

ACUTE EFFECTS OF PHYSIOLOGICAL FATIGUE INDICATORS ON THE MOTOR REACTION SPEED AMONG THE KARATE PLAYERS AT DIFFERENT LEVEL OF COMPETITION

JASMIN BILALIĆ¹, OSMO BAJRIĆ², OSMAN LAČIĆ¹, TARIK HUREMOVIĆ¹, DŽEMAL HUREMOVIĆ¹

¹Faculty of Physical Education and Sports, University of Tuzla, Bosnia and Herzegovina

²Faculty of Education, University of Travnik, Bosnia and Herzegovina

Correspondence:

Jasmin Bilalić

Faculty of Physical Education and Sports, University of Tuzla
jasmin.bilalic@untz.ba

Abstract: This study was conducted on a sample of 40 senior and junior male and female karate fighters, chronological ages 18 to 27 from the Tuzla Canton, who are part of the regular training and competition process. The aim of this paper is to determine the differences in the motor reaction speed among the karate players with the same specializations but at different levels of competition, in conditions of fatigue induced by intense physical work in combination with complex visual signalization, which determines certain karate techniques. The study was conducted with the application of sophisticated technologies used in sport that enable the collection of data. The light stimuli was generated by the usage of the RIR 102 reaction meter and the quantitative valorization of the investigated parameters was carried out by a sophisticated kinematic analysis of the videos collected using two high-speed Casio Exilim EX-F1 digital cameras synchronized with the data from the Polar Team heart monitoring system. By processing and analyzing data, it was concluded that fatigue induced by situational conditions such as performing a series of strikes that simultaneously generate muscular, cognitive and sensory strain, produces negative effects on reaction time of the karate players. The intensity of limiting factors grows gradually in function of time, but is manifested differently in relation to the international and state level of competition.

Keywords: acute effects, motor speed reaction, physiological fatigue indicators, karate.

INTRODUCTION

The development of karate as a sport requires innovative technologies and a modern approach to the conceptualization of training and competition models as

AKUTNI EFEKTI FIZIOLOŠKIH INDIKATORA ZAMORA NA BRZINU MOTORNE REAKCIJE KOD KARATISTA RAZLIČITOG TAKMIČARSKOG NIVO

JASMIN BILALIĆ¹, OSMO BAJRIĆ², OSMAN LAČIĆ¹, TARIK HUREMOVIĆ¹, DŽEMAL HUREMOVIĆ¹

¹Fakultet za tjelesni odgoj i sport, Univerzitet u Tuzli, Bosna i Hercegovina

²Edukacijski fakultet, Univerzitet u Travniku, Bosna i Hercegovina

Korespondencija:

Jasmin Bilalić

Fakultet za tjelesni odgoj i sport, Univerzitet u Tuzli
jasmin.bilalic@untz.ba

Abstract: Ova studija sprovedena je na uzorku od 40 seniorskih i juniorskih karate boraca muškog i ženskog spola hronološke dobi od 18 do 27 godina iz Tuzlanskog kantona koji su u redovnom trenažnom i takmičarskom procesu. Cilj rada je da se utvrde razlike u brzini motorne reakcije kod karatista iste specijalizacije ali različitog takmičarskog nivoa u uslovima zamora koji je induciran intenzivnim fizičkim radom u kombinaciji sa kompleksnom vizuelnom signalizacijom koja determinira određene karate tehnike, a uz primjenu softificiranih tehnologija u sportu koje omogućavaju prikupljanje podataka. Generiranje svjetlosnih stimulusa izvršeno je pomoću Reakciometra RIR 102, a kvantitativna valorizacija istraživanih parametara vršena je softificiranom kinematičkom analizom video zapisa prikupljenih pomoću dvije high speed digitalne kamere Casio Exilim EX-F1 koje su sinhronizovane sa podacima srčanog monitoringa Polar tim sistema. Obradom i analizom podataka utvrđeno je da zamor induciran situacionim uslovima izvođenjem serije udaraca koje simultano generiraju mišićno, kognitivno i senzorno opterećenje, proizvodi negativne efekte na vrijeme reagovanja kod karatista. Intenzitet limitirajućih faktora sukcesivno raste u funkciji vremena ali se različito manifestuje u odnosu na međunarodni i državni takmičarski nivo.

Ključne riječi: akutni efekti, vrijeme motorne reakcije, fiziološki indikatori zamora.

Uvod

Razvoj karatea kao sporta zahtijeva inovirane tehnologije i savremeni pristup konceptualizacije trenažnih i takmičarskih obrazaca te dijagnostičkih postupaka usmje-

well as the diagnostic procedures aimed at analysis of anthropological dimensions structure, their relations and specific impacts on sporting events (Milošević, R. Mudrc, & M. Mudrić, 2012). Successful resolution of complex tasks of sports fight in karate depends on great number of factors, mostly related to abilities relating to time of reaction and anticipation as the key aspects of perception abilities (Mori, Ohtani, & Imanaka, 2002). The ability of an athlete to process relevant information quickly and accurately facilitates him to make adequate decisions and gives him more time to organize and prepare the motor apparatus for action (Mudrić, 2015). The first phase in the formation of movement is the sensory and pre-motor phase, i.e., latent time passed since the onset of the nerve impulse to the excitation of motor units. The occurrence of the nerve impulse is often associated with the external stimuli of the auditory and visual nature. *The latent motor reaction time* is determined by the physiological mechanisms for the transmission of nerve impulses, the creation of the action nerve potential, the realization of neuromuscular synapse, and the excitation of myofilaments in the structure of the muscle fiber. The manifestation of movement or motion, which is determined by complex contractile processes, is a *manifested motor reaction time* (Mikić, 2000). Sports competitions take place under severe stress conditions, due to high physical and mental strain, as well as the expectations and pressure to perform sports activity at a high level. Under such conditions, an athlete is required to process the relevant information quickly and accurately in order to reduce time for decision-making. Considering that *strains of maximum and sub-maximal intensity* prevail in karate fights (Kuleš, 1998), the focus of this study is on the *onset of fatigue* and its impact on the motor reaction time of karate players in complex situational conditions.

