Original article
DOI: 10.14529/hsm220211

THE EFFECTS OF WEARABLE RESISTANCE LOADING ON KINEMATIC OF FRONT KICK AMONG ELITE TAEKWONDO ATHLETES

A.M. Nadzalan, *ali.nadzalan@fsskj.upsi.edu.my, https://orcid.org/0000-0002-0621-2245*
M. Janep, *mandrajanep@yahoo.com, https://orcid.org/0000-0001-7846-0347*
A.A.M. Jahizi, *aqilmohamadjahizi@gmail.com, https://orcid.org/0000-0001-6135-9904*
N.I. Mohamad, *nur.ikhwan@fsskj.upsi.edu.my, https://orcid.org/0000-0001-8392-8274*
N.A. Rahim, *norhazira@fsskj.upsi.edu.my, https://orcid.org/0000-0003-3235-0155*
N.A.A.M. Shalan, *aijratul@fsskj.upsi.edu.my, https://orcid.org/0000-0002-6133-3138*
F.F. Zainudin, *fairus.fz@fsskj.upsi.edu.my, https://orcid.org/0000-0001-9969-8573*
University Pendidikan Sultan Idris, Tanjung Malim, Malaysia

Abstract. **Aim.** This study aimed to determine the acute effects of WR on Taekwondo front kick kinematics. **Methodology.** 24 elite taekwondo athletes were recruited and were required to perform front kick in four conditions; 1) WR with 3% of body mass (3WR), 2) WR with 5% of body mass (5WR), 3) WR with 8% of body mass (8WR) and 4) without WR (0WR). Movement kinematics (foot velocity, knee velocity and peak height) were analyzed during the movement in both dominant and non-dominant leg. Cameras attached to motion analysis systems were used to record participant's kicking kinematics. The kinematics data obtained were compared between each conditions. **Results.** Results showed that only wearing WR of 3% body mass did not changed the knee velocity and kicking peak height as without WR. The foot velocities were found to be significantly different between each loadings with velocities become lower as loading increased. **Conclusion.** Wearing WR of 3% body mass were found to be suitable for athletes during training session as they can maintain their technical effectiveness while also increase stimulus for body to adapt in long term. Chronic studies need to be conducted to determine the long term effects of WR loadings on the kicking techniques.
Keywords: wearable resistance, specificity, transferability, resistance training, training loads
Acknowledgements. Authors would like to express their gratitude to the Ministry of Higher Education Malaysia for the Fundamental Grant Research Scheme provided for this study (Code: RACER/1/2019/SKK06/UPSI//2). Special thanks also to the Sultan Idris Education University for the laboratory and equipment used approval given.

For citation: Nadzalan A.M., Janep M., Jahizi A.A.M., Mohamad N.I., Rahim N.A., Shalan N.A.A.M., Zainudin F.F. The effects of wearable resistance loading on kinematic of front kick among elite taekwondo athletes. *Human. Sport. Medicine*. 2022;22(2):92–99. (DOI: 10.14529/hsm220211

Научная статья
УДК 796.856.2.012.1
DOI: 10.14529/hsm220211

ВЛИЯНИЕ НОШЕНИЯ УТЯЖЕЛИТЕЛЕЙ НА КИНЕМАТИКУ ПРЯМОГО УДАРА НОГОЙ У ЭЛИТНЫХ ТХЭКВОНДИСТОВ

А.М. Надзалан, *ali.nadzalan@fsskj.upsi.edu.my, https://orcid.org/0000-0002-0621-2245*
М. Жанеп, *mandrajanep@yahoo.com, https://orcid.org/0000-0001-7846-0347*
А.А.М. Джахизи, *aqilmohamadjahizi@gmail.com, https://orcid.org/0000-0001-6135-9904*
Н.И. Мохамад, *nur.ikhwan@fsskj.upsi.edu.my, https://orcid.org/0000-0001-8392-8274*
Н.А. Рахим, *norhazira@fsskj.upsi.edu.my, https://orcid.org/0000-0003-3235-0155*
Н.А.А.М. Шалан, *aijratul@fsskj.upsi.edu.my, https://orcid.org/0000-0002-6133-3138*
Ф.Ф. Зайнудин, *fairus.fz@fsskj.upsi.edu.my, https://orcid.org/0000-0001-9969-8573*
Образовательный университет Султана Идриса, Танджунг Малим, Малайзия

