraživači su zaključili da se pri reaktivnom kretanju postiže kraće vreme do vršne brzine i vremena kretanja nego pri samoinicijativnom kretanju, kao i veća tačnost kretanja.

Fucsh et al. imali su za cilj da identifikuju i razlikuju dva koncepta izvođenja udaraca: uzastopni i simultani niz pokreta. Korišćeno je snimanje pokreta sa 61 reflektujućim markerom i osam Vicon kamera, a u studiji je učestvovalo pet iskusnih karatista. Glavni nalaz je potvrdio proksimalno-distalno sekvenciranje maksimalnih brzina zgloba u oba koncepta. Goethel i saradnici proučavali su fazni odnos između proksimalnih i distalnih zglobova tokom Giako Tsuki udarca upoređujući elitne i sub-elitne karate sportiste. Izmeren je vrhunac linearne brzine ručnog zgloba. Otkrili su da koordinativni motorički obrasci performansi postaju stabilniji i kontrolisaniji zbog iskustva. Kuinzi et al. ispitali su da li postoji veza između maksimalne snage donjih ekstremiteta i brzine udarca pri izvođenju kombinovane tehnike u statičkim i dinamičkim uslovima. Utvrđeno je da su maksimalna relativna snaga donjih ekstremiteta i brzina udarca u značajnoj korelaciji bez obzira na zadatak i primenjeno stanje. Analizirajući performanse elitnih sportista Marković i sar. utvrdili su razlike u vremenskoj strukturi reverznog udarca u odnosu na

postignutu maksimalnu brzinu. Na osnovu kinematičkih parametara i njihovih vremenskih indikatora koji stvaraju prepoznatljivu vremensku strukturu, udarac se može kategorisati kao spor, prosečan i brz.

Nakon analize prethodnih nalaza, autor ukazuje na ograničenja dosadašnjih istraživanja. Kao što je već istaknuto, kinematika zglobova je tradicionalno ograničena na laboratorijska istraživanja. U takvim okruženjima, sportisti se suočavaju sa ograničenjima koja nisu uobičajena u realističnoj borbi. Shodno tome, ograničenja koja nameću oprema i okruženje mogu uticati na motoričku veštinu koja se analizira. Znajući da se vrhunski sport bavi finim modifikacijama i odgovorima na varijacije, implikacije su očigledne. Pojavljuje se još jedan problem. Raznolikost metodološkog pristupa u malom broju studija otežava upoređivanje i sistematski prikaz kinematičkih nalaza pojedinih studija kako bi se dobila sveobuhvatna biomehanička ilustracija analiziranog motoričkog zadatka. Konkretno, glavni problemi su: (1) Raznolikost učesnika i uslovi poređenja; (2) Različiti uslovi ispitivanja koji su uticali na praćene kinematičke parametre; (3) Eksperimentalna postavka i uslovi specifični za zadatak; (4) Različite faze izvođenja udaraca ili kinematika pojedinih segmenata koji se analiziraju.

Prema glavnom cilju predložene studije, autorka je dala više informacija o primeni senzora u proceni sportskih performansi, kao i primeni senzora u borilačkim sportovima. Praćenje promena relevantnih parametara performansi omogućeno je merenjem. Dakle, glavno pitanje je kako prevazići adresirana ograničenja i da li kinematički senzori (KS) mogu poboljšati proces merenja. Upotreba KS se brzo širi u širokom polju sporta (uzimajući u obzir elitni sport i rekreaciju visokog nivoa). Između ostalih, kao najvažniji ističu se sledeći uzroci: prevazilaženje ograničenja laboratorijske procene i ograničenja konvencionalnih metoda obuke zasnovanih na subjektivnoj evaluaciji trenera. Ograničavajući faktori u prikupljanju podataka i analizi sportskih tehnika su brojni, a potiču od zahteva za procenom maksimalnog nivoa performansi tokom treninga ili takmičenja. Pored toga, promene u performansama su konstantne i brzo se dešavaju, što utiče na tačnost merenja. Dalje, motorički zadaci specifični za sport i kinematičke parametre relevantne za analizu određuju najpogodniji sistem merenja, koji uvek mora da zadovolji kriterijume visoke validnosti i pouzdanosti. Ukratko, sistem bi trebalo da bude ergonomski, prikladan za upotrebu na terenu, bežični, primenljiv na bilo kojoj površini bez obzira na uslove okoline, dovoljan kapacitet snage, dinamički opseg, frekvenciju uzorkovanja i/ili tačnost.

U proučavanju borilačkih sportova (uključujući boks, džudo, tekvondo i karate) inercijski senzor se koristi u više domena: unapređenje takmičarskog i trenažnog procesa, tehničko modeliranje, kao i analiza opreme, performansi i tehnike. Primenjeni su različiti pristupi, odnosno

postavljanje senzora na sportsku opremu, na sportistu ili na oboje. Sa stanovišta individualnog pristupa i fokusirane dubinske analize kod elitnih karate takmičara, jasan cilj istraživanja treba da dovede do utvrđivanja odgovarajućih mernih zahteva sprave i stavi fokus na ključne momente u izvođenju tehnike. Strogo govoreći, ako je centralni problem istraživanja sam udarac, biće primenljiv samo uređaj sa visokim radnim opsegom (RO) i frekvencijom uzorkovanja. Nasuprot tome, ako istraživanje ima za cilj određenu fazu u izvođenju tehnike koja prethodi udarcu, najverovatnije će to učiniti uređaji nižeg RO. Isto se može primeniti ako je glavni interes proksimalni ekstremitet ili segment. Izolovane faze koje prethode udarcu mogu se smatrati razvojnim u smislu progresivnog povećanja kinematičkih veličina. Naprotiv, završnu fazu izvođenja karakteriše postizanje najvećih vrednosti ubrzanja, pa su zato potrebni senzori koji mogu da registruju visoke kinematičke vrednosti. Razumevanje biomehaničkih aspekata tehnike koja se analizira, kao i znanje zasnovano na uobičajenoj praksi trebalo bi da pruži širu perspektivu u pogledu svojstava uređaja, kao i broja neophodnih senzora i njihovog pozicioniranja.

Na kraju, autor je predstavio pilot rezultate kako bi podržao predložene hipoteze. Pilot rezultati u vezi sa ovom studijom su već objavljeni (Vuković i sar., 2019; Vuković i sar., 2021; Marković i sar., 2021). Obrazloženje i glavni nalazi ovih istraživanja su sledeći:

Pilot istraživanje 1 – Opisni profil kinematičkih karakteristika reverznog udarca (Giako Tsuki) merenih IMU senzorskom tehnologijom. Cilj rada bio je kvantitativna procena kinematičkih obrazaca kretanja merenih kinematičkim senzorima. Stoga je studija istraživala segmentno ubrzanje reverznog udarca kako bi se odredio njegov opisni profil i kako bi se razumelo kako se promene u ubrzanju pokreta pojavljuju u samom udarcu.

Pilot istraživanje 2 - Metričke karakteristike i pouzdanost kinematičkih senzorskih uređaja primenjenih u različitim modalitetima reverznog udarca kod karatista. Pouzdanost i validnost su neki od bitnih uslova merenja. Naročito kada se merenje vrši novim instrumentom ili kada se instrument primenjuje u novim uslovima. Počevši odatle, studija je imala za cilj da proceni merna svojstva i pouzdanost kinematičkih senzora (KS) u uobičajenim uslovima obuke.

Pilot istraživanje 3 – Specifičan dizajn testa za detaljnu analizu tehnike elitnih karate takmičara sa primenom kinematičkih senzora. Dinamičnost savremenog karatea zahteva visok nivo adaptacije i stalnu težnju ka usavršavanju tehnike. Stoga je potreban svež pristup u analizi tehnika bodovanja. Za razliku od prethodnih studija koje su bile fokusirane na fazu reverznog udarca, ovo istraživanje ima za cilj da opiše kinematičku i vremensku strukturu reverznog udarca u početnoj fazi izvođenja. Novina predloženog pristupa je podržana sa deset specifičnih testova i primenom Kinematičkih senzora primenjenih na pažljivo odabranim položajima tela.