During the strain, metabolic processes are underway with a whole series of highly complex biochemical reactions (Jakovljević, 1979). At the core of the fatigue is the temporarily disturbed internal balance of the organism (homeostasis), whose main consequence is reduced work capacity, i.e., sports performance. During the fatigue diagnosis, the most common practice is to start from *the objective physiological symptoms of fatigue*, which represent qualitative changes in the reaction of certain organic systems to the applied strain (Blagajac, 2014). The heart rate is in high correlation with the level of physical activity, and therefore is used in practice as an optimal physiological load indicator (Papišta, 2013). With the development of modern technology, new opportunities and conditions for testing neuromuscular abilities of athletes have opened up, with the goal to bring the

renih na analizu strukture antropoloških dimenzija, njihovih relacija i specifičnih uticaja na sportske manifestacije (Milošević, R. Mudrc i M. Mudrić, 2012). Uspješno rješavanje složenih zadataka sportske borbe u karateu zavisi od velikog broja faktora, a najčešće se povezuje sa sposobnostima koje se odnose na *vrijeme reagovanja i anticipaciju* kao ključne aspekte perceptivnih sposobnosti (Mori, Ohtani i Imanaka, 2002). Sposobnost sportiste da brzo i tačno obradi relevantne informacije olakšavaju mu donošenje adekvatnih odluka i više vremena za organizaciju i pripremu motornog aparata za djelovanje (Mudrić, 2015).

Prvu fazu u formiranju pokreta čini senzorna i pre-motorna faza tj. latentno vrijeme proteklo od pojave nervnog impulsa do eksitacije motornih jedinica. Pojava nervnog impulsa često je u konkretnim okolnostima povezana sa spoljašnjim nadražajem auditivne i vizuelne prirode. *Latentno vrijeme motorne reakcije*, determinirano je fiziološkim mehanizmima za transmisiju nervnih impulsa, stvaranje akcionog nervnog potencijala, ostvarenje neuromuskularne sinapse i pobuđivanje miofilamenata u strukturi mišićnog vlakna. Sama manifestacija pokreta ili kretanja, koja je determinirana složenim kontraktilnim procesima, predstavlja *manifestno vrijeme motorne reakcije* (Mikić, 2000). Takmičenja u sportu odvijaju se u izraženim stresnim uslovima, kako zbog visokih fizičkih i psihičkih naprezanja, tako i zbog očekivanja i pritiska da se sportska aktivnost vrši na visokom nivou. U takvim uslovima, od sportiste se zahtijeva da brzo i precizno obrađuju relevantne informacije i skraćuju vrijeme za donošenje odluka. S obzirom da u karate borbama uglavnom prevladavaju *opterećenja maksimalnog i submaksimalnog intenziteta* (Kuleš, 1998) fokus ovog istraživanja usmjeren je na *pojavu zamora* te njegovom uticaju na vrijeme motorne reakcije karatista u složenim situacionim uslovima.

U toku napora odvijaju se metabolički procesi sa čitavim nizom vrlo složenih biohemijskih reakcija (Jakovljević, 1979). U osnovi zamora nalazi se privremeno narušena unutrašnja ravnoteža organizma (homeostaza) čija je osnovna posljedica smanjena radna sposobnost tj. sportska performansa. Pri dijagnosticiranju zamora najčešće se u praksi polazi od *objektivnih fizioloških simptoma zamora* koji predstavljaju kvalitativne promene reakcije pojedinih organskih sistema na primijenjena opterećenja (Blagajac, 2014). Frekvencija srca se nalazi u visokoj korelaciji sa nivoom tjelesne aktivnosti, te se zbog toga u praksi koristi kao optimalan fiziološki indikator opterećenja (Papišta, 2013). Razvojem savremene tehnologije danas su se otvorile nove mogućnosti i uslovi za ispitivanje neuromišićnih sposobnosti sportista sa ciljem

test conditions closer to realistic competitive situations. In order to carry out detailed biomechanical analysis of moving structures in sports activities, *kinematics* increasingly becomes an integral part of the efficient diagnostics technology, programming and control of the training process (Mejovšek, Hraski, Hofman, & Kuleš, 1997). Kinematic analyses of moving structures ensure a very precise registration of the sizes and parameters of the athletes' movement during the performance of any technical elements, especially those that cannot be registered with the naked eye, but have to be performed under the laboratory conditions. Under such conditions it is possible to register spatial-temporal movements of any anatomical points on the body or individual parts of the athlete's body, their speed and acceleration, etc. (Malacko & Rado, 2004)

RESEARCH METHODOLOGY

Sample of respondents

For the purposes of this research, a sample of 40 senior and junior male and female karate fighters, chronological ages 18 to 27 from the Tuzla Canton, who are part of the regular training and competition process, was selected. Karate players are of the same specialization and level of training, but differentiate according to the results achieved, which was the basic criterion for the selection and classification of athletes on 20 international level competition participants (Group A) and 20 state level competition participants (Group B)

Sample of variables

Taking in account the problems and the aim of this research, the selection of relevant karate techniques was made: *kisame tsuki jodan* (KTJ), *gyaku tsuki chudan* (GTC), *mawashi geri jodan* (MGJ), *mawashi geri chudan* (MGC). **The total** (BR), **latent** (LBR), and **manifest** (MBR) velocity of the motor reaction of the analyzed karate techniques were detected in defined areas of physiological load: **I zone** (40–55% HR_{max}), **II zone** (56–70% HR_{max}), **III zone** (71–85% HR_{max}), **IV zone** (86–100% HR_{max}).