Аннотация. **Цель.** Целью исследования было определение мгновенного эффекта от ношения утяжелителей на кинематику прямого удара ногой в тхэквондо. **Материалы и методы.** В исследовании участвовали 24 элитных тхэквондиста. Спортсменам предстояло выполнить прямой удар ногой в четырех условиях; 1) ношение утяжелителя (WR) весом 3 % от массы тела (3WR), 2) ношение утяжелителя весом 5 % от массы тела (5WR), 3) ношение утяжелителя весом 8 % от массы тела (8WR) и 4) без утяжелителя (0WR). Кинематику движений (скорость стопы, скорость колена и максимальная высота удара ногой) анализировали во время движений как ведущей, так и неведущей ноги. Камеры, подключенные к системам анализа движения, использовали для записи кинематики ударов ногами. Полученные данные кинематики сравнивали для разных условий выполнения ударов. **Результаты.** По результатам исследования установили, что только ношение утяжелителей весом 3 % от массы тела не повлияло на скорость колена и максимальную высоту удара ногой. Обнаружено, что скорость стопы значительно меняется под воздействием нагрузки, снижаясь при каждом ее увеличении. **Заключение.** Установлено, что ношение утяжелителей весом 3 % от массы тела подходит для тренировки тхэквондистов, поскольку при данной нагрузке спортсмены сохраняют свою техническую эффективность, стимулируя при этом адаптацию организма в долгосрочной перспективе. Требуется проведение долгосрочных исследований, чтобы определить влияние длительного ношения утяжелителей на технику прямого удара ногой.

Ключевые слова: силовая тренировка, отягощение, специфичность, тренировка с отягощением, тренировочные нагрузки

Благодарность. Авторы хотели бы выразить благодарность Министерству высшего образования Малайзии за поддержку исследования в рамках программы грантового финансирования фундаментальных исследований (Код гранта: RACER/1/2019/SKK06/UPSI//2). Выражаем особую благодарность университету имени Султана Идриса за предоставленную лабораторию и оборудование.

Для цитирования: The effects of wearable resistance loading on kinematic of front kick among elite taekwondo athletes / A.M. Nadzalan, M. Janep, A.A.M. Jahizi et al. // Человек. Спорт. Медицина. 2022. Т. 22, № 2. С. 92–99. DOI: 10.14529/hsm220211

Introduction

Originated from Korea in 1940s, Taekwondo has been improved in terms of the technical and tactical features by various masters from Korean army during 1950s [14]. Taekwondo involves kicking and punches as the main strike techniques. 98 % of scoring in Taekwondo has been shown to be produced by kicking [17]. Athlete's ability to produce a good kicking is measured by the velocity and force of the kick. Ability to produce fast and powerful kick will result in opponents have less time to react and are more likely to concede points because of the forces produced.

Many aspects of Taekwondo have been scientifically investigated such as speed of kicking foot and movement time [4, 10, 11, 13, 25], impact force of participants of distinct level of expertise [26] and nutritional aspects [27]. Some authors have focused in the kinematics and kinetics of the lower extremity and pelvis [2, 5, 6]. Throughout many researches that had been conducted, it is obvious that kicking ability will affect the match outcomes, thus, explosive kick should be a principle focus of Taekwondo training, and training with resistance is recommended to fulfil the need [3, 7, 12, 24].

Resistance training is a kind of training that involve any kinds of equipment/tools to become the resistance. The traditional methods of resistance training involved individuals to go to the gym and lift weights. This is due to the mounting evidences that had shown the effectiveness of gym training to improve maximal strength by increasing muscle contraction velocity [8, 29, 30]. However, until now, the issue of transferability of strength gains achieved from traditional resistance training methods to sport-specific performance is still debated among strength and conditioning coaches, practitioners and athletes [1, 8, 22]. Several strength and conditioning researchers have argued that a better training transfer can be achieved from exercises that display mechanical specificity to the movement performed in competition [16, 23] and specificity of velocity of movement [15].

