

Physical and physiological characteristics of high-level combat sport athletes

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Summary

Background. This study attempted to establish physical and physiological characteristics of different high-level combat sport athletes (judo, karate, and taekwondo) and to determine possible differences between these athletes.

Material and methods. Fifty-four elite judo (n = 19), karate (n = 19) and taekwondo (n = 16) athletes took part in the present study. The experimental design consisted of two test sessions. On the first one, athletes performed the squat jump (SJ), countermovement jump (CMJ), and a maximal treadmill test to determine O_{2max} . The second session included the five jump test (5JT), 30m sprint, and one repetition-maximum (1RM) during three exercises: bench-press, half-squat and lying row.

Results. The results showed that SJ and CMJ heights and 5JT performances were higher in karate athletes than in judo and taekwondo athletes. Conversely, bench-press, half-squat and lying row 1RM were higher in judo athletes compared to karate and taekwondo athletes. However, no significant difference was found in O_{2max} and 30-m sprint between groups.

Conclusion. These results can be used for athlete selection in the different combat sports.

Key words: combat sports, elite, physiological, aerobic

Introduction

Combat sports take a significant place in sport today, being part of many international multi-sport events (e.g., Olympic Games and Continental Games), as well as having their exclusive event, the World Combat Games and each sport's world championships. Combat sports arguably contain unique characteristics in comparison to other sports: one must directly attack the opponent's body and the attack can be conducted simultaneously [1]. Most combat sports require a high level of technique, tactical excellence and physical fitness, especially strength, aerobic fitness, muscle power, and speed [2-4].

In general, combat sports have been classified as grappling (e.g. Brazilian jiu-jitsu, judo, wrestling), striking (e.g., boxing, karate, taekwondo) or mixed (e.g., hapkido, jujutsu) sports, depending on their technical actions and rules [2,3,5]. As the technical actions and rules vary according to the sport, it is probable that physical fitness requirements to achieve high-level in each combat sport are also different. Judo is today the grappling combat sport with more practitioners around the world and with highest television interest, while karate and taekwondo are the two most practiced striking

combat sports worldwide, where both kicks and punches are allowed. Additionally, judo and taekwondo are Olympic sports [6]. Despite their popularity and the determination of physical and physiological profiles of judo [3], karate [2] and taekwondo [7-9] athletes, to our knowledge, no direct comparison was conducted between combat sport athletes of the same competitive level. This information could be useful for athletes' detection programs for the different combat sports. Therefore, the purpose of this study was to determine and compare the physical and the physiological characteristics of high-level judo, karate and taekwondo athletes.

Material and methods

Participants

Fifty-four elite judo (n = 19), karate (n = 19) and taekwondo (n = 16) athletes volunteered to participate in the present study. The participants were members of the national Tunisian team in their respective combat sports and were preparing to the All-Africa Games – conducted one month after the evaluation –, they were black belt and had more than 10 years of experience in their

combat sport. All subjects trained at least nine sessions per week for at least three years (excluding the off-season periods). Before participation, all athletes received verbal and written explanations of the procedures and potential risks. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Clinical Research Ethics Committee of the National Center of Medicine and Sciences in Sport of Tunis.

Procedures

Testing procedures were carried out approximately one month before a continental event (the All-Africa Games), thus all athletes were at the same period of preparation. Tests were made between 08-11 AM.

On the first visit to laboratory, athletes were tested for anthropometric parameters and vertical jumping. They then rested 10 minutes before performing the treadmill test to determine O_{2max} . The second laboratory visit was scheduled one week after the first one. It included the five jump test (5JT), 30 m sprint, and one repetition-maximum (1RM), respectively, with at least 10 minutes of rest between tests.

Measures

O_{2max} assessment

Subjects ran on a flat treadmill (Ergo XELG 90; Woodway, Weil, Germany) for three minutes at 9 km/h. The speed was then increased by 1 km/h every minute until exhaustion [10]. The following criteria were met by all athletes when O_{2max} was reached: a leveling off in O_2 despite an increase in treadmill speed and a respiratory exchange ratio higher than 1.1. Respiratory variables were determined using a breath by breath system (ZAN 680; Messgeräte, Oberthulba, Germany) allowing continuous measurement of oxygen uptake. Before each test, the gas analyzers were calibrated with gases of known concentration and the ventilatory membrane was calibrated with a 1 liter syringe. The highest velocity associated with O_{2max} (O_{2max}) was established as described by Paavolaïnen et al. [11].

