HUMAN MOVEMENT (ISSN 1899-1955)
2025; 26(4): 107–119

Unveiling the link: nutritional intake and body composition in elite male Olympic combat sport athletes

original paper
DOI: https://doi.org/10.5114/hm/205883

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ABSTRACT
Purpose. This study investigates the anthropometric, body composition (BC), and nutritional intake profiles of elite Olympic combat sports athletes in taekwondo (TKD), judo, karate, and boxing. The aim is to assess sport-specific differences in body fat percentage (%BF), fat-free mass (FFM), and nutrient intake, including macronutrients and key micronutrients such as B-complex vitamins.
Methods. A cross-sectional study was conducted on 57 elite male Iranian combat athletes preparing for the 2018 Asian Games. Anthropometric measurements were assessed using ISAK-standard skinfold thickness, while dietary intake was analysed via a three-day food logbook and the NutriBase 8.1.9 software. Statistical comparisons between combat sports groups were performed using ANOVA and Bonferroni post-hoc tests ($p < 0.05$).
Results. TKD athletes exhibited significantly lower %BF than judo and boxing athletes ($p < 0.001$), whereas boxers had higher %BF than karatekas ($p = 0.006$). Judo athletes had the highest energy ($p = 0.014$) and carbohydrate intake ($p = 0.003$), while TKD athletes consumed less protein ($p < 0.001$) and vitamin B12 ($p < 0.001$) than the other groups. Boxing athletes displayed higher vitamin B6 intake ($p < 0.001$).
Conclusions. Distinct sport-specific BC and nutritional intake patterns exist among combat sports athletes. TKD athletes demonstrated leaner profiles, while judo athletes exhibited higher energy and carbohydrate consumption. These findings highlight the need for tailored dietary strategies to optimise performance and recovery based on the physiological demands of each combat discipline. Further research should explore individualised nutrition plans considering weight categories and gender differences.
Key words: anthropometry, dietary intake, combat sports, body fat, Olympic athletes, elite athletes

Introduction

Combat sports, such as boxing, judo, taekwondo (TKD), and karate, represent a major category of individual disciplines in the sporting arena, attracting millions of spectators worldwide. These sports account for nearly one-quarter of the medals awarded during the Olympic Games [1], with combat sports comprising approximately 26% of all Olympic medals [2]. Each discipline has a distinctive 'signature' in terms of rules,

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Received: April 07, 2025
Accepted for publication: September 10, 2025

Citation: Mohammadian S, Samanipour MH, Ceylan HI, Mevaloo SF, Akbari Z, Kerksick CM, Baker J, Atarod H, Bragazzi NL. Unveiling the link: nutritional intake and body composition in elite male Olympic combat sport athletes. Hum Mov. 2025;26(4):107–119; doi: https://doi.org/10.5114/hm/205883.

competitive formats, scoring systems, required skills, number of rounds, round durations, and recovery times between rounds. These factors, combined with the unique techniques used by athletes, broadly classify combat sports athletes into three categories: grapplers, strikers, or mixed-style competitors [1].

Grappling-based combat sports include Brazilian jiu-jitsu, judo, and wrestling, while striking disciplines encompass boxing, karate, and TKD. Mixed combat sports, such as hapkido and Japanese jujutsu, incorporate elements of both grappling and striking. These sport-specific characteristics make each discipline unique, presenting both opportunities and challenges for experimental research. Despite their differences, all combat sports share common elements, particularly their intermittent nature. Competitors generally engage in bouts lasting between 2 and 5 min, followed by rest periods of 30 s to 1 min. Depending on the competition format, athletes may participate in multiple rounds (up to 11–12) [1, 3–7]. Additionally, in certain local, national, or international tournaments, athletes may compete in 4 to 7 matches on the same day [1].

In championship settings, combat sports athletes engage in brief bursts of high-intensity activity, alternating between offensive and defensive actions lasting between 1 and 30 s. These high-intensity efforts are interspersed with periods of submaximal, low-intensity activity, commonly referred to as ‘pauses’. Several studies have observed that the attack-to-pause ratio in various combat sports typically falls between 1:2 and 1:7 [8–20]. As a result, combat sports are classified as high-intensity, intermittent activities [1], requiring athletes to develop adaptations to sustain repeated explosive efforts with short recovery periods [13, 20–25]. Success in combat sports depends on the ability to generate high-force, high-velocity movements consecutively while maintaining rapid recovery between efforts [26].