Description of the research

The testing and measurement of the complex motor reaction speed in relation to visual stimulus in international and state competition karate players was carried out at the diagnostic center of the Faculty of Physical Education and Sport at the University of Tuzla that provides optimal spatial, technical and human resources required for a professional approach to this research. The RIR 102 reaction meter was used to generate light signals that transmitted

da se uslovi testiranja što je moguće više približe realnim takmičarskim situacijama. U cilju sprovođenja detaljnih biomehaničkih analiza kretnih struktura u sportskim aktivnostima **kinematika** sve više postaje sastavni dio tehnologije efikasne dijagnostike, programiranja i kontrole trenažnog procesa (Mejovšek, Hraski, Hofman i Kuleš, 1997). Kinematičke analize kretnih struktura omogućavaju veoma preciznu registraciju veličina i parametara kretanja sportista prilikom izvođenja bilo kojih tehničkih elemenata, pri čemu su posebno interesantni oni koji se ne mogu registrirati okom, već se moraju obaviti u laboratorijskim uslovima. U takvim uslovima moguće je registrirati prostorno-vremenske pomake bilo koje anatomske tačke na tijelu ili pojedinih dijelova tijela sportista, njihove brzine i ubrzanja itd. (Malacko i Rado, 2004).

METODOLOGIJA ISTRAŽIVANJA

Uzorak ispitanika

Za potrebe ovog istraživanja odabrana je uzorak od 40 seniorskih i juniorskih karate boraca muškog i ženskog spola hronološke dobi od 18 do 27 godina iz Tuzlanskog kantona koji su u redovnom trenažnom i takmičarskom procesu. Karatisti su iste specijalizacije i nivoa obučenosti ali se diferenciraju s obzirom na ostvarene rezultate što je i predstavljalo osnovni kriterijum za selekciju i klasifikaciju sportista na 20 ispitanika međunarodnog takmičarskog nivoa (Grupa A) i 20 ispitanika državnog takmičarskog nivoa (Grupa B).

Uzorak varijabli

Imajući u vidu problematiku i cilj ovog istraživanja izvršen je odabir relevantnih karate tehnika: **kizame tsuki jodan** (KTJ), **gjaku tsuki chudan** (GTC), **mawashi geri jodan** (MGJ), **mawashi geri chudan** (MGC). **Ukupna** (BR), **latentna** (LBR) i **manifestna** (MBR) brzina motorne reakcije analiziranih karate tehnika detektovane su u definiranim zonama fiziološkog opterećenja: **I-zona** (40–55% HR_{max}), **II-zona** (56–70% HR_{max}), **III-zona** (71–85% HR_{max}), **IV-zona** (86–100% HR_{max}).

Opis istraživanja

Testiranje i mjerenje složene brzine motorne reakcije u odnosu na vizuelne stimuluse kod karatista međunarodnog i državnog takmičarskog nivoa izvršeno je u dijagnostičkom centru Fakulteta za tjelesni odgoj i sport Univerziteta u Tuzli koji pruža optimalne prostorne, tehničke i kadrovske resurse koje zahtijeva profesionalni pristup ovom istraživanju. Reakciometra RIR 102 korišten je za generiranje svjetlosnih signala koji

over four mobile LED projectors to the frontal and lateral areas of the head and torso of the training doll. The reaction meter is programmed so that the measurement process is automatically carried out. The measuring cycle consisted of 28 iterations of signaling units that are activated for a period of 3 seconds, with different resting intervals. Each partial unit is activated 7 times during a single measurement cycle in random order, with the sequence of activation being automatically changed in each subsequent cycle. The total workload was 170 seconds. The respondent had the task of taking the basic combat stance (Kumite dachi) at the individual effective distance from the training doll, and considering the projected visual signals, which were emitted to certain segments of the training doll, reacting at the maximum speed with the performance of a certain karate technique. Projecting the signal to the frontal part of the head a *kisame tsuki jodan* strike was performed, a *gyaku tsuki chudan* was performed to the frontal part of the torso, *mawashi geri jodan* was performed by the projection of the light signal to the lateral part of the head, and when the signal was projected on the lateral part of the torso *mawashi geri chudan* was performed (Figure 1).

su se preko četiri mobilna LED projektora emitovali na frontalne i lateralne zone glave i trupa trenažne lutke. Reakciometar je programiran na način da se vrši automatsko vođenje mjernog procesa. Mjerni ciklus sastojao se od 28 iteracija signalnih jedinica koje se aktiviraju u trajanju od 3 sekunde sa različitim intervalima odmora. Svaka parcijalna jedinica aktivira se 7 puta u toku jednog mjernog ciklusa i to slučajnim redoslijedom, pri čemu se redoslijed aktivacije automatizovano mijenja u svakom narednom ciklusu. Ukupni ekstenzitet rada iznosio je 170 sekundi. Ispitanik je imao zadatak da zauzme osnovni borbeni stav (Kumite dachi) na individualnoj efektivnoj distanci od trenažne lutke te s obzirom na projektovane vizuelne signale, koji su emitovani na određene segmente trenažne lutke, maksimalnom brzinom reaguje izvođenjem određene karate tehnike. Projektovanjem signala na frontalni dio glave izvođen je udarac *kizame tsuki jodan*, na frontalni dio trupa izvođen je *gjaku tsuki chudan*, *mawashi geri jodan* izvođen je projekcijom svjetlosnog signala na lateralni dio glave, a kada je signal projiciran na lateralni dio trupa izvođen je *mawashi geri chudan* (Slika 1.).