Currently, similar to most other sports, strength training protocols for combat sports utilize the normal available weight machines and free weight apart from the most widely used bodyweight strength training [19, 28]. It is thus proposed here that training should utilize loading methods that are more functional in nature, and able to be loaded while performing the actual combat sports movement. Therefore, loadings that permit performer to move freely according to sports movement is suggested.

Wearable resistance training involves an external load being attached to certain segments of the body during various sporting movements, and is an example of the application of the concept of training specificity [9, 21]. Wearable resistance is used in athletic training with the aim of increasing power output and performance by enabling specific movements to occur with additional loading without adversely affecting the technical execution of the action being performed [20]. The new wearable resistance technologies (e. g. the Lila TM Exogen TM exoskeleton suit) enable much greater customisation of load magnitudes, orientations and locations around the body. This kind of wearable resistance enables sport specific actions to be performed in an overloaded manner [20].

Compared to the traditional resistance training, wearable resistance allow the performer to train more specific to the main movements involved in the sport. It is the author's interest to find out the effects of wearable resistance during kicking execution. Currently, as to the authors' knowledge after articles searching through several databases, no studies had yet been conducted on determining the effects of wearable resistance on martial art kicking biomechanics. Thus a study in this area will provide new knowledge on the wearable resistance training, with also considering the loading effects.

It is the aim of this study to determine and compare the movement kinematics (foot velocity, knee velocity and peak height) between WR with 3% of body mass (3WR), WR with 5% of body mass (5WR) and WR with 8% of body mass (8WR) with without WR (0WR) during Taekwondo front kick.

Methodology

Participants

Twenty-four elite Taekwondo athletes were recruited as participants in this study. Participants should have black belt in Taekwondo and should currently active participating in any Taekwondo tournament at least at University level. All participants should be free of any injuries. Participants were needed to fill in the Physical Activity Readiness Questionnaire (PAR-Q) and inform consent. All participants were reminded that their participation in this study is based on volunteerism they are free to withdraw from the study at any time. This study has been approved by researchers' University Human Research Ethics Committee [Code: UPSI/PPPI/PYK/ETIKA(M)/014(164)]

Procedures

Participants were required to attend five testing sessions. The first sessions was the briefings and familiarization sessions. The second, third, fourth and fifth sessions were the testing sessions separated by 72 hours in between. Each session lasted approximately one hour, considering the preparation of participants by the researcher and the actual testing of the protocols.

For the first session, participants were given the briefings which include details of the study, personal rights to withdraw, consent letter and pre-exercise questionnaire screening. Once agreed by participants with the participant's signing in the consent letter, the session continued with introduction to all testing apparatus that will be used, and trial of all the equipment for the purpose of the study. During the other four testing occasions, the exercise protocol were completed with three different percentages of loads to body mass (3, 5 and 8% of body weight) and one more, without WR in each day. Each loading were done in separated days as a way to minimize training effects from other loading used. During data collection sessions, as participants arrived at laboratory, they were given fifteen minutes to perform general and specific warm up. After that, participants were given three trials in each dominant and non-dominant leg sides. Each trials were separated by five minutes to allowed recovery for the participants. The best technique performed was selected to be analyzed and compared between loading. During the four testing sessions, while participant performed the kicks, cameras attached to motion analysis systems were used to record participant's kicking kinematics (foot velocity, knee velocity and peak height) in both dominant and non-dominant leg.

Front kick procedure

Front kick begin with participant stand in L stance (L shape) position with shoulder-widths apart. During this position, one foot was placed in front of the other, the front foot was face forward as a supporting leg and the back foot was turned out 90 degrees as kicking leg. With body pointing about 45 degrees diagonal towards the target and arm in guarding block position. Participant then raising the knee of the kicking leg approximately to hip level and extending the knee towards the target with the toes. Following by return foot back to starting position.