One repetition maximum (1RM)

1RM is defined as the heaviest weight a participant could lift once with a proper lifting technique, without compensatory movements. 1RM strength was assessed during three different exercises: bench-press, half-squat and lying row. In order to facilitate recovery and reduce the effect of fatigue, upper and lower body exercises were alternated. The tests commenced after a light warm-up (3 minutes walking). The maximal strength protocol included one set of 10 repetitions at a relatively light load that served as a specific warm-up, followed by a gradual increase in load until 1RM was achieved. The rate of the gradual increase in load was dependent on the participant's self-perceived capacity. The 1RM was achieved within 3-6 attempts. The rest period between attempts was 4 minutes. [12]

30-m sprint

The subjects performed 20 minutes of individual warm-up including several accelerations. They then performed three

30m sprints including 10 m and 20 m lap timing with three minutes of recovery in-between. Speed was measured with infrared photoelectric cells (Brower Training System, USA) positioned at start, 10 m, 20 m, and 30 m from the starting line at a height of 1 m. The subject had to start from a standing position placing his forward foot just behind the starting line. The best 30m sprint-time was selected for analysis.

Five Jump test

The Five Jump Test (5JT) consists of five consecutive strides with joined feet position at the start and end of the jumps. From the starting joined feet position, the participant was not allowed to perform any back step with any foot; rather, he had to directly jump to the front with a leg of his choice. After the first 4 strides, i.e., alternating left and right feet for 2 times each, he had to perform the last stride and end the test again with joined feet. If the athlete fell back on completion of the last stride, the test was performed again. 5JT performance was measured with a tape measure from the front edge of the athlete's feet at the starting position to the rear edge of the feet at the final position. The person assessing the landing had to focus on the last stride of the subject in order to exactly determine the last foot print, as the athletes could not always stay on their feet on landing. The starting position was set on a fixed point [13].

Vertical Jumping

Vertical squat jump (SJ) and countermovement jump (CMJ) were performed on a force platform Quattro Jump (Kistler, Amherst, NY). Each athlete performed three SJs and three CMJs with two minutes of rest in-between. The best jump of each jumping protocol was selected for analysis.

Statistics

Data are presented as mean \pm standard deviation for parametric data and median and percentiles 25th and 75th for non-parametric data. The Levene test was used to verify the homogeneity of variances for each variable analyzed. An one-way analysis of variance was used to compare combat sport groups for each variable. The Tukey test was used for post-hoc comparisons. For half-squat 1RM test, O_{2max} , and VO_{2max} , the test of homogeneity of variances assumption was violated and the Kruskal-Wallis test was used, followed by a Mann-Whitney test. Effect sizes were calculated using partial eta-squared. Significance level was set at 5%.

Results

Table 1 presents the general characteristics and the muscle power and sprint performance in judo, karate and taekwondo athletes investigated.

There were no significant differences between the groups concerning age ($F_{2,53} = 1.69$, $p = 0.195$, $h^2 = 0.06$), height ($F_{2,53} = 0.40$, $p = 0.678$, $h^2 = 0.02$) and body mass ($F_{2,53} = 1.91$, $p = 0.159$, $h^2 = 0.07$). Groups differed in the 5JT ($F_{2,53} = 9.31$, $p < 0.001$, $h^2 = 0.27$), with higher performances in the karate group

compared to taekwondo ($p = 0.012$) and judo ($p < 0.001$) groups. An effect of group was found for the SJ performance ($F_{2,53} = 9.19$, $p < 0.001$, $h^2 = 0.27$), with superior performances in the karate group compared to the taekwondo one ($p < 0.001$), while the judo group was superior to the taekwondo group ($p = 0.05$). Significant difference was also observed for the CMJ height ($F_{2,53} = 7.22$, $p = 0.002$, $h^2 = 0.22$), with higher values for the karate group compared to the taekwondo one ($p = 0.001$).