Nakon predstavljanja problematike predložene studije, autor je definisao problem, predmet, ciljeve i zadatke. Tehnički aspekti reverznih udaraca u telo, najdominantnije tehnike udaranja u sportskim karate borbama, predstavljaju problem istraživanja. Da budemo precizniji, predmet istraživanja je kvalitet tehnike kroz nekoliko modaliteta izvođenja. Cilj istraživanja je procena razlika između kinematičkih i vremenskih pokazatelja u različitim modalitetima izvođenja reverznog udarca primenom tehnologije kinematičkih senzora u realnim uslovima rada. Iz navedenog proizilaze sledeći istraživački zadaci: Regrutovanje uzorka; Prikupljanje podataka uzorka (telesna težina, telesna visina, godine, godine treniranja i iskustva u takmičenju, dominantan borbeni stav); Procena kinematičkih i vremenskih karakteristika udarca u različitim modalitetima izvođenja; Obrada signala; Statistička obrada i analiza podataka.

Na osnovu pregleda prethodnog istraživanja, postavljene su sledeće hipoteze:

HG – IMU senzorska tehnologija je validna i diskriminatorna u pogledu specifičnih indikatora reverznog udarca u okviru različitih modaliteta performansi.

H1 – Postoji razlika u kinematičkim parametrima obrnutog udarca između testova.

H2 – Najveće maksimalne vrednosti kinematičkih parametara postižu se u testu u kome učesnici optimalno koriste svoje biološke potencijale.

H3 – Postoji pozitivna korelacija između kinematičkih parametara na telu i šaci.

H4 – Optimalna vremenska sekvenca kinematičkih parametara doprinosi efikasnosti probijanja.

U cilju prikupljanja podataka koji će omogućiti proveru formulisanih hipoteza, autorka je osmislila kompleksnu studiju čiji je dizajn detaljno objašnjen u okviru sledećeg poglavlja (Materijali i metode). U studiji će učestvovati četrnaest takmičara – članova seniorske i kadetske reprezentacije Srbije u karateu. Da bi učestvovali u studiji, učesnici moraju biti u potpunosti informisani o rizicima i koristima povezanim sa studijom. Svi učesnici moraju potpisati formular za pismenu saglasnost. Studija mora da prati etičke standarde priznate Helsinškom deklaracijom i mora da bude odobrena od strane Etičkog istraživačkog komiteta Fakulteta sporta i fizičkog vaspitanja Univerziteta u Beogradu.

Nakon sesije zagrevanja, sportisti će dobiti usmena uputstva i praktične demonstracije testova. Biće im naloženo da zadaju reverzni udarac, ciljajući telo, dominantnom rukom, otprilike 5 s nakon audio signala. Tri uzastopna udarca će biti zadata u dva pokušaja sa dovoljno vremena za odmor između. Svi takmičari će izvesti udarac dominantnom rukom, te stoga stoje u

odgovarajućem stavu (levo ili desno). Početne pozicije će biti: osnovni stav (Zenkotsu dachi) i borbeni stav (Fudo dachi). Udar će biti testiran u ukupno 10 modaliteta performansi. Osim prvog (RPNH: rotacija kuka isključena iz RU izvršenja); i drugi (RPH: rotacija kuka uključena u RU) testovi koji zahtevaju od učesnika da ne pomeraju stopala, preostala četiri testa će biti obavljena u odnosu na dva glavna uslova: statički (S) i dinamički (D) početni položaj: RPSM: klizni pokret koji prethodi RU; RPSMO: klizni pokret koji prethodi RU, sa protivnikom kao metom; RPSMP: klizni pokret koji prethodi RU, sa partnerom koji drži podlogu za udarce u grudi; RPSMR: klizni pokret koji prethodi RU-u izveden sa vizuelnim signalom. Osnovna ideja predstavljenog pristupa testiranju leži u pretpostavci da će se kinematički parametri menjati usled različitih nivoa tehničke složenosti. Odnosno, uključivanje većeg broja segmenata tela će uticati na ubrzanje i brzinu, odnosno na performanse RU. Osim toga, dosadašnja istraživanja daju dovoljno razloga da se pretpostavi da uključenost konkretnog zadatka ili cilja može uticati i na parametre od interesa. Sa biomehaničke tačke gledišta, složenost se povećava od RPNH do RPSMR i praćena je početnim stavom. Sa pronicljivim postavljanjem senzora, predloženi sistem može biti pouzdan, ergonomski, optimalan i lak za upotrebu u realnom okruženju.

Dva kinematička senzora (KS) biće pričvršćena na ruku i telo. Mikrokontroleri sa komunikacionim ViFi modulom integrisanim u senzore omogućavaju čitanje KS podataka i prenos ih u odvojene LabViev aplikacione petlje koje rade na laptopu. Uzorci sa oba kinematička uređaja će biti očitani u glavnoj programskoj petlji. Procedura će biti kontrolisana i tempirana u ciklusima od 5ms. Komunikacija će biti uspostavljena putem protokola korisničkih datagrama na visoko opterećenom ISM opsegu. Pošto raznolikost paketa može dovesti do gubitka podataka, ispravke grešaka će biti raspoređene tako da se mogući izgubljeni uzorci zamene prethodnim vrednostima. Valjanost rezultata će biti potvrđena kroz praćenje kvaliteta kanala. Za snimanje testiranja koristiće se dve kamere. Kamere će biti postavljene na udaljenosti od 2 metra od učesnika i bočno (levo i desno) u odnosu na sportiste na stativu na 1,3 metra iznad poda. Za svaki modalitet tehnike i svako ispitivanje, podaci će biti uskladišteni u dve video datoteke (.avi i .MP4). Podaci inercijalnog senzora će se čuvati pomoću LabViev aplikacije kao .tdms datoteke.

Tehnički učinak sportiste biće procenjen korišćenjem signala akcelerometra sa oba uređaja i signala žiroskopa sa uređaja koji se nosi na telu. U obzir će se uzeti i vreme njihovog nastanka. Podaci će biti naknadno obrađeni i analizirani korišćenjem softvera za numeričko računanje MathCAD 7. Analiza signala će biti izvedena korišćenjem batervortovog niskopropusnog filtera 5. reda sa graničnom frekvencijom od 40Hz. Da bi se sprečilo lažno otkrivanje događaja, za ubrzanje i brzinu rotacije će se primeniti različiti pragovi. Maksimalna granična vrednost biće postavljena na 5%. Prvi korak u izračunavanju varijabli koje definišu tehničke performanse biće

pomeranje signala u referentnom trenutku analize. Analiza signala će se vršiti u vremenskom prozoru koji sadrži 120 uzoraka, u vremenskom intervalu od 0,6 sekundi.

Selekcija varijable se zasniva na znanju koje ističe: ubrzanje i brzinu kao važne parametre udarca; kritični uticaj kinetičkih lanaca kinematičkih veličina vremenske linije na sekvencijalnu strukturu RU. Kinematske i vremenske veličine koje se smatraju relevantnim za procenu RU su: HA – maksimalno ubrzanje ruke, izraženo u g; tHAS – vreme za početak ubrzanja ruke; tHA – vreme za maksimalno ubrzanje ruke; HV – maksimalna brzina ruke, izražena u m/s; tHV – vreme za maksimalnu brzinu ruke; BV – maksimalna brzina tela, izražena u m/s; tBV – vreme za maksimalnu brzinu tela; tBAS – vreme početka ubrzanja tela; BRa – maksimalni ugao rotacije tela, izražen u st.

Statistička analiza koja će biti sprovedena u cilju provere predloženih hipoteza biće sledeća:

HG – IMU senzorska tehnologija je validna i diskriminatorna u pogledu specifičnih indikatora reverznog udarca u okviru različitih modaliteta performansi: koeficijent unutarklasne korelacije (ICC); Pirsonova korelacija, ANOVA.