Existing research indicates that while the oxidative energy system primarily fuels Olympic combat sports, anaerobic pathways play a crucial role in executing key scoring actions [2]. These decisive moments, such as punch and kick combinations in striking sports or grip disputes and scrambles in grappling sports, are predominantly powered by the phosphagen (ATP-PCr) and anaerobic glycolytic systems [13, 20–24, 26–29]. However, each discipline has distinct energy demands. Striking-based combat sports rely on a combination of phosphagen, glycolytic, and oxidative energy systems, with varying contributions. For example, the oxidative system accounts for 62% of energy production in karate and TKD and 86% in boxing, while the ATP-PCr system contributes between 10% (boxing) and 31% (TKD). The glycolytic system’s contribution ranges from 3% (TKD) to 21% (karate) [2]. In grappling-based sports such as judo, a four-minute match is fuelled primarily by the oxidative system (79%), with ATP-PCr (14%) and glycolysis (7%) playing supplementary roles [2].

To summarise, although combat sports are predominantly aerobic, grappling-based disciplines require higher anaerobic power and strength, along with lower body fat percentages (%BF). In contrast, striking-based disciplines demand flexibility, anaerobic power, and capacity [28] (Table 1).

The distinct physiological, biochemical, and metabolic demands of each combat sport influence anthropometric and body composition (BC) characteristics, which in turn impact performance outcomes. For example, heavyweight judo athletes demonstrate higher absolute peak and mean power values than their lighter counterparts. However, when the power output is normalised to body mass, lighter athletes exhibit greater relative power than heavyweight athletes [28]. This discrepancy is likely due to the higher %BF observed in heavier athletes, as increased body fat has been asso-

Table 1. Competition structure, energy demands, and key traits of the Olympic combat sports in this study

Combat sport	Typical bout structure	Work:rest ratio	Predominant energy system contribution	Key performance traits
Taekwondo	3 × 2 min rounds	1:6–1:8	oxidative ~62%, ATP-PCr ~31%, glycolytic ~3%	speed, flexibility, agility
Judo	1 × 4 min bout	1:2–1:4	oxidative ~79%, ATP-PCr ~14%, glycolytic ~7%	strength, power, grip endurance
Karate	1 × 3 min bout	1:5–1:6	oxidative ~62%, glycolytic ~21%, ATP-PCr ~17%	explosive strikes, speed
Boxing	3 × 3 min (up to 12 rounds in professional bouts)	1:2–1:3	oxidative ~86%, ATP-PCr ~10%, glycolytic ~4%	power, endurance, tactical pacing

ATP-PCr – adenosine triphosphate-phosphocreatine ciated with reduced relative total work output in high-level judo athletes during Wingate tests [28].

Dietary intake is a critical factor influencing an athlete's performance, body weight (BW), and BC [30]. This is particularly important for combat sports athletes, as they compete in weight categories and often undergo weight reduction strategies to qualify for lower weight divisions [31]. Regarding diet composition and anaerobic performance, a previous review [32] suggested that athletes engaged in intense training may require an increased intake of vitamins B1, B2, and B6 due to their essential roles in energy metabolism. These athletes may need approximately twice the Recommended Dietary Allowance (RDA), which can typically be met through increased food consumption during periods of intense training. However, a roundtable discussion among sports nutrition experts [33] highlighted that some combat sports athletes may be at risk of vitamin deficiencies, particularly those who engage in extreme weight-cutting practices without maintaining a balanced diet.

Hydration and dehydration (H/DH) status have also been extensively studied, as rapid weight loss through dehydration is a common practice among combat athletes [34–37]. Research emphasises the importance of monitoring hydration status not only for weight management but also to assess training effectiveness and recovery during stable weight periods. A recent study found that elite judo athletes displayed significant hypohydration even during a weight-stable training camp, underlining the need for proper hydration strategies [38].

Within this background, the present study aims to investigate the morphological profiles (BC) and nutritional intake of Olympic combat sports athletes competing in TKD, judo, karate, and boxing. Given the distinct physiological, biochemical, and metabolic demands of each combat sport, the study will examine how sport-specific energy system contributions influence anthropometric characteristics, including relative and absolute power output, fat-free mass, and %BF. Furthermore, considering the critical role of dietary intake in weight management, particularly in weight-classified sports, the study will assess macronutrient and micronutrient consumption, with a focus on energy metabolism-related vitamins (B1, B2, and B6) and the potential risks of deficiencies due to extreme weight-cutting practices. Finally, hydration status and its implications for training effectiveness, recovery, and performance will be explored, given the prevalence of dehydration strategies among combat sports athletes.

Material and methods

Study design

This cross-sectional study sampled athletes from four Olympic combat sports disciplines: boxing, judo, TKD, and karate. The present investigation was carried out on elite athletes eight weeks before the beginning of the 2018 Asian Games at a continental multi-sport event held from 18 August to 2 September 2018 in Jakarta and Palembang (Indonesia). The testing was performed while the athletes were engaged in a macrocycle focused on achieving a state of the highest physiological and psychological readiness for the Asian Games.

