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Investigation of Oxygen Uptake Kinetics and Anthropometric Profiles in Elite Kickboxing Athletes

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Resumen

Introducción: Este estudio explora la intrincada relación entre diversas variables fisiológicas y su impacto en el rendimiento de los atletas de kickboxing de élite. **Métodos:** Una cohorte de diez atletas masculinos, distinguidos por sus títulos nacionales, asiáticos o mundiales, participó en una evaluación integral que abarcó el consumo máximo de oxígeno (VO2pico), la masa muscular, el umbral de lactato (LT) y el punto de compensación respiratoria (RCP). **Resultados:** Los hallazgos aclaran una correlación convincente y positiva entre la masa muscular y el VO_2pico, iluminando el papel fundamental del desarrollo muscular en el aumento de la capacidad aeróbica y la destreza atlética general en el contexto del kickboxing. Además, la evaluación de LT y RCP proporciona información valiosa sobre los umbrales fisiológicos que rigen la intensidad del ejercicio y las limitaciones de rendimiento. Estos resultados tienen implicaciones significativas para el diseño de regímenes de entrenamiento y acondicionamiento personalizados, que permitan a los practicantes de kickboxing optimizar sus capacidades físicas dentro de los límites de sus límites fisiológicos. **Conclusiones**: En resumen, esta investigación enriquece nuestra comprensión de los determinantes multifacéticos del éxito en los deportes de combate, enfatizando el papel crítico de la masa muscular, las capacidades aeróbicas y anaeróbicas y los umbrales fisiológicos en el rendimiento de los atletas de kickboxing de élite.

Palabras Clave: Consumo máximo de oxígeno, Masa muscular, Umbral de lactato, Punto de compensación respiratoria, Deportes de combate

Abstract

Introduction: This study explores the intricate relationship between various physiological variables and their impact on the performance of elite kickboxing athletes. **Methods:** A cohort of ten male athletes, distinguished by their national, Asian, or world titles, participated in a comprehensive assessment encompassing peak oxygen consumption (VO2peak), muscle mass, lactate threshold (LT), and respiratory compensation point (RCP). **Results:** The findings elucidate a compelling and positive correlation between muscle mass and VO2peak, illuminating the pivotal role of muscular development in augmenting aerobic capacity and overall athletic prowess in the context of kickboxing. Furthermore, the assessment of LT and RCP provides valuable insights into the physiological thresholds governing exercise intensity and performance limitations. These results carry significant implications for the design of tailored training and conditioning regimens, enabling kickboxers to optimize their physical capacities within the confines of their physiological boundaries. **Conclusions:** In summary, this investigation enriches our understanding of the multifaceted determinants of success in combat sports, emphasizing the critical role of muscle mass, aerobic and anaerobic capabilities, and physiological thresholds in the performance of elite kickboxing athletes.

Keywords: Peak oxygen consumption, Muscle mass, Lactate threshold, Aerobic and Anerobic threshold, Combat sports