H1 – Postoji razlika u kinematičkim parametrima obrnutog udarca između testova: Dvosmerna ANOVA.

H2 – Najveće maksimalne vrednosti kinematičkih parametara postižu se u testu u kome učesnici optimalno koriste svoje biološke potencijale: Dvosmerna ANOVA (Post Hoc test: Tukeieva značajna razlika [HSD], Bonferoni test)

H3 – Postoji pozitivna korelacija između kinematičkih parametara na telu i šaci: Pirsonova korelacija.

H4 – Optimalna vremenska sekvenca kinematičkih parametara doprinosi efikasnosti probijanja: Pirsonova korelacija.

Statistička značajnost korelacije biće definisana prema studiji Koena. Nivo statističke značajnosti biće definisan za verovatnoću od 95%, tj. $p \leq .050$. Statističke analize će se vršiti korišćenjem Microsoft Office Ekcel 2007 i statističkog paketa za društvene nauke (IBM, SPSS Statistics, verzija 20.0) za Windows.

Očekivani rezultati i naučni doprinos

Razumno je pretpostaviti da će primena pouzdanog instrumenta u merenju parametara od interesa u specifičnoj tehnici karatea pomoći u otkrivanju razlika između testova, kao i prirode odnosa između parametara tela i ruke i njihovog uticaja na konačan ishod u izvođenju udaraca.

Stoga se očekuje da će rezultati istraživanja povećati bazu teorijskih i praktičnih znanja tako što će:

(1) Povećanje izvora znanja o kvalitetu tehnike čija je osnovna struktura zajednička među borilačkim sportovima;

(2) Poboljšanje merenja i procene korišćenjem kinematičkih senzora kao alternative konvencionalnom laboratorijskom pristupu.

U smislu praktične primene, in situ akvizicija podataka u realnim uslovima omogućava razumevanje prave razmere odnosa između segmenata kinetičkog lanca i kinematičkih razlika analiziranog udarca. Takav pristup pomera fokus treninga elitnih sportista na različite detalje koje dele borilački sportovi. Ovo dovodi do poboljšanja analize tehnike i prevazilazi obim samog karatea. Štaviše, specifični testovi u kombinaciji sa pronicljivim pozicioniranjem mernih uređaja daju vredne podatke, omogućavajući nepristrasnu procenu kao osnovu za obuku i konkurentna poboljšanja. Ova studija će otkriti da li isključenje/uključivanje segmenata tela utiče na kinematičke parametre. Pored toga, biće jasno da li odnos kinematičkih i vremenskih parametara utiče na izvršenje udarca. Ukratko, očekuje se da će doprinos studije biti u oblasti: poboljšanja treninga i takmičarske prakse karatista elitnog nivoa kroz ukazivanje na potencijalno slabe tačke u izvođenju RU; Razumevanje kinematičkih i vremenskih obrazaca udaraca u fazi razvoja RU u različitim modalitetima izvođenja, kao osnova za individualni pristup u povećanju efikasnosti udaraca; Unapređenje procedura testiranja i metodologije proučavanja primenom senzora i specifičnih testova u najistraženijoj karate tehnici; Poboljšanje kontrole udarca i performansi kroz primenu novog pristupa koji dovodi do smanjenja povreda usled loše strukture pokreta.

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Predlog mentora, saglasnost mentora i spisak njihovih radova

S obzirom na kompleksnost istraživanog problema kojim se kandidat bavi u obrazloženju teme doktorske disertacije, kao i s obzirom na saradanju u toku pripreme istraživanja, koju je kandidat imao sa Fakultetom za elektrotehniku i inžinjerstvo Univerziteta u Ljubljani, predlažemo dva mentora u realizaciji projekta doktorske disertacije:

1. Dr Milivoj Dopsaj, redovni profesor, Univerzitet u Beogradu – Fakultet sporta i fizičkog vaspitanja,
2. Dr Anton Umek, vanredni profesor, Univerzitet u Ljubljani - Fakultet za elektrotehniku i inžinjerstvo.

Oba predložena mentora, red. prof. dr Milivoj Dopsaj i van. prof. dr Anton Umek ispunjavaju uslove predviđene Standardima za akreditaciju studijskih programa doktorskih studija i saglasni su da, po predloženoj temi, budu mentori u realizaciji doktorske disertacije Vesne Vuković.

Prilažemo spisak radova koje su red. prof. dr Milivoj Dopsaj i van. prof. dr Anton Umek objavili u međunarodnim naučnim časopisima u poslednjih 5 godina, a koji po svojoj temi pripadaju naučnoj oblasti Fizičko vaspitanje i sport, kojoj pripada i predložena tema. Takođe, naglašavamo da su pojedini radovi usko vezani sa predloženom temom:

Dr Milivoj Dopsaj, redovni profesor

1. Erman B, Ozkol MZ, Ivanović J, Arslan H, Ćosić M, Yuzbasioglu Y, **Dopsaj M,** Aksit T. Assessments of Ground Reaction Force and Range of Motion in Terms of Fatigue during the Body Weight Squat. Int J Environ Res Public Health. 2021 Apr 11;18(8):4005. doi: 10.3390/ijerph18084005.
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6. Zarić I, Kukić F, Jovićević N, Zarić M, Marković M, Toskić L, **Dopsaj M.**Body Height of Elite Basketball Players: Do Taller Basketball Teams Rank Better at the FIBA World Cup? Int J Environ Res Public Health. 2020 Apr 30;17(9):3141. doi: 10.3390/ijerph17093141.
7. Vuković M, Kukić F, Čvorović A, Janković D, Prćić I, **Dopsaj M.** Relations Between Frequency and Volume of Leisure-Time Physical Activity and Body Composition in Police Officers. Res Q Exerc Sport. 2020 Mar;91(1):47-54. doi: 10.1080/02701367.2019.1646391. Epub 2019 Sep 10.
8. Trajkov M, Cuk I, Eminovic F, Kljajic D, **Dopsaj M.** Relationship between hand grip strength and endurance and postural stability in active and sedentary older women. J Electromyogr Kinesiol. 2018 Dec;43:62-67. doi: 10.1016/j.jelekin.2018.09.006. Epub 2018 Sep 12.

Dr Anton Umek, vanredni profesor

1. Guo J, Yang L, **Umek A,** Bie R, Tomažič S, Kos A. A Random Forest-Based Accuracy Prediction Model for Augmented Biofeedback in a Precision Shooting Training System. Sensors (Basel). 2020 Aug 12;20(16):4512. doi: 10.3390/s20164512.
2. Taborri J, Keogh J, Kos A, Santuz A, **Umek A,** Urbanczyk C, van der Kruk E, Rossi S. Sport Biomechanics Applications Using Inertial, Force, and EMG Sensors: A Literature Overview. Appl Bionics Biomech. 2020 Jun 23;2020:2041549. doi: 10.1155/2020/2041549. eCollection 2020.
3. Pustišek M, **Umek A,** Kos A. Approaching the Communication Constraints of Ethereum-Based Decentralized Applications. Sensors (Basel). 2019 Jun 11;19(11):2647. doi:10.3390/s19112647.
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Mišljenje i predlog Komisije

Predlog teme doktorske disertacije Vesne Vuković napisan je na engleskom jeziku zbog predloženih mentora, ali i međunarodnog sastava same komisije. Predložena tema je usmerena na istraživanje problema validne i pouzdane procene performansi u karateu primenom kinematičkih senzora. Tema je formulisana na osnovu pažljive analize obimnog bibliografskog materijala. Ispitivanje uočenog problema predviđeno je u ekološki validnim uslovima čime se značajno povećava eksterna validnost samog eksperimantalnog istraživanja.

Problem istraživanja detaljno je obrazložen, a cilj i hipoteze jasno su formulisani. Predviđene metode u istraživanju omogućavaju realizaciju postavljenih ciljeva istraživanja.