Participants

All participants were national team athletes with a history of participating in international competitions. From an initial list of 520 elite Iranian athletes, 57 combat elite-level males (boxing: n = 11, age: 25.1 ± 2.0 years, body weight: 71.0 ± 6.7 kg, height: 181.6 ± 4.7 cm, training experience: 13 years; judo: n = 17, age: 26.4 ± 2.5 years, body weight: 69.9 ± 5.5 kg, height: 182.0 ± 3.9 cm, training experience: 14 years; TKD: n = 12, age: 25.7 ± 2.1 years, body weight: 72.5 ± 8.4 kg, height: 183.5 ± 4.1 cm, training experience: 14 years; and karate: n = 17, age: 22.5 ± 2.1 years, body weight: 67.7 ± 6.1 kg, height: 181.6 ± 3.3 cm, training experience: 10 years) belonging to the Iranian national teams volunteered to be sampled.

Athletes were medallists in the Asian and World Championships in the four combat sports. The athletes trained for about 20 h (14 sessions) per week. Participants consistently underwent resistance training at an intensity of 60–70% of one-repetition maximum (1RM) for the upper and lower limbs for five sessions per week during the week that they underwent the testing and measurements. They also performed plyometric and resistance band training. The athletes were recruited from the Olympic National Academy of Iran before the outbreak of the COVID-19 pandemic. All athletes were also involved in sparring during the camp training.

The research procedure was thoroughly described to all participants, who gave their written informed consent to participate in this study before data collection. Participants were also informed that they were free to withdraw from the study at any time. To be eligible to participate in the study, participants were required to meet the following criteria: (i) no medical conditions or musculoskeletal injuries; (ii) no consumption of drugs or alcohol for at least one week before the evaluations. Moreover, during the study, athletes were advised (iii) not to change their typical food and fluid intake for the entire duration of data collection.

Procedures

The research team consisted of two researchers for measuring the anthropometric and BC-related variables, with four years of experience. Registered dietitians instructed athletes and collected their 24-h dietary recall. Coaches and athletes fully cooperated with the research team in estimating food intake and evaluating anthropometric characteristics. All testing was performed at the same time of day to minimize diurnal variation (9:00 am–1:00 pm). All athletes were tested under the same environmental conditions.

Anthropometric measurements

All anthropometric characteristics and BC-related assessments were performed separately for each sports discipline to prevent errors and to ensure high accuracy. All measurements for all cohorts were conducted in the morning or very early afternoon (9:00 am–1:00 pm) [39]. Body weight was measured utilising a calibrated digital scale (SECA 803, Hamburg, Germany) with an accuracy of ± 0.1 kg, whilst height was assessed using a stadiometer (SECA 206, Hamburg, Germany) with an accuracy of ± 5 mm. Body mass index (BMI, kg/m^2) was calculated using weight (kg) divided by the square of the height (m). BC was assessed using the International Society for the Advancement of Kinanthropometry (ISAK) 8-site skinfold profile [40]. Skinfold thickness (biceps, triceps, subscapular, iliac crest, supraspinal, abdominal, anterior thigh, and medial calf) was obtained using a skinfold calliper (Model 68902, Cambridge Scientific Industries, Inc, Cambridge, MD, USA). Skinfold thickness was measured to the nearest 0.5 mm at eight sites. The measurements were performed twice on the right side of the body. Each score was recorded, and the mean value of the two measurements was computed. A level 1-accredited anthropometrist performed all skinfold measurements in line with standardised ISAK procedures and previous studies [41, 42] during the camp, separately for every sport, with a technical error of measurement (TEM) of 2.5% for skinfolds. The skinfold thickness values were then used to calculate body density (BD) by utilising Jackson and Pollock's method, and fat percentage was computed by employing Brozek's formula [43]. Fat-free mass index (FFMI) was calculated using the following equation [44]: FFM (kg)/height^2 (m^2).

Nutrient analysis

Participants recorded all foods and beverages consumed over three consecutive days (two weekdays and one weekend day) in a food logbook [45], with portion sizes estimated using household measures and a photographic atlas of common food portions. Nutrient intake was calculated following the procedures described by Samanipour et al. [46]. Detailed information on energy, macronutrients (protein, carbohydrate, fat), specific fatty acids (monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), fibre, cholesterol, vitamins (A, B, C, D, E), and minerals (sodium, potassium, calcium, phosphorus, iron, selenium) was obtained using the NutriBase 8.1.9 clinical software (version 7.18, Cyber Soft, Phoenix, AZ, USA). Participants were instructed not to alter their usual eating patterns during the recording period.