Data Analysis

Six infra-red cameras motion analysis system (Vicon T10s, Oxford Metrics, UK) were used to collect kinematics data, sampled at 100 Hz. Based on the Plug-in-Gate Marker Set, reflective markers were attached to participant body at the second metatarsal, lateral malleolus, calcaneus, lateral shank, lateral femoral epicondyle, lateral thigh and anterior superior iliac spine at both sides of body. Analysis of data were conducted using

Vicon Nexus Workstation software. The kinematic model of the lower body consisted of the shank, thigh and pelvis of the kicking leg. The joint displacement and movement time were obtained through tracking the reflective makers automatically, and then the joint velocity were derived from the time series.

Statistical Analysis

Descriptive statistic was used to show mean standard deviations of participants' demographic background and kinematics data. One way repeated measure analysis of variances (ANOVA) were used to determine if significant differences existed across different percentage of loads. An alpha level of 0.05 were set to assess statistical significance for all tests.

Results

Table 1 showed the demographic background of participants involved in this study.

Table 1

Participants' demographic background

Age (years old)	22.19 ± 1.34
Height (m)	1.73 ± 0.08
Body mass (kg)	69.84 ± 4.53

Analysis of both the dominant and non-dominant leg showed significant main effects for all the kinematic variables investigated in all loadings: 1) dominant leg foot velocity, $F(3,69) = 435.89$; $p < 0.001$, 2) non-dominant leg foot velocity, $F(3,69) = 176.38$; $p < 0.001$, 3) dominant leg knee velocity, $F(3,69) = 934.02$; $p < 0.001$, 4) non-dominant leg knee velocity, $F(3,69) = 341.28$; $p < 0.001$, 5) dominant leg peak height, $F(3,69) = 1129.34$; $p < 0.001$, 6) non-dominant leg peak height, $F(3,69) = 1265.52$; $p < 0.001$. Table 2 showed the mean and standard deviation of foot velocity, knee velocity and peak height of both dominant and non-dominant leg.

Pairwise comparison then was conducted to compare specifically between all the variables between loads. Foot velocities were different between each of the loadings used in both dominant and non-dominant legs ($p < 0.05$). Knee velocities were found to be significantly different between 0WR with 5WR and 8WR, 3WR with 5WR and 8WR, and 5WR and 8WR. Peak heights were found to be significantly different between 0WR with 5WR and 8WR, and 3WR with 8WR.

Discussion

The purpose of this study is to determine the acute effects of wearable resistance on Taekwondo front kick kinematics. Knee velocity, foot velocity and peak height were analyzed in both dominant and non-dominant leg and were compared between four loading conditions (3% body mass, 5% body mass, 8% body mass and without wearing wearable resistance).

After analysis of data collected in table 2, we can assume that the loading of WR influences the kinematics of lower limb during front kick. The highest velocity was recorded when there were no WR worn by participants. The speed of the dominant leg knee was faster than the non-dominant one. The difference appeared in all participants. This is in line with findings from several previous studies [32] and contrast to other studies [18].

As like other kicks, front kick need to be performed fast to enhance chances to hit the target. Therefore, speed training is crucial to achieve victory. As a way to enhance kicking speed, training should include resistance to create more challenge for adaptation. A more specific training is recommended, to enhance the transferability of training to sports skill. Thus, using WR is believed to be beneficial, as it allow athletes to do their movement while carrying the loads.

A good front kick should be started with a great knee and foot velocity. [31] in their study found kick velocity is influenced by the knee velocity. With just one component lack, the effectiveness of the kicking will be affected.

Table 2

Score mean and standard deviation

Variables	0 WR	3 WR	5 WR	8 WR
Dominant leg foot velocity (m/s)	7.43 ± 0.17^{bcd}	7.32 ± 0.39^{acd}	7.15 ± 0.45^{abd}	6.94 ± 0.74^{abc}
Non-dominant leg foot velocity (m/s)	7.39 ± 0.26^{bcd}	7.23 ± 0.47^{acd}	7.04 ± 0.74^{abd}	6.80 ± 0.87^{abc}
Dominant leg knee velocity (m/s)	5.09 ± 0.19^{cd}	5.05 ± 0.32^{cd}	4.97 ± 0.56^{abd}	4.88 ± 0.74^{abc}
Non-dominant leg knee velocity (m/s)	5.05 ± 0.24^{cd}	4.99 ± 0.42^{cd}	4.88 ± 0.67^{abd}	4.79 ± 0.86^{abc}
Dominant leg peak height (m)	1.75 ± 0.05^{cd}	1.73 ± 0.08^{d}	1.70 ± 0.10^{a}	1.67 ± 0.11^{ab}
Non-dominant leg peak height (m)	1.73 ± 0.09^{cd}	1.71 ± 0.05^{d}	1.68 ± 0.12^{a}	1.65 ± 0.09^{ab}

Note: [a] – significantly different from 0 WR; [b] – significantly different from 3 WR; [c] – significantly different from 5 WR; [d] – significantly different from 8 WR.