Istraživanje će omogućiti nova, metodološki zasnovana, znanja u odnosu na mogućnosti korišćenja kinematičkih senzora u merenju performansi u karateu. Potencijalni nalazi istraživanja će imati neposrednu primenu u praksi, jer će direktno ukazati na mogućnost primene rezultata u proceni performansi u najčešće korišćenoj napadačkoj tehnici u karateu. Standardna primena kinematičkih senzora će omogućiti specifičniju i potpuniju dijagnostiku trenutnih performansi u sportu.

Predlažemo da autorka u srpskog verziji naslova koristi termin Gjaku Zuki umesto Đako Zuki, s obzirom da je ovaj termin pravilniji i uobičajeno se koristi u literaturi.

Predlažemo da Nastavno-naučno veće prihvati Izveštaj komisije i Veću naučnih oblasti društveno-humanističkih nauka uputi odluku kojom se odobrava tema doktorske disertacije Vesne Vuković pod naslovom "KINEMATIC AND TEMPORAL PARAMETERS IN DIFFERENT MODALITIES OF THE REVERSE PUNCH MEASURED BY IMU SENSORS (KINEMATIČKI I VREMENSKI POKAZATELjI UDARCA GJAKU ZUKI U RAZLIČITIM MODALITETIMA IZVOĐENjA MERENI IMU SENZORIMA)", i kojom se redovni profesor dr Milivoj Dopsaj i vanredni profesor dr Anton Umek imenuju za mentore.

U Beogradu, 16.01.2023. godine

Članovi Komisije:

_____

Dr Aleksandar Nedeljković, redovni profesor,
Univerzitet u Beogradu – Fakultet sporta i fizičkog vaspitanja, predsednik komisije

_____

Dr Miloš Mudrić, vanredni profesor,
Univerzitet u Beogradu – Fakultet sporta i fizičkog vaspitanja, član

_____

Dr Nenad Koropanovski, redovni profesor, Kriminalističko-policijski univerzitet, Beograd, član;

THE COMMITTEE FOR EVALUATION OF THE SCIENTIFIC FOUNDATION OF THE TOPIC OF DOCTORAL DISSERTATION

TO THE TEACHING-SCIENTIFIC COUNCIL OF THE FACULTY OF SPORT AND PHYSICAL EDUCATION

Subject: The report on the review and evaluation of the topic of the doctoral dissertation of Vesna Vuković, a student from the doctoral study program.

At the 3rd session of the Teaching-Scientific Council of the Faculty of Sport and Physical Education, held on December 15th 2022., in accordance to the Art. 42 and 43 of the Statute of the Faculty, the Decision has been reached to form a Committee for evaluation of the scientific foundation of the topic of the doctoral dissertation entitled: "KINEMATIC AND TEMPORAL PARAMETERS IN DIFFERENT MODALITIES OF THE REVERSE PUNCH MEASURED BY IMU SENSORS (KINEMATIČKI I VREMENSKI POKAZATELjI UDARCA ĐAKO ZUKI U RAZLIČITIM MODALITETIMA IZVOĐENjA MERENI IMU SENZORIMA)" which is written by the student of the doctoral academic studies Vesna Vuković, (act-02-no. 2761/22-3 dated 16th December 2022.). The following committee has been formed:

- Aleksandar Nedeljković, PhD, Full Professor, University of Belgrade, Faculty of Sport and Physical Education, chairman of the committee;
- Miloš Mudrić, PhD, Associate Professor, University of Belgrade, Faculty of Sport and Physical Education, committee member;
- Nenad Koropanovski, PhD, Full Professor, University of Criminal Investigation and Police Studies, Belgrade, committee member;

After reviewing the submitted material, the Commission submits the following to the Teaching-Scientific Council

REPORT

Biography

Vesna Vuković was born on April 25th 1977. in Belgrade. She graduated in 1995. from III Belgrade High School. In 2016. she graduated from basic academic studies at the Faculty of Physical culture and management in sports, in Belgrade. At the same university, she earned the

title of Master of Physical Education and Sports in 2017. She enrolled the doctoral studies at the Faculty of Sports and Physical Education University of Belgrade in same year.

She has been actively engaged in karate since 1987., as a competitor, coach and referee. She has been employed in elementary school „Mladost“ as a teacher of Physical and Health Education since 2019.

She speaks English language.

The list of published papers:

1. **Vuković, V.,** Koropanovski, N. (2011). Tehničko-taktičke karakteristike osvajača medalja iz Srbije na Svetskom prvenstvu u karateu 2010. godine u mečevima za medalju. International Scientific Conference: Effects of Physical Activity Application to Anthropological Status with Children, Youth and Adults. 230-237.
2. **Vuković, V.,** Koropanovski, N. (2018). Handgrip differences between young karate athletes and non-athletes in relation to gender. XXI Scientific Conference „FIS COMMUNICATIONS 2018", October 18-20.2018. Nis. 21-27.
3. Dopsaj, M., Marković, S., Jovanović, J., **Vuković, V.,** Maksimović, M., Miljuš, D., Tomanić, M., Aničić, Z., Tomić, L. D., & Stanković, A. (2018). BMI: Analysis of the Population Indicators in Working Population of the Republic of Serbia in Relation to Gender and Age. Fizička Kultura, 72(2), 148 160. https://doi.org/10.5937/fizkul1802148D
4. **Vuković, V.,** Koropanovski, N., Markovic, S., Umek, A. (2019). Descriptive profile of the reverse punch (gyako tsuki) kinematic characteristics measured by IMU sensor technology. XXII Scientific Conference „FIS COMMUNICATIONS 2019", October 17-19.2019. Nis. 40-44.
5. Marković, S., Dopsaj, M., **Vuković, V.,** Majstorovic, N., Koropanovski, N., Umek, A. (2019). Differences in visual reaction time in children and adolescents involved in open skill sports. XXII Scientific Conference „FIS COMMUNICATIONS 2019", October 17-19.2019. Nis. 247-253.
6. **Вуковић, В.,** Марковић, С., Коропановски, Н., Миловановић, М., Допсај, М. (2019). Разлике простог и изборног времена реакција код младих каратиста оба пола различитог нивоа обучености. Физичка култура. 73(2): 238-248. https://doi.org/10.5937/fizkul1902238V
7. **Vuković, V.,** Marković, S., Koropanovski, N., Umek, T., & Dopsaj, M. (2019). Reaction Time in Young Karate Athletes in Relation to Gender and Level of Training [Abstract]. In T. Volmut & K. Koren (Eds.), The 10th International Scientific and Professional Conference “Child in Motion” Book of Abstract (p. 108). Science and Research Centre Koper.
8. Marković, S., **Vuković, V.,** Koropanovski, N., & Majstorović, N. (2021). Differences in Reaction Time Capabilities in Physically Active Subjects of Different Age. Serbian Journal of Sport Science, 12(1), 25-30.

9. **Vuković, V.,** Dopsaj, M., Koropanovski, N., Marković, S., Kos, A., Umek, A. (2021). Metrical characteristics and the reliability of kinematic sensor devices applied in different modalities of reverse punch in karate athletes. Measurement. 177: 309-315. https://doi.org/10.1016/j.measurement.2021.109315
10. Marković, S., Kos, A., **Vuković, V.,** Dopsaj, M., Koropanovski, N., & Umek, A. (2021). Use of IMU in Differential Analysis of the Reverse Punch Temporal Structure in Relation to the Achieved Maximal Hand Velocity. Sensors, 21(12), 41-48. https://doi.org/10.3390/s21124148
11. **Vuković, V.,** Koropanovski, N., Marković, S., Kos, A., Dopsaj, M., & Umek, A. (2022). Specific Test Design for the In-Depth Technique Analysis of Elite Karate Competitors with the Application of Kinematic Sensors. Applied Sciences, 12(16), 40-48.