Statistical analysis

Statistical analyses were conducted using the commercial software SPSS (v24.0, IBM, United States). Following the confirmation of a normal distribution using the Shapiro-Wilk test, descriptive data were presented as means (*M*) and standard deviations (*SD*). One-way analysis of variance (ANOVA) in conjunction with the Bonferroni post-hoc test was used to compare the combat sports in terms of anthropometric, BC, and nutrient measures. Partial eta squared (η_p^2) was calculated and interpreted using the criteria: large effect size ($\eta_p^2 > 0.14$), medium effect size ($0.06 < \eta_p^2 < 0.14$), and small effect size ($\eta_p^2 < 0.06$). 95% confidence intervals (CI) were calculated, and a significance level of $p < 0.05$ was set for all statistical tests.

Results

Table 2 presents the descriptive analysis of the anthropometric variables according to each combat sport.

Statistical analysis indicated differences in %BF values between the combat sports ($F = 12.475$, $p < 0.001$, $\eta_p^2 = 0.409$ – large effect size), where TKD athletes had a lower %BF than judo and boxing ($p < 0.001$, for all comparisons), and boxers had higher values than karatekas ($p = 0.006$). The analysis demonstrated differences for fat mass (FM) between boxing ($F = 5.565$, $p = 0.002$, $\eta_p^2 = 0.236$ – large effect size) and karate ($p = 0.031$), and TKD ($p = 0.03$). No differences were ob-

Table 2. Descriptive analysis of BMI (kg/m²), BF (%), FM (kg), FFM (kg), and FFMI (kg/m²) according to each combat sport

Combat sport	BMI (kg/m²)		BF (%)		FM (kg)		FFM (kg)		FFMI (kg/m²)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Judo	21.0	1.0	11.5	1.6	8.0	1.3	61.6	4.8	18.8	1.0
Karate	20.5	1.3	10.4	1.7	7.1	1.6	59.3	16.2	18.5	1.3
Boxing	21.5	1.4	12.4	$1.2^{@}$	8.8	$1.6^{@}$	62.1	5.2	18.8	1.1
Taekwondo	21.5	1.6	8.9	$1.5^{\&@}$	6.4	1.8	66.1	6.9	19.7	1.3

BF – body fat, BMI – body mass index, FM – fat mass, FFM – fat-free mass, FFMI – fat-free mass index
$^{@}$ different from karate, $^{\&}$ different from judo, $p < 0.05$

Table 3. Nutrient intake analysis, according to each combat sport

Nutrients	Combat sport							
	judo		karate		boxing		taekwondo	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
EI (kcal/kg)	69.5	9.4	52.7	$9.8^{\&}$	57.8	$11.8^{\&}$	52.5	$5.3^{\&}$
CHO (g/kg)	10.3	2.1	8.0	$2.6^{\&}$	8.6	$2.3^{\&}$	7.2	$2.2^{\&}$
Pro (g/kg)	2.6	0.2	2.5	0.2	2.6	0.2	2.1	$0.2^{\#}$
Fat (g/kg)	2.2	$0.3^{\&}$	1.8	0.2	1.6	0.2	1.5	0.1
Fibre (g/kg)	0.2	0.1*	0.2	0.05*	0.4	0.1*	0.1	0.05*
MUFA (g)	15.0	4.2	9.9	4.7*	14.8	3.3	15.3	3.8
PUFA (g)	41.5	$9.5^{@}$	23.8	10.8	43.6	7.1	28.1	4.1*
Cholesterol (mg)	206.8	22.6*	168.9	$21.3^{@}$	134.1	9.2*	147.1	18.0
Vit. B1 (mg)	2.75	0.68	3.74	$0.94^{\&}$	3.64	$0.74^{\&}$	3.04	0.96
Vit. B2 (mg)	4.71	1.23	4.74	1.30	4.00	0.81	4.54	1.25
Vit. B3 (mg)	4.52	0.76	3.94	$0.76^{@\&}$	8.01	0.66	9.71	0.99*
Vit. B6 (mg)	41.9	8.1	44.3	5.3	55.1	11.1*	33.3	3.5*
Vit. B9 (μg)	339	104	244	46	356	514	225	37
Vit. B12 (μg)	14.7	1.1	9.0	2.0*	15.0	1.5	10.5	$0.5^{\&\beta}$
Vit. C (mg)	161.2	17.5	149.9	8.0	104.6	$21.2^{@\&}$	124.2	$44.4^{@\&}$
Vit. D (μg)	33.1	$2.8^{\beta@}$	38.1	$4.6^{\beta@}$	40.6	$5.0^{\&}$	28.9	5.1
Vit. E (mg)	41.9	$5.2^{@}$	31.7	3.1	54.6	6.7*	25.7	$5.4^{@\&}$
Vit. A (μg)	3037	422	2908	239	3196	642	3213	561
Fe^{+} (mg)	42.9	8.0*	28.9	7.4	26.1	3.8	34.00	11.8
Se^{+} (μg)	29.7	4.5^{β}	16.7	3.3	52.0	10.9	30.8	2.7^{β}
Ca^{+} (mg)	2262	364	2080	819	946	94	1564	162*
P^{+} (mg)	1904	277	2078	100	3114	989*	1418	329*
Na^{+} (mg)	6394	777^{β}	4497	342*	5386	431	6217	553^{β}
K^{+} (mg)	3783	400^{β}	3694	29^{β}	2577	99	2742	$142^{@\&}$

