Relationship Between Attack and Skipping in Taekwondo Contests

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Abstract

Santos, VGF, Franchini, E, and Lima-Silva, AE. Relationship between attack and skipping in Taekwondo contests. *J Strength Cond Res* 25(6): 1743–1751, 2011—The purpose of this study was to determine the relationship between attack time (AT) and skipping time (ST) during the 2007 Taekwondo World Championship and 2008 Beijing Olympic Games. A total of 22 matches (65 rounds, 13 semifinals, and 8 finals) from the World Championship and 23 matches (63 rounds, 22 rounds with 16 athletes each and 1 quarterfinal round) from the Olympic Games, both in the male category, were assessed using time–motion analysis. The AT was considered as the total time during which the athlete attacked or tried to attack, whereas ST was the total time without attempting to attack. The ratio of AT to ST was ~1:7 based on the data pooled from the 2 competitions. The AT/ST ratio was significantly lower for the World Championship than for the Olympic Games ($p \leq 0.05$). In the Olympic Games, no consistent differences across weight divisions were found. However, during the World Championship, the heavier weight divisions (>78 kg) exhibited a lower average AT, lower summed AT, lower attack numbers (ANs)and higher average ST than lighter weight divisions (<58 kg, $p \leq 0.05$). For both competitions, the ST was lower, and the ANs and AT/ST ratio were higher in round 3 than in round 1 or 2. In conclusion, the results of this study suggest that matches in the Olympic Games were less cadenced than in the World Championship, but that in both competitions, the intensity of the match increased in round 3. Practically, these data suggest that coaches need to structure Taekwondo training sessions in a manner that allows the work/pause ratio to mirror the physical demand imposed during competitions.

Key Words Olympic Games, World Championship, match, time–motion analysis

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Introduction

Taekwondo has been an official Olympic sport since 2000. Score points are computed when contact is made by punches or kicks to the torso or by kicks to the head that are strong enough to cause displacement of the opponent's body segment. However, during taekwondo matches, the most common technique is fast kick (*Bandal Tchagui*), directed to the abdominal area of the opponent (5,7,9). One important aspect of a taekwondo match is its intermittent nature. For example, after a high-intensity bout of kicking and punching, a period of low-intensity effort follows for a long balancing time. This period is known as "skipping" and is used to approach the opponent and to prepare a new attack. Therefore, an understanding of the relationship between kicks and punches and balancing time, indicative of the physical demands experienced by athletes during a competition, is an important factor in developing a specific conditioning program (2).

In an intermittent exercise, such as taekwondo, physiological responses are dependent on the duration and intensity of the effort and the duration and intensity of the pause (3). Nevertheless, to the best of our knowledge, only 2 studies have investigated the relationship between effort and pause during competitive taekwondo combat (4,6). Heller et al. (4), using time–motion analysis, revealed that only 17–18% of the total time corresponds to contact fighting, whereas 57 and 50% (corresponding to rounds 1 and 2, respectively) are spent in noncontact fighting activities (4). Activity was shown to be intermittent, with 3- to 5-second bouts of maximum exercise alternating with low-intensity periods at an average ratio of 1:3–1:4. Additionally, Matsushigue et al. (6) investigated Songahm Taekwondo and found that a high-intensity technique was performed about every 31 seconds, generating a ratio of high- to low-intensity movement duration >1:6. Although these values are slightly higher than those observed by Heller et al. (4), the 3- to 6-times-longer recovery time after intense exercise still may be sufficient for recovery of the phosphocreatine degraded during powerful movement. However, it is important to note that these studies analyzed different taekwondo styles and national championships (4,6). It remains to be investigated whether similar results could be obtained by studying 2 major high-level international

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Table 1. Values (mean ± *SD*) for AT; ST; PT; total time of AT, ST, and PT, AN; ratio between AT and ST; and ratio between summed time of the AT + ST and PT during the 2008 Olympic Games, 2007 World Championship and pooled data.*