No significant difference was found between groups for the 10-m sprint ($F_{2,53} = 0.36$, $p = 0.669$, $h^2 = 0.01$), 20-m sprint ($F_{2,53} = 0.71$, $p = 0.498$, $h^2 = 0.03$) and 30-m sprint performances ($F_{2,53} = 1.01$, $p = 0.370$, $h^2 = 0.04$).

Table 2 presents the strength profile of the groups investigated.

Groups differed in bench-press 1RM ($F_{2,53} = 94.30$, $p < 0.001$, $h^2 = 0.79$), with higher values in judo athletes compared to karate and taekwondo athletes ($p < 0.001$ for both comparisons). There was also a significant difference between groups in lying row 1RM ($F_{2,53} = 78.18$, $p < 0.001$, $h^2 = 0.75$), with higher values in judo athletes than the two other groups ($p < 0.001$ for both comparisons), and higher values in the karate compared to the taekwondo athletes ($p = 0.031$). A significant difference was also found between groups in the half-squat 1RM ($c^2 = 27.26$, $df = 2$, $p < 0.001$), with higher values in the judo group compared to the two other groups ($Z = -4.49$, $p < 0.001$ and $Z = -4.46$, $p < 0.001$ for karate and taekwondo, respectively).

Concerning the treadmill test, a significant difference was found between groups concerning O_{2max} ($c^2 = 9.12$, $df = 2$, $p = 0.010$), with the judo (median: 17.5, quartiles: 15.5; 19.5 $km \cdot h^{-1}$) and karate (median: 17.0, quartiles: 16.0; 18.5 $km \cdot h^{-1}$) groups

presenting higher values ($Z = -2.59$, $p = 0.010$ and $Z = -2.58$, $p = 0.010$, respectively) compared to taekwondo (median: 15.5, quartiles: 14.2; 17.1 $km \cdot h^{-1}$). However, O_{2max} (Figure 1) did not differ between groups ($c^2 = 0.98$, $df = 2$, $p = 0.614$; judo – median: 51.7, quartiles: 42.2; 60.6 $mL \cdot kg^{-1} \cdot min^{-1}$; karate – median: 54.0, quartiles: 51.0; 58.0 $mL \cdot kg^{-1} \cdot min^{-1}$; taekwondo – median: 50.5, quartiles: 50.3; 57.8 $mL \cdot kg^{-1} \cdot min^{-1}$).

Discussion

The main finding of the present study was that high level judo, karate and taekwondo athletes tested before a continental event had different physical characteristics. Indeed, karate athletes presented higher lower-body muscle power compared to judo and taekwondo athletes, while judo athletes presented higher level of maximal strength in both lower and upper-body exercises. The O_{2max} assessed during the treadmill test and 10 m, 20 m, and 30 m sprint times did not differ between athletes.

Concerning lower-limb muscle power, this study demonstrated that 5JT, SJ, and CMJ performances were higher in karate athletes compared to judo and taekwondo athletes. This advantage of karate athletes in lower-limb power could be explained by the characteristics of the game. Indeed, karate sparring is characterized by the execution of defensive and offensive techniques while freely moving against an opponent [14]. Basic techniques such as punching, kicking, blocking and striking are practiced either in the stationary position or with body movements in various formal stances [14]. Hence, the whole body is continuously in movement during a karate combat, which may explain the higher level of explosive power in the lower-limbs. Although these features of karate

Tab. 1. General characteristics, muscle power and sprint performance in judo, karate and taekwondo athletes