EI – energy intake, CHO – carbohydrate, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, Vit. – Vitamin, Pro – protein, K^{+} – potassium, Na^{+} – sodium, P^{+} – phosphorus, Ca^{+} – calcium, Se^{+} – selenium, Fe^{+} – iron
* difference when compared with all other combat groups
$^{@}$ different from karate, $^{\&}$ different from judo, $^{\beta}$ different from boxing, $^{\#}$ different from taekwondo, $p < 0.05$

served between groups in the BMI index, FFM, and FFMI values for all comparisons. Table 3 outlines the nutrient intake analysis of combat sports athletes, separated by group.

Statistical analysis indicated differences in energy intake (EI) between combat sports ($F = 8.363$, $p < 0.001$, $\eta_p^2 = 0.32$ – large effect size), where judokas had higher values than karate ($p < 0.022$), boxing ($p = 0.014$), and TKD ($p < 0.001$) athletes. Combat sports athletes showed differences in CHO intake ($F = 5.167$, $p = 0.003$, $\eta_p^2 = 0.23$ – large effect size): more specifically, judo demonstrated higher CHO (g/kg) intake than karate ($p = 0.026$), boxing ($p < 0.004$), and TKD ($p < 0.005$) athletes. The analysis also showed differences between groups for PRO (g/kg) intake ($F = 28.365$, $p < 0.001$, $\eta_p^2 = 0.61$ – large effect size), whereby boxing athletes had higher values than karate ($p < 0.002$), TKD was higher than judo and karate ($p < 0.001$) athletes, while no difference was observed between TKD and judo ($p > 0.05$) competitors. Comparisons indicated differences in Fat (g/kg) intake between combat modalities ($F = 21.381$, $p < 0.001$, $\eta_p^2 = 0.55$ – large effect size), where judo athletes had higher values ($p < 0.001$) when compared with TKD, while TKD and boxing athletes displayed no difference ($p = 1.000$). Furthermore, the analysis revealed differences in fibre (g/kg) ingestion between combat groups ($F = 63.981$, $p < 0.001$, $\eta_p^2 = 0.78$): karate, boxing, TKD, and judokas had differences among them ($p < 0.001$, for all comparisons). Comparisons indicated differences in MUFA values between sports modalities ($F = 6.135$, $p < 0.001$, $\eta_p^2 = 0.26$), where karate athletes consumed lower amounts of MUFA than judo ($p = 0.003$), boxing ($p = 0.020$), and TKD ($p = 0.006$) athletes. Intakes of PUFAs were found to be different between sports ($F = 18.476$, $p < 0.001$, $\eta_p^2 = 0.51$), with TKD having lower PUFA intakes when compared with all other sports ($p < 0.001$, for all comparisons) while karate had lower intakes than judo ($p < 0.001$) athletes. Also, cholesterol intake ($F = 40.947$, $p < 0.001$, $\eta_p^2 = 0.70$) was different between sports with boxing athletes having lower values than judo and TKD ($p < 0.001$, for all comparisons), judo having higher cholesterol intakes than all other groups ($p < 0.001$, for comparisons), and karate having more cholesterol than TKD ($p = 0.023$) athletes.

