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LAS PALMAS DE GRAN CANARIA

ANTHROPOMETRY AND ANAEROBIC PERFORMANCE IN ELITE AMERICAN TAEKWONDO ATHLETES

ANTROPOMETRÍA Y RENDIMIENTO ANAERÓBICO EN TAEKWONDISTAS ESTADOUNIDENSES DE ELITE

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Abstract

Taekwondo demands a unique blend of physical skills such as strength, speed, power, balance, and flexibility, making it a highly specialized sport. Additionally, certain anthropometric characteristics are fundamental to performance in this sport. Objective: To determine the relationship between anthropometric variables and aerobic performance in the markers of the RAST test in American taekwondo practitioners. Methodology: A quasi-experimental cross-sectional study, of quantitative, descriptive, and correlational nature, was conducted on a sample of (n=470) taekwondo athletes. Anthropometric measurements included height, weight, and body mass index (BMI). Anaerobic performance was assessed using the sprint-based running test (RAST). Results: Statistically significant correlations were found in all anaerobic performance variables and anthropometrics ($p<0.000$). Regarding anthropometric characteristics, it was recorded that the median height was 65.00 inches (with an interquartile range of 62.00 to 68.00 inches), and the weight averaged 125.60 pounds with a standard deviation of ±28.03, resulting in a body mass index (BMI) of 20.75 (lb/in^2), falling within the normal range according to the classification corresponding to this measurement. Conclusions: Finally, it could be concluded that there is a positive and statistically significant relationship between anthropometric characteristics and RAST test variables. This indicates that greater height, higher weight, and higher body mass index increase power, anaerobic capacity, and allow for a better fatigue index.

Keywords: Anaerobic performance, anaerobic power, anthropometry, taekwondo practitioners.

Resumen

El taekwondo exige una mezcla especial de destrezas físicas como fuerza, velocidad, potencia, equilibrio y flexibilidad, lo que lo hace un deporte altamente especializado. Asimismo, ciertas características antropométricas son fundamentales para el rendimiento en este deporte. Objetivo: determinar la relación entre las variables antropométricas y el rendimiento aeróbico en los marcadores del test de rast en taekwondistas estadounidenses. Metodología: Se llevó a cabo un estudio cuasiexperimental de corte transversal, de naturaleza cuantitativa, descriptiva y correlacional, en una muestra de (n=470) atletas de taekwondo. Las mediciones antropométricas incluyeron la altura, el peso y el índice de masa corporal (IMC). El rendimiento anaeróbico fue evaluado mediante el test del sprint basado en la carrera (RAST). Resultados: Se encontraron correlaciones estadísticamente en todas las variables de rendimiento anaeróbico y las antropométricas ($p<0,000$). En relación a las características antropométricas, se registró que la estatura mediana fue de 65.00 pulgadas (con un rango intercuartílico de 62.00 a 68.00 pulgadas), y el peso promedió 125.60 libras con una desviación estándar de ±28.03, lo que da como resultado

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un índice de masa corporal (IMC) de 20.75 (lb/in^2), situándose dentro del rango normal según la clasificación correspondiente a esta medida. Conclusiones: Finalmente, se pudo concluir que existe una relación positiva y estadísticamente significativa entre las características antropométricas y las variables del test de rast. Indicando que una mayor altura, un mayor peso, y un índice de masa corporal superior aumenta la potencia, la capacidad anaeróbica y permite un mejor índice de fatiga.

Palabras clave: Rendimiento anaeróbico, Potencia anaeróbica, antropometría, taekwondistas.

Introduction

The interaction between anthropometric characteristics and athletic performance in taekwondo has sparked increasing interest in the fields of sports science and physical conditioning (Formalioni et al., 2020; Arazi et al., 2016; Wheeler et al. 2012). Given the unique nature of this sport, which requires a precise combination of physical skills such as strength, speed, agility, balance, and flexibility, as well as specific anthropometric characteristics (Vargas, Vargas et al. 2010; Bridge, Ferreira et al. 2014; Pieter, 2009), the latter play a fundamental role in the performance of taekwondo athletes (Villalba et al. 2018; Ojeda et al., 2020).