Introduction

Kickboxing is a demanding combat sport that involves intense, intermittent striking between two competitors (Slimani, Chaabene, et al., 2017). These athletes are classified based on factors such as gender, body mass, and age categories (Slimani, Miarka, & Chéour, 2017). According to the World Association of Kickboxing Organizations (WAKO), a standard kickboxing bout typically consists of three 2-minute rounds with 1-minute breaks (Ambroży, Bąk, Niewczas, & Rydzik, 2022). Given the substantial physical and physiological demands inherent in this sport, athletes must be well-prepared to manage the rigors of combat effectively (Podrigalo et al., 2023). Achieving this level of conditioning necessitates a comprehensive understanding of both the physiological demands of competition and the physical capabilities of the athletes (Ghadiri, Nemati, & Frouzandeh Hafshejani, 2018). In championship kickboxing bouts, competitors engage in brief periods of intense fighting activity lasting between 1 to 5 seconds, interspersed with longer periods of non-fighting activity (Volodchenko, 2017). These bouts entail near-maximal heart rate responses, reaching approximately 90% of the individual's peak heart rate, and result in high lactate concentrations, typically ranging from 7.0 to 12.2 mmol/l. This suggests that both aerobic and anaerobic metabolism are significantly taxed during these matches (Øvretveit, 2018b). An elevated aerobic capacity (VO2 max) is essential as it allows athletes to recover more effectively during intervals between rounds and low-intensity actions (Spanias, Nikolaidis, Rosemann, & Knechtle, 2019). Effective kickboxing techniques require precise timing for striking, either once or multiple times, relying on high anaerobic power for each strike, while the intervals between strikes rely on aerobic metabolism (Burdukiewicz, Pietraszewska, Andrzejewska, & Stachoń, 2016). Despite the considerable physical demands of kickboxing, there is a lack of comprehensive research on the physiological aspects of combat sports (Podrigalo et al., 2019). To address this gap, maximal graded exercise testing is commonly employed to assess the physiological response to exercise (Opstoel et al., 2015). This testing involves the determination of key parameters such as maximum oxygen uptake (V.O2 max), which serves as a critical marker of aerobic fitness (Schwartz, Takito, Del Vecchio, Antonietti, & Franchini, 2015). Additionally, graded maximal exercise testing allows for the identification of ventilatory thresholds, including the first ventilatory threshold (VT1) and the second ventilatory threshold (VT2) (Øvretveit, 2018a). VT1 corresponds to the point at which there is an abrupt increase in the ventilatory equivalent for O2 (VE/VO2) without a corresponding increase in the ventilatory equivalent for CO2 (VE/VCO2) in the plot of carbon dioxide production (VCO2) against oxygen uptake (VO2) (Ahmaidi et al., 1999). VT2 occurs between VT1 and VO2 max when VE/VCO2 begins to rise as VE/VO2 continues to increase. These thresholds serve as practical tools for prescribing exercise and classifying exercise intensity (Stanzione, 2020). Understanding the kinanthropometric attributes, including body size, body proportions, physique, body shape, and body composition, is crucial for optimizing the development of nutritional and training programs tailored to maximize athletic performance in kickboxing (Shahidi, Al-Gburı, Karakas, & Taşkıran, 2023; S. H. Shahidi, B. Carlberg, & J. D. Kingsley, 2023). Research has indicated that a higher degree of fat-free mass and a lower degree of fat mass are directly associated with improved athletic skills (S. H. Shahidi, B. Carlberg, & D. Kingsley, 2023; Shahidi, Yilmaz, & Esformes, 2023). Moreover, anthropometric features such as endomorphy, mesomorphy, and ectomorphy play a significant role in an athlete's success in a specific sport when compared to non-athletes.

This study aims to investigate the physiological parameters of elite kickboxing athletes and establish a connection between their anthropometric characteristics and maximal oxygen consumption.

Materials and Methods

This study comprised a purposive sample consisting of 10 elite male athletes, each of whom had achieved national, Asian, or world titles in kickboxing. Prior to their participation, written informed consent was diligently obtained from all participants after providing a comprehensive explanation of the study's objectives, measurement procedures, and potential adverse events that might arise during the course of the study. To ensure a controlled and standardized testing environment, all procedures were meticulously conducted within a laboratory setting, maintaining a constant temperature of approximately 21°C and a relative humidity of approximately 36%. Furthermore, all testing sessions were scheduled to take place at a consistent time of day for each participant. In preparation for the exercise tests, participants were deliberately kept unaware of the elapsed time, receiving visual feedback solely for pedal cadence. Participants were explicitly instructed to abstain from engaging in vigorous physical activity for a minimum of 24 hours preceding each testing session. The testing protocol was systematically executed over two weeks, encompassing three distinct sessions. It is essential to note that all aspects of this research adhered to the principles outlined in the Declaration of Helsinki and were granted approval by the Institutional Review Board of Istanbul Gedik University.

Anthropometric Measurements

Anthropometric variables were assessed following the International Society for the Advancement of Kinanthropometry (ISAK) protocol guidelines (Shahidi, Al-Gburı, et al., 2023). The anthropometric measures assessed were weight, stature, sitting height, arm span, segment lengths, bone breadths, muscle girths, and skinfolds. Body composition was determined using the five-way fractionation model, which partitions the body into distinct anatomical components: adipose, muscle, bone, residual, and skin tissue masse (Kerr, 1988) (Norton et al., 1996). The proportionality of body mass fractionation was assessed using the Phantom Z-score stratagem (Ross & Marfell-Jones, 1991). Anthropometric somatotype was calculated using the equations proposed by Carter and Heath. Additionally, the following anthropometric indices were calculated: body mass index (BMI; body mass in kg/height in m²), the sum of four, six, and eight skinfolds, and muscle-to-bone ratio as kg muscle kg bone^{-1}.