A number of differences were also observed regarding micronutrient intake. Differences in thiamine (vitamin B1) intake were observed between sports modalities ($F = 4.962$, $p < 0.001$, $\eta_p^2 = 0.22$), where judo had lower vitamin B1 intake than karate ($p = 0.006$) and boxing ($p = 0.048$). No differences were observed between groups for riboflavin (vitamin B2) ($F = 0.928$, $p < 0.066$, $\eta_p^2 = 0.03$). Niacin (vitamin B3) intake was different between sports ($F = 167.486$, $p < 0.001$, $\eta_p^2 = 0.91$), where TKD showed lower vitamin B3 intake than karate, judo, and boxing ($p < 0.001$, for all comparisons) athletes, while boxing had greater vitamin B3 intake than judo and karate ($p < 0.001$, for both comparisons). Differences were observed in the amount of pyridoxine (vitamin B6) that was consumed each day ($F = 17.318$, $p < 0.001$, $\eta_p^2 = 0.50$). Boxing athletes showed more vitamin B6 consumption than judo ($p < 0.001$), karate ($p = 0.002$), and TKD ($p < 0.001$), while TKD demonstrated lower intakes than other sports ($p < 0.001$, for all comparisons). The statistical analysis did not demonstrate differences between combat groups when comparing folate (vitamin B9) ($F = 0.880$, $p < 0.34$, $\eta_p^2 = 0.05$). Cobalamin (vitamin B12) intake ($F = 64.637$, $p < 0.001$, $\eta_p^2 = 0.79$) was different between groups with karate having lower values than judo ($p < 0.001$), boxing ($p < 0.001$), and TKD ($p = 0.026$) while TKD demonstrated a lower vitamin B12 quantity than judo and boxing ($p < 0.001$, for both comparisons) athletes. The statistical analysis indicated differences in vitamin C intake between sports modalities ($F = 14.385$, $p < 0.001$, $\eta_p^2 = 0.45$), where boxing and TKD had lower vitamin C intake compared with karate ($p < 0.001$ and $p = 0.037$, respectively) and judo ($p < 0.001$, for both comparisons) athletes. The results showed differences in vitamin D intake ($F = 18.230$, $p < 0.001$, $\eta_p^2 = 0.51$) with judo and TKD having lower values than karate ($p = 0.007$ and $p < 0.001$, respectively) and boxing ($p < 0.001$ for both comparisons). Also, there were significant differences between sports for vitamin E intake ($F = 75.815$, $p < 0.001$, $\eta_p^2 = 0.81$), with boxing demonstrating higher values of tocopherol than other groups ($p < 0.001$, for all comparisons), as judokas had greater intakes than karate competitors ($p < 0.001$) and TKD had lower vitamin E quantity than judo ($p < 0.001$) and karate ($p = 0.014$) athletes.

The analysis of vitamin A demonstrated no differences for all comparisons ($F = 0.928$, $p < 0.78$, $\eta_p^2 = 0.05$). The analysis showed differences between groups in iron (Fe^+) ingestion ($F = 12.286$, $p < 0.001$, $\eta_p^2 = 0.41$), with judo having higher intakes than other combat sports groups ($p < 0.001$, for all comparisons). Statistical comparisons indicated differences in selenium (Se^+) values between combat sports modalities ($F = 84.190$, $p < 0.001$, $\eta_p^2 = 0.83$), with boxing demonstrating higher selenium values than judo and TKD ($p < 0.001$, for all comparisons). Also, there were differences in calcium (Ca^+) ingestion between combat sports groups ($F = 18.232$, $p < 0.001$, $\eta_p^2 = 0.51$), whereby boxing presented with a higher calcium quantity than karate, judo, and TKD ($p < 0.001$, for all comparisons) athletes. At the same time, TKD showed lower calcium intake values than all other groups ($p < 0.001$, for all comparisons). The data showed differences in the phosphorus (P^+) intake quantities per day ($F = 25.074$, $p < 0.001$, $\eta_p^2 = 0.58$) with TKD demonstrating lower values than other combat sports groups ($p < 0.001$, for all comparisons), while boxing demonstrated higher P+ intake than karate, judo and TKD ($p < 0.001$, for all comparisons). The statistical analysis also showed differences between groups in sodium (Na^+) ingestion ($F = 38.488$, $p < 0.001$, $\eta_p^2 = 0.69$), and karate had lower values than judo, boxing, and TKD ($p < 0.001$, for all comparisons) while judo and TKD had higher Na+

intakes than boxing ($p < 0.001$ and $p = 0.005$, respectively). Finally, comparisons indicated differences in potassium (K^+) intake between the sports ($F = 66.545$, $p < 0.001$, $\eta_p^2 = 0.7$), where judo and karate had higher values than boxing and TKD ($p < 0.001$, for all comparisons).

Discussion

This study analysed anthropometric measures and nutrient intake in elite TKD, judo, karate, and boxing athletes. The results outlined differences in several anthropometric and BC parameters among various combat sports, with large effect sizes for %BF and FM values. Additionally, differences in nutrient intake between types of combat sports athletes were also identified for energy, CHO, PRO, fat, MUFA, PUFA, cholesterol, fibre, iron, selenium, calcium, phosphorus, sodium, potassium, thiamine, niacin, pyridoxine, cobalamin, and vitamins C, D, and E.

In the sporting arena, 'morphological and anthropometric optimisation' [47–51] describes associations between specific physique traits and performance-related outcomes. For instance, it is well established that muscle mass is paramount in sports disciplines involving strength and power. However, knowledge of the link between specific physical traits and performance-related outcomes is limited when applied to complex sports disciplines, such as those requiring strategic and tactical components, as well as coordination and movement pattern-based skills [52]. Combat sports represent an example of complex sports based on weight categories, and, as such, morphological and anthropometric optimisation is expected to play a role in performance and, ultimately, success in the sports [52]. Reale et al. [53] confirmed that, in combat sports, the type of sport can affect physique traits and physiological requirements, ranging from lean mass and lean mass distribution to stature and BMI. Regarding combat sports, Reale et al. [54] demonstrated that TKD athletes possessed the lowest lean mass, followed by judokas, wrestlers, and boxers. Additionally, previous studies showed a high anthropometric dependence for performance outcomes in TKD athletes when interactions between BW and height were observed [1]. Weight management is, indeed, crucial in combat sports, given the importance of weight categories. Some athletes may exploit and rely on (either acute or chronic) weight loss strategies to achieve success in competitions by leveraging an advantage over opponents [1]. Our study revealed notable differences in BC among combat sports athletes. Specifically, TKD athletes exhibited a lower body fat percentage than judo and boxing athletes, a finding that may be attributed to the sport's technical and physiological demands, which prioritise speed, agility, and flexibility, all of which are negatively affected by excess adiposity. The dynamic kicking techniques and rapid directional changes characteristic of TKD require a favourable power-to-weight ratio, prompting athletes to maintain lower fat mass through targeted training and nutritional strategies. In contrast, boxers demonstrated significantly higher body fat percentages than karatekas, which may reflect the sport's greater reliance on absolute strength, punching power, and the ability to absorb blows, attributes that are not as adversely impacted by moderate increases in fat mass. Moreover, boxing's higher oxidative energy system contribution compared with karate may reduce the performance penalty of carrying additional body fat, leading to a physiological and tactical profile distinct from that of karate athletes.

Beyond the effects of training and exercise, weight management in combat sports often involves various dietary restriction strategies aimed at reducing total body mass, either by controlling total energy intake or targeting specific macronutrients. Given the critical role of adequate nutrient intake in optimising performance, sustaining energy availability, and facilitating post-workout recovery, monitoring both BC and nutritional intake is essential for combat sports and team sports athletes alike [1, 55, 56]. Nutrition is closely linked to anthropometric characteristics, sports performance outcomes, and recovery processes, highlighting the need for tailored dietary strategies to support both training demands and competition requirements.

This study also reported on the micronutrient intake of varying groups of combat athletes. Karate athletes had a lower intake of vitamin B12 than judo ($p < 0.001$), boxing ($p < 0.001$) and TKD ($p = 0.026$). Furthermore, TKD athletes have lower intakes of vitamin B12 compared to the judo and boxing athletes ($p < 0.001$, for both comparisons). The lower vitamin B12 intake observed in karate and TKD athletes compared with judo and boxing athletes may be related to the distinct physiological demands and weight-management practices of these sports. Striking-based disciplines such as karate and TKD often emphasise leanness and rapid weight control, which can involve dietary restrictions that inadvertently reduce the intake of B12-rich foods. In contrast, judo and boxing athletes may follow dietary patterns that support greater absolute strength and muscle mass, resulting in higher overall energy and protein consumption and, consequently, greater B12 intake.

From an energy intake and availability perspective, the need to consume adequate energy to meet energy needs is paramount and is a key driver of recovery and optimal training adaptations. These intakes seem to align well and exceed current recommendations for energy intake (44–50 kcals/kg) [57, 58], especially when martial art athletes need to induce skeletal muscle hypertrophy, a process that requires more energy [59]. Our study showed that EI in judokas had higher values than karate, boxing, and TKD athletes, likely reflecting the greater absolute strength, muscle mass, and training load characteristic of this grappling-based discipline.

Moreover, in the present study, a difference between the groups was found for CHO ingestion: more specifically, judo demonstrated higher CHO intake (g/kg) than karate, boxing, and TKD athletes. In general, athletes are advised to adopt specific CHO intake strategies to optimise their performance. In the 48 h leading up to a competition, it is recommended that athletes consume approximately 10–12 g of CHO per kilogram of body weight per day, a quantity similar to that advised prior to high-intensity interval sessions [60–62]. Reduced CHO intake can negatively impact performance, leading to reduced levels of glycogen, which could potentially compromise training quality and competition success [57]. The variation in CHO intake among combat sports may reflect sport-specific energy demands and physiological requirements. Data obtained in this study demonstrated a greater intake of CHO in judo athletes compared to other combat sports, whilst TKD showed a difference versus judo and karate. The judo athletes in this study had greater intakes of CHO, suggesting increased energy requirements. In most comparisons, TKD showed lower values than the other combat modalities.