Evaluation of the candidates more important papers related to the proposed topic of the doctoral dissertation

1. In order to understand the complexity of punches, measurement under realistic conditions in a training environment is necessary. A crucial element to achieving valid results is a reliable instrument. The aim of the study titled **"Metrical characteristics and the reliability of kinematic sensor devices applied in different modalities of reverse punch in karate athletes"** was to evaluate the metrical characteristics and reliability of kinematic sensors (KS) in specific karate testing as a novel method in the training process. Fourteen male competitors, members of a Serbian national senior and cadet karate team, participated in the study. Segmental acceleration in the different modalities of reverse punch (Gyako tsuki) were measured using KS placed on the hand and body. In relation to the qualitative criterion of the intraclass correlation coefficient (ICC) significance, good reliability (ICC = 0.75–0.90) was observed for eight kinematic variables, while excellent reliability (ICC > 0.90) was confirmed for ten kinematic variables. KS can be considered sophisticated measuring tools providing a reliable base of information for the objectification of assessment as the primary approach to top-level athletes.
2. Karate fighters are under constant pressure to find adequate scoring solutions in ever-changing combat conditions. Thus, technique improvement at high levels of mastery demands a novel approach to key data acquisition and in-depth analysis of more than just the impact phase in punch execution. The paper titled **"Specific Test Design for the In-Depth Technique Analysis of Elite Karate Competitors with the Application of Kinematic Sensors"** was aimed to describe the kinematic and temporal structure of a reverse punch in the developmental phase. For this purpose two wireless sensors were used for the acquisition of selected quantities in ten modalities performed by a continental

and world medallist. The results show that the timeline of kinematic parameters may be a reliable factor regarding the efficiency of the reverse punch. The obtained hand results show a tendency towards maintaining greater levels of stability in comparison to the body. Additionally, the differences between parameters in relation to applied tests that replicated training and combat conditions were noted. The highest acceleration values were obtained in sliding motion preceding RP, with a partner holding chest punch pad, both static (7.35 ± 0.47 g0) and dynamic (6.99 ± 1.23 g0) tests. The same applies for velocity (8.39 ± 0.14 and 7.30 ± 1.28 m/s). The obtained results indicate the need for specific testing and an individual approach in the analysis of the techniques of elite competitors, along with the use of sensors in data acquisition. Such an approach may help improve the training and competition practice of karate fighters.

3. To achieve good performance, athletes need to synchronize a series of movements in an optimal manner. One of the indicators used to monitor this is the order of occurrence of relevant events in the movement timeline. However, monitoring of this characteristic of rapid movement is practically limited to the laboratory settings, in which motion tracking systems can be used to acquire relevant data. The aim of paper titled **„Use of IMU in Differential Analysis of the Reverse Punch Temporal Structure in Relation to the Achieved Maximal Hand Velocity“** is to implement a simple-to-use and robust IMU-based solution suitable for everyday praxis. In this way, repetitive execution of technique can be constantly monitored. This provides augmented feedback to coaches and athletes and is relevant in the context of prevention of stabilization of errors, as well as monitoring for the effects of fatigue. In this research, acceleration and rotational speed signal acquired from a pair of IMUs (Inertial Measurement Unit) is used for detection of the time of occurrence of events. The research included 165 individual strikes performed by 14 elite and national-level karate competitors. All strikes were classified as slow, average, or fast based on the achieved maximal velocity of the hand. A Kruskal–Wallis test revealed significant general differences in the order of occurrence of hand acceleration start, maximal hand velocity, maximal body velocity, maximal hand acceleration, maximal body acceleration, and vertical movement onset between the groups. Partial differences were determined using a Mann–Whitney test. This paper determines the differences in the temporal structure of the reverse punch in relation to the achieved maximal velocity of the hand as a performance indicator. Detecting the time of occurrence of events using IMUs is a new method for measuring motion synchronization that provides a new insight into the coordination of articulated human movements. Such application of IMU can provide

additional information about the studied structure of rapid discrete movements in various sporting activities that are otherwise imperceptible to human senses.

Proposed topic of the doctoral dissertation

Vesna Vuković has proposed the following topic of the doctoral dissertation "KINEMATIC AND TEMPORAL PARAMETERS IN DIFFERENT MODALITIES OF THE REVERSE PUNCH MEASURED BY IMU SENSORS (KINEMATIČKI I VREMENSKI POKAZATELjI UDARCA ĐAKO ZUKI U RAZLIČITIM MODALITETIMA IZVOĐENjA MERENI IMU SENZORIMA)". In accordance with Art. 31, Par. 2 of the Rule-book on doctoral academic studies, a public presentation of the proposed topic of the doctoral dissertation was held on 29th June 2021 in front of the members of the Council of Doctoral Academic Studies. Based on the presentation, the proposed topic and the research project for the preparation of the doctoral dissertation were positively evaluated.

Topic rationale

In the explanation of the topic, the author, at the beginning, dealt with the research problems from the theoretical aspect, referring to the fact that enhancement of sports skills is one of the most important requests in the carrier of an athlete, irrespective of the level of competition. The aim of the training is what changes. Shifting the training focus in some combat sports is possible on account of fundamental knowledge in punches. For that reason reverse punch (RP) aiming the body (in Japanese language Gyako Tsuki chudan) is perhaps the top studied karate technique. Yet, its core kinematic elements still seem to provoke undiminished research interest.

Punches are the most recognizable arm technique in various combat sports. In order to understand complexity of punches, kinematic analysis could provide adequate feedback. This issue has mainly been discussed under laboratory conditions, using either force platform or electromyography in combination with reflective markers and cameras. Due to complexity of the human neuromuscular and skeletal systems, this approach requires the usage of expensive and extensive equipment, as well as experts who will use it adequately, thus reducing the scope of applications. Some authors, however, emphasize the importance of measurement under realistic conditions in a training environment. This might be achieved through application of wearable sensors which are rapidly becoming integrated in a broad field of a human movement and sport research, providing monitoring out of laboratory settings. Even so, it appears that new technology in combat sports has not been subjected to extensive application.

The following Chapter includes the review of previous research relevant to the problem that supposed to be investigated. The author provides the analysis of previous findings from the aspect of the recognized problem. The fundamentals of karate technique have been discussed in details. From a traditional point of view, karate training takes place in several stages. It is characterized by gradual mastery of the technique curriculum, which includes: stances, transitional movements, punches, kicks, blocks, and swiping technique. Although the essence of traditional martial art is maintained in persistent fighting orientation, contemporary karate evolved into a complex sport divided into two distinguished disciplines – kata and kumite. Although each discipline has its own requirements, the basis of the punch execution remains constant.

In contrast to kata, which can be considered as a closed skill distinguished by the absence of the opponent, kumite is an open skill sport meaning that modification in combat settings are constant. Athletes have to process great amount of information simultaneously and adapt accordingly, in order to be efficient. Variability is also reflected in high intensity and speed of offensive, defensive or counter attack actions against the opponent at a continually changing distance. In spite of the type of action, punches are by far more frequent in compare to kicking techniques. Although, being faster to execute, they are not less demanding and their sequential structure coordinating lower and upper limbs, indicates the next level of variability.

The reverse punch (RP) is the most frequently used pointing technique in elite karate competitors, with over 60% of occurrence. Also, RP aiming the opponent's torso in compare to RP aiming the opponent's head is more rewarded pointing technique on the top-level competitions. The acceleration and velocity are key elements of the punches' kinematic pattern. In addition, timely inclusion of body parts in the sequential structure of the movement affects punching speed as well. Considering contribution of the lower part of the body in the punch execution the angular speed of the pelvis should also be taken into account.

Diverse aspects of the reverse punch have been investigated under numerous performance conditions and methodological approaches. Analyzing the reverse punch of four males with different combat backgrounds Stull and Barham revealed differences in obtained kinematics. Chiu and Shiang investigated reaction time, attacking speed and punch force in elite male and female karate athletes, under four different conditions regarding standing positions. They revealed no systematic differences between straight and reverse punches. In addition to the study of the effect of stance on attack-time during a karate movement Wang and Liu studied reverse punch under two stance conditions at 24 elite karate competitors. They concluded that, apart from the slight

difference in punch speed, it was not significant. But, regarding attack time, combat stance influences optimization of the performance.