Results showed that each loading conditions caused the foot velocities to be significantly different between each other in both dominant and non-dominant leg. It is the interest of this study to look at how the use of wearable resistance affect the kinematics during the front kick when compared to 0WR. For the dominant leg, it was found that 3WR, 5 WR and 8WR caused 1.48%, 3.77% and 6.59% changes to the foot velocities respectively. What can we see here is that, foot velocities di significantly affected by just wearing WR with 3% body mass. As the loading increased, the changes become bigger. The changes in the non-dominant leg is greater as the similar loadings caused 2.17%, 4.74% and 7.98% changes respectively. Thus, we can see that asymmetry (dominant vs non-dominant) become greater as loading increased.

Next, results showed that knee velocities to be significantly different between 0WR with 5WR and 8WR, 3WR with 5WR and 8WR, and 5WR and 8WR. This happened to both dominant and non-dominant leg. Compared to the foot velocity, it can be seen here that significant changes to the knee velocity didn't occur when wearing 3% of body mass. This might be due to the simple movement of knee in which the knee is just lift upward. For the dominant leg, it was found that 3WR, 5 WR and 8WR caused 0.79%, 2.36% and 4.13% changes to the knee velocities respectively. Compared to the foot velocity, the changes here is lesser, again, probably due to the simple movement of knee lift. The changes in the non-dominant leg is greater as the similar loadings caused 1.19%, 3.37% and 5.15% changes respectively. Again, asymmetry (dominant versus non-dominant) become greater as loading increased even the movement is simple.

Finally results showed that peak heights were found to be significantly different between 0WR with 5WR and 8WR, and 3WR with 8WR for both dominant and non-dominant legs. As knee velocity, again the results showed 3% of body mass WR did not change the height of kicking. This showed that the leg is able to lift the foot high enough even when carrying 3% WR loading. For the dominant leg, it was found that 3WR, 5WR and 8WR caused 1.14%, 2.86% and 4.57% changes to the peak height respectively. The changes in the non-dominant leg is not so much differences, as the similar loadings caused 1.16%, 2.89% and 4.62% changes respectively. Unlike the knee and foot velocity, it is seen here that the peak height did not differed too much between dominant and non-dominant leg. This could be possibly contributed by the facts that both legs are similarly strong and flexible enough to move with weights.

In terms of comparison between dominant and non-dominant leg, pairwise comparison was also conducted to compare specifically in all the variables in each loads. Foot and knee velocities were significantly different between dominant and non-dominant during 3WR, 5WR and 8WR ($p < 0.05$). No significant differences in terms of peak heights between dominant and non-dominant leg in all loading conditions. This results showed that asymmetry occur in terms of velocity but not flexibility.

Conclusions

Until now, there are still coaches that unsure about the effectiveness of resistance training as how it was performed, the loads lifted and the efforts given might cause coaches and athletes fear to have much increment of muscle mass that could affect their movement effectiveness. Wearable resistance permits athletes to wear it and move specifically according to their sport, thus given a bigger opportunity for athletes to train more specific and maintain the movement effectiveness during the training session. However, it is a need to find appropriate weights to be used during training to maintain its specificity with the actual movement. Wearing too much load might affect the movement effectiveness as athletes might perform the movement slower, while wearing too light will not give enough stimuli for better body adaptation. Wearing WR of 3% body mass were found to be suitable for athletes during training session as they can maintain majority of kicking kinematics data that were studied. Thus, it is concluded that 3 % of body mass is the preferred choice of WR loadings as participant can move while lifting loads on their body while at the same time could maintain their kicking effectiveness. It is recommended for the studies in the future to focus on other loadings to be used, the effects of WR if used during warming up session, and how the WR affect a more simple or complex movement.