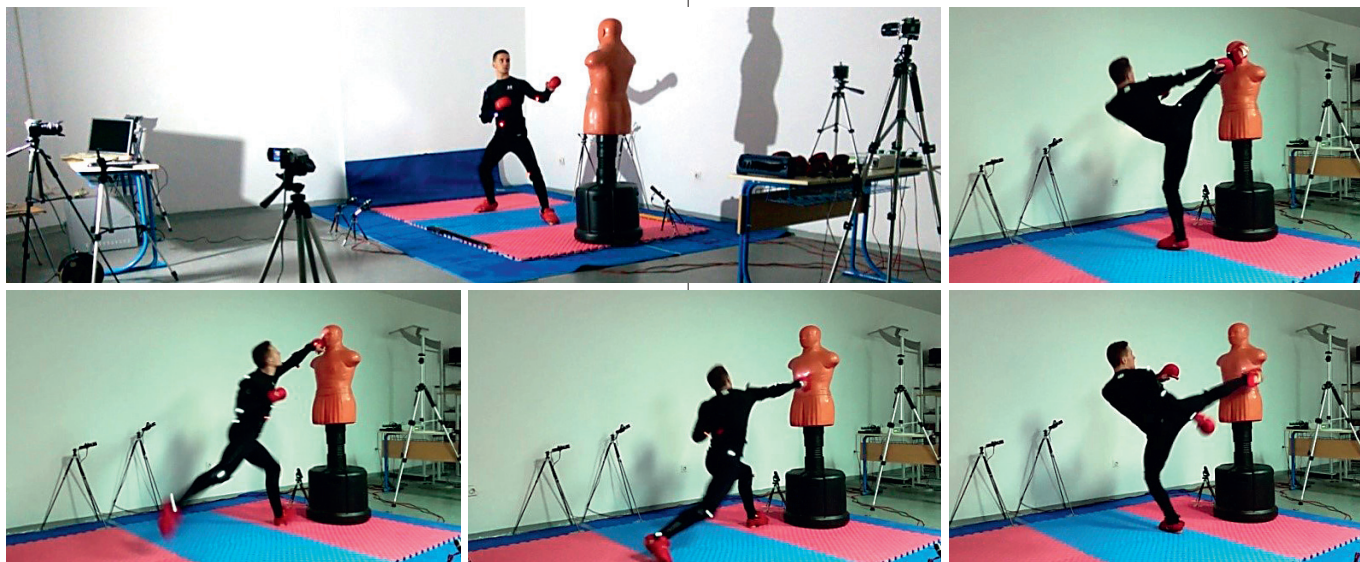


Figure 1. Kumite dachi; *kisame tsuki jodan*; *gyaku tsuki chudan*; *mawashi geri jodan*; *mawashi geri chudan*

Slika 1. Kumite dachi; *kizame tsuki jodan*; *gjaku tsuki chudan*; *mawashi geri jodan*; *mawashi geri chudan*

The quantitative valorization of the total, latent and manifested velocity of the motor reaction of the investigated karate techniques was performed by a sophisticated **kinematic analysis** of the videos collected using two high-speed Casio Exilim EX-F1 digital cameras, which were positioned in the medial frontal plane. Kinematic processing was done using the software package Kinovea 0.8.15 (Video analysis software), and proce-

Kvantitativna valorizacija ukupne, latentne i manifestne brzine motorne reakcije istraživanih karate tehnika izvršena je sofisticiranom **kinematičkom analizom** video zapisa prikupljenih pomoću dvije high speed digitalne kamere Casio Exilim EX-F1, koje su se pozicionirale u sagitlanoj u frontalnoj ravni. Kinematička obrada izvršena je pomoću softverskog paketa Kinovea 0.8.15 (Video analysis software), a obrada i prikazivanje po-

ssing and displaying data using the SPSS 20 statistical package. Polar Team system was used for the heart rate monitoring and the analysis of the registered data was performed with the Polar Precision Performance 4SW software package. The classification of the investigated parameters of the motor reaction was done by time synchronization of heart monitoring and video recordings.

RESULTS AND DISCUSSION

Analysis of variance and covariance (Table 1.) using the General Linear Model (GLM) algorithm, taking into account the characteristics of the error variation homogeneity according to the Levene's Test of Equality of Variances, determined the quantitative differences between total, latent and manifested velocity between groups within the I-zone and the effect differences within the II, III and IV zones with the neutralization of the I-zone, with graphical illustration of total speed of motor reaction (Graph 1).