Dworak et al. studied velocity and kinetic parameters in punches and kicks performed by Shotokan competitors in laboratory settings. The main findings were: punches seem to be approximately two times weaker than kicks. Analyzing five karate athletes with different levels of performance Emmermacher et al. concluded that acceleration is under the influence of individual characteristics in the pushing phase of punch execution. Girodet et al. used 12-segment marker model in kinematic and dynamic analysis of straight punch. They found that the peak force (1745 N) was reached 5 ms after the initial contact with the makiwara. Gulledge and Dapena compared mechanical factors in the reverse and three-inch power punches performed into a padded target. The smaller velocities immediately before impact were evidenced for the power punch (0.14 m/s) than the reverse punch (0.31 m/s). Cesari and Bertucco tested different ways of punch execution comparing expert and novice performances. It was evidenced that karate experts tend to: use specific strategy to maintain body stability; reach higher upper limb velocity, punch impulse, and a larger box displacement. Ionete et al. confirmed sequential structure of the reverse punch.

Vences Brito et al. compared the kinematic and electromyographic patterns of the Choku Tsuki punch between group of experienced karate athletes and participants without karate background. They found that punch activity: occurs within 400 ms; has near-distal end; intensity of activation is greater with the arm muscles compering to forearm. A part of that, experience has a great role in technical skill, meaning that karate athletes execute the punch with smaller amplitude (the arm – flexion and internal rotation; the forearm – extension and pronation). In the extensive research Koropanovski compared characteristics of neuromuscular function in senior male national karate team, kata, and kumite competitors. The kinematic and dynamic characteristics of the Gyako Tsuki punch performed in different modalities (in the air or the platform; with or without withdrawing the punching fist to the starting position; with or without stance elongation) revealed performance differences between athletes of different specialization.

Loturco et al.13 studied the relationship between punching acceleration and strength and power variables. The main findings were: male in compare to female achieve higher acceleration values; different conditions and goal orientation influences punch acceleration (executing punch from a self-selected distance aiming the maximum impact produces higher accelerations in compare to speed-oriented goal and fixed distance); lower values of acceleration are obtained aiming maximum speed from a fixed distance than from a self-selected distance; maximal strength

and power of upper- and lower-body is positively correlated to punch acceleration in the different conditions. Martinez de Quel and Bennett compared group of karate athletes to the group without karate experience to determine if expert knowledge and practice influences the execution time of movement performed under two conditions: 1) as a reaction, and 2) self-initiated. On the basis of the kinematic analysis the investigators concluded that shorter time to peak velocity and movement time, as well as greater accuracy of the movement is achieved in reactive than self-initiated movement.

Fucsh et al. aimed to identify and discriminate two concepts of punch execution: consecutive and simultaneous sequence of motion. Motion capture with 61 reflective markers and eight Vicon cameras was used, and five experienced karate athletes participated in the study. The main finding confirmed proximal-to-distal sequencing of maximal joint velocities in both concepts. Goethel et al.32 studied the phase relationship between the proximal and distal joints during Gyako Tsuki punch comparing elite and sub-elite karate athletes. The linear velocity peak of the wrist was measured. They found that coordinative motor patterns of performance become more stable and controlled due to experience. Quinzi et al. investigated if there is connection between lower limb maximal power and punch speed while performing combined technique in static and dynamic conditions. It was determined that lower limb maximal relative power and punch speed are significantly correlated regardless of task and condition applied. Analysing elite athletes' performance Marković et al.34 determined the differences in the temporal structure of the reverse punch in relation to the achieved maximal velocity. On the basis of the kinematic parameters and their temporal indicators which create recognizable time structure, punch could be categorized as slow, average and fast.

After analyzing the previous findings, the author indicates the limitations of previous research. As already pointed out, joint kinematics is traditionally restricted to laboratory research. In such settings, athletes face limitations that are not common in realistic combat. Consequently, constrains imposed by the equipment and environment may affect the motor skill under analysis. Knowing that top-level sport is dealing with fine modifications and responses to variations, the implications are obvious. One more problem occurs. The diversity of the methodological approach in the small number of studies makes it difficult to compare and systematically present the kinematic findings of particular studies in order to obtain a comprehensive biomechanical illustration of the analysed motor task. In particular, major problems are: (1) Diversity of participants and comparison conditions; (2) Various test conditions which influenced the monitored kinematic parameters; (3) Experimental setup and task specific conditions; (4) Different phases of punch execution or kinematics of particular segments under analysis.

According to the main aim of the proposed study, the author provided more information on sensors application in sport performance evaluation as well as sensors application in combat sports. Tracking changes in relevant performance parameters is sports necessity enabled through measurement. So, the main question is how to overcome addressed limitations and whether kinematic sensors (KS) can improve measuring process. The use of KS is rapidly expanding in a broad field of sport (taking into account elite, high level sport and recreation). Among others, the following causes stand out as the most important: overcoming limitations of laboratory-based assessment and constraints of conventional training methods founded on coaches subjective evaluation. Constraining factors in data acquisition and analysis of sports techniques are numerous, and they originate from a requirement for assessment of the maximum level of performance during training or competitions. Additionally, modifications in performance are constant and rapidly occurring, thus affecting the accuracy of the measurement. Further, motor tasks specific for the sport and kinematic parameters relevant for the analysis determine the most suitable measurement system, which always has to meet high precision criteria and reliability. In summary, the system supposed to be ergonomic, appropriate for in-field use, wireless, applicable on any surface regardless of the environmental conditions, sufficient power capacity, dynamic range, sampling frequency and/or accuracy.

In combat sports studies (including boxing, judo, taekwondo and karate) inertial sensor are used in more than one domain: improvement of competition and training process, technical modelling, as well as equipment, performance and technique analysis. Different approaches have been applied, that is, placing sensors on a sport's equipment, on the athlete, or on both. Speaking from a standpoint of individual approach and focused in-depth analysis in elite karate competitors, a clear research goal should lead to determination of the appropriate measurement requirements of the device and put the focus on key moments in technique execution. Strictly speaking, if the central problem of the research is the impact itself, only device with high operating range (OR) and sampling frequency will be applicable. In contrast, if the research aims a particular phase in the technique execution preceding the impact, it is most probably that devices of a lower OR will do. The same may apply if the main interest is the proximal limb or a segment. The isolated phases preceding the impact can be considered as a developmental in terms of progressive increase of kinematic quantities. On the contrary, final phase of execution is characterised by achieving the highest acceleration values, hence sensors that can register high kinematic values are needed. Understanding the biomechanics of the technique under analysis, as well as knowledge based on common practice is supposed to provide a broader perspective regarding device properties, as number of necessary sensors and their positioning.

Finally, author presented the pilot results in order to support the proposed hypotheses. The pilot results related to the present study have already been published (Vuković et al., 2019; Vuković et al., 2021; Marković et al., 2021). The rationale and main findings of this research are following:

Pilot research 1 - Descriptive profile of the reverse punch (Gyako Tsuki) kinematic characteristics measured by IMU sensor technology. The aim of the study was quantitative evaluation of kinematic motion patterns of the RP measured by kinematic sensors. Therefore, study investigated segmental acceleration of the reverse punch in order to determine its descriptive profile and to understand how changes in movement acceleration appear in punch motion.

Pilot research 2 - Metrical characteristics and the reliability of kinematic sensor devices applied in different modalities of reverse punch in karate athletes. Reliability and validity are some of essential conditions of measurement. Especially when measurement is performed with novel instrument or when an instrument is applied in novel conditions. Starting from there, study aimed to assess the measurement properties and reliability of kinematic sensors (KS) under training common conditions.

