

Correlation Analysis of Body Fat Percentage, Muscle Mass, and Bone Mass with Punch Speed in Kumite Karate Athletes

Análisis de correlación del porcentaje de grasa corporal, masa muscular y masa ósea con la velocidad de golpe en atletas de Karate Kumite

*Lita Mulia , *Tomoliyus,*Lismadiana, *Abdul Alim,**Sri Indah, **Sandi Prayudho ***Khairul Azhar Bin Rosawi

*Universitas Negeri Yogyakarta (Indonesia), **Universitas Negeri Jakarta (Indonesia), ***National University of Singapore (Singapore)

Abstract. Objective. Anthropometry is recognized as a significant determinant of athletic performance. Despite extensive research on anthropometric factors in conventional sports, limited attention has been given to specific martial arts disciplines, notably elite karate athletes. Hence, this investigation seeks to explore the correlation between muscle mass, body fat percentage, bone mass, and punch speed among karate athletes. Methods. A total of 15 male elite-level karate athletes participated in this study. Body weight, body fat percentage, bone mass, and muscle mass were assessed utilizing the Xiaomi Scale 2, whereas punch speed was gauged employing the Hykso Punch Tracker. Results. There was a positive relationship with body fat percentage of 0.679, right speed had a positive relationship with body fat percentage of 0.609, and maximal speed had a negative relationship with body fat percentage of -0.692. While the muscle mass variable shows a correlation value with a left speed of -0.687, a right speed of -0.616, and a maximum speed of 0.701. In addition, the bone mass variable has a correlation value with left speed of -0.734, right speed of 0.592, and maximum speed of 0.805. Conclusion. A positive correlation between body fat percentage, muscle mass, and bone mass with punch speed among karate athletes. Athletes exhibiting lower muscle mass and higher body fat tend to demonstrate slower punching speeds. Consequently, the assessment of body fat percentage, muscle mass, and bone mass emerges as a valuable tool for informing the technical aspects of training, particularly in enhancing punch speed for karate practitioners.

Keywords: Body Fat, Muscle Mass, Bone Mass, Punch, Karate

Resumen. Objetivo. La antropometría es reconocida como un determinante importante del rendimiento deportivo. A pesar de una extensa investigación sobre los factores antropométricos en los deportes convencionales, se ha prestado una atención limitada a disciplinas específicas de artes marciales, especialmente en los atletas de karate de élite. Por lo tanto, esta investigación busca explorar la correlación entre la masa muscular, el porcentaje de grasa corporal, la masa ósea y la velocidad de golpe entre los atletas de karate. Métodos. En este estudio participaron un total de 15 atletas masculinos de karate de élite. El peso corporal, el porcentaje de grasa corporal, la masa ósea y la masa muscular se evaluaron utilizando la Xiaomi Scale 2, mientras que la velocidad de golpe se midió empleando el Hykso Punch Tracker. Resultados. Hubo una relación positiva con el porcentaje de grasa corporal de 0,679, la velocidad correcta tuvo una relación positiva con el porcentaje de grasa corporal de 0,609 y la velocidad máxima tuvo una relación negativa con el porcentaje de grasa corporal de -0,692. Mientras que la variable masa muscular muestra un valor de correlación con una velocidad izquierda de -0,687, con una velocidad derecha de -0,616 y con una velocidad máxima de 0,701. Además, la variable masa ósea tiene un valor de correlación con la velocidad izquierda de -0,734, la velocidad derecha de 0,592 y la velocidad máxima de 0,805. Conclusión. Una correlación positiva entre el porcentaje de grasa corporal, la masa muscular y la masa ósea con la velocidad del golpe entre los atletas de karate. Los atletas que exhibían menor masa muscular y mayor grasa corporal tendían a demostrar velocidades de golpe más lentas. En consecuencia, la evaluación del porcentaje de grasa corporal, la masa muscular y la masa ósea emerge como una herramienta valiosa para informar los aspectos técnicos del entrenamiento, particularmente para mejorar la velocidad del golpe para los practicantes de karate.