	Olympic Games ($n = 63$)	World Championship ($n = 65$)	Pooled data ($n = 128$)
AT (s)	1.4 ± 0.5	1.3 ± 0.3	1.3 ± 0.4
ST (s)	8.3 ± 3.2	10.1 ± 4.5†	9.2 ± 3.9
PT (s)	5.1 ± 2.9	7.0 ± 4.5†	6.0 ± 3.9
AT sum (s)	9.7 ± 4.4	10.7 ± 5.6	10.2 ± 5.1
ST sum (s)	90.1 ± 21.1	105.2 ± 20.0†	97.3 ± 21.9
PT sum (s)	26.9 ± 20.2	38.0 ± 31.0†	32.2 ± 26.4
AN (times)	7.4 ± 2.6	7.9 ± 3.3	7.6 ± 3.0
AT/ST ratio	0.20 ± 0.18	0.16 ± 0.09†	0.18 ± 0.12
(AT + ST)/PT ratio	2.30 ± 1.31	2.22 ± 1.68	2.25 ± 1.49

*AT = attack time; ST = skipping time; PT = pause time; AN = number of AT.
†Significantly different from the Olympic Games ($p < 0.05$). Effect sizes for ST, PT, ST sum, PT sum, and AT/ST ratio were 0.46, 0.50, 0.73, 0.42, and 0.28, respectively.

taekwondo tournaments. Additionally, no study of the effect of rounds and weight division on the effort/pause ratio has been conducted. Some effect is expected because the deciding events of the match often occur in the final round, and athletes may "accelerate" the rhythm to finish the combat. Meanwhile, heavier athletes may exhibit a slower rhythm in comparison to their lighter counterparts (2) because of higher energy expenditure by the heavier athletes. More research is warranted to better understand the dynamics of taekwondo matches.

An understanding of the demands experienced by athletes during high-level competitions may be useful for developing taekwondo-specific conditioning programs. These specially designed training sessions may result in more adequate preparation for competition (2). Time–motion analyses allow determination of movement sequences, which has important practical implications for athletes and coaches, helping them to select an effort/pause ratio during training that is similar to that of competitions. Given the limited information available about the relationship between effort and pause during high-level international taekwondo competitions, the purpose of this study was to determine the effort/skipping ratio during the 2007 World Championship and 2008 Beijing Olympic Games in all weight categories and rounds. Based on previous studies (4,6) that demonstrated a longer recovery time than attack time (AT), we hypothesized that athletes competing at the World Championship and Olympic Games also expend more time in recovery than in attacking but that the matches at the Olympic Games would be less cadenced than those of the World Championship. We expected that the pause times (PTs) in general would be shortened during the last round

Table 2. Values (mean ± *SD*) for AT; ST; PT; total time of AT, ST, and PT, AN; ratio between AT and ST; and ratio between summed time of the AT + ST and PT for winners and defeated athletes during the 2008 Olympic Games, the 2007 World Championship and pooled data.*

	Olympic Games		World Championship		Pooled data	
	Winners ($n = 23$)	Losers ($n = 23$)	Winners ($n = 21$)	Losers ($n = 21$)	Winners ($n = 44$)	Losers ($n = 44$)
AT (s)	1.3 ± 0.6	1.3 ± 0.3	1.3 ± 0.2	1.3 ± 0.3	1.3 ± 0.5	1.3 ± 0.3
ST (s)	8.4 ± 3.2	8.3 ± 3.2	10.2 ± 4.4	10.1 ± 4.5	9.3 ± 3.9	9.2 ± 4.0
PT (s)	5.1 ± 2.3	5.1 ± 2.9	7.0 ± 4.5	7.0 ± 4.5	6.0 ± 3.9	6.1 ± 3.9
AT sum (s)	9.6 ± 4.5	9.8 ± 4.4	10.3 ± 5.4	11.1 ± 5.9	9.9 ± 4.9	10.4 ± 5.2
ST sum (s)	91.2 ± 20.8	88.9 ± 21.5	106.3 ± 19.7	104.1 ± 20.4	98.4 ± 21.6	96.4 ± 22.57
PT sum (s)	27.1 ± 20.3	26.7 ± 20.2	38.0 ± 31.1	38.0 ± 31.1	32.3 ± 26.5	32.5 ± 26.7
AN (times)	7.3 ± 2.4	7.5 ± 2.9	7.7 ± 3.2	8.1 ± 3.47	7.5 ± 2.8	7.8 ± 3.2
AT/ST ratio	0.20 ± 0.15	0.18 ± 0.08	0.15 ± 0.08	0.17 ± 0.09	0.18 ± 0.12	0.17 ± 0.09
AT+ST/PT ratio	2.24 ± 1.31	2.24 ± 1.33	2.19 ± 1.67	2.17 ± 1.71	2.22 ± 1.5	2.20 ± 1.53

*AT = attack time; ST = skipping time; PT = pause time; AN = number of AT.