Pilot research 3 - Specific Test Design for the In-Depth Technique Analysis of Elite Karate Competitors with the Application of Kinematic Sensors. The dynamism of modern karate requires high level of adaptation and constant pursuit in technique improvement. Therefore, the fresh approach in the analysis of the scoring techniques is needed. In contrast to previous studies that were focused on the impact phase of the reverse punch this research aims to describe the kinematic and temporal structure of a reverse punch in the initial phase of the execution. The novelty of proposed approach is supported with ten specific tests and application of Kinematic sensors applied on carefully chosen body positions.

After presenting the problem of the proposed study, the author defined the problem, subject, aims and tasks. The technical aspects of the reverse punch aiming the body, the most dominant punching technique in sports karate fights, are the research problem. To be more specific, the subject of the research is the quality of technique across several performance modalities. The aim of the research is to assess the differences between the kinematic and temporal indicators of RP in different modalities by application of the kinematic sensors technology in realistic performance conditions. The following research tasks arise from the above: Sample recruitment; Sample data collection (body weight, body height, age, years of training and competition experience, dominant fighting stance); Estimation of kinematic and temporal

characteristics of the punch in different performance modalities; Signal processing; Statistical data processing and analysis.

Based on a review of a previous research, the following hypotheses have been set:

HG – IMU sensor technology is valid and discriminatory with the respect to the specific indicators of the reverse punch and within different modalities of performance.

H1 – There is a difference in the kinematic parameters of the reverse punch between the tests.

H2 – The highest maximum values of kinematic parameters are achieved in a test in which the participants make optimal use of their biological potentials.

H3 – There is a positive correlation between kinematic parameters on the body and the hand.

H4 – The optimal time sequence of kinematic parameters contributes to the punch efficiency.

In order to collect data that will enable testing of the formulated hypotheses, the author designed a complex study, which design has been explained in details within the following chapter (Materials and Methods). Fourteen male competitors – members of the Serbian national senior and cadet karate team – will participate in the study. In order to take part in the study, participants must be fully informed of the risks and benefits associated with the study. All participants must sign a written consent form. The study must follow the ethical standards recognised by the Declaration of Helsinki and has to be approved by the Ethics Research Committee of the Faculty of Sport and Physical Education, University of Belgrade.

After the warm-up session, athletes will receive verbal instructions and practical demonstrations of tests. They will be instructed to deliver a reverse punch, aiming the body, by the dominant hand, approximately 5 s after the audio signal. Three consecutive punches will be delivered in two trials with enough time to rest in between. All competitors will perform the punch with dominant hand, and therefore stand in appropriate stance (left or right). Initial positions will be: basic stance (Zenkotsu dachi) and combat stance (Fudo dachi). The punch will be tested in a total of 10 performance modalities. Apart of first (RPNH: hip rotation excluded from RP execution); and second (RPH: hip rotation included in RP) tests which require the participants not to move the feet, the remaining four tests will be performed in regard to two major conditions: static (S) and dynamic (D) starting position: RPSM: sliding motion preceding RP; RPSMO:

sliding motion preceding RP, with opponent as a target; RPSMP: sliding motion preceding RP, with partner holding chest punch pad; RPSMR: sliding motion preceding RP executed on a visual signal. The basic idea of presented testing approach lies in the assumption that kinematic parameters will change due to different levels of technical complexity. That is to say, the inclusion of a larger number of body segments will influence acceleration and velocity, i.e. the RP performance. Apart of that, researches up to date give enough reason to assume that involvement of specific task or a target may affect the parameters of interest as well. From a biomechanical point of view, the complexity increases from the RPNH to the RPSMR and is followed by the initial stance. With the insightful sensors placement, the proposed system may be reliable, ergonomic, optimal and easy to use in realistic environment.

Two kinematic sensor (KS) will be attached on the hand and body as shown in Figure 5. Microcontrollers with communication WiFi module integrated in sensors enable reading the KS data and transfer it to separate LabView application loops running on a laptop. The samples from both kinematic devices will be read by the main program loop. The procedure will be controlled and timed in cycles of 5ms. Communication will be established via User Datagram Protocol on high loaded ISM band. Since packet diversity could result in data loss, error-corrections will be arranged so that the possible lost samples are replaced with previous values. The validity of the results will be confirmed through channel quality monitoring. Two cameras will be used to record the testing. Cameras will be placed at 2 meters distanced from the participants and laterally (left and right) relative to the athlete on a tripod at 1.3 meters above the floor. For each technique modality and each trial, the data will be stored in two video (.avi and .MP4) files. The inertial sensor data will be stored using the LabView application as .tdms files.

The athlete's technical performance will be evaluated using accelerometer signals from both devices and gyroscope signals from the body-worn device. The time of their occurrence will also be taken into account. The data will be post-processed and analysed using the MathCAD 7 numerical computation software. The signal analysis will be performed using a Butterworth 5th order low–pass filter with a cut–off frequency of 40Hz. In order to prevent false detection of event, different threshold will be applied for acceleration and rotation speed. The maximum limit value will be set at 5%. The first step in calculating the variables defining technical performance will be shifting the signals in the reference moment of analysis, which is an impact. Signal analysis will be performed in a time window containing 120 samples, within a time interval of 0.6 seconds.

Variable selection is based on knowledge that points out: acceleration and velocity as important parameters of the punch;13,32 and critical influence of the kinetic chains kinematic

quantities timeline on the sequential structure of the RP.34 The kinematic and temporal quantities regarded as relevant for RP evaluation are: HA – maximum hand acceleration, expressed in g0; tHAS – time for the onset of a hand acceleration; tHA – time for the maximum hand acceleration; HV – maximum hand velocity, expressed in m/s; tHV – time for the maximum hand velocity; BV – maximum body velocity, expressed in m/s; tBV – time for the maximum body velocity; tBAS – time for the onset of a body acceleration; BRa – maximal body rotation angle, expressed in deg.

The statistical analysis that will be conducted in order to test the proposed hypotheses will be as follows:

HG – IMU sensor technology is valid and discriminatory with the respect to the specific indicators of the reverse punch and within different modalities of performance: Intraclass correlation coefficient (ICC); Pearson correlation, ANOVA.

H1 – There is a difference in the kinematic parameters of the reverse punch between the tests: Two-way ANOVA.

H2 – The highest maximum values of kinematic parameters are achieved in a test in which the participants use their biological potentials optimally: Two-way ANOVA (Post Hoc Test: Tukey's honestly significant difference [HSD], Bonferroni test)

H3 – There is a positive correlation between kinematic parameters on the body and the hand: Pearson Correlation.

H4 – The optimal time sequence of kinematic parameters contributes to the punch efficiency: Pearson Correlation.

The power of correlations will be defined according to the study of Cohen. The level of statistical significance will be defined for the probability of 95%, i.e., $p \leq .050$. The statistical analyses will be carried out using Microsoft Office Excel 2007, and the statistical package for social sciences (IBM, SPSS Statistics, version 20.0) for Windows.

The expected results and scientific contribution

It is reasonable to assume that application of reliable instrument in measuring parameters of interest in specific karate technique will help in revealing differences between tests, as well as the nature of relationship between body and hand parameters and their influence on the final outcome in punch performance.

Therefore, it is expected that results of the research will increase base of theoretical and practical knowledge by:

(1) Increasing the source of knowledge with respect to the quality of technique whose basic structure is shared among combat sports;

(2) Improving measurement and assessment using kinematic sensors as an alternative to the conventional laboratory approach.

In terms of practical application, in situ data acquisition in realistic performance conditions enables understanding of the true extent of the relationship between the segments of the kinetic chain and the kinematic differences of the analysed punch. Such an approach shifts the training focus of elite athletes to the distinct details shared by combat sports. This leads to enhancement technique analysis and surpasses the scope of karate itself. Moreover, specific tests combined with the insightfully positioning of the measurement devices provide valuable data, enabling unbiased evaluation as a basis for training and competing improvements. The present study will reveal if the exclusion/inclusion of the body segments affects kinematic parameters. In addition, it will clear if the kinematic and temporal parameters relationship affects punch execution. In short, the contribution of the study is expected to be in field of: Improving the training and competitive practice of the elite level karate athletes through indication of the potentially weak points in the RP execution; Understanding the kinematic and temporal punch patterns in the developmental phase of RP in different modalities of execution, as a foundation for individual approach in enhancing punch efficiency; Improvement of the testing procedures and study methodology with employment of sensors and specific tests in the most researched karate technique; Enhancing punch control and performance through application of novel approach leading to reduction of injuries due to poor movement structure.

The proposed literature to be used

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Mentor proposal, mentor consent and list of their publications

Taking into account the complexity of the research problem addressed by the candidate in the rationale of the doctoral dissertation and his cooperation with the University of Ljubljana, Faculty of Electrical Engineering, we propose two mentors in realization of the project of doctoral dissertation:

1. Milivoj Dopsaj, PhD, Full Professor, University of Belgrade, Faculty of Sport and Physical Education,
2. Anton Umek, PhD, Associate Professor, University of Ljubljana, Faculty of Electrical Engineering.

Both proposed mentors, Full Prof. Milivoj Dopsaj, PhD and i Assoc. Prof. Anton Umek, PhD, meet the requirements of the Standards for accreditation of doctoral study programs and agree to be mentors in the implementation of the doctoral dissertation of Vesna Vukovic on the proposed topic.

The list of publications of Full Prof. Milivoj Dopsaj, PhD and i Assoc. Prof. Anton Umek, PhD which are published in the international scientific journals within the last 5 years and, according to their topic, belong to the scientific field of Physical Education and Sports, to which the proposed topic also belongs is attached bellow. Also, we emphasize that some works are closely related to the proposed topic:

Full Prof. Milivoj Dopsaj, PhD

1. Erman B, Ozkol MZ, Ivanović J, Arslan H, Ćosić M, Yuzbasioglu Y, **Dopsaj M,** Aksit T. Assessments of Ground Reaction Force and Range of Motion in Terms of Fatigue during the Body Weight Squat. Int J Environ Res Public Health. 2021 Apr 11;18(8):4005. doi: 10.3390/ijerph18084005.
2. **Dopsaj M,** Zuoziene IJ, Milić R, Cherepov E, Erlikh V, Masiulis N, di Nino A, Vodičar J. Body Composition in International Sprint Swimmers: Are There Any Relations with Performance? Int J Environ Res Public Health. 2020 Dec 17;17(24):9464. doi: 10.3390/ijerph17249464.
3. Kukić F, Heinrich KM, Koropanovski N, Poston WSC, Čvorović A, Dawes JJ, Orr R, **Dopsaj M.** Differences in Body Composition across Police Occupations and Moderation Effects of Leisure Time Physical Activity. Int J Environ Res Public Health. 2020 Sep 18;17(18):6825. doi: 10.3390/ijerph17186825.
4. **Dopsaj M,** Kukić F, Đorđević-Nikić M, Koropanovski N, Radovanović D, Miljuš D, Subošić D, Tomanić M, Dopsaj V. Indicators of Absolute and Relative Changes in Skeletal Muscle Mass during Adulthood and Ageing. Int J Environ Res Public Health. 2020 Aug 18;17(16):5977. doi: 10.3390/ijerph17165977.
5. Marković S, **Dopsaj M,** Tomažič S, Umek A. Potential of IMU-Based Systems in Measuring Single Rapid Movement Variables in Females with Different Training Backgrounds and Specialization. Appl Bionics Biomech. 2020 Jun 30;2020:7919514. doi: 10.1155/2020/7919514. eCollection 2020.
6. Zarić I, Kukić F, Jovićević N, Zarić M, Marković M, Toskić L, **Dopsaj M.**Body Height of Elite Basketball Players: Do Taller Basketball Teams Rank Better at the FIBA World Cup? Int J Environ Res Public Health. 2020 Apr 30;17(9):3141. doi: 10.3390/ijerph17093141.
7. Vuković M, Kukić F, Čvorović A, Janković D, Prćić I, **Dopsaj M.** Relations Between Frequency and Volume of Leisure-Time Physical Activity and Body Composition in Police Officers. Res Q Exerc Sport. 2020 Mar;91(1):47-54. doi: 10.1080/02701367.2019.1646391. Epub 2019 Sep 10.
8. Trajkov M, Cuk I, Eminovic F, Kljajic D, **Dopsaj M.** Relationship between hand grip strength and endurance and postural stability in active and sedentary older women. J Electromyogr Kinesiol. 2018 Dec;43:62-67. doi: 10.1016/j.jelekin.2018.09.006. Epub 2018 Sep 12.

Assoc. Prof. Anton Umek, PhD

1. Guo J, Yang L, **Umek A,** Bie R, Tomažič S, Kos A. A Random Forest-Based Accuracy Prediction Model for Augmented Biofeedback in a Precision Shooting Training System. Sensors (Basel). 2020 Aug 12;20(16):4512. doi: 10.3390/s20164512.
2. Taborri J, Keogh J, Kos A, Santuz A, **Umek A,** Urbanczyk C, van der Kruk E, Rossi S. Sport Biomechanics Applications Using Inertial, Force, and EMG Sensors: A Literature

Overview. Appl Bionics Biomech. 2020 Jun 23;2020:2041549. doi: 10.1155/2020/2041549. eCollection 2020.

3. Pustišek M, **Umek A,** Kos A. Approaching the Communication Constraints of Ethereum-Based Decentralized Applications. Sensors (Basel). 2019 Jun 11;19(11):2647. doi:10.3390/s19112647.
4. **Umek A,** Zhang Y, Tomažič S, Kos A. Suitability of Strain Gage Sensors for Integration into Smart Sport Equipment: A Golf Club Example. Sensors (Basel). 2017 Apr 21;17(4):916. doi: 10.3390/s17040916.
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Opinion and proposal of the Committee

The proposal of doctoral dissertation of Vesna Vukovic is written in English language due to the proposed mentors and the international structure of the committee. The proposed topic is aimed on research problems of valid and reliable performance evaluation in karate using kinematic sensors. The theme is formulated based on the careful analysis of the extensive bibliographic material. The research of the observed problem is to be performed in ecologically valid conditions, which considerably increases the external validity of this experimental research.

The research problem is explained in detail, and the aim and hypotheses are clearly formulated. The proposed research methods enable the realization of the research aims.

The research will enable new, methodologically based, knowledge in relation to the possibility of use of kinematic sensors in measurement of sports performance in karate. The potential findings of the research will have direct applicability in praxis, due to the fact that they will point to the possibility of application of the results in evaluation of performance in mostly used attack technique. The standard application of kinematic sensors will enable a more specific and more complete diagnostics of the current sport performance.

We suggest to the author to use the term Gjaku Zuki instead of Đako Zuki in Serbian version of title as more appropriate and regularly used through the literature.

We propose that the Teaching-Scientific Council accept the Report of the Commission and send a decision to the Council of Scientific Areas of Social Sciences and Humanities approving the topic of Vesna Vukovic's doctoral dissertation entitled: "KINEMATIC AND TEMPORAL PARAMETERS IN DIFFERENT MODALITIES OF THE REVERSE PUNCH MEASURED BY IMU SENSORS (KINEMATIČKI I VREMENSKI POKAZATELJI UDARCA GJAKU ZUKI U RAZLIČITIM MODALITETIMA IZVOĐENJA MERENI IMU SENZORIMA)" and by which Full Professor Milivoj Dopsaj, PhD and Associate Professor Anton Umek, PhD are appointed as mentors.

Belgrade, 16th January 2023

Committee members:

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Aleksandar Nedeljković, PhD, Full Professor,University of Belgrade, Faculty of Sport and Physical Education, chairman of the committee;

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Miloš Mudrić, PhD, Associate Professor, University of Belgrade, Faculty of Sport and Physical Education, committee member;

_____

Nenad Koropanovski, PhD, Full Professor, University of Criminal Investigation and Police Studies committee member.