Palabras clave: Grasa corporal, Masa muscular, Masa ósea, Puñetazo, Karate

Fecha recepción: 20-02-24. Fecha de aceptación: 17-05-24

Lita Mulia

litamulia.2023@student.uny.ac.id

Introduction

A number of studies state that martial arts disciplines demand exceptional physical fitness as attributes such as strength, velocity, agility, and stamina significantly influence the athlete's performance and achievements (Apriantono et al., 2020; Arazi & Izadi, 2017; Martínez-Rodríguez et al., 2023; Shariat et al., 2017). Furthermore, anthropometric characteristics represent integral biological variables associated with athletic performance (Dopsaj et al., 2020; Kim & Nam, 2021; Němá & Ružbarský, 2023). It is widely acknowledged that anthropometry serves not only as a pivotal criterion in athlete selection but also as a tool for identifying prospective sporting talent (Dopsaj et al., 2020; Pion et al., 2014; Ramos-Campo et al., 2016).

Karate, a martial discipline originating from Japan, is

experiencing a notable surge in prominence, evident in the escalating public enthusiasm for the sport witnessed over recent decades (Martínez-Rodríguez et al., 2023). This trend underscores a burgeoning global interest in karate, reflective of its evolving cultural significance and widespread appeal (Slankamenac et al., 2021). Moreover, the inclusion of karate competition in the 2020 Tokyo Olympics serves as a pivotal validation of the sport's international recognition, cementing its status as a mainstream athletic pursuit with growing traction on the global stage (Molinario et al., 2020). Kata and kumite represent the foundational elements underpinning the discipline of Karate, each presenting distinct methodologies in both training regimens and competitive arenas (Molinario et al., 2020; Slankamenac et al., 2021). Kata emphasizes structured sequences of movements, simulating engagements with imaginary adversaries,

thereby reinforcing both the technical proficiency and philosophical underpinnings inherent to this martial discipline (Martinez-De-Quel et al., 2021). Conversely, kumite entails dynamic engagements between two practitioners, simulating combat scenarios, with a focus on cultivating rapid reactions, strategic acumen, and adaptability to varying combat dynamics (Güler & Ramazanoglu, 2018). The updated regulations governing competitions render kumite more dynamic compared to kata. Consequently, the specialization of elite karate practitioners should be tailored to encompass specific techniques accordingly (da Silva et al., 2020; Němá & Ružbarský, 2023).

Earlier studies have underscored the significance of body metrics such as arm length, stature, and muscularity in dictating an athlete's punching velocity across various combat disciplines. For instance, an investigation into taekwondo and pencak silat revealed that competitors with elongated arms typically exhibited a propensity for attaining heightened punch velocities in contrast to counterparts with shorter arm spans (Kim & Nam, 2021; Mejia et al., 2024; Sousa et al., 2024). Corresponding outcomes were also observed in other investigations, indicating that the proportion of body fat and muscle mass can impact the capacity for delivering strikes at considerable speeds (Lopez- Laval et al., 2019; Quinzi et al., 2022).

Nevertheless, despite numerous studies delving into the correlation between anthropometry and punching speed across diverse martial arts disciplines (Liu et al., 2023; Lopez- Laval et al., 2019; Vuković et al., 2023), further comprehensive research specifically concentrated on karate remains imperative and offers substantial scope for deeper exploration. Certain studies indicate that additional factors including muscle mass, the ratio of arm length to body length, and flexibility could potentially exert significant influence on punch speed. Therefore, the primary objective of this investigation is to comprehensively examine the interrelation between muscle mass, body fat percentage, and bone mass with punch velocity among elite Kumite karate athletes at elite levels in Indonesia.

Materials and methods

Participant

This study enlisted 15 male elite-level karate athletes aged between 20 and 24 years, all originating from Indonesia. These participants, on average, committed 21 hours per week to training and boasted 8 years of experience in the domain of sport karate. Additionally, the karate athletes under examination had actively engaged in numerous national and international tournaments.

Anthropometric Measurement

The evaluation conducted in this study utilized the Xiaomi Scale 2 (Alidadi et al., 2019) to measure body weight, assess muscle mass, determine body fat percentage, and evaluate bone mass. Meanwhile, a stadiometer was employed to collect height data.

Punch Speed Measurement

Punch speed was assessed using the Hykso Punch Tracker (Omcirk et al., 2023), which provides a punch intensity score calculated from factors such as speed, type, and force exerted during the punch. Researchers employed this sensor by executing a straight punch movement akin to the kizami tsuki and gyaku tsuki punches in karate.

Statistical Analysis

Initially, the data underwent normality testing employing the Kolmogorov-Smirnov method. Subsequently, the study's findings were subjected to descriptive analysis to comprehensively elucidate the respondents' characteristics. Following this, inferential statistical analysis was conducted utilizing the Spearman correlation test to examine the association between the independent and dependent variables. A significance threshold of $p < 0.05$ was employed, indicating a statistically significant relationship between the variables when the obtained p-value fell below this threshold.

Results

The Kolmogorov-Smirnov test verified that the data obtained for all variables in this investigation exhibited a normal distribution. Table 1 presents the mean values for age, height, body mass, body mass index, body fat percentage, muscle mass, and bone mass. These values were recorded as 23.87 ± 3.20 years, 167.93 ± 7.26 centimetres, 64.51 ± 9.38 kilograms, 23.21 ± 1.95 kg/cm², 20.67 ± 7.33 percent, 75.18 ± 7.07 percent, and 2.67 ± 0.36 kilograms, respectively.

Table 1.
Participants Characteristics

Variables	Mean \pm SD
N	15
Age (years)	23.87 ± 3.20
height (cm)	167.93 ± 7.26
BM (kg)	64.51 ± 9.38
BMI (kg/m ²)	23.21 ± 1.95
body fat (%)	20.67 ± 7.33
muscle mass (%)	75.18 ± 7.07
bone mass (kg)	2.67 ± 0.36

Table 2 presents the correlation coefficients between left, right, and maximum speed and body fat percentage. The correlation coefficient between left speed and body fat percentage is 0.679. The ** symbol denotes that this correlation is statistically significant at a significance level of $p = 0.005$, indicating a robust positive relationship between left speed and body fat percentage. Similarly, the correlation coefficient between right speed and body fat percentage is 0.609, with the * symbol indicating statistical significance at $p = 0.016$. This finding underscores a strong positive association between right speed and body fat percentage. Conversely, the correlation coefficient between maximum speed and body fat percentage is -0.692. The ** symbol denotes statistical significance at $p = 0.004$. However, this correlation is negative, suggesting that higher maximum speed is associated with lower body fat percentage.

Table 2.

The relationship between left speed, right speed and maximum speed with body fat percentage

	Body fat	P
left velocity	.679**	0.005
right velocity	.609*	0.016
max velocity	-.692**	0.004

Table 3 illustrates the correlation coefficients pertaining to muscle mass. The correlation between left speed and muscle mass was -0.687, with a notable p-value of 0.005, indicating a robust negative relationship between left speed and muscle mass. Similarly, the correlation coefficient between right velocity and muscle mass was -0.616, with a significant p-value of 0.014, highlighting a strong negative association between right speed and muscle mass. Conversely, the correlation coefficient between maximal speed and muscle mass was 0.701, with a significant p-value of 0.004, revealing a robust positive relationship between maximum speed and muscle mass.

Table 3.

The relationship between left speed, right speed and maximum speed with muscle mass

	Muscle mass	P
left velocity	-.687**	0.005
right velocity	-.616*	0.014
max velocity	.701**	0.004

Table 4 presents the correlation coefficients concerning bone mass. The correlation between left velocity and bone mass was -0.734, with a noteworthy p-value of 0.002, indicating a robust negative association between left velocity and bone mass. Likewise, the correlation coefficient between right velocity and bone mass was -0.592, with a significant p-value of 0.020, revealing a negative relationship between right velocity and bone mass. Conversely, the correlation coefficient between maximal velocity and bone mass was 0.805, with an extremely significant p-value of 0.000, demonstrating a strong positive relationship between maximal speed and bone mass.

Table 4.