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Table 3. Values (mean ± *SD*) for AT; ST; PT; total time of AT, ST, and PT, AN; ratio between AT and ST; and ratio between summed time of the AT + ST and PT for medalist and nonmedalist athletes in the 2008 Olympic Games, and gold and silver vs. bronze athletes in the 2007 World Championship.*†

	Olympic Games		World Championship	
	Medalists ($n = 10$)	Nonmedalists ($n = 38$)	Gold and silver ($n = 16$)	Bronze ($n = 14$)
AT (s)	1.5 ± 0.9	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.2
ST (s)	9.0 ± 2.8	8.2 ± 3.3	10.0 ± 4.5	10.3 ± 4.5
PT (s)	5.0 ± 3.2	5.1 ± 2.8	6.8 ± 4.4	7.3 ± 4.7
AT sum (s)	10.6 ± 5.7	9.5 ± 4.0	10.6 ± 5.4	10.8 ± 6.2
ST sum (s)	98.1 ± 22.4†	87.8 ± 20.3	104.3 ± 18.9	106.9 ± 22.2
PT sum (s)	22.7 ± 20.3†	28.1 ± 20.1	36.9 ± 29.8	40.3 ± 33.5
AT number (times)	7.4 ± 2.5	7.4 ± 2.7	7.8 ± 3.2	8.1 ± 3.6
AT/ST ratio	0.18 ± 0.09	0.19 ± 0.13	0.16 ± 0.09	0.16 ± 0.09
AT + ST/PT ratio	2.74 ± 1.51†	2.10 ± 1.23	2.17 ± 1.72	2.20 ± 1.64

*AT = attack time; ST = skipping time; PT = pause time; AN = number of AT.
†Significantly different from nonmedalists in the Olympic Games ($p < 0.05$). Effect size for ST sum, PT sum, and AT + ST/PT ratio in the Olympic Games were 0.48, 0.27, and 0.46, respectively.

and that PTs for the heavier weight division would be longer than those for the lighter division.

Methods

Experimental Approach to the Problem

To evaluate the effort/skipping ratio during high-level taekwondo competitions, the official videotapes of matches in the male category of the 2 main world competitions (the 2007 World Championship and the 2008 Beijing Olympic Games) were obtained. Each competitor was analyzed individually, round by round, per match. A total of 65 rounds, recorded during 22 matches during the World Championship (13 semifinals and 8 finals), were analyzed. The corresponding values for the Olympic Games were 63 rounds recorded during 23 fights (22 rounds of 16 athletes and 1 quarterfinals). The match comprised 3 rounds of 2 minutes, with 1 minute of rest between them. Fourth rounds occurred in only 8 matches and were also assessed. Although the absolute number of matches analyzed was similar between the 2 competitions, this number corresponded to 4.4 and 30.3% of the total

Table 4. Values (mean ± *SD*) for AT; ST; PT; total time of AT, ST, and PT, AN; ratio between AT and ST; and ratio between summed time of the AT + ST and PT in the 4 2008 Olympic Games weight divisions.*†

	<58 kg ($n = 14$)	58–68 kg ($n = 16$)	68–80 kg ($n = 22$)	>80 kg ($n = 11$)
AT (s)	1.2 ± 0.2	1.4 ± 0.3‡	1.3 ± 0.7§	1.4 ± 0.3‡‖
ST (s)	9.0 ± 3.6	9.1 ± 3.3	7.5 ± 3.0§	8.0 ± 3.2
PT (s)	4.3 ± 2.1	4.0 ± 1.5	6.3 ± 3.7§	4.1 ± 1.7‖
AT sum (s)	10.6 ± 3.7	9.0 ± 3.3	9.8 ± 5.3	9.6 ± 5.3
ST sum (s)	92.7 ± 13.6	93.6 ± 15.4	89.1 ± 26.4	81.9 ± 24.7
PT sum (s)	23.5 ± 16.6	21.1 ± 15.1	32.5 ± 23.0§	21.9 ± 14.1
AN (times)	8.6 ± 2.7	6.6 ± 1.9‡	7.5 ± 2.7	6.8 ± 3.1
AT/ST ratio	0.16 ± 0.06	0.17 ± 0.08	0.22 ± 0.17	0.20 ± 0.09‡
(AT + ST)/PT ratio	2.19 ± 0.80	2.97 ± 1.45‡	1.94 ± 1.37§	2.17 ± 0.77

*AT = attack time; ST = skipping time; PT = pause time; AN = number of AT.
†Effect sizes for AT, ST, PT, PT sum, AT number, AT/ST ratio and AT + ST/PT ratio were 0.19, 0.22, 0.47, 0.29, 0.29, 0.25 and 0.37, respectively.
‡Significantly different from <58 kg.
§Significantly different from 58–68 kg.
‖Significantly different from 68–80 kg ($p \leq 0.05$).

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TABLE 5. Values (mean ± *SD*) for AT; ST; PT; total time of AT, ST, and PT, AN; ratio between AT and ST; and ratio between summed time of the AT + ST and PT in rounds 1–3 in the 2008 Olympic Games.*†

	Round 1 ($n = 23$)	Round 2 ($n = 21$)	Round 3 ($n = 19$)
AT (s)	1.4 ± 0.8	1.3 ± 0.2	1.3 ± 0.3
ST (s)	9.3 ± 3.2‡	8.8 ± 3.4‡	6.5 ± 2.0
PT (s)	4.6 ± 2.3‡	4.8 ± 3.2‡	6.16 ± 3.0
AT sum (s)	9.2 ± 5.0‡	9.4 ± 4.5‡	11.2 ± 3.3
ST sum (s)	94.9 ± 12.7‡	90.5 ± 28.2‡§	83.5 ± 17.8
PT sum (s)	20.5 ± 16.8‡	23.0 ± 19.5‡	39.9 ± 19.4
AN (times)	6.7 ± 2.1‡	7.2 ± 3.1‡	8.5 ± 2.3
AT/ST ratio	0.18 ± 0.13‡	0.18 ± 0.14‡	0.22 ± 0.07
(AT+ST)/PT ratio	2.82 ± 1.47‡	2.44 ± 1.25‡	1.45 ± 0.51‡

*AT = attack time; ST = skipping time; PT = pause time; AN = number of AT.

†Effect sizes for ST, PT, AT sum, ST sum, PT sum, AT number, AT/ST ratio and AT + ST/PT ratio were 0.41, 0.24, 0.20, 0.24, 0.45, 0.30, 0.17, and 0.52, respectively.

‡Significantly different from round 3.

§Significantly different from round 1 ($p \leq 0.05$).

matches performed during the World Championship and Olympic Games, respectively, because a lower number of athletes qualified to compete in the Olympic Games.

Subjects

In our study, we analyzed 8 World Championship weight divisions for male athletes who were ≤54 kg (6 semifinal rounds and 3 final rounds), 54–58 kg (3 semifinal rounds and 3 final rounds), 58–62 kg (3 semifinal rounds and 3 final rounds), 62–67 kg (5 semifinal rounds and 3 final rounds), 67–72 kg (6 semifinal rounds and 3 final rounds), 72–78 kg (6 semifinal rounds and 3 final rounds), 78–84 kg (6 semifinal rounds and 3 final rounds), and ≥84 kg (6 semifinal rounds and 3 final rounds). In the Olympic Games, there were 4 weight divisions for male athletes who were ≤58 kg (11 rounds with 16 athletes each and 3 quarterfinal rounds), 58–68 kg (16 rounds with 16 athletes each), 68–80 kg (22 rounds with 16 athletes each), and ≥80 kg (11 rounds with 16 athletes each).

Procedures

A single investigator who is highly experienced in, and familiar with, taekwondo matches analyzed all videos to determine the time expended in attack and pause in each round. The time–motion analyses for the World Championship and Olympic Games were chosen in an attempt to obtain realistic work/rest ratios during high-level taekwondo competitions. This analysis adhered to the same procedures previously used in other studies of combat sports (5,6,8). Such an analysis was reported to be both objective and reliable, because it is used to determine the score with an intraclass correlation coefficient (ICC) >0.93 (8). To verify the reliability of the present study's results, a total of 82 randomly chosen rounds were reanalyzed, and a reliability analysis was performed using an ICC. The ICC revealed that the time–motion analysis conducted in this study was highly reliable for all 9 variables investigated, with values ranging from 0.71 to 0.94 ($p < 0.001$). The lowest ICC values were found for AT per strike attempt (ICC = 0.73, $p < 0.001$), total AT during the entire round (ICC = 0.71, $p < 0.001$), and total attack number (AN) during the round (ICC = 0.80, $p < 0.001$). The highest ICC values pertained to PT between attacks (ICC = 0.90, $p < 0.001$), skipping time (ST) between attacks (ICC = 0.91, $p < 0.001$) and total ST during the round (ICC = 0.94, $p < 0.001$).

The official videotapes were recorded onto DVD and analyzed using the Nero Show Time program (Version 2, Toshiba Samsung Storage Technology Corporation, Tokyo, Japan). All fights analyzed were recorded during live broadcast on an open television channel. The AT, AN, ST, and PT were registered separately for each round. The AT was the total time during which the athlete attacked or tried to attack his opponent. Specifically, we recorded the time elapsed between the moment that the athlete began to move his foot or hand in the direction of the opponent and the moment when the athlete finished the attack movement. Meanwhile, the ST was defined as the total time in which there was no attempt to attack and the PT was characterized by time-outs determined by the referees. The following indexes were calculated from these measurements: (a) AT average for each round; (b) ST average for each round; (c) PT average for each round; (d) sum of AT for each round; (e) sum of ST for each round; (f) sum of PT for each round; (g) total AN for each round; (h) average AT/ST ratio for each round; and (i) average (AT + ST)/PT ratio for each round.

Statistical Analyses

The data distribution was verified using a Kolmogorov–Smirnov test. A nonnormal distribution was found and a Mann–Whitney *U* test was used to determine whether

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TABLE 6. Values (mean ± *SD*) for AT; ST; PT; total time of AT, ST and PT, AN; ratio between AT and ST; and ratio between summed time of the AT + ST and PT in rounds 1–3 in the 2008 Olympic Games.*†

Variables	<54 kg (n = 9)	54–58 kg (n = 6)	58–62 kg (n = 6)	62–67 kg (n = 8)	67–72 kg (*n* = 9)	72–78 kg (*n* = 9)	78–84 kg (*n* = 9)	>84 kg (*n* = 9)
AT (s)	1.4 ± 0.3	1.5 ± 0.4	1.5 ± 0.4	1.4 ± 0.1	1.3 ± 0.2‡	1.2 ± 0.2‡¶	1.2 ± 0.2§‖	1.2 ± 0.2‡§‖¶
ST (s)	9.7 ± 5.5	7.9 ± 1.8	9.8 ± 3.9	12.9 ± 2.9‡§¶	7.5 ± 2.4‖	10.2 ± 4.6§‖¶#	12.5 ± 5.6§#	10.9 ± 4.4§#
PT (s)	9.7 ± 5.8	6.8 ± 2.8	8.6 ± 5.0	5.9 ± 4.7	4.3 ± 2.0‡§¶	4.9 ± 1.5‖¶	9.2 ± 6.6#	7.0 ± 2.5#**
AT sum (s)	14.0 ± 7.8	13.8 ± 3.9	13.0 ± 5.8	8.3 ± 2.5§¶	12.2 ± 4.4‖	8.7 ± 3.9§¶#	8.5 ± 5.2‡§¶#	7.5 ± 5.1‡§¶#
ST sum (s)	110.8 ± 43.3	94.3 ± 11.3	104.7 ± 13.2	101.5 ± 20.2	105.1 ± 6.5§	109.4 ± 6.8¶	04.2 ± 12.1§**	106.8 ± 12.4
PT sum (s)	49.9 ± 43.6	31.2 ± 20.3	46.3 ± 35.1	14.5 ± 9.0‡§¶	40.7 ± 38.8	32.4 ± 15.2	35.1 ± 24.6	45.4 ± 28.8‖
AN (times)	9.7 ± 3.7	9.6 ± 2.1	8.6 ± 2.6	5.8 ± 1.8‡§¶	9.4 ± 3.0‖	7.4 ± 2.6§¶#	6.7 ± 3.7§¶#	5.9 ± 3.5‡§¶#**
AT/ST ratio	0.19 ± 0.11	0.20 ± 0.08	0.18 ± 0.10	0.12 ± 0.03‡§¶	0.19 ± 0.07‖	0.14 ± 0.06#	0.12 ± 0.07#	0.14 ± 0.10#
(AT + ST)/PT ratio	1.42 ± 1.38	1.71 ± 0.99	1.95 ± 1.63	2.92 ± 2.03¶	2.58 ± 1.36¶	2.52 ± 1.41‡¶	2.38 ± 2.00	2.29 ± 2.16¶

*AT = attack time; ST = skipping time; PT = pause time; AN = number of AT.
†Effect sizes for AT, ST, PT, AT sum, ST sum, PT sum, AT number, AT/ST ratio and AT + ST/PT ratio were 0.58, 0.46, 0.49, 0.53, 0.28, 0.39, 0.53, 0.44 and 0.29, respectively.
‡Significantly different from the 58–62 kg.
§Significantly different from the 54–58 kg.
‖Significantly different from the 62–67 kg.
¶Significantly different from the <54 kg.
#Significantly different from the 67–72 kg.
**Significantly different from the 72–78 kg ($p \leq 0.05$).

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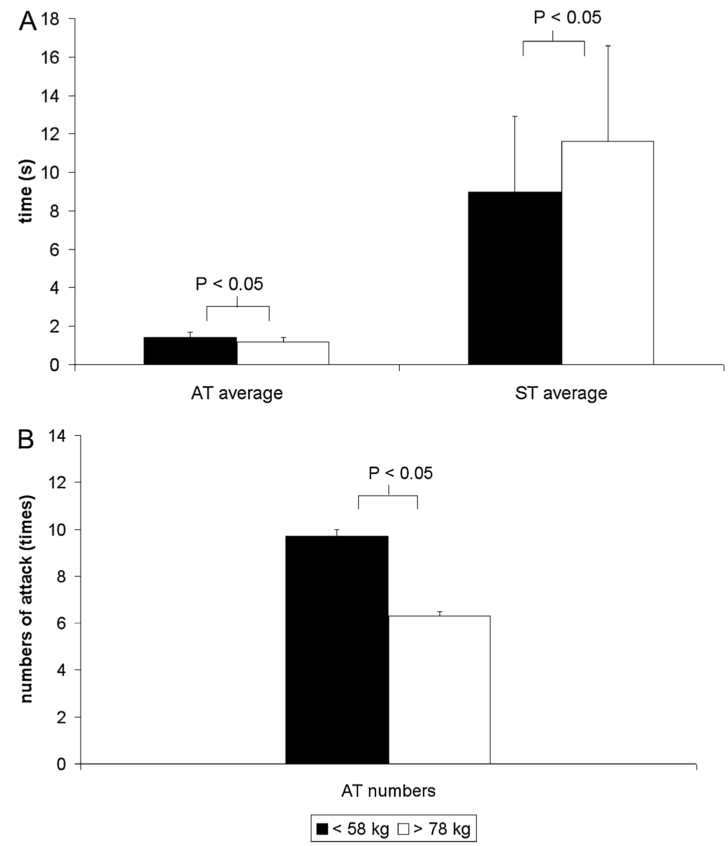

Figure 1. Attack and skipping times (A) and attack numbers (B) for the pooled data of the weight divisions below 58 kg (black columns, $n = 15$) and above 78 kg (white columns, $n = 18$). The effect sizes for AT, ST, