Original Article

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# Sex differences in utilizing effective mass among taekwon-do athletes performing turning and side kick

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*Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection*

**Abstract:** *Introduction:* The gender type of fighters and the technique of movement may have a significant impact on the level of effectiveness of sporting rivalry, yet their significance may differ depending on a multitude of factors. Hence, the aim of this research was to evaluate the impact of the effective mass and foot acceleration on the force of the turning kick and the side kick depending on the gender type of competitors represented. *Material and Methods:* The research was participated in by nine practitioners of taekwon-do, four men and five women of a minimum age of 18, all of whom have a black belt. They executed a series of kicks on a tensometric platform known as AMTI, model MC12-2K, series 2000 mounted on a stable construction and a padded training target in order to protect the fighters from injury. The data relating to the acceleration was acquired by means of installing a wireless sensor IMU Ultium by the firm Noraxon near the foot, which is synchronized with the tensometric platform registering the force of the blow. *Results:* The registered differences between the force pressure in the analysed kicks (turning kick $F=84.14$; $p<0.001$) (side kick $F=46.62$; $p<0.001$), while also the lack of statistical significance between the effective mass in the case of the turning kick ($H=2.80$; $p=0.094$) and the side kick ($H=0.02$; $p=0.879$) between men and women. By comparison with men, a strong correlation was noted amongst women between the effective mass and pressure force ($r=0.79$; $p<0.05$). *Conclusion:* Our research reveals that there is a lack of significant differences between women and men in terms of the effective mass acquired in the blows administered, both in the case of turning kicks and side kicks. Nevertheless, due to the lower mass of women that is determined genetically, this factor will always reduce the value of the force of kick acquired. Interdependency of the effective mass and foot acceleration exists depending on the gender type represented while executing a turning kick. However, the execution of the side kick reveals a similar interdependency between these indicators both in the cases of women and men.

Keywords: effective mass, taekwon-do, sex, kinetics martial arts, turning kick, side kick

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# INTRODUCTION

Since the beginning of its existence, fighters of both the traditional version and the Olympic version of taekwon-do have connected their tactical and technical activities with the potential use of kicks in order to gain an advantage over an opponent [1–4]. In the search for efficiency in this form of martial arts, it was noted that success is dependent on the high velocity of hits administered on the one hand [5,6], while on the other hand on their force despite these extreme priorities [7]. Hence, the high degree of advancement in taekwon-do is frequently connected with the possibility of generating significant power, as well as the acquired velocity of the foot while executing blows [8]. Research indicates that the impact of these factors is exerted by, among others, the skilful use of body mass [9–11], as the involvement of a specified muscle group, including the muscles of the legs, hips and torso all play a key role [12]. With relation to this fact, due to the different body structure of women and men, we may expect a different proportion of effective mass depending on the gender type of the fighter despite availing of the same technique of movement. The term "effective mass" in combat sports is defined as the amount of engaged mass in a blow with relation to the body mass of the fighter. Effective mass is frequently the key factor in terms of effectiveness, e.g. boxers use this with the aim of generating greater power in their blows [13], while in judo it is used for throwing and manoeuvres of subduing an opponent [14]. Interestingly, there is no linear interdependency between the effective mass and the total body mass of a sportsperson [15], while it is possible to suppose that a higher effective mass is gained by means of the appropriate technique and experience [16].

The hitherto models of calculating the effective mass in combat sports were based on the models with the principle of maintaining momentum [10,15,17]. This model is theoretically correct, albeit it does not reveal in its entirety the transfer of momentum during the course of administering a blow by a person [9]. Thus, we have decided to designate the effective mass by basing it on the classic dependency of the second principle of the dynamics of Newton, in which:

$$M_e = \frac{F_{max}}{a} \quad (1)$$

where $M_e$ – effective mass participating in the blow; $F_{max}$ – maximum power with which the kick landed on its target; a – maximum foot acceleration prior to contact with the target.

Turning kicks and side kicks are two fundamental techniques used in taekwon-do and are effective in terms of attacking the opponent from various angles and also play a key role in sporting rivalry, while are furthermore described on multiple occasions in subject-related literature [18–21]. The basic difference between these two techniques is the direction of the blow. In the turning kick, the foot moves in an arc along the axis of the body, whereas in terms of the side kick, the foot is placed at the side in the direction of the opponent [1,8].