Experimental Protocol

On a single occasion, participants visited the laboratory after a 2-hour fasting period after their last meal. They were explicitly instructed to refrain from the consumption of caffeine, alcohol, and any form of intense physical exercise for 24 hours leading up to the commencement of the experimental procedure. A maximal ramp incremental test, designed to continue until volitional exhaustion, was conducted employing a custom-designed electromagnetically braked recumbent cycle ergometer (Monark, Sweden). The objective of this test was to determine critical parameters, including peak oxygen consumption (VO2peak), peak power output (PPO), and the values of oxygen uptake (VO2) corresponding to both the gas exchange threshold (GET) and the respiratory compensation point (RCP). The test initiation involved a 4-minute phase of cycling at a constant power output of 20 W, after which the power output was systematically increased at a rate of 30 W per minute until the point of task failure as shown in Figure 1. Blood lactate concentration ([La]) was promptly measured upon reaching the point of task failure, utilizing equipment provided by EKF Diagnostics (Barleben, Germany). For real-time monitoring, a Polar Electronics HR monitor (Polar Electronics, FS1, Kempele, Oulu, Finland) was employed, given the compatibility of the metabolic system utilized in this study with a receiver unit designed to capture the signal. Throughout the ramp exercise, participants were granted the liberty to cycle at a cadence of their preference within the prescribed range of 70 to 90 revolutions per minute. The ramp-incremental test was terminated when individuals demonstrated an inability to maintain the specified rpm for a continuous period of 10 seconds, notwithstanding persistent verbal encouragement.