The relationship between left speed, right speed and maximal speed with bone mass

	Bone mass	P
left velocity	-.734**	0.002
right velocity	-.592*	0.020
max velocity	.805**	0.000

Discussion

Outstanding athletic accomplishments hinge on a multitude of factors. In this context, a comprehensive comprehension of the distinctive characteristics inherent in elite athletes aligned with their respective sports undoubtedly facilitates success. In the present study, we endeavored to delineate anthropometric parameters and body composition. Furthermore, the primary objective of this investigation is to establish correlations between anthropometric measurements and body composition with the punching velocity exhibited by elite-level karate athletes representing Indonesia on the international stage.

The mean stature and mass of the karate competitors under investigation were recorded as 167.5 cm and 64 kg, respectively. Our investigation reveals notable disparities in the anthropometric measurements of Indonesian athletes when compared to their counterparts from Serbia (174 cm and 69 kg) (Slankamenac et al., 2021), Italy (171 cm and 71.1 kg) (Quinzi et al., 2022), Brazil (170 cm and 67 kg) (Spigolon et al., 2018), and Iran (175 cm and 68 kg) (Arazi & Izadi, 2017) within the same category.

Discrepancies in height and weight among karate athletes originating from Indonesia and those hailing from other nations stem from multifaceted determinants. Among these factors is the variability in genetics and ethnic attributes prevalent within the athlete cohort of each respective country (Ashar et al., 2018; Brown et al., 2017; Squibb et al., 2022; Wang et al., 2023). Each nation harbors a distinct array of variables encompassing genetics, dietary patterns, and levels of physical activity, all of which exert influence on the physical maturation and development of individuals (Alemdaroğlu et al., 2017; Baron et al., 2020; Bojkowski et al., 2022; Theodorou et al., 2017). Moreover, prior studies validate that environmental factors like climatic conditions, resource accessibility, and economic parameters can impact dietary patterns, levels of physical activity, and other variables influencing an individual's physical maturation and development (Bahri et al., 2021; Capling et al., 2021; Harris & Raynor, 2017; Thomas et al., 2016).

The results of our study indicate a positive correlation between body fat percentage and punching speed, suggesting that individuals with lower body fat percentages tend to exhibit higher punching speeds. Our findings are consistent with previous research demonstrating an association between lower body fat percentage and improved athlete performance (Ashtary-Larky et al., 2018; Esco et al., 2018). Previous research has shown that athletes with lower body fat percentages tend to have advantages in terms of strength, speed and endurance, all of which are important factors in achieving optimal performance (Esco et al., 2018; Suarez-Arrones et al., 2019).

However, the mean body fat percentage observed among the karate athletes under scrutiny amounted to 20%. Our findings reveal substantial disparities compared to the body fat percentages of karate athletes hailing from Poland (15%) (Němá & Ružbarský, 2023), Brazil (13%) (Spigolon et al., 2018), and Iran (<15%) (Arazi & Izadi, 2017). We speculate that this striking difference in fat percentage is due to differences in training methods, dietary habits, and overall physical preparation between Indonesian karate athletes compared to karate athletes from other countries.

The results of our research show that the average muscle mass of the karate athletes we studied was 75%. Our results show striking differences in the muscle mass of karate athletes from Brazil (56%) (Spigolon et al., 2018), Serbia (89%) (Slankamenac et al., 2021), Poland (70%) (Němá & Ružbarský, 2023) and Iran (<67%) (Arazi & Izadi, 2017). However, our research findings indicate a positive relation-

ship between muscle mass and punch speed in karate athletes. This illustrates that the greater the muscle mass an athlete has, the faster the punch speed he can produce. Our results corroborate earlier research indicating a relationship between muscle mass and performance, particularly in terms of punch velocity (Lopez- Laval et al., 2019; Vuković et al., 2023). These findings validate the significant contribution of muscle mass in influencing an athlete's capacity to execute efficient and swift punching actions in the context of karate or martial arts in general (Liu et al., 2023; Quinzi et al., 2022).