Enhancement of techniques in taekwon-do is an important element of training that has an impact on the level of effectiveness in a fight [22].The resulting skill of generating significant power and speed of administering kicks, among others, are key elements of the techniques of attack and defence. We know from hitherto research that both the technique of movement and the gender type may have an important impact on sporting efficiency, yet their significance may differ depending on multiple factors [23,24]. In some cases, technique may be the key determinant of success, while in others the gender type may be of greater importance. The ultimate assessment depends on the specific context and sporting discipline. The question arises as to how this works out in taekwon-do. Thus, the aim of this research was to evaluate the impact of the effective mass and foot acceleration on the power of the turning kick and the side kick, depending on the gender type represented by the fighters. With relation to this, the following research questions have been formulated:

1. Will gender type constitute a statistically significant factor in the differentiation of effective mass ?
2. How is the interdependency of the power of the kick, effective mass and foot acceleration formed?
3. Is the interdependency of the chosen kinetic indicators dependent on the gender type of those analysed?

The answers to these questions may lead to the use of the unrevealed technical potential of fighters and help trainers and fighters in terms of enhancing the effectiveness of training, which in turn may increase the effectiveness of the kicks in sport and in self-defence.

# MATERIAL AND METHODS

*Participants*

Nine practitioners of International Taekwon-do Federations: four men (age: 28.5 ± 6.5 years; body mass: 77.5 ± 6.1 kg; height: 180.0 ±1.4 cm) and five women (age: 27.0 ± 4.8 years; body mass: 64.2 ± 5.8 kg; height: 163.0 ± 6.5 cm) participated in this study. The conditions for inclusion in the study group were being male, 18 years old or older, hold a 1st Dan (black belt) or higher and active participation in sports competition at national level for at least 4 years.

*Ethics*

The Human Subjects Research Committee of the Jan Dlugosz University Czestochowa scrutinized and approved the test protocol as meeting the criteria of Ethical Conduct for Research Involving Humans (KE-O/4/2022). All participants in the study were injury free, informed of the testing procedures and voluntarily participated in the data collection.

*Equipment*

To gain the impact force a force plate as the target was used, padded with a training shield to protect the participants from hitting the force plate directly, mounted onto a stable structure (AMTI, model MC12-2K, 2000 series). The force plate dimensions were 305 x 406 x 79 mm. The force plate was synchronized in time and space to Noraxon (MR3 3.18). Acceleration data was obtained by mounting wireless IMU sensor Ultium manufactured by Noraxon, synchronized with a force plate. Sampling rate of IMU sensors was 2000 Hz. Sensors were equipped with acceleration-only attachment, allowing measurements up to 4000 g. Sensor was attached to a side of a foot, near lateral malleolus.

*Protocol*

Data was collected at the Center for Human Movement Analysis, Jan Dlugosz University Częstochowa. Participants performed a self-selected 10-minute warm-up. After the warm-up, participants performed side kick (yop chagi) to the target five times with their right leg, starting in sport stance. After a one-minute rest, the participants performed a turning kick (dollyo chagi) five times from sport stance to the target with their right leg. Then, the same procedure was repeated for the left leg for all participants. Participants were asked kick with maximum effort to achieve the highest impact force they can, with no time constraints to execute the kicks.

*Data processing and data analysis*

After collecting the data, namely, the values of the maximum force of pressure on the platform were exported from the program Noraxton to Excel from the package Microsoft Office Professional Plus 2010 with the aim of ordering them in accordance with

a division into gender type, type of kick and the left or right leg. In this manner, data was collected for 180 measurement positions (9 people x 5 attempts x 2 types of kicks x 2 legs)

*Statistical analysis*

Following the data analysis, it was exported to the program Statistica 13 (TIBCO software). Subsequently, the basic descriptive statistics were calculated and the Shapiro-Wilk test was conducted. With the aim of defining the significance of the differences between the groups depending on the claim of normality of the dispersion, the Kruskal-Wallis test or the ANOVA test was conducted. Additionally, Spearman's correlation coefficients were calculated, in terms of whether interdependency exists between gender types, the type of kicks, force pressure, foot acceleration, effective mass and body mass. The statistical significance was accepted at the level of $p<0.05$.