Success in taekwondo is based on athletes' ability to quickly execute kicks and defensive techniques with precision, requiring a unique combination of muscular power and agility (Vargas et al., 2010; Bridge et al., 2014; Pieter, 2009). Variability in anthropometric characteristics, such as the ratio of muscle mass to body fat, can influence a taekwondo practitioner's ability to generate explosive force and move adeptly on the mat (Campos et al. 2009; Ojeda et al. 2020; Peña et al., 2022; Villalba et al. 2018;). Specifically, limb length plays a critical role in the execution of precise jumps and kicks, as well as in maintaining balance during competitions (Campos et al., 2009; Peña Mieles et al., 2022).

In this context, the pursuit of improved athletic performance has led to a multidisciplinary approach that encompasses nutrition, physiology, sports psychology, cineantropometry, and other areas investigating the influence of various factors on athletes' strength, speed, and endurance (Queiroga, Ferreira & Romanzini, 2005). Sports training, in turn, plays an essential role in enhancing physical capacities, including exercise intensity, frequency, and duration, as well as recovery periods (Platonov, 2007). With this perspective in mind, studies on the performance and optimization of taekwondo conditions focus on understanding the interaction between morphological, functional, motor, psychological, genetic, and environmental aspects of the athlete (Weineck, 2005). Cineantropometry emerges as a crucial tool in this field, providing methods to quantify aspects such as size, shape, proportions, and motor function of the body (Belando y Chamorro, 2009). This discipline reveals a trend toward the homogenization of physical profiles within specific groups of competitive athletes, suggesting an intrinsic relationship between body shape and physical performance (Granja y frometa et al., 2018; Slaughter, Lohman & Misner, 1997). Therefore, it is essential to regularly conduct different inquiries in athletes, both regarding performance aspects and various anthropometric characteristics. These measures can provide valuable information about athletes' physical performance and body composition, directly influencing taekwondo success (Sáez, 2016; Sáez y Ariza, 2019). Proper weight, proportional height, and a BMI within healthy ranges are important for optimizing strength, speed, agility, and endurance during practice and competition. Knowing the weight, height, and BMI of taekwondo practitioners allows coaches to design personalized and specific training programs for each athlete. This allows them to focus on specific areas of improvement and set realistic goals based on each athlete's individual characteristics (Wheeler et al., 2012).

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Additionally, as mentioned earlier, physical skills play a crucial role in sports performance, particularly highlighting anaerobic capacity and power, as this ability is decisive in disciplines like taekwondo (Aponte y Segura, 2022). This capacity refers to maximal efforts sustained over brief periods, being essential in sports like taekwondo, where bouts involve rapid and demanding actions such as accelerations, displacements, kicks, strikes, jumps, and changes of direction (Barbero et al., 2006; Pieter, 2010; Sáez, 2016). This physical skill is fundamental to be evaluated in these populations. Power is crucial for the effective execution of explosive techniques like kicks and strikes in taekwondo. An accurate assessment of power can help identify areas for improvement and design specific training programs to optimize performance in the sport. There are various validated tests, both specific and nonspecific, to assess the power of taekwondo practitioners. In this context, the sprint-based running test, known as the Rast test, has gained popularity as a reliable and widely used tool to evaluate anaerobic capacity and power in athletes (Keir, et al. 2013). It consists of performing a series of short-duration maximum sprints with recovery periods between them, being applicable in various sports disciplines, including taekwondo (Seo et al. 2015; Lui y He, 2022; Panda et al. 2022; Zagatto, et al. 2009). Given all the aforementioned reasons, the present study aims to investigate the relationship between anthropometric characteristics and performance in the Rast test in taekwondo practitioners, with the objective of deepening our understanding of how these factors influence sports performance in this discipline.