Our research findings indicate that the mean muscle bone mass among the karate athletes under study was 2.67 kg. These results align with prior studies reporting bone masses among elite karate athletes in Brazil ranging from 2 to 3.5 kg (Almeida-Neto et al., 2023). Additionally, other research reveals that karate athletes in Europe exhibit a bone mass of approximately 2.5 kg, while those in Asia demonstrate a bone mass of around 2.8 kg (Bridge et al., 2014; Chaabene et al., 2018).

The association between bone mass and speed remains relatively unexplored, preventing us from making definitive assertions regarding the correlation between bone mass and punching speed. Nonetheless, existing research suggests that engaging in martial arts activities may potentially enhance bone mineral density (Almeida-Neto et al., 2023). This augmentation of bone mineral density and alterations in body composition could potentially bolster an athlete's performance and resilience during both training and competitive endeavors, thereby potentially lowering the risk of injuries (Chaabene et al., 2018).

Given the correlation identified between body composition, specifically fat percentage, muscle mass, and bone mass, with punch speed in this investigation, these findings reinforce the recommendation for ongoing body composition assessment to enhance the physical and technical proficiency of karate athletes, particularly concerning punch speed.

A body composition characterized by higher muscle mass and lower body fat percentage exhibits a positive correlation in sports emphasizing explosive power and strength (Spigolon et al., 2018), particularly evident in karate where body weight plays a pivotal role. As indicated by our results, the monitoring of anthropometric variables can provide valuable insights into implementing strategies aimed at optimizing body composition and tailoring training regimens to enhance athletes' readiness for competition, strength, and overall performance.

The limitations of this study should be acknowledged to contextualize the findings. Firstly, the relatively modest sample size utilized in this research may constrain the generalizability of the results to broader populations of karate practitioners. A larger and more diverse sample would offer greater representation across various skill levels, ages, and training backgrounds within the karate community, thus enhancing the validity and applicability of the findings. Sec-

ondly, The accuracy and precision of measurement techniques used to assess variables such as body composition and punch speed may vary, potentially introducing measurement error and affecting the reliability of the results.

Conclusion

The results of this investigation revealed a positive correlation between body fat percentage, muscle mass, and bone mass with punch speed among karate athletes. Athletes exhibiting lower muscle mass and higher body fat tended to demonstrate slower punching speeds. Consequently, the assessment of body fat percentage, muscle mass, and bone mass emerges as a valuable tool for improving the technical aspects of training, particularly in enhancing punch speed for karate practitioners. Such evaluations can improve the development of tailored training protocols aimed at optimizing the physical attributes essential for karate performance.

References

- Alemdaroğlu, U., Köklü, Y., & Koz, M. (2017). The acute effect of different stretching methods on sprint performance in taekwondo practitioners. *Journal of Sports Medicine and Physical Fitness*, 57(9), 1104–1110. <https://doi.org/10.23736/S0022-4707.16.06484-7>
- Alidadi, Y., Metanati, M., & Ataie-Jafari, A. (2019). *The validity of a bioelectrical impedance analyzer, Xiaomi MI scale 2, for measurement of body composition*.
- Almeida-Neto, P. F., Bulhoes-Correia, A., de Matos, D. G., Cesario, T. de M., das Neves, E. S., Mousinho, G. C., Dantas, P. M. S., & Cabral, B. G. A. T. (2023). Kinanthropometric Profile and Maximum Oxygen Consumption in Male Karate Athletes at Different Competitive Levels. *Ido Movement for Culture*, 23(3), 1–9. <https://doi.org/10.14589/ido.23.3.1>
- Apriantono, T., Herman, I., Winata, B., Hasan, M. F., Juniarasyah, A. D., Ihsani, S. I., Hidayat, I. I., Safei, I., & Hindawan, I. (2020). Differences of physiological characteristics of taekwondo junior players vs pencak silat junior players. *Physical Activity Review*, 8(2), 9–15. <https://doi.org/10.16926/par.2020.08.16>
- Arazi, H., & Izadi, M. (2017). Physical and physiological profile of Iranian world-class karate athletes. *Biomedical Human Kinetics*, 9(1), 115–123. <https://doi.org/10.1515/bhk-2017-0017>
- Ashar, H., Clinical, I. K.-E. J. of M. &, & 2020, undefined. (2018). Intervention Strategy to Increase Growth and Development for Stunted Children Under Two Years with Developmental Delay. *Ejmcm.Com*, 2(6), 280–292. https://ejmcm.com/article_3811.html
- Ashtary-Larky, D., Nazary Vanani, A., Hosseini, S. A., Rafie, R., Abbasnezhad, A., & Alipour, M. (2018). Relationship Between the Body Fat Percentage and Anthropometric Measurements in Athletes Compared with Non-Athletes. *Zahedan Journal of Research in Medical Sciences*, 20(2). <https://doi.org/10.5812/zjrms.10422>
- Bahri, S., Resmana, D., Tomo, H. S., & Apriantono, T. (2021). The effect of exercising under particulate matter 2.5 condi-