Furthermore, it has been well documented that strength/power athletes need greater amounts of protein, approximately 2.2 g/kg of body mass daily [63]. Indeed, combat athletes' daily requirements for PRO would be like those of strength athletes. In the present study, the total daily amount of PRO was between 2.1 and 2.6 g/kg, which aligns well with current recommendations. Studies investigating various sports found that dietary intake of PRO [1, 63–66] and fat [67, 68] generally exceeds recommendations. In the current study, the total daily amount of fat was between 1.5 and 2.2 g/kg.

In our study, judo athletes have greater energy expenditure (EE) compared to the other combat disciplines. As a result, this group of athletes required more EI than other combat sports. The training regime and sports specifics might explain this, as judokas do not fight only standing up but, in the majority of cases, continue and transition their fight to the ground, where an extensive amount of energy is needed for a successful application of ground techniques (end hold, leverages, chokes) or to escape/defend from these techniques. Additionally, judokas are exposed to numerous concentric/concentric and/or eccentric/concentric movement patterns where the opponent's actions frequently induce eccentric movements [69]. It has been reported that exposure to extensive amounts of eccentric muscle work prolongs and raises post-exercise resting EE and may promote higher protein turnover due to micro-muscle damage, which causes repair of muscular myofibrillar damage up to 72 hours post-exercise [70]. From the point of view of EI, several additional studies have also provided evidence that the EI of team sport athletes assessed was suboptimal and did not meet recommendations [55, 56, 71, 72], while our study showed that judo athletes had more EI than karate, boxing, and TKD, respectively.

In this study, TKD and boxing athletes demonstrated different intakes of macronutrients. This may be a consequence of the training model used, weight category regulations, level of readiness, or possible nutritional support via nutritionists and specialised dietary programs. Indeed, studies found that overall total fat intake in some athletic populations (soccer and rugby) may exceed general recommendations, and PUFA intake may fall below recommended intakes of 10% of EI [67, 73]. This may reflect the sport-specific performance requirements of combat sports, where the EI from total fat was 26–27%, respectively. Nevertheless, the lower nutritional intake can be explained by the need to maintain a weight category. In our case, as previously mentioned, TKD athletes had a lower %BF than judo and boxing, and boxers had higher values than karatekas. Moreover, in other combat sports, it has been noted that some elite athletes maintain habits and regimes from their weight-loss periods during training camps despite unrestricted nutrition availability and consumption [38], which might be the case of TKD athletes in the present study. However, whether this is due to habits, lack of knowledge, or done on purpose remains unclear and needs further investigation.

Strengths and limitations

The main strengths of this study include the simultaneous and systematic collection of BC and nutritional intake among elite combat sports disciplines. These investigations are quite limited, and with the growing popularity of combat sports, the need for this data will help athletes, coaches, researchers, and practitioners better evaluate and assess the health and performance of these athletes. Results from this study clearly characterise and present the nutritional profiles of TKD, judo, karate, and boxing athletes, which have not been reported elsewhere in the literature.

On the other hand, this study has some limitations that should be adequately acknowledged, starting from the cross-sectional study design. Also, vitamins' well-established and consolidated effects and impacts could not be observed. Future studies should measure BC with bioelectrical impedance or dual-energy X-ray absorptiometry (DEXA) for greater insight into hydration status, bone mass, and regional distribution of hard and soft tissues. Also, athletes from selected combat sports were recruited from different weight categories. Thereafter, presenting the data in a g/kg/day fashion would provide specific information and some idea of the differences between combat sports.

Conclusions

Our study has important practical implications for athletes, coaches, and sports nutritionists involved in combat sports, particularly in understanding the differences and relationships between the various combat disciplines. By highlighting key associations between BC and nutritional status, our findings provide valuable insights into areas where targeted interventions may be necessary to optimise performance, recovery, and weight management strategies in elite combat athletes. This knowledge can aid athletes and practitioners in identifying sport-specific dietary adjustments and refining nutritional strategies to enhance training adaptations and competitive outcomes. Future research should further explore the interplay between nutritional status, weight categories, gender differences, and age groups to develop more personalised and evidence-based nutritional recommendations for combat sports athletes.

Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Sport Science Research Institute of Iran (approval No.: IR.SSRC.REC.1399.062).

Informed consent

Informed consent was obtained from all individuals included in this study.

Conflict of interest

The authors state no conflict of interest.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Funding

This research received no external funding.

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