# RESULTS

Table 1 contains the medians of the registered values of force pressure, effective mass, as well as foot acceleration for the chosen kicks with a division into the gender types represented. The calculated statistical values indicate that a significant difference exists in the force pressure (turning kick $F=84.14$; $p<0.001$) (turning kick $F=46.62$; $p<0.001$). Figure 1 presents the percentage values of the effective mass in the case of the turning kick ($H=2.80$; $p=0.094$) and the side kick ($H=0.02$; $p=0.879$) between men and women in graphic form.

Table 1. Medians of value of force pressure, effective mass in kg and percentages, while also foot acceleration while executing the chosen kicks divided into gender type and type of kick.

| Kick type | Sex | Force pressure [N] | Effective mass [kg] | Effective mass [%] | Foot acceleration [m/s²] |
|---|---|---|---|---|---|
| Turning kick | Female | 1379.13 | 10.88 | 18.11 | 129.73 |
| | Male | 2628.79 | 14.53 | 19.06 | 155.99 |
| | SS | F=84.14; p<0.001* | H=9.68; p=0.001* | H=2.80; p=0.094 | F=45.16; p<0.001* |
| Side kick | Female | 1770.92 | 56.85 | 85.30 | 52.68 |
| | Male | 4855.36 | 54.82 | 73.98 | 71.53 |
| | SS | F=46.62; p<0.001* | H=0.77; p=0.380 | H=0.02; p=0.879 | F=0.55; p=0.577 |

SS - statistical significance, * statistically significant

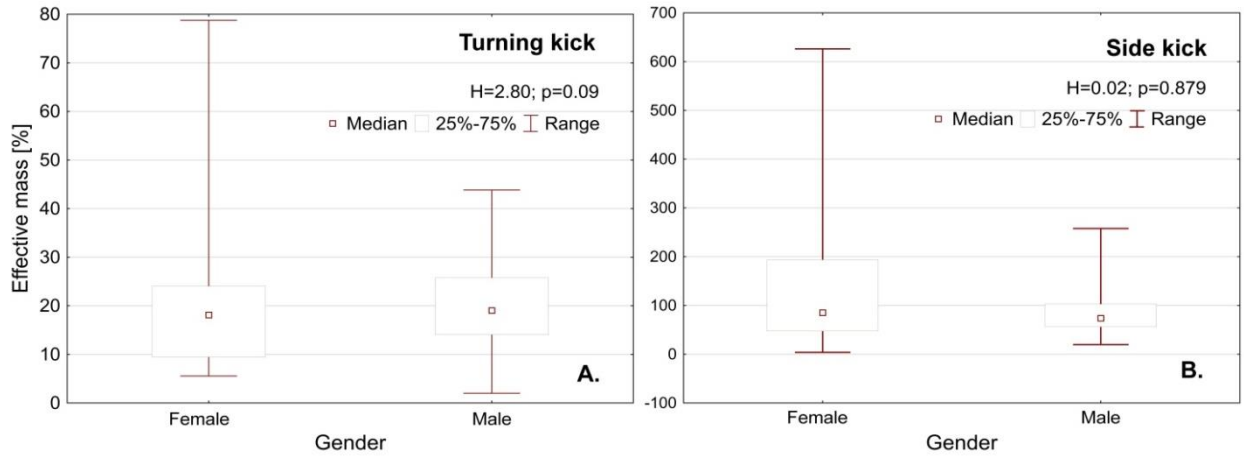


Figure 1. Graphic presentation of medians of percentage values of effective mass in the cases of turning kick (A) and side kick (B) ($H=96.80$; $p<0.001$).