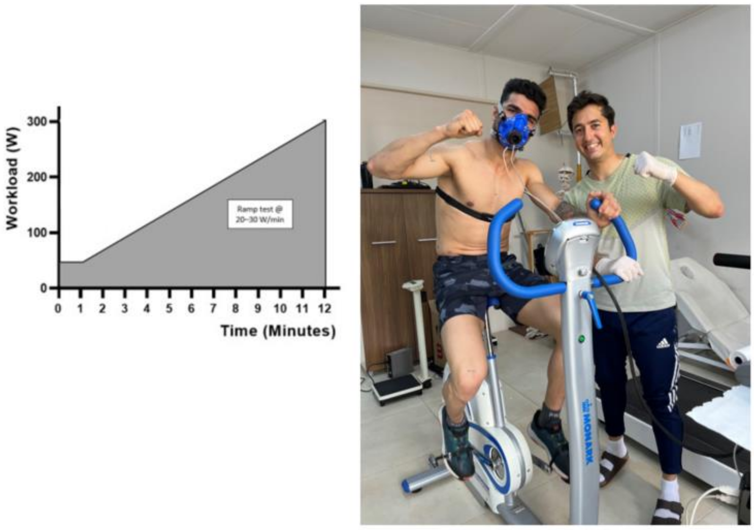

Figure 1. Study design

Pulmonary Oxygen Uptake

A breath-by-breath metabolic cart system, specifically the Fitmate system from COSMED, Rome, Italy, was employed to measure various ventilatory and gas exchange variables. Before each testing session, the system underwent calibration in strict accordance with the manufacturer's recommended procedures. The gas analyzer continuously sampled gases exchanged at the mouth level, facilitating the measurement of exposed oxygen (O2). For real-time monitoring and data recording, a Polar Electronics HR monitor (Polar Electronics, FS1, Kempele, Oulu, Finland) was integrated into the metabolic system used in this study. This HR monitor was equipped with a receiver unit designed to capture the relevant signals. The determination of maximal oxygen consumption (VO2 max) adhered to established criteria consistent with conventional guidelines for VO2 max assessment. These criteria included an individual's inability to sustain the workload, resulting in a heart rate (HR) exceeding 95% of the age-predicted maximum, a respiratory exchange ratio (RER) exceeding 1.1 at maximal exercise, and the observation of a VO2 plateau, which signifies a point at which VO2 exhibits minimal increase (less than 150 mL · min−1) with a corresponding increase in workload. The following parameters, averaged over 30-second intervals, were obtained: VO2 (mL min−1) under standard barometric pressure at sea level, minute ventilation (V̇E) expressed in liters per minute (L·min−1), respiratory rate (expressed in breaths per minute [bpm]) at body temperature and pressure-saturated conditions, ventilatory equivalents for oxygen (V̇E/V̇O2), ventilatory threshold, respiratory compensation point, blood lactate concentration (expressed in Mmol), and heart rate (HR) in beats per minute (bpm). All post-data collection activities, encompassing data editing, processing, and statistical modeling, were rigorously executed through estimates derived from least squares non-linear regression. These analyses were conducted using the Whippr open-source R package, which is accessible at https://exphyslab.com (Keir, Iannetta, Mattioni Maturana, Kowalchuk, & Murias, 2022).

Statistical Analyses

Statistical analyses were conducted using SPSS for Windows software (version 26.0, SPSS Inc., Chicago, Illinois, USA). Descriptive statistics are reported as means (M) ± standard deviation (SD). The descriptive parameters encompass mean values, standard deviations, Pearson correlation coefficients (r), and coefficients of determination (R2). The assessment of statistical significance involved the utilization of a t-test, with the predetermined level of significance set at α = 0.05.

Results

The characteristics anthropometric and physiological of the kickboxer are presented in Figure 2 and Table 1. Figure 2. Somatotype chart of the study.

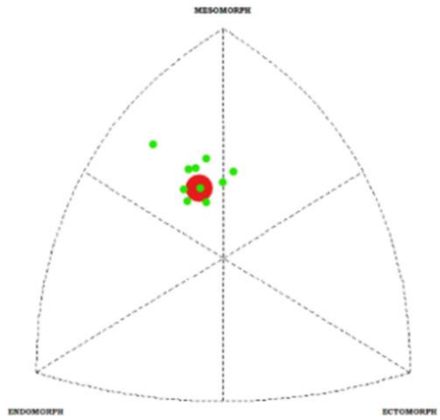

Figure 2. Somatotype chart of the study

Note. The green cycle represents each athlete and the red circle represents the mean of all the athletes.

VȮ 2peak, maximal heart rate, Peak power output, lactate threshold, respiratory compensation point, and blood lactate measured during the maximal ramp incremental test were 3.58 ± 0.25 (L/min), 190 ± 13 (beats/min), 285 ± 65 (W), 11.9 ± 1.4 (mmol), 2.6 ± 0.2 (L/min), 1.8 ± 0.4 (L/min) respectively.

Table 1. Anthropometric and physical performance descriptive characteristics

Descriptive Statistics (N=10)	Minimum	Maximum	Mean ± SD
Age (y)	22	27.19	25 ± 1.6
Weight (kg)	63.3	79.8	74 ± 5.2
Height (cm)	169.1	181.5	174.3 ± 3.7
Sitting height (cm)	92.3	102.83	97.5 ± 3.8
Arm Span (cm)	168.3	182.87	178.5 ± 4.4
Adipose Mass (kg)	12.6	20.66	17.4 ± 2.3
Muscle Mass (kg)	29.9	38.5	33.6 ± 2.7
Residual Mass (kg)	9.9	13.7	11.6 ± 1
Bone Mass (kg)	6.6	8.9	7.7 ± 0.6
Skin Mass (kg)	3	3.9	3.6 ± 0.2