- tions on forced vital capacity and blood lead levels. *Physiotherapy Quarterly*, 29(3), 24–27. <https://doi.org/10.5114/pq.2020.100288>
- Baron, J., Bieniec, A., Swinarew, A. S., Gabryś, T., & Stanula, A. (2020). Effect of 12-week functional training intervention on the speed of young footballers. *International Journal of Environmental Research and Public Health*, 17(1). <https://doi.org/10.3390/ijerph17010160>
- Bojkowski, Ł., Kalinowski, P., Śliwowski, R., & Tomczak, M. (2022). The Importance of Selected Coordination Motor Skills for an Individual Football Player's Effectiveness in a Game. *International Journal of Environmental Research and Public Health*, 19(2). <https://doi.org/10.3390/ijerph19020728>
- Bridge, C. A., Ferreira Da Silva Santos, J., Chaabène, H., Pieter, W., & Franchini, E. (2014). Physical and physiological profiles of Taekwondo athletes. *Sports Medicine*, 44(6), 713–733. <https://doi.org/10.1007/s40279-014-0159-9>
- Brown, K. A., Patel, D. R., & Darmawan, D. (2017). Participation in sports in relation to adolescent growth and development. In *Translational Pediatrics* (Vol. 6, Issue 3, pp. 150–159). AME Publishing Company. <https://doi.org/10.21037/tp.2017.04.03>
- Capling, L., Tam, R., Beck, K. L., Slater, G. J., Flood, V. M., O'Connor, H. T., & Gifford, J. A. (2021). Diet quality of elite Australian athletes evaluated using the athlete diet index. *Nutrients*, 13(1), 1–16. <https://doi.org/10.3390/nu13010126>
- Chaabene, H., Negra, Y., Bouguezzi, R., Capranica, L., Franchini, E., Prieske, O., Hbacha, H., & Granacher, U. (2018). Tests for the assessment of sport-specific performance in Olympic combat sports: A systematic review with practical recommendations. In *Frontiers in Physiology* (Vol. 9, Issue APR). Frontiers Media S.A. <https://doi.org/10.3389/fphys.2018.00386>
- da Silva, J. F., Aguilar, J. A., Moya, C. A. M., Junior, M. G. A. C., Gomes, W. D. S., de Oliveira, V. M. A., Dos Santos, M. A. M., & Queiroz, D. da R. (2020). Association between body composition and aerobic capacity in karate athletes. *Revista Brasileira de Cineantropometria e Desempenho Humano*, 22, 1–9. <https://doi.org/10.1590/1980-0037.2020v22e71989>
- Dopsaj, M., Zuoziene, I. J., Milić, R., Cherepov, E., Erlikh, V., Masiulis, N., Di Nino, A., & Vodičar, J. (2020). Body composition in international sprint swimmers: Are there any relations with performance? *International Journal of Environmental Research and Public Health*, 17(24), 1–14. <https://doi.org/10.3390/ijerph17249464>
- Esco, M. R., Fedewa, M. V., Cicone, Z. S., Sinelnikov, O. A., Sekulic, D., & Holmes, C. J. (2018). Field-based performance tests are related to body fat percentage and fat-free mass, but not body mass index, in youth soccer players. *Sports*, 6(4). <https://doi.org/10.3390/sports6040105>
- Güler, M., & Ramazanoglu, N. (2018). Evaluation of physiological performance parameters of elite karate-kumite athletes by the simulated karate performance test. *Universal Journal of Educational Research*, 6(10), 2238–2243. <https://doi.org/10.13189/ujer.2018.061022>
- Harris, J. E., & Raynor, H. A. (2017). Crossover Designs in Nutrition and Dietetics Research. *Journal of the Academy of Nutrition and Dietetics*, 117(7), 1023–1030. <https://doi.org/10.1016/j.jand.2017.03.017>