Figure 2 illustrates four charts of data spread with a linear regression marked in with regard to the relation of the pressure force with foot acceleration and effective mass with a division into gender type and type of kick: A. turning kick - female, B. side kick - female, C. turning kick - male, D. side kick - male. In Table 2, Spearman's correlation coefficients have been stipulated for three kinetic variables registered while executing two kicks in taekwon-do with a division into gender types. In the group of women, a positive interdependency was noted between the pressure force and the effective mass (in the case of the turning kick r=0.79; p<0.05; side kick r=0.47; p<0.05) and a negative correlation between the foot acceleration and effective mass (in the case of the turning kick r=-0.85; p<0.05; side kick r=-0.91; p<0.05). In the group of men, it was noted that while performing the side kick, together with the growth in the pressure force, the effective mass rises (r=0.72; p<0.05), while also the rising foot acceleration coexists with the reducing values of the effective mass (in the case of the turning kick r=-0.83; p<0.05; side kick r=-0.53; p<0.05).

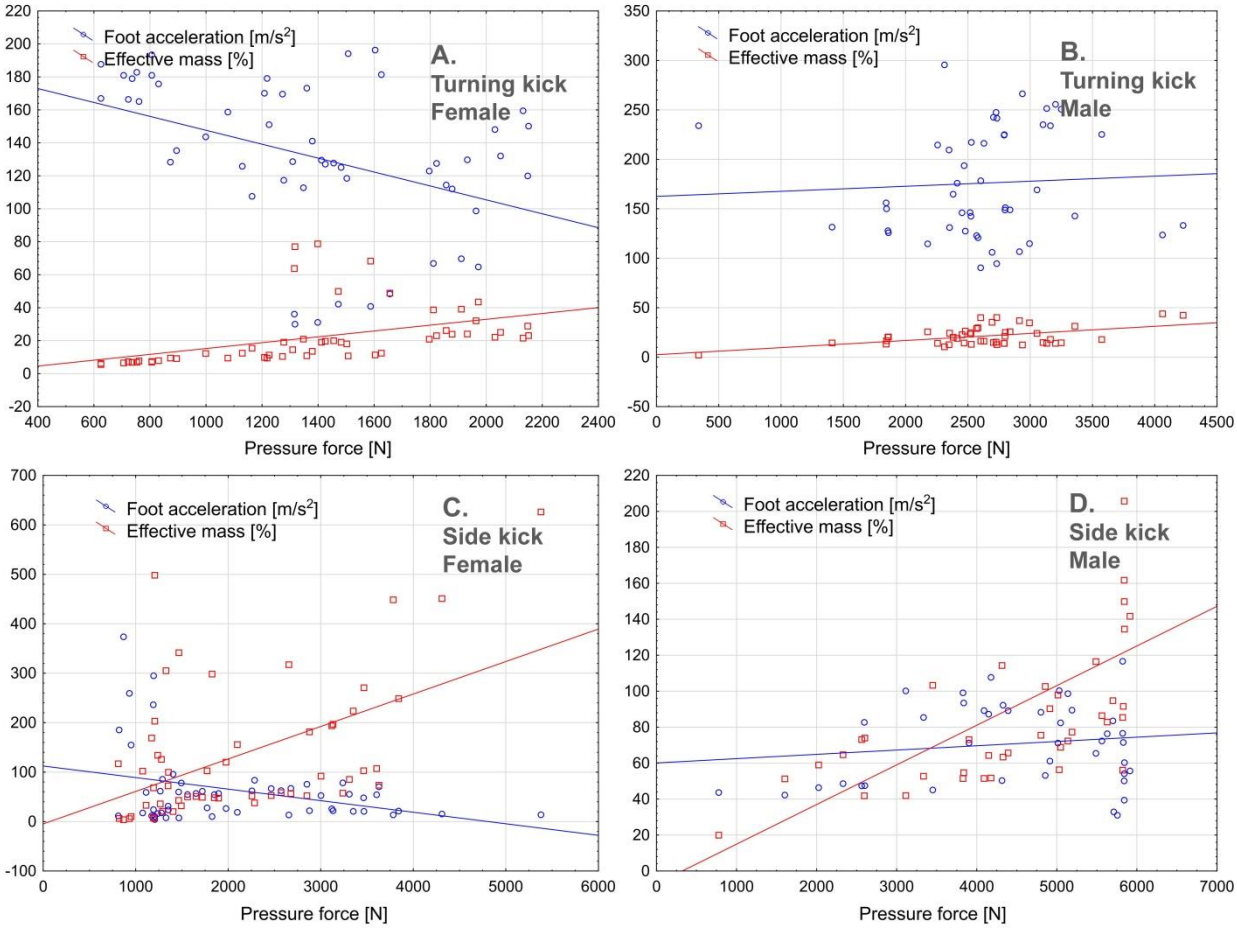


Figure 2. Diagram of spread of data with linear regression marked in relating to the pressure force with foot acceleration and effective mass.