Table 1. Analysis of variance and covariance

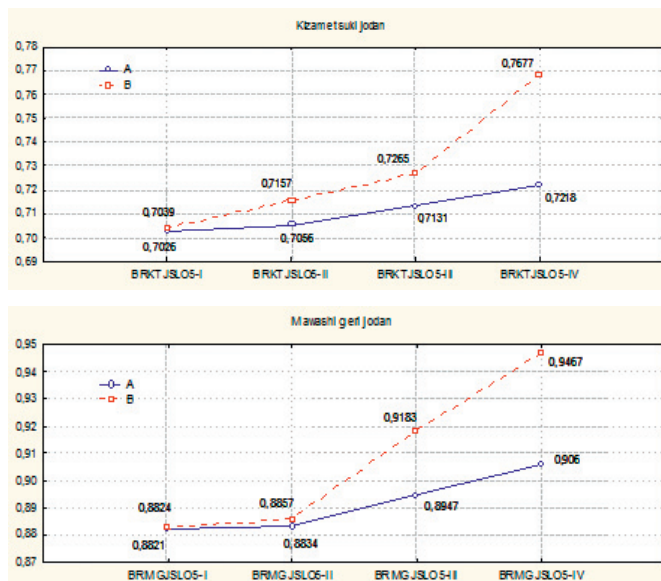
Pairwise Comparisons - Covariate I-zone													
Variable			Mean - Group		Mean Difference (A-B)	Sig.	Variable			Mean - Group		Mean Difference (A-B)	Sig.
			A	B						A	B		
KTJ	I - zone	BR	0.7026	0.7039	-.001	.862	GTC	I - zone	BR	0.7427	0.7430	.000	.962
		LBR	0.2809	0.2806	.000	.939			LBR	0.2816	0.2817	.000	.990
		MBR	0.4220	0.4230	-.001	.778			MBR	0.4611	0.4614	.000	.933
	II - zone	BR	0.7056	0.7157	-.009	.186		II - zone	BR	0.7430	0.7458	-.003	.258
		LBR	0.2816	0.2816	-.005	.211			LBR	0.2808	0.2815	-.001	.116
		MBR	0.424	0.4290	-.004	.166			MBR	0.4621	0.4644	-.002	.312
	III - zone	BR	0.7131	0.7265	-.012	.026		III - zone	BR	0.7536	0.7696	-.016	.007
		LBR	0.2813	0.2993	-.018	.000			LBR	0.2815	0.3027	-.021	.000
		MBR	0.4318	0.4340	-.001	.251			MBR	0.4721	0.4724	.000	.744
	IV - zone	BR	0.7218	0.7677	-.044	.000		IV - zone	BR	0.7652	0.8065	-.041	.000
		LBR	0.2821	0.3220	-.040	.000			LBR	0.2820	0.3246	-.042	.000
		MBR	0.4421	0.4457	-.003	.312			MBR	0.482	0.4832	.001	.378
MGJ	I - zone	BR	0.8821	0.8824	.000	.963	MGC	I - zone	BR	0.8216	0.8219	.000	.966
		LBR	0.2813	0.2814	.000	.969			LBR	0.2807	0.2809	.000	.969
		MBR	0.6008	0.6010	.000	.956			MBR	0.5409	0.5410	.000	.963
	II - zone	BR	0.8834	0.8857	-.002	.315		II - zone	BR	0.8219	0.8250	-.003	.464
		LBR	0.2851	0.2834	-.002	.412			LBR	0.2808	0.2828	-.002	.355
		MBR	0.6019	0.6022	.000	.672			MBR	0.5411	0.5422	-.001	.522
	III - zone	BR	0.8947	0.9183	-.023	.000		III - zone	BR	0.8352	0.8570	-.021	.000
		LBR	0.2818	0.3044	-.022	.000			LBR	0.2811	0.3020	-.021	.000
		MBR	0.6129	0.6139	-.001	.256			MBR	0.5542	0.5550	-.001	.416
	IV - zone	BR	0.9060	0.9467	-.040	.000		IV - zone	BR	0.8454	0.8828	-.037	.000
		LBR	0.2823	0.3224	-.040	.000			LBR	0.2822	0.3226	-.040	.000
		MBR	0.6237	0.6243	.000	.436			MBR	0.5632	0.5641	-.001	.398

dataka pomoću statističkog paketa SPSS 20. Polar tim sistemom (Polar team system) izvršen je monitoring frekvencije srca a analiza registrovanih podataka izvršena je softverskim paketom Polar Precision Performance 4SW. Vremenskom sinhronizacijom srčanog monitoringa i video zapisa izvršena je klasifikacija istraživanih parametara motorne reakcije.

REZULTATI I DISKUSIJA

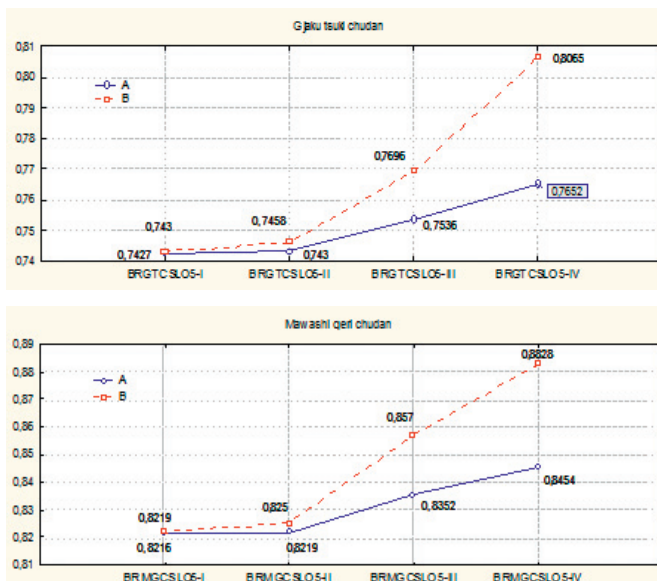
Analizom varijanse i kovarijanse (Tabela 1.) prema algoritmu **Generalnog linearnog modela** (GLM) uvažavajući karakteristike homogenosti varijansi greške prema Leven-ovom testu (Levene's Test of Equality of Variances) utvrđene su kvantitativne razlike ukupne, latentne i manifestne brzine između grupa u okviru I-zone i razlike efekata u okviru II, III i IV zone uz neutralizaciju I-zone, sa grafičkim prikazom ukupne brzine motorne reakcije (Grafikon 1.).