References

1. Amaro N., Morouço P., Marques M. et al. A Systematic Review on Dry-Land Strength and Conditioning Training on Swimming Performance. *Science & Sports*, 2019, vol. 34 (1), pp. 1–14. DOI: 10.1016/j.scispo.2018.07.003

2. Buśko K., Nikolaidis P.T. Biomechanical Characteristics of Taekwondo Athletes: Kicks and Punches vs. Laboratory Tests. *Biomedical Human Kinetics*, 2018, vol. 10 (1), pp. 81–88. DOI: 10.1515/bhk-2018-0013

3. Carazo-Vargas P., Moncada-Jiménez J. Reducing Training Volume During Tapering Improves Performance in Taekwondo Athletes. *Journal of Physical Education and Sport*, 2018, vol. 18 (4), pp. 2221–2229. DOI: 10.7752/jpes.2018.04334

4. Castro-Garrido N., Valderas-Maldonado C., Herrera-Valenzuela T. et al. Effects of Post-Activation Potentiation Exercises on Kicking Frequency, Fatigue Rate and Jump Performance in Taekwondo Athletes: a Case Study. *Retos,* 2020, vol. 38, pp. 679–683. DOI: 10.47197/retos.v38i38.76755

5. Chang W.-G., Lin K.-Y., Chu M.-Y., Chow T.-H. Differences in Pivot Leg Kinematics and Electromyography Activation in Various Round House Kicking Heights. *Journal of Sports Science and Medicine*, 2021, vol. 20 (3), pp. 457–465. DOI: 10.52082/jssm.2021.457

6. da Silva A.J., Misuta M.S., Silvatti A.P. et al. Kinematical Analysis of Bandal and Dolyo Taekwondo Kicks of a High Level Female Athlete. *ISBS-Conference Proceedings Archive*, 2011. Available at: https://ojs.ub.uni-konstanz.de/cpa/article/view/4833

7. da Silva Santos J.F., Franchini E. Frequency Speed of Kick Test Performance Comparison Between Female Taekwondo Athletes of Different Competitive Levels. *The Journal of Strength & Conditioning Research*, 2018, vol. 32 (10), pp. 2934–2938. DOI: 10.1519/JSC.0000000000002552

8. da Silva Santos J.F., Valenzuela T.H., Franchini E. Can Different Conditioning Activities and Rest Intervals Affect the Acute Performance of Taekwondo Turning Kick? *The Journal of Strength & Conditioning Research*, 2015, vol. 29(6), pp. 1640–1647. DOI: 10.1519/JSC.0000000000000808

9. Dolcetti J.C., Cronin J.B., Macadam P., Feser E.H. Wearable Resistance Training for Speed and Agility. *Strength & Conditioning Journal*, 2019, vol. 41 (4), pp. 105–111. DOI: 10.1519/SSC.0000000000000436

10. Estevan I., Álvarez O., Castillo I. Autoeficacia Percibida y Rendimiento Técnico-Táctico en Taekwondistas Universitarios. *Cuadernos de Psicología del Deporte*, 2016, vol. 16 (2), pp. 51–64. Available at: https://revistas.um.es/cpd/article/view/264421

11. Estevan I., Alvarez O., Falco C. et al. Impact Force and Time Analysis Influenced by Execution Distance in a Roundhouse Kick to the Head in Taekwondo. *The Journal of Strength & Conditioning Research*, 2011, vol. 25 (10), pp. 2851–2856. DOI: 10.1519/JSC.0b013e318207ef72

12. Ferreira da Silva Santos J., Herrera-Valenzuela T., Franchini E. Establishing Frequency Speed of Kick Test Classificatory Tables in Male and Female Taekwondo Athletes. *Kinesiology*, 2019, vol. 51 (2), pp. 213–218. DOI: 10.26582/k.51.2.12

13. Gavagan C.J., Sayers M.G. A Biomechanical Analysis of the Roundhouse Kicking Technique of Expert Practitioners: A Comparison Between the Martial Arts Disciplines of Muay Thai, Karate, and Taekwondo. *PloS One*, 2017, vol. 12 (8), e0182645. DOI: 10.1371/journal.pone.0182645