Table 2. Table of Spearman's correlation coefficients of chosen indicators.

| Kick type | Indicator | Female | | Male | |
|---|---|---|---|---|---|
| | | Foot acceleration | Effective mass | Foot acceleration | Effective mass |
| Turning kick | Pressure force | -0.451* | 0.792* | 0.196 | 0.257 |
| | Foot acceleration | - | -0.846* | - | -0.832* |
| Side kick | Pressure force | -0.160 | 0.473* | 0.009 | 0.721* |
| | Foot acceleration | - | -0.913* | - | -0.533* |

* statistical significance p<0.05

# DISCUSSION

Our research reveals that the difference in the values of the effective mass while conducting research on the kicks between fighters of both female gender and male gender is statistically insignificant. Hence, it is possible to suppose that in this case the technique of motion is a greater determinant than gender type. Nevertheless, with regard to the lower mass of women that is determined genetically, this factor will always reduce the value acquired in terms of the force of the kick, which was noted in our research where it was possible to observe that with a similar mass, men acquire greater power in their kicks. This conforms with the obvious differences between women and men.

The available research suggests that in sport, the significance of gender type and the power of movement may differ depending on the sporting discipline and the specifics of the situation at hand. For instance, in gymnastics or figure skating, the technique of movement may be the key determinant of success. Precise and fluid execution of the intricate technical moves may be decisive in terms of accomplishing high performance, regardless of the gender type of the competitor [25,26]. In rivalry that requires great physical strength, such as weightlifting or rugby, the gender type may be of significant importance [27,28]. In certain cases, men may have a natural advantage with regard to physical strength, which in turn, may have an impact on the achievement of better performance. Of course, every sportsperson has his/her own physical and technical predisposition. Regardless of the gender type, some sportspeople may have a natural talent for specified techniques of movement or sporting disciplines, which in turn, may have a significant impact on their efficiency. Another key element is training and experience, even if the gender type may have an impact on certain aspects of efficiency, systematic training and consistent enhancement of techniques may drastically reduce these differences.

Our research also reveals another interdependency between the effective mass and foot acceleration depending on the gender type represented while executing the turning kick. However, executing the side kick reveals a similar interdependency between these indicators both in the cases of women and men. In accordance with the second principle of the dynamics of Newton, power is directly proportional to mass and acceleration [29], albeit it is different in this case. Power clearly grows with the growth of the effective mass, however a correlation of this variable was not observed between the accelerations of the feet. Nevertheless, a strong negative relation emerges between the effective mass and foot acceleration, regardless of the type of kick performed and the gender type represented. This hypothesis of course requires more profound analysis and verification.

An interesting fact is that the linear regression on the charts relating to the dependencies between effective mass and foot acceleration in the case of a side kick (Figure 2), we see lines that mark out the intersection point. Perhaps this is some specific point that indicates the characteristic difference between women and men.

To sum up, both the technique of movement, as well as the gender type may have a significant impact on the level of efficiency in taekwon-do, yet their significance may differ depending on a multitude of factors. During the course of executing kicks in taekwon-do, it is possible to observe certain differences between women and men. Generally speaking, men have the tendency to display greater force in their kicks and foot acceleration while executing kicks in taekwon-do. The technique of kicks may also differ between the gender types. Although the technical aspects of kicks are similar both amongst women as amongst men, certain differences may result from a different body mass and flexibility of the body. However, it is worth noting that the afore-mentioned differences are general and individual differences exist between the particular sportspeople, regardless of gender type. Ultimately, the effectiveness of kicks in taekwon-do depends on individual abilities, techniques and the level of training of each fighter, regardless of gender type.