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Body fat %	9	15.83	12.8 ± 2.2
The sum of 3 skinfolds (mm)	27	59	42.8 ± 11.5
The sum of 6 skinfolds (mm)	48	87.3	69.7 ± 12.9
The sum of 8 skinfolds (mm)	59	111.2	87.8 ± 17.2
Muscle/bone index	3.672	5.38	4.2 ± 0.4
Body mass index (kg/m2)	21.7	27.9	24.5 ± 1.8
Crural index:	1	1.15	1 ± 0
Sitting ht. Index (%)	52.3	59.1	55 ± 2.3
Braquial index:	0.69	0.885	0.8 ± 0
Biacromial/Biiliocristal:	1.3	1.63	1.4 ± 0.1
ENDO	2.1	4.1	3.1 ± 0.6
MESO	4.57	6.7	5.1 ± 0.6
ECTO	0.6	3	2 ± 0.6
X	-3	0.5	-0.8 ± 1
Y	2.8	7	4.1 ± 1.3
Leg Strenght (kg)	141.5	179	161.8 ± 9.4
Hand R (kg)	31.6	66.03	53.1 ± 9.9
Hand L (kg)	33	63.77	51.9 ± 9.2
Max Blood Lactate (mmol)	9.4	13.69	11.9 ± 1.4
Vo2max (ml/min)	3169	4153	3580.1 ± 256.1
Vo2max(ml/kg/min)	46.8	52.6	49 ± 1.5
LT (L/min)	1.6	1.9	1.8 ± 0.4
RCP (L/min)	2.4	2.8	2.6 ± 0.2

The findings derived from the Pearson correlation analysis revealed a robust positive association between peak oxygen consumption and the percent of muscle mass as shown in figure 3 (R = 0.82).