Tabela 1. Analiza varijanse i kovarijanse



Graph 1. Total speed of motor reaction technique *kisame tsuki jodan*, *gyaku tsuki chudan mawashi geri jodan mawashi geri chudan*

Analysis of the quantitative indicators show that the values of total, latent and manifested motor reaction stagnate with minimal changes between the I and II zones, while in the III and IV zone, a linear increase of different intensity is noted, depending on the investigated level of competition. The latent response time of the analyzed karate techniques in the load zone I among the surveyed groups is on average around 282 ± 4 ms, and no significant differences have been recorded in the variance analysis between the international and state levels of competitions. At the international level of competitions, latent values do not significantly change in the II, III and IV areas of physiological load. At the state level of competition, the latent values stagnate with minimal changes in the zone II, while in the III and IV zones the average linear increase of 40 ± 4 ms is registered. Bearing in mind the statistical indicators, the analysis of covariance did not record significant differences in effects within the load zone II, while in the III and IV zones the statistically significant differences were registered in the effects of physiological fatigue on the latent time of the motor reaction. The manifest response time in the load zone I does not differ significantly between the groups, and in the case of *kisame tsuki jodan* strike, the average is 422 ± 1 ms, *gyaku tsuki chudan* 461 ± 1 ms, *mawashi geri jodan* 600 ± 1 ms, and the average manifested response time when performing *mawashi geri chudan* is 540 ± 1 ms. In the load zone II, the manifested time increases minimally, while in the III and IV zones the average linear



Grafikon 1. Ukupna brzina motorne reakcije tehnike *kisame tsuki jodan*, *gyaku tsuki chudan mawashi geri jodan mawashi geri chudan*

Analizom kvantitativnih pokazatelja možemo zapaziti da vrijednosti ukupne, latentne i manifestne brzine motorne reakcije uz minimalne promjene stagniraju između I i II zone opterećenja, dok u III i IV zoni bilježe linearni porast različitih intenziteta u zavisnosti od istraživanog takmičarskog nivoa. Latentno vrijeme reagovanja analiziranih karate tehnika u I zoni opterećenja kod istraživanih grupa u prosjeku iznosi oko 282 ± 4 ms, te analizom varijanse nisu evidentirane signifikantne razlike između međunarodnog i državnog takmičarskog nivoa. Na međunarodnom takmičarskom nivou latentne vrijednosti se bitno ne mijenjaju u II, III i IV zoni fiziološkog opterećenja. Na državnom takmičarskom nivou latentne vrijednosti stagniraju uz minimalne promjene u II zoni, dok u III i IV zoni bilježe prosječni linearni porast od 40 ± 4 ms. Imajući u vidu statističke pokazatelje analizom kovarijanse nisu evidentirane signifikantne razlike u efektima u okviru II zone opterećenja, dok su se u III i IV zoni isprofilirale statistički značajne razlike u efektima fiziološkog zamora na latentno vrijeme motorne reakcije. Manifestno vrijeme reagovanja u I zoni opterećenja značajno se ne razlikuje između grupa te kod udarca *kisame tsuki jodan* u prosjeku iznosi 422 ± 1 ms, *gyaku tsuki chudan* 461 ± 1 ms, *mawashi geri jodan* 600 ± 1 ms, a prosječno manifestno vrijeme reagovanja kod udarca *mawashi geri chudan* iznosi 540 ± 1 ms. U II zoni opterećenja manifestno vrijeme minimalno raste dok se u III i IV zoni bilježi prosječni linearni porast od 22 ± 3 ms na međunarodnom i državnom takmičarskom nivou. S obzirom da

increase of 22 ± 3 ms is recorded at the international and state levels of competitions. Since the dynamics of these changes is homogeneously conducted at the level of the investigated groups, no statistically significant differences in the effects of physiological fatigue indicators on the manifestation of the motor reaction have been recorded in the covariance analysis in the load zones II, III and IV. In relation to latent and manifested indicators, the total motor reaction time in the load zone I does not differ significantly between the analyzed groups. Is at an average of 702 ± 1 ms during the *kisame tsuki jodan* strike, 742 ± 1 ms *gyaku tsuki chudan*, 882 ± 1 ms *mawashi geri jodan*, and the average total reaction time for the *mawashi geri chudan* kick is 821 ± 1 ms. Bearing in mind the above-mentioned facts in the investigated karate techniques, the analysis of the covariance did not show significant differences in effects of the load zone II, while in the III and IV zones statistically significant differences in the effects of physiological fatigue on the total motor reaction time were recorded.