	Judo (n = 19)	Karate (n = 19)	Taekwondo (n = 16)
Age (years)	24.2 ± 4.1	23.0 ± 2.9	22.1 ± 2.9
Body mass (kg)	80.0 ± 15.0	74.2 ± 10.5	75.7 ± 12.4
Height (cm)	179.3 ± 9.8	178.3 ± 6.6	178.0 ± 6.8
5JT (m)	10.5 ± 0.9	11.8 ± 1.1 ^{a,b}	10.8 ± 1.0
SJ (cm)	43.9 ± 4.5	47.2 ± 6.2 ^b	39.7 ± 4.5
CMJ (cm)	47.1 ± 4.9	50.0 ± 5.7 ^b	43.2 ± 5.2
10 m (s)	1.87 ± 0.12	1.84 ± 0.12	1.84 ± 0.13
20 m (s)	3.17 ± 0.16	3.17 ± 0.14	3.12 ± 0.14
30 m (s)	4.38 ± 0.18	4.41 ± 0.17	4.33 ± 0.11

Values are mean ± standard deviation; 5JT: Five Jump Test; n: number of athletes; SJ: Squat Jump; CMJ: Counter Movement Jump.

^a = significantly different from judo, ^b = significantly different from taekwondo. $p < 0.05$.

Tab. 2. One repetition-maximum (1RM) in judo, karate and taekwondo athletes

	Judo (n = 19)	Karate (n = 19)	Taekwondo (n = 16)
Bench-press 1RM (kg)	125 ± 16 ^{a,b}	75 ± 13	68 ± 12
Lying row 1RM (kg)	121 ± 17 ^{a,b}	79 ± 12 ^b	67 ± 11
Half-squat 1RM (kg)	250 (220; 262) ^{a,b}	190 (180;200)	188 (182;200)

Values are mean ± standard deviation, except for half squat where median and second and third quartiles are presented; n: number of athletes.

^a = significantly different from karate, ^b = significantly different from taekwondo. $p < 0.05$.

are also observed in taekwondo, this study showed that SJ, CMJ, and 5JT performances were lower in taekwondo athletes than karate athletes. This difference is difficult to explain because it has been reported that taekwondo athletes use kicks more frequently during a match than karate players [2, 7,15,16]. The difference between karate and taekwondo athletes during the SJ, CMJ, and 5JT may be a consequence of the frequent use of kicks by the taekwondo athletes. In fact, much emphasis is placed on lower-limb power generation, which is necessary to generate powerful kicks in taekwondo [17]. This emphasis on kicks could result in a better lower-limb endurance rather than power development. However, this speculation should be confirmed by future studies.

Traditionally, grappling combat sports rely more on maximum strength than striking combat sports due to the close contact between athletes during the match and the need of maximum strength during groundwork actions [3,4]. The present study confirmed these observations and showed that judo athletes had higher lower- and upper-body 1RM values compared to karate and taekwondo athletes. This result could be explained by the fact that a judo athlete has to grip the opponent's uniform (judogi) to throw him and score. Additionally, Calmet et al. [18] showed that gripping seems to be one essential characteristic determining expertise in judo matches, as the grip is related to the effectiveness of throwing technique execution and success during the match [19].

Again, the differences observed between karate and taekwondo athletes in maximal strength are difficult to explain based on match demands and training characteristics. However, although national karate, judo, and taekwondo teams were selected for the present study, there was no guarantee that athletes did not differ in terms of international competitive level.

When a maximal continuous treadmill test was conducted, no differences in O_{2max} were found between groups. This result could be assigned to the demands of the three sports studied. Indeed, combat sports' matches are intermittent activities that involve high-intensity movements alternating with low-intensity periods or even periods of recovery [20]. As an international event involves many matches for the finalists, the aerobic system contributes to the athlete's ability to sustain effort for the total duration of the combat, to recover during the brief periods of rest or reduced effort, and to effectively recover between [3].

The results of the present study showed that 10 m, 20 m, and 30 m sprint times did not differ between the three groups. This finding could be explained by the fact that speed is necessary for effective use of the techniques in martial arts and to react with maximal speed to the opponents' actions [21], and thus this characteristic was equally developed between groups.

Conclusion

1. The purpose of this study was to compare physical and physiological characteristics between three martial arts: one grappling (judo) and two striking (karate and taekwondo) combat sports. The results indicated that:
2. Judo athletes had higher level of maximal strength than taekwondo and karate athletes;
3. Karate athletes had higher lower-limbs' power than taekwondo and judo athletes
4. No significant differences in O_{2max} and 30 m sprint were found between groups.

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