The findings of this research may be of significance for trainers by emphasizing the not so obvious differences in the biomechanics of blows depending on the gender type of taekwon-do fighters as they should ensure feedback and corrective training in order to eliminate technical drawbacks and maximize the generation of power. The observations stipulated here facilitate the coordination of the effectiveness of kicks depending on whether training is conducted with a woman or with a man, while also various scenarios of rivalry. This may be of assistance in the choice of the strategy of kicks and to enhance techniques. It is worth noting that future research should encompass greater and more differentiated groups of competitors, while also collect data in the actual environment of rivalry in order to ensure a more comprehensive perception of the biomechanics of kicks and other blows in taekwon-do.

# CONCLUSION

It was observed that the difference in effective mass values when testing kicks between female and male athletes was not statistically significant. Thus, it is likely that movement technique is a greater determinant than gender. However, the technique of the kicks may also differ according to gender. When performing a spin kick, the correlation between effective mass and foot acceleration is different depending on the gender represented. In contrast, the same correlation for the side kick marks the intersection point on the linear regression graphs. Perhaps this is a characteristic point that indicates a specific difference between men and women in taekwon-do. The aforementioned differences are of a general nature, while individual differences occur between individual athletes, regardless of gender.

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# REFERENCES

1. Choi HH. Taekwon-Do: The Korean art of self-defence. vol. 15. New Zealand: International Taekwon-do Federation; 1995.
2. Choi C-H, Oh H, Jeon M. Adequacy of setting standards for kick impact in the Taekwondo electronic scoring system: comparison of a reference group model based on empirical data. BMC Sports Sci Med Rehabil 2021; 13: 110. doi: 10.1186/s13102-021-00340-x.
3. Valdes-Badilla P, Barramuno Medina M, Astudillo Pinilla R, Herrera-Valenzuela T, Guzman-Munoz E, Perez-Gutierrez M, et al. Differences in the electromyography activity of a roundhouse kick between novice and advanced taekwondo athletes. Ido Mov Cult 2018; 18: 31–8. doi: 10.14589/ido.18.1.5.
4. Boyanmis AH, Akin M. Effectiveness of plyometric or blood flow restriction training on technical kick force in taekwondo. Balt J Health Phys Act 2021; 14: Article-5. doi: 10.29359/BJHPA.14.1.05.
5. Wąsik J, Ferreira da Silva Santos J, Franchini E. Movement structure and kinetics of the traditional straight punch: measurements in taekwon-do athletes. Ido Mov Cult 2013; 13: 42–47. doi: 10.14589/ido.13.1.6.
6. OLMEZ C, YUKSEK S. Development of the Taekwondo Performance Protocol to Assess Technical Speed and Quickness. Balt J Health Phys Act 2023; 15: Article1–Article1. doi: 10.29359/BJHPA.15.1.01.
7. Wasik J, Shan G. Target effect on the kinematics of Taekwondo Roundhouse Kick - Is the presence of a physical target a stimulus, influencing muscle-power generation? Acta Bioeng Biomech 2015; 17: 115–20.
8. Moreira PVS, Falco C, Menegaldo LL, Goethel MF, de Paula LV, Gonçalves M. Are isokinetic leg torques and kick velocity reliable predictors of competitive level in taekwondo athletes? PLoS One 2021; 16: e0235582. doi: 10.1371/journal.pone.0235582.
9. Lenetsky S, Nates RJ, Brughelli M, Harris NK. Is effective mass in combat sports punching above its weight? Hum Mov Sci 2015; 40: 89–97. doi: 10.1016/j.humov.2014.11.016.