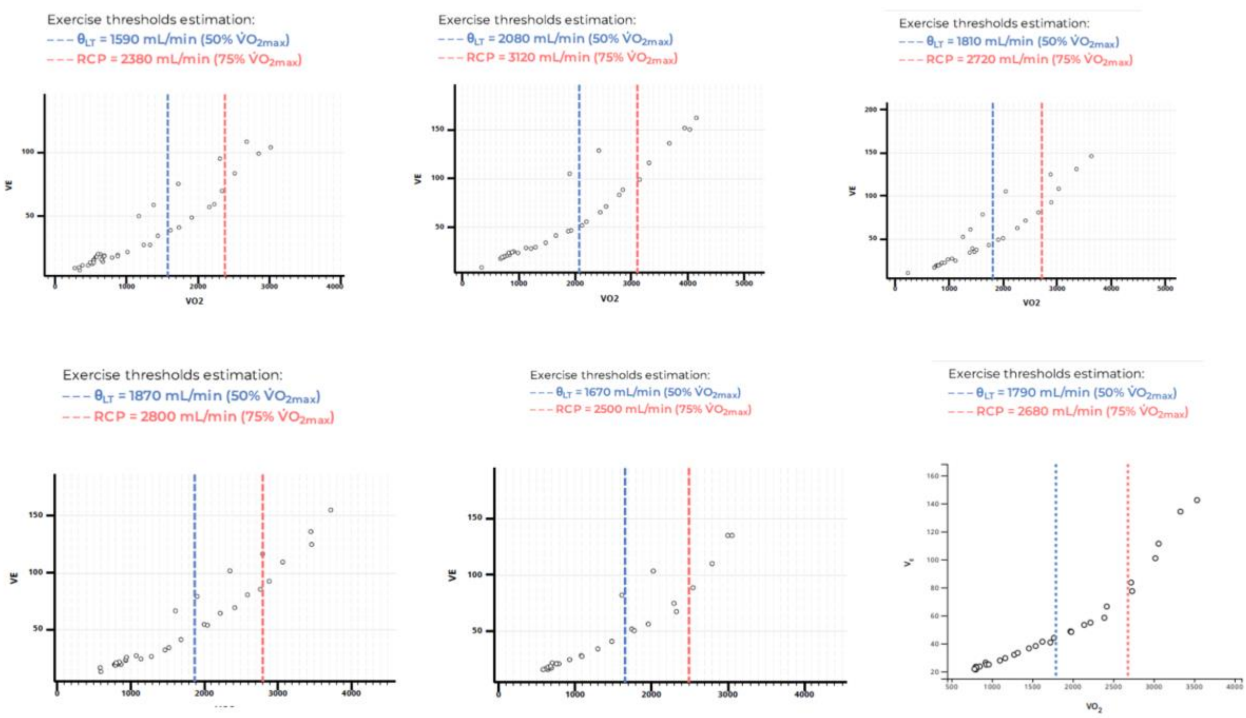

Figure 3. The oxygen consumption during the ramp incremental test

Discussion

The present study examined the relationship between peak oxygen consumption (VO2peak) and muscle mass in elite kickboxing athletes. The analysis of data revealed a strong and positive correlation between these two variables, indicating that as muscle mass increased, so did peak oxygen consumption. This finding has important implications for the understanding of the physiological factors contributing to athletic performance in kickboxing and other high-intensity combat sports (Slimani, Chaabene, et al., 2017). The observed positive relationship between VO2peak and muscle mass aligns with existing literature on the importance of muscle mass in aerobic capacity. An increase in muscle mass typically results in an increased oxygen demand, which is met by an elevated VO2 peak (Volodchenko, 2017). This relationship suggests that, in kickboxing, athletes with greater muscle mass may have a physiological advantage in terms of aerobic capacity, which is crucial for sustaining high-intensity efforts throughout a match. The presented descriptive statistics encapsulate the anthropometric and physiological profiles of ten elite kickboxers, offering insights into their characteristics and capabilities. The athletes, with an average age of 25 years, exhibit a range of body weights (63.3 to 79.8 kg) and heights (169.1 to 181.5 cm), accompanied by a comprehensive assessment of body composition, including adipose, muscle, residual, bone, and skin mass. Notably, their body fat percentage is relatively low, averaging at 12.8%. Also, the assessment of lactate threshold (LT) and respiratory compensation point (RCP) is fundamental in understanding the physiological responses of elite kickboxing athletes during maximal effort. In this study, these key parameters were measured to gain insights into the athletes' aerobic and anaerobic capacities. The results provide valuable information for optimizing training and conditioning programs in the context of combat sports (Podrigalo et al., 2023). The LT, a point at which lactate accumulation in the bloodstream begins to rise significantly, is often used as a marker of an individual's transition from predominantly aerobic to anaerobic metabolism (Ribeiro, de Castro, Rosa, Baptista, & Oliveira, 2006). The observation of LT during the ramp-incremental test in kickboxers is significant because it signifies the intensity at which their aerobic energy production can no longer meet the demands of the exercise (De Oliveira et al., 2015). Beyond this point, energy production increasingly relies on anaerobic pathways. The elevation of LT in elite athletes suggests a higher aerobic capacity, enabling them to work at a higher intensity before transitioning to anaerobic metabolism. This capacity is particularly advantageous in a sport like kickboxing, where bouts involve repeated high-intensity efforts interspersed with brief recovery periods (Rydzik, 2021). The RCP is another critical parameter identified in this study. It marks the point at which ventilation increases significantly in response to elevated carbon dioxide production. RCP represents a high-intensity threshold beyond which the athlete experiences a sharp increase in the physiological stress of exercise. The determination of RCP provides insights into the upper limits of exercise intensity that can be sustained. In the context of kickboxing, this parameter may have implications for pacing and tactical considerations, as athletes strive to maximize their effort while avoiding premature exhaustion (Almeida-Neto et al., 2023). Blood lactate concentration (BLC) is closely related to both LT and RCP. The measurement of BLC at task failure during the maximal test offers insights into the athletes' capacity to buffer and clear lactate (Hübner-Woźniak, Kosmol, & Błachnio, 2011). Higher BLC values at this point indicate greater anaerobic contributions, underscoring the intensity of kickboxing bouts and the athletes' ability to perform at near-maximal efforts. In summary, this study highlights the importance of muscle mass for peak oxygen consumption in elite kickboxing athletes (Franchini, 2020). Additionally, it emphasizes the significance of lactate threshold and respiratory compensation points in understanding exercise intensity and performance in this sport. These findings offer valuable insights for training and competition strategies, enhancing the overall understanding of the physiological factors contributing to success in kickboxing.

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Author Contributions

Conceptualization, S.H.S, G.C; Methodology, S.H.S; Formal Analysis, S.H.S., F.H; Writing Original Draft Preparation, S.H.S;

Data availability

Full access to data on request (Houtan.shahidi@gedik.edu.tr / Hootan.shahidi@yahoo.com).

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Conflicts of Interest

The Authors have no conflict of interest to declare

Informed Consent Statement

All the athletes included in the study provided written informed consent.