14. Gillis A. A Killing Art: The Untold History of Tae Kwon Do, Updated and Revised. ECW Press, 2016.

15. Guerriero A., Varalda C., Piacentini M.F. The Role of Velocity Based Training in the Strength Periodization for Modern Athletes. *Journal of Functional Morphology and Kinesiology*, 2018, vol. 3 (4), p. 55. DOI: 10.3390/jfmk3040055

16. Haff G.G., Triplett N.T. *Essentials of Strength Training and Conditioning*. 4th Edition. Human Kinetics, 2015.

17. Kazemi M., De Ciantis M.G., Rahman A. A Profile of the Youth Olympic Taekwondo Athlete. *The Journal of the Canadian Chiropractic Association*, 2013, vol. 57 (4), p. 293. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3845466/

18. Kim Y.-K., Kim Y.-H. Unilateral Performance Comparison for Taekwondo Kicks Between Dominant Leg and Non-Dominant Leg. *Korean Journal of Sport Biomechanics*, 2010, vol. 20 (2), pp. 183–189. DOI: 10.5103/KJSB.2010.20.2.183

19. Lenetsky S., Harris N., Brughelli M. Assessment and Contributors of Punching Forces in Combat Sports Athletes: Implications for Strength and Conditioning. *Strength & Conditioning Journal*, 2013, vol. 35 (2), pp. 1–7. DOI: 10.1519/SSC.0b013e31828b6c12

20. Macadam P., Cronin J.B., Simperingham K.D. The Effects of Wearable Resistance Training on Metabolic, Kinematic and Kinetic Variables During Walking, Running, Sprint Running and Jumping: A Systematic Review. *Sports Medicine*, 2017, vol. 47 (5), pp. 887–906. DOI: 10.1007/s40279-016-0622-x

21. Macadam P., Simperingham K.D., Cronin J.B. Forearm Wearable Resistance Effects on Sprint Kinematics and Kinetics. *Journal of Science and Medicine in Sport*, 2019, vol. 22 (3), pp. 348–352. DOI: 10.1016/j.jsams.2018.08.012

22. McGuigan M.R., Wright G.A., Fleck S.J. Strength Training for Athletes: Does it Really Help Sports Performance? *International Journal of Sports Physiology and Performance*, 2012, vol. 7 (1), pp. 2–5. DOI: 10.1123/ijspp.7.1.2

23. Moir G.L., Brimmer S.M., Snyder B.W. et al. Mechanical Limitations to Sprinting and Biomechanical Solutions: a Constraints-Led Framework for the Incorporation of Resistance Training to Develop Sprinting Speed. *Strength & Conditioning Journal*, 2018, vol. 40 (1), pp. 47–67. DOI: 10.1519/SSC.0000000000000358

24. Moreira P.V.S., Falco C., Menegaldo L.L. et al. Are Isokinetic Leg Torques and Kick Velocity Reliable Predictors of Competitive Level in Taekwondo Athletes? *PloS One*, 2021, vol. 16 (6), e0235582. DOI: 10.1371/journal.pone.0235582

25. Nadzalan A.M., Janep M., Jahizi A.A.A. et al. The Influence of Wearable Resistance Loading on Taekwondo Axe Kick Kinematics Among Elite Taekwondo Athletes. *International Journal of Human Movement and Sports Sciences*, 2021, vol. 9 (5), pp. 893–898. DOI: 10.13189/saj.2021.090509

26. O'Sullivan D., Chung C., Lee K. et al. Measurement and Comparison of Taekwondo and Yongmudo Turning Kick Impact Force for Two Target Heights. *Journal of Sports Science & Medicine*, 2009, vol. 8 (CSSI3), p. 13. Available at: https://pubmed.ncbi.nlm.nih.gov/24474880/

27. Pak İ.E., Cuğ M., Volpe S.L., Beaven C.M. The Effect of Carbohydrate and Caffeine Mouth Rinsing on Kicking Performance in Competitive Taekwondo Athletes During Ramadan. *Journal of Sports Sciences*, 2020, vol. 38 (7), pp. 795–800. DOI: 10.1080/02640414.2020.1735033

28. Saraiva A.R., Reis V.M., Costa P.B. et al. Chronic Effects of Different Resistance Training Exercise Orders on Flexibility in Elite Judo Athletes. *Journal of Human Kinetics*, 2014, vol. 40 (1), pp. 129–137. DOI: 10.2478/hukin-2014-0015

29. Singh D.K. Effect of Resistance Training and Plyometric Training on Explosive Strength in Adolescent Male Taekwondo Players. *International Journal of Behavioral Social and Movement Sciences*, 2012, vol. 1 (2), pp. 49–56.

30. Topal V., Ramazanoglu N., Yilmaz S. et al. The Effect of Resistance Training with Elastic Bands on Strike Force at Taekwondo. *American International Journal of Contemporary Research*, 2011, vol. 1, pp. 140–144.

31. Wasik J., Czarny W., Malolepszy E., Drozdek-Malolepsza T. Kinematics of Taekwon-Do front Kick. *Archives of Budo Science of Martial Arts and Extreme Sports*, 2015, vol. 11, pp. 23–28.

32. Wąsik J., Góra T. Impact of Target Selection on Front Kick Kinematics in Taekwondo – Pilot Study. *Physical Activity Review*, 2016, vol. 4, pp. 57–61. DOI: 10.16926/par.2016.04.07

Information about the authors

Ali Md Nadzalan, PhD in Coaching Science, Senior Lecturer atFaculty of Sports Science and Coaching, Sultan Idris Education University, Tanjung Malim, Malaysia.

Mandra Janep, postgraduate student, Faculty of Sports Science and Coaching, Sultan Idris Education University, Tanjung Malim, Malaysia.

Ahmad Aqil Mohamad Jahizi, postgraduate student, Faculty of Sports Science and Coaching, Sultan Idris Education University, Tanjung Malim, Malaysia.

Nur Ikhwan Mohamad, PhD in Strength and Conditioning, ProfessoratFaculty of Sports Science and Coaching, Sultan Idris Education University, Tanjung Malim, Malaysia.

Norhazira Abdul Rahim, PhD in Biochemistry, Senior Lecturer atFaculty of Sports Science and Coaching, Sultan Idris Education University, Tanjung Malim, Malaysia.

Nor Aijratul Asikin Mohamad Shalan, PhD in Medical Biotechnology, Senior Lecturer atFaculty of Sports Science and Coaching, Sultan Idris Education University, Tanjung Malim, Malaysia.

Fairus Fariza Zainudin, PhD in Physiotherapy, Senior Lecturer atFaculty of Sports Science and Coaching, Sultan Idris Education University, Tanjung Malim, Malaysia.

Информация об авторах

Надзалан Али Мд, PhD в области тренерской работы, старший преподаватель, факультет спортивных наук и тренерской работы, Образовательный университет Султана Идриса, Танджунг Малим, Малайзия.

Жанеп Мандра, аспирант, факультет спортивных наук и тренерской работы, Образовательный университет Султана Идриса, Танджунг Малим, Малайзия.

Джахизи Ахмад Акиль Мохамад, аспирант, факультет спортивных наук и тренерской работы, Образовательный университет Султана Идриса, Танджунг Малим, Малайзия.

Мохамад Нур Икхван, PhD в области силовой и физической подготовки, профессор, факультет спортивных наук и тренерской работы, Образовательный университет Султана Идриса, Танджунг Малим, Малайзия.

Рахим Норхазира Абдул, PhD в области биохимии, старший преподаватель, факультет спортивных наук и тренерской работы, Образовательный университет Султана Идриса, Танджунг Малим, Малайзия.

Шалан Нор Айратул Азикин Мохамад, PhD в области медицинской биотехнологии, старший преподаватель, факультет спортивных наук и тренерской работы, Образовательный университет Султана Идриса, Танджунг Малим, Малайзия.

Зайнудин Файруз Фариза, PhD в области физиотерапии, старший преподаватель, факультет спортивных наук и тренерской работы, Образовательный университет Султана Идриса, Танджунг Малим, Малайзия.

The article was submitted 10.02.2022
Статья поступила в редакцию 10.02.2022