10. Neto OP, Magini M, Saba MMF. The Role of Effective Mass and Hand Speed in the Performance of Kung Fu Athletes Compared with Nonpractitioners. J Appl Biomech 2007; 23: 139–48. doi: 10.1123/jab.23.2.139.
11. Wąsik J, Mosler D, Góra T, Scurek R. Conception of effective mass and effect of force – measurement of taekwon-do master. Phys Act Rev 2023; 11: 11–6. doi: 10.16926/par.2023.11.02.
12. Wąsik J, Mosler D, Ortenburger D, Góra T, Cholewa J. Kinematic Effects of the Target on the Velocity of Taekwon-Do Roundhouse Kicks. J Hum Kinet 2021; 80: 61–9. doi: 10.2478/hukin-2021-0103.
13. Gu Y, Popik S, Dobrovolskiy S. Hand punch movement kinematics of boxers with different qualification levels. Int J Biomed Eng Technol 2018; 28: 366–76.
14. Párraga Montilla JA, Latorre Román PÁ, Serrano Huete V, Cabrera Linares JC, Lozano Aguilera ED, Jiménez Reyes P. Differences in the Force-Velocity profile between Judoist and freestyle wrestlers. Phys Act Rev 2022; 10: 141–9. doi: 10.16926/par.2022.10.15.
15. Walilko TJ, Viano DC, Bir CA. Biomechanics of the head for Olympic boxer punches to the face. Br J Sports Med 2005; 39: 710–9. doi: 10.1136/bjsm.2004.014126.
16. Blum H. Physics and the art of kicking and punching. Am J Phys 1977; 45: 61–4. doi: 10.1119/1.10911.
17. Neto OP, Silva JH, Marzullo AC de M, Bolander RP, Bir CA. The effect of hand dominance on martial arts strikes. Hum Mov Sci 2012; 31: 824–33. doi: 10.1016/j.humov.2011.07.016.
18. Bujak Z. Wybrane aspekty treningu taekwon-do. Warszawa: AWF Warszawa, ZWWF Biała Podlaska; 2004.
19. Pyciarz T. Analysis of sport fight structure in taekwondo during the Olympics in Beijing in 2008 and Senior World Championships in 2009 in terms of technical skills after regulation amendments and implementation of the electronic system of score recording. J Combat Sport Martial Arts 2011; 2: 109–15. doi: 10.5604/20815735.1047143.
20. Estevan I, Álvarez O, Falco C, Molina-García J, Castillo I. Impact force and time analysis influenced by execution distance in a roundhouse kick to the head in Taekwondo. J Strength Cond Res 2011; 25: 2851–6. doi: 10.1519/JSC.0b013e318207ef72.
21. Hölbling D, Preuschl E, Hassmann M, Baca A. Kinematic analysis of the double side kick in pointfighting, kickboxing. J Sports Sci 2017; 35: 317–24. doi: 10.1080/02640414.2016.1164333.
22. Falco C, Alvarez O, Castillo I, Estevan I, Martos J, Mugarra F, et al. Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo. J Biomech 2009; 42: 242–8. doi: 10.1016/j.jbiomech.2008.10.041.
23. Zech A, Hollander K, Junge A, Steib S, Groll A, Heiner J, et al. Sex differences in injury rates in team-sport athletes: A systematic review and meta-regression analysis. J Sport Heal Sci 2022; 11: 104–14. doi: 10.1016/j.jshs.2021.04.003.
24. Pryor JL, Burbulys ER, Root HJ, Pryor RR. Movement Technique During Jump-Landing Differs Between Sex Among Athletic Playing Surfaces. J Strength Cond Res 2022; 36: 661–6. doi: 10.1519/JSC.0000000000003520.
25. Saks BR, Monahan PF, Maldonado DR, Jimenez AE, Ankem HK, Sabetian PW, et al. Pathologic Findings on Hip Arthroscopy in High-Level Athletes Competing in Flexibility Sports. Am J Sports Med 2022; 50: 1028–38. doi: 10.1177/03635465221077002.
26. Sands WA, Kimmel WL, McNeal JR, Murray SR, Stone MH. A comparison of pairs figure skaters in repeated jumps. J Sports Sci Med 2012; 11: 102–8.
27. Huebner M, Meltzer DE, Perperoglou A. Age-associated Performance Decline and Sex Differences in Olympic Weightlifting. Med Sci Sports Exerc 2019; 51: 2302–8. doi: 10.1249 /MSS.0000000000002037.
28. Cohen TR, Rosenstein B, Rizk A, Frenette S, Fortin M. Body Composition Asymmetry in University Rugby Players: Influence of Sex, Position, and Injury. J Sport Rehabil 2023; 32: 385–94. doi: 10.1123/jsr.2021-0398.
29. Hay J. The Biomechanics of Sports Techniques. 4th ed. Benjamin Cummings; 1993.