The results showed that fatigue induced by situational conditions by performing a series of strikes in combination with complex visual signaling that determines certain karate techniques negatively reflects on the time of the motor reaction of the investigated karate techniques. The intensity of limiting factors gradually grows over time, but is manifested differently in relation to the international and state levels of competitions. At the *international level of competition*, the total motor response time in conditions of progressive fatigue detected by physiological indicators increases exclusively at the expense of increase of the *manifested motor reaction component*. While at the *state level of competition*, in addition to the increase of the mentioned component, an increase in the *latent motor reaction component* is generated, which ultimately reflects on the quantitatively higher but qualitatively lower values of the overall speed of the motor reaction compared to the international level of competition.

The results of this study confirmed the results in the work of Zemkova, Miklovič, and Hamar (2009) which concluded that fatigue was induced by hard exercise connected with increased time of reaction, as well as in the work of Ilić et al. (2017) which showed that progressive physical load produced greater negative effects on manifested speed of punch by karate fighter on state completion level compared to karate fighter on world competition level. Minimum differences in the speed of kick are consequence of reduced height of a kick by state level karate fighter, which leads to a fact that world level

se dinamika navedenih promjena homogeno odvija na nivou istraživanih grupa, analizom kovarijanse u okviru II, III i IV zone opterećenja nisu evidentirane statistički značajne razlike u efektima fizioloških indikatora zamora na manifestno vrijeme motorne reakcije. U relaciji sa latentnim i manifestnim pokazateljima ukupno vrijeme motornog reagovanja u I zoni opterećenja se značajno ne razlikuje između analizirani grupa te kod udarca *kizame tsuki jodan* u prosjeku iznosi 702 ± 1 ms, *gyaku tsuki chudan* 742 ± 1 ms, *mawashi geri jodan* 882 ± 1 ms, a prosječno ukupno vrijeme reagovanja kod udarca *mawashi geri chudan* iznosi 821 ± 1 ms. Imajući u vidu navedene činjenice kod istraživanih karate tehnika analizom kovarijanse nisu evidentirane signifikantne razlike u efektima u II zoni opterećenja, dok su se u okviru III i IV zone isprofilirale statistički značajne razlike u efektima fiziološkog zamora na ukupno vrijeme motorne reakcije.

Rezultati su pokazali da se zamor induciran situacionim uslovima izvođenjem serije udaraca u kombinaciji sa kompleksnom vizuelnom signalizacijom koja determinira određene karate tehnike negativno reflektuje na vrijeme motorne reakcije istraživanih karate tehnika. Intenzitet limitirajućih faktora sukcesivno raste u funkciji vremena ali se različito manifestuje u odnosu na međunarodni i državni takmičarski nivo. Na *međunarodnom takmičarskom nivou ukupno vrijeme motorne reakcije* se u uslovima progresivnog zamora detektivnog fiziološkim indikatorima povećava isključivo na račun povećanja *manifestne komponente motorne reakcije* dok se na *državnom takmičarskom nivou* pored povećanja navedene komponente generira i povećanje *latentne komponente motorne reakcije* što se u konačnici reflektuje i na kvantitativno veće ali kvalitativno slabije vrijednosti ukupne brzine motorne reakcije u odnosu na međunarodni takmičarski nivo.

Rezultatima ove studije potvrđeni su rezultati u radu Zemkova, Miklovič i Hamar (2009) koji su zaključili da je zamor induciran napornim vježbanjem povezan sa povećanjem vremena reagovanja te rezultati u radu Ilić i sar. (2017) koji su pokazali da progresivno fiziološko opterećenje proizvodi znatno veće negativne efekte na manifestnu brzinu udarca rukama kod karatista državnog takmičarskog nivoa u odnosu na karatistu svjetskog takmičarskog nivoa. Minimalne razlike u brzini udarca nogom posljedica su smanjene visine udarca kod karatista državnog takmičarskog nivoa što ukazuje na činjenicu da karatista svjetskog takmičarskog nivoa s obzirom na ostvarenu visinu udaraca ostvaruje znatno veću manifestnu brzinu.

Jovanović (1988) je u svom radu utvrdio da vrijeme izbornog reagovanja u rješavanju tipičnih zadataka sport-

karate fighter in relation to height of a kick accomplishes greater manifested speed of a kick.

Jovanović (1988) established in his work that the time of reaction of typical task of sports fight by karate master is aprox 520ms in relation to a group of lower level fighters whose time was 533ms, which is in relation to this study. Milošević et al. (2012) conducted analysis of execution of right lag front kick in optimal physical conditions without kicking any surface, where they registered 240ms as time of kick realization. Mentioned measurement describes manifested component of reaction which is lower compared to manifested analysis of measurements of karate techniques in this study. This can be explained by simple situational conditions in comparison to complex situational conditions utilized by karate fighters in this study. Comparison of manifested time of front kick between local and world level karate fighters conducted in work Pozo, Bastien, and Dierick (2011) which concluded that the time of execution of front kick is lot lower for world level fighters compared to national standard.

Latent speed of motor reaction in complex condition has been tested by Mudrić (2015) in his doctoral dissertation, where he compared reactions of defensive actions in optimal physical conditions between karate fighters of various levels of training and specialization. Results showed that elite karate fighters react significantly faster compared to beginners, and minimally faster and statistically negligible compared to kata fighters, which is in relation with results accomplished in frame of zone I and II of this study. This has also been confirmed in work of Mori et al. (2002), where better results were accomplished by karate fighters of higher level.

Having in mind functional classification of fatigue we can conclude that manifested time of motor reaction is determined by peripheral motor fatigue, while the latent time of motor reaction is determined by complex interaction peripheral sensory I central fatigue. The mentioned aspects of fatigue are product of certain biochemical and neuron physical changes which are taking place in muscles, central and peripheral neurons which are limiting contractual processes of aktino-miozin filaments and functional relation of CNS with receptors and effectors (Davis & Bailey, 1997). Fatigue of inter neuron and neuron muscular transmission in conditions of intense physical workload is result of depletion of transmitting substances in synoptic endings, gradual accumulation of abnormal quantities of ions inside postsynaptic neurons and muscle fibers, as well as progressive deactivation of greater number postsynaptic membrane receptors, which manifests itself as a result

ske borbe kod karate majstora iznosi oko 520ms u odnosu na grupu ispitanika sa nižim zvanjima koji su ostvarili vrijeme od 533ms, što je u relaciji sa rezultatima ove studije. Milošević i sar. (2012) su na vrhunskom takmičaru izvršili kinematičku analizu izvođenja desnog mae gerija iz lijevog stava u optimalnim fiziološkim uslovima, bez udaranja u bilo kakvu površinu, gdje su registrovali vrijeme realizacije udarca od 240ms. Navedeni parametar opisuje manifestu komponentu reagovanja koja je znatno niža u poređenju sa manifestnim vrijednostima analiziranih karate tehnika u ovoj studiji, a navedeno se može opravdati prostim situacionim uslovima u odnosu na složene situacione uslove u kojima su testirani karatisti u ovoj studiji. Poređenje manifestnog vremena izvođenja karate udarca mae-geri između domaćih i međunarodnih takmičara u karateu izvršeno je u radu Pozo, Bastien i Dierick (2011) koji su konstatovali da je vrijeme izvođenja udarca znatno kraće za karatiste međunarodnog u odnosu na nacionalni standard.

Latentnu brzinu motorne reakcije u složenim uslovima testirao je Mudrić (2015) u svojoj doktorskoj disertaciji, gdje je poredio reagovanja odbrambenih akcija u optimalnim fiziološkim uslovima između karatista različitog nivoa obučenosti i specijalizacije. Rezultati su pokazali da elitni karate borci signifikantno brže reaguju u odnosu na početnike te minimalno brže i statistički beznačajno u odnosu na kataše, što je u relaciji sa rezultatima dobivenim u okviru I i II zone opterećenja ove studije. Navedeno je potvrđeno i u radu Mori i sar. (2002), gdje su statistički bolje rezultate ostvarili karatisti većeg takmičarskog nivoa.

Imajući u vidu funkcionalnu klasifikaciju zamora možemo konstatovati da je **manifestno vrijeme motorne reakcije** determinisano **periferno-motornim zamorom**, dok je **latentno vrijeme motorne reakcije** determinisano kompleksnom interakcijom **periferno-senzornog i centralnog zamora**. Navedeni aspekti zamora proizvod su određenih biohemijskih i neurofizioloških promjena koje se odvijaju na nivou mišića, centralnih i perifernih neurona koji limitiraju kontraktilne procese aktinsko-miozinskih filamenata te funkcionalne veze CNS-a sa receptorima i efektorima (Davis i Bailey, 1997). Zamor interneuronske i neuromuskularne transmisije u uslovima intenzivnog fizičkog i kognitivnog opterećenja rezultat je iscrpljivanja depoa transmitterskih supstanci u sinaptičkim završecima, postepenog nakupljanja nenormalno velike količine jona u unutrašnjosti postsinaptičkih neurona i mišićnih vlakana, te progresivne inaktivacije sve većeg broja postsinaptičkih membranskih receptora koja se javlja kao odgovor (senzorni feedback) organizma kada po-

of body during exaggerated activity. This mechanism is taking place while lowering number of receptor protein on postsynaptic membrane, releasing transmitters which inhabit postsynaptic membrane or releasing substances which are blocking work of transmitters on postsynaptic membrane (Guyton & Hall, 2017).

CONCLUSION

We can conclude that fatigue induced by intense physical work in combination with complex visual signaling, which simultaneously generates muscular, cognitive and sensory strain, produces a negative effect on the reaction speed in karate players. It should be noted that, in relation to the international level of competition, where peripheral motor fatigue is manifested, at the state level of competition, in addition to the aforementioned fatigue, there is also a central and sensory fatigue that limits the effective processing of information and decision-making, which is reflected on the analyzed sports performances. This suggests that the perceptual-cognitive component is an essential factor that determines the sports results in karate fights.

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stoji prekomjerna aktivnost. Ovaj mehanizam odvija se umanjanjem broja receptorskih proteina na postsinaptičkoj membrani, ispuštanjem transmitera koji inhibišu postsinaptičku membranu ili ispuštanjem supstanci koje blokiraju dejstvo transmitera na postsinaptičku membranu (Guyton i Hall, 2017).

ZAKLJUČAK

Možemo zaključiti da zamor induciran intenzivnim fizičkim radom u kombinaciji sa kompleksnom vizuelnom signalizacijom, koji simultano generiraju mišićno, kognitivno i senzorno opterećenje, proizvodi negativan efekat na brzinu reagovanja kod karatista. Treba istaći da se u odnosu na međunarodni takmičarski nivo gdje se uglavnom manifestuje periferni motorni zamor, na državnom takmičarskom nivou pored navedenog zamora manifestuje i centralni i senzorni zamor koji limitiraju efikasno procesuiranje informacija i donošenje odluka što se reflektuje na analizirane sportske performanse. Navedeno upućuje na zaključak da je perceptivno-kognitivna komponenta esencijalni faktor koji determinira sportski rezultat u karate borbama.

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