Methodology

Design

A quantitative research approach was implemented, employing a quasi-experimental observational design to describe and establish correlations within a cohort of elite taekwondo practitioners. The study focused on participants from sports camps organized by the United States Taekwondo Association (USAT) in the year 2023.

Population and Sample

The sample selection was non-random, with taekwondo athletes chosen based on the accessibility of the population through Taekwondo camps associated with USAT. Athletes without signs of metabolic, cardiovascular, or musculoskeletal risks were selected through a brief interview and the PAR-Q questionnaire (Shephard, 1988). All participants, especially minors, obtained voluntary consent from themselves and their parents or legal guardians. Those experiencing injuries or discomfort during assessments or failing to complete all stages were excluded. The final sample comprised (n=470) taekwondo practitioners across various categories.

Procedure

Formal permission was obtained through letters addressed to the directors and coaches of each Taekwondo camp affiliated with USA Taekwondo (USAT). After receiving the authorization, the study's procedures and objectives were explained, and informed consent and assent documents were provided, particularly for underage athletes. Sociodemographic data, such as age, gender, and group affiliation, were recorded.

Data collection occurred in the morning at Taekwondo camps during the preparation period, avoiding the competition phase. Before assessments, athletes were briefed on protocols and tests. A supervised pilot test, conducted by exercise and sports science experts, familiarized participants with the tests.

Firstly, for the evaluation of anthropometric dimensions such as weight (kg), height (m), and Body Mass Index (BMI, kg/m^2), the following protocol was followed: The weight of Taekwondo athletes was determined using a TANITA®

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BC-585F scale. Measurements were taken in the morning, on an empty stomach, with athletes wearing loose clothing and barefoot. Three measurements were taken for each athlete, and the final one was chosen for verification. Height measurements utilized the Zybek Sport stadiometer standardized by ISAK, with athletes standing barefoot. BMI was calculated using the formula Weight (kg) / (Height (m) * Height (m)) (Norton, 2018).

After the anthropometric assessments, athletes performed supervised warm-up exercises, including mobility and ballistic movements. The perceived intensity of the warm-up was rated from 2 to 3 on the modified Borg scale. After the warm-up, the Running-based Anaerobic Sprint Test (RAST) was administered to measure power and anaerobic capacity through repeated sprints. Participants performed six maximal sprints over 35 meters, with 10-second breaks between each sprint. Three evaluators recorded sprint times for accuracy, and the average result was calculated. Times were recorded in hundredths of a second (Keir et al., 2013; Tayech et al., 2018; Zagatto et al., 2009).

After data collection, relevant calculations were performed, including relative power, anaerobic capacity, minimum power, maximum power, average power, and fatigue index.

To calculate relative power, the following formula was employed:

$$\text{Body mass (kg)} * \text{distance (m)}^{2} \div \text{time (s)}^{3}$$

After obtaining the six relative power measurements corresponding to each sprint, anaerobic capacity was calculated. This calculation is based on the total work performed during the entire test duration, i.e., the sum of all relative power measurements:

Sum of the six sprint power outputs

Applying the power calculation formula, the sprint with the lowest value was chosen to determine minimum power, while for maximum power, the sprint with the highest value was selected. To obtain average power, all six sprint power outputs were summed and then divided by the same quantity.

Additionally, fatigue index was calculated to assess the rate at which power (W) decreases during participant performance. A lower value would indicate a better ability of the participant to maintain performance, and vice versa. Participants with higher fatigue indices may need to improve both their anaerobic capacity and fatigue resistance. To calculate the fatigue index, the following formula was used:

(Maximum power – Minimum power) ÷ Total time used for the 6 sprints

Ethical Considerations

The study adhered strictly to the guidelines set by the 1974 Human Subjects Protection Act and the 2013 Declaration of Helsinki issued by the World Medical Association (WMA, 2013). Participants received a detailed explanation of the study's objectives, procedures, voluntary participation, and confidentiality of personal data. Informed consent, signed by each participant, was obtained to ensure compliance with regulations. To protect privacy, codes were used in the database instead of participants' names.