- Kim, J. W., & Nam, S. S. (2021). Physical characteristics and physical fitness profiles of Korean taekwondo athletes: A systematic review. *International Journal of Environmental Research and Public Health*, 18(18). <https://doi.org/10.3390/ijerph18189624>
- Liu, Y., Li, L., Yan, X., He, X., & Zhao, B. (2023). Biomechanics of the lead straight punch and related indexes between sanda fighters and boxers from the perspective of cross-border talent transfer. *Frontiers in Physiology*, 13. <https://doi.org/10.3389/fphys.2022.1099682>
- Lopez-Laval, I., Sitko, S., Pardos, B. M., Sastre, R. C., & Gonzalez, J. C. (2019). Lopez_Relationship between upper-body strength and punch performance in male professional boxers. *The Journal of Strength and Conditioning Research*, 00(00), 1–5.
- Martinez-De-Quel, O., Alegre, L. M., Castillo-García, A., & Ayán, C. (2021). Anthropometric and fitness normative values for young karatekas. *Biology of Sport*, 38(3), 351–357. <https://doi.org/10.5114/BIOLOSPORT.2021.99324>
- Martínez-Rodríguez, A., Alacid, F., Cuestas-Calero, B. J., Matłosz, P., & López-Plaza, D. (2023). Physical and Morphological Differences between Young Elite Taekwondo and Karate Players. *Applied Sciences (Switzerland)*, 13(18). <https://doi.org/10.3390/app131810109>
- Mejia, N. F., Marin, A., Cohen, D., Sanchez, A., & Marulanda, S. (2024). Association between power in SJ, CMJ and the force applied in the Bandal Chagi and Yeop Chagi kicks of Taekwondo. *Retos. Nuevas Tendencias En Educación Física, Deporte y Recreación*, 55(1), 642–649. <https://doi.org/https://doi.org/10.47197/retos.v55.102997>
- Molinero, L., Taborri, J., Montecchiani, M., & Rossi, S. (2020). Assessing the effects of kata and kumite techniques on physical performance in elite karatekas. *Sensors (Switzerland)*, 20(11), 1–19. <https://doi.org/10.3390/s20113186>
- Němá, K., & Ružbarský, P. (2023). RELATIONSHIPS BETWEEN SELECTED PERFORMANCE PARAMETERS AND BODY COMPOSITION IN KARATE. *Journal of Kinesiology and Exercise Sciences*, 33(104), 18–24. <https://doi.org/10.5604/01.3001.0053.9658>
- Omcirk, D., Vetrovsky, T., Padecky, J., Malecek, J., & Tufano, J. J. (2023). *Validity of Commercially Available Punch Trackers*. *Journal of Strength and Conditioning Research* 37(11): p 2273-2281. doi: 10.1519/JSC.0000000000004535
- Pion, J., Fransen, J. B., Lenoir ADE, M., & Segers ACD, V. (2014). *The value of non-sport-specific characteristics for talent orientation in young male judo, karate and taekwondo athletes*. 10, 147. www.archbudo.com
- Quinzi, F., Rosellini, G., & Sbriccoli, P. (2022). Lower Limb Maximal Power Predicts Punching Speed in Different Static and Dynamic Attacking Techniques in Karate. *Journal of Strength and Conditioning Research*, 36(5), 1353–1359. <https://doi.org/10.1519/JSC.0000000000003653>
- Ramos-Campo, D. J., Rubio-Arias, J. A., Carrasco-Poyatos, M., & Alcaraz, P. E. (2016). Physical performance of elite and subelite Spanish female futsal players. *Biology of Sport*, 33(3), 297–304. <https://doi.org/10.5604/20831862.1212633>
- Shariat, A., Shaw, B. S., Kargarfarid, M., Shaw, I., & Lam, E. T. C. (2017). Características cineantropométricas de atletas do sexo masculino de Judô, Karatê e Taekwondo. *Revista Brasileira de Medicina Do Esporte*, 23(4), 260–263. <https://doi.org/10.1590/1517-869220172304175654>