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Statistical Analysis

All collected data were entered into an Excel spreadsheet and transferred to SPSS Version 25 for statistical analysis. Categorical variables were described using percentages and frequencies. The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. Normally distributed variables were presented with mean and standard deviation (SD), while non-normally distributed variables were described with median and interquartile range (IQR). Spearman's correlation test, with a significance level set at $p \leq 0.05$, was employed for correlation analysis.

Results

The contingent of Taekwondo enthusiasts hailing from the United States, under the auspices of USAT, showcased a varied representation in various divisions: with (n=153) cadets, (n=149) juniors, and (n=168) seniors. In terms of gender distribution, (n=265) were male, while (n=205) were female. On average, the athletes were aged 15.2 ± 3.75 years.

Table 1.

Sociodemographic Characteristics of the Population

Characteristics	N	%
Athletes' Gender		
Male	265	56,38
Female	205	43,62
Total	470	100
Athletes' Category		
Cadet	153	32,55
Junior	149	31,7
Senior	168	35,74
Total	470	100
	M	SD
Age of Athletes	15,28	±3,75

*Note: M = mean; SD = standard deviation

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Based on the findings outlined in Table 2, it's clear that most of the key variables examined in this research displayed a distribution that deviated from normality, given their significance levels were below 0.005. Consequently, the null hypothesis (H0) is refuted, and the alternative hypothesis (H1) is upheld. Only the relative power and height variables demonstrated a normal distribution, with respective significance values of 0.018 and 0.011.

Table 2.

Kolmogorov-Smirnov Test for fundamental Variables

Characteristics	N	Test Statistic	Significance
Height (in)	470	0,076	0,011*
Weight (lb)	470	0,048	0,000
BMI (lb/in^2)	470	0,085	0,000
Minimum Power (W)	470	0,107	0,000
Maximum Power (W)	470	0,099	0,000
Average Power (W)	470	0,109	0,000
Relative Power (W)	470	0,046	0,018*
Anaerobic Capacity (W)	470	0,104	0,000
Fatigue Index (W/s)	470	0,161	0,000

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Based on the data presented in Table 3, it was found that the power varied from 293.89 W to 390.37 W, with an average power of 346.16 W. Additionally, a relative power of 7.41 W, adjusted based on the athlete's body mass, was observed. Concerning anaerobic capacity, a value of 2052.23 W was recorded, with an interquartile range (IQR) ranging from 1410.76 at the 25th percentile to 2849.17 at the 75th percentile. The overall fatigue index for the population was 4.39. Additionally, the median measure of competitive experience was determined to be 12.00, indicating the number of competitions up to the date of this research. Regarding anthropometric characteristics, it was noted that the median height was 65.00 inches (with an IQR of 62.00 – 68.00), and the weight was 125.60 pounds ±28.03, resulting in a body mass index (BMI) of 20.75 (lb/in^2), falling within the normal range according to the classification of this measurement.

Table 3.

Measures of central tendency and dispersion of fundamental variables

Characteristics	N	ME	IQR
Minimum Power (W)	470	293,89	P25=191,71; P75=403,24
Maximum Power (W)	470	390,37	P25=276,42; P75=557,96
Average Power (W)	470	346,16	P25=237,24; P75=490,03
Anaerobic Capacity (W)	470	2052,23	P25=1410,76; P75=2859,17
Fatigue Index (W/s)	470	4,39	P25=2,55 ; P75=8,37
Weight (lb)	470	123,00	P25=106,00; P75=142,00
BMI (lb/in^2)	470	20,37	P25=18,54; P75=22,45
	N	M	SD
Relative Power (W)	470	7,41	2,84
Height (in)	470	64,86	±5,01

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The table presents the Spearman's Rho correlation coefficients and corresponding p-values that relate different characteristics (height, weight, and BMI) to various measures of anaerobic performance (minimum power, maximum power, average power, relative power, anaerobic capacity, and fatigue index). The findings reveal positive and significant relationships between anaerobic performance variables and anthropometric characteristics. This suggests that greater height, weight, and BMI may positively influence power, anaerobic capacity, and fatigue index, and vice versa, meaning that lower height, weight, and BMI could impair it.

Table 4.

Spearman correlation between the variables of interest

Characteristics	Height (in)		Weight (lb)		BMI (lb/in^2)	
	Spearman's Rho coefficient	P value	Spearman's Rho coefficient	P value	Spearman's Rho coefficient	P value
Minimum Power (W)	0,434	0,000*	0,465	0,000*	0,323	0,000*
Maximum Power (W)	0,508	0,000*	0,558	0,000*	0,395	0,000*
Average Power (W)	0,488	0,000*	0,533	0,000*	0,377	0,000*
Relative Power (W)	0,234	0,000*	0,241	0,000*	0,112	0,015*
Anaerobic Capacity (W)	0,435	0,000*	0,490	0,000*	0,353	0,000*
Fatigue Index (W/s)	0,395	0,000*	0, 461	0,000*	0,354	0,000

Discussion

The primary purpose of this study was to explore the relationship between anaerobic performance variables, assessed using the Rast test, and various anthropometric characteristics in taekwondo practitioners. The results revealed direct and statistically significant associations between weight, height, body mass index (BMI), and performance in the test. This relationship is supported by previous studies highlighting how height and body weight can influence the ability to generate force and power in accelerations and speed movements, due to the mechanical advantage provided by longer limbs and greater muscle mass (Tayech et al., 2018; Zagatto et al., 2009).

Taller individuals tend to have longer limbs, providing them with a greater distance to perform sprint movements during the Rast test. This greater leg length, in particular, may result in longer strides and greater distance coverage

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with each step, which can translate into improved performance in speed and power tests like the Rast test. Running biomechanics may vary with height. Generally, taller individuals may have more efficient strides and a better ability to generate force during the propulsion phase, allowing them to reach higher speeds over short distances as required in the Rast test (Lozano, 2018; Rebolledo et al., 2018).

Overall, greater body weight may indicate greater muscle mass. During sprinting, the ability to generate explosive force is crucial for achieving high speeds. Individuals with greater muscle mass have more muscle tissue available to generate this explosive force, which can result in higher speed and power during sprinting, as measured in the Rast test. Although in some cases, greater body weight may pose a challenge in terms of acceleration and change of direction, during the straight sprint of the Rast test, the additional weight may contribute to greater downward force and thus greater forward propulsion. This can result in higher running speed and, consequently, better performance in the test (Figueiredoet al., 2021; Sáez, 2016).

Greater height, weight, and BMI correlate with a potentially improved fatigue index in taekwondo practitioners. This can be attributed to the possibility that greater weight and muscle mass provide an additional energy reserve to withstand fatigue during high-intensity anaerobic efforts. Additionally, greater height and weight may indicate a greater storage capacity for glycogen and fats, the main sources of fuel during such efforts. However, it is important to note that these relationships may be influenced by other factors and require further research to be fully understood (Figueiredo et al., 2021; Sáez, 2016; Lozano, 2018; Rebolledo et al., 2018).

High body mass index (BMI) has been associated with better performance in the Rast test, indicating greater power, anaerobic capacity, and a lower fatigue index in athletes. Research such as that conducted by Nikolaidis, 2012, and Taskin, 2016, support this relationship. Contrary to traditional notions, a high BMI can be beneficial for taekwondo athletes in terms of their performance in the Rast test. This phenomenon can be explained in several ways. For example, a high BMI could be related to greater muscle mass, which would increase athletes' power and anaerobic capacity. Furthermore, a higher BMI could imply a greater energy reserve, allowing them to maintain optimal performance levels during prolonged periods of intense physical activity. In summary, a high BMI correlates with better performance in the Rast test in taekwondo athletes, providing them with greater power, anaerobic capacity, and fatigue resistance. However, this study did not consider other values such as lean mass and fat mass to determine the relationship between these two components, which could limit this argument (Figueiredo et al., 2021; Lozano, 2018; Rebolledo et al., 2018; Sáez, 2016).

The results obtained regarding average power and fatigue index compared to other sports disciplines provide relevant insight into the performance of taekwondo practitioners. Although the average power of taekwondo practitioners may be lower than that of certain endurance athletes, it is important to note that it significantly exceeds that of other sports such as volleyball and Pencak Silat (Santosa et al., 2019; Subiela et al., 2007). Similarly, the fatigue index observed in taekwondo practitioners is comparable to that of sports such as American football and Pencak Silat, suggesting a similar level of endurance and recovery capacity (Santosa et al., 2019). On the other hand, a recent study evaluating a sample of (n=121) juvenile taekwondo practitioners obtained an average power of (Median 321.75; P25=248.97; P75=434.32), an anaerobic capacity of (median 1881.65; P25=1434.10; P75=2540.80), and a fatigue index of (MEDIAN 4.30 P25= 2.92; P75= 7.35). Our results were superior in terms of power and anaerobic capacity, but the fatigue index remained similar to this sample (Laurin, et al. 2024). These almost similar results are due to the fact that it was a similar sample of taekwondo practitioners.

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Although the Rast test is not specifically designed for taekwondo practitioners, its utility in this population is evidenced by the intermittent and intense nature of the physical efforts required in this sport, which is reflected in the sprint-based running test. While more specific tests exist, limited resource availability and the complexity of assessment protocols may make the Rast test a viable and reliable option for measuring anaerobic capacity in taekwondo practitioners (Keir et al., 2013; Tayech et al., 2018; Zagatto et al., 2009). The Rast test is used to evaluate anaerobic power in athletes and has been shown to have both relative and absolute reliability among taekwondo practitioners (Tayech et al., 2018). Researchers supporting this instrument for these populations also point out that both non-specific and taekwondo-specific training can result in improvements in power and aerobic capacity overall. Furthermore, both specific and non-specific taekwondo tests can be used to assess and monitor these improvements (Ouergui et al., 2020).

Strengths and Limitations

A strength of this study lies in the use of a considerable sample size, which is uncommon in research of this kind. However, the convenient selection of the population by the researchers could influence the magnitude of the observed effects, as well as the extrapolation of the methodology to future studies. It is suggested that future research continue to explore the relationship between these two constructs and seek to establish causal explanations for the findings obtained, as well as experimental study methodologies.

An additional limitation of this study lies in considering only height, weight, and BMI as anthropometric variables, which could restrict a comprehensive analysis of muscle mass and fat mass, as well as their relationship with power, anaerobic capacity, and fatigue index in taekwondo practitioners. It is suggested that future research incorporate these components of body composition, as well as bone weight and somatotype, to allow for more robust and complete comparisons.

Conclusions

In conclusion, it can be inferred that there is a positive and statistically significant relationship between anthropometric characteristics and variables of the Rast test. This indicates that greater height, higher weight, and a higher body mass index (BMI) increase power, anaerobic capacity, and allow for a better fatigue index, supported by previous findings on how height and body weight can influence the ability to generate strength and power. Discrepancies were observed in power, fatigue index, and anaerobic capacity compared to other disciplines; however, they remained similar when compared to a similar sample of taekwondo practitioners. Although the study was based on a considerable sample, the limitation of considering only some anthropometric variables suggests the need for more comprehensive future research addressing other aspects of body composition. Ultimately, the Rast test emerges as a valuable tool for evaluating anaerobic capacity in taekwondo practitioners, despite its limitations, and it is expected that future research will delve into this relationship and explore other relevant variables to better understand performance in this sport.

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