- Slankamenac, J., Bjelica, D., Jaksic, D., Trivic, T., Drapsin, M., Vujkov, S., Modric, T., Milosevic, Z., & Drid, P. (2021). Somatotype profiles of montenegrin karatekas: An observational study. *International Journal of Environmental Research and Public Health*, *18*(24). <https://doi.org/10.3390/ijerph182412914>
- Sousa, J. L., Gamonales, J. M., Beltran, V., Louro, H., & Ibanez, S. (2024). Effective techniques analysis in taekwondo: A systematic review. *Retos. Nuevas Tendencias En Educación Física, Deporte y Recreación*, *53*(1), 78–90. <https://doi.org/https://doi.org/10.47197/retos.v53.102399>
- Spigolon, D., Hartz, C. S., Junqueira, C., & Longo, A. (2018). The Correlation of Anthropometric Variables and Jump Power Performance in Elite Karate Athletes. *Article in Journal of Exercise Physiology Online*, *21*(1), 139–148. <https://www.researchgate.net/publication/323120602>
- Squibb, M., Sheerin, K., & Francis, P. (2022). Measurement of the Developing Foot in Shod and Barefoot Paediatric Populations: A Narrative Review. In *Children* (Vol. 9, Issue 5). Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/children9050750>
- Suarez-Arrones, L., Lara-Lopez, P., Maldonado, R., Torreno, N., De Hoyo, M., Nakamura, F. Y., Salvo, V. Di, & Mendez-Villanueva, A. (2019). The effects of detraining and retraining periods on fat-mass and fat-free mass in elite male soccer players. *PeerJ*, *2019*(8). <https://doi.org/10.7717/peerj.7466>
- Theodorou, A. S., Paradisis, G., Smpokos, E., Chatzinikolaou, A., Fatouros, I., King, R. F. G. J., & Cooke, C. B. (2017). The effect of combined supplementation of carbohydrates and creatine on anaerobic performance. *Biology of Sport*, *34*(2), 169–175. <https://doi.org/10.5114/biolsport.2017.65336>
- Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *Journal of the Academy of Nutrition and Dietetics*, *116*(3), 501–528. <https://doi.org/10.1016/j.jand.2015.12.006>
- Vuković, V., Umek, A., Dopsaj, M., Kos, A., Marković, S., & Koropanovski, N. (2023). Variability and the Correlation of Kinematic and Temporal Parameters in Different Modalities of the Reverse Punch Measured by Sensors. *Applied Sciences (Switzerland)*, *13*(18). <https://doi.org/10.3390/app131810348>
- Wang, Y., Jiang, H., Yu, L., Gao, Z., Liu, W., Mei, Q., & Gu, Y. (2023). Understanding the Role of Children's Footwear on Children's Feet and Gait Development: A Systematic Scoping Review. In *Healthcare (Switzerland)* (Vol. 11, Issue 10). MDPI. <https://doi.org/10.3390/healthcare11101418>

Datos de los/as autores/as:

Lita Mulia	litamulia.2023@student.uny.ac.id	Autor/a
Tomoliyus Tomoliyus	tomoliyus@uny.ac.id	Autor/a
Lismadiana Lismadiana	lismadiana@uny.ac.id	Autor/a
Abdul Alim	abdulalim@uny.ac.id	Autor/a
Sri Indah	sri_indah@unj.ac.id	Autor/a
Sandi Prayudho	sandiiprayudhoo@gmail.com	Autor/a
Khairul Azhar Bin Rosawi	Khairulazhar.rosawi@gmail.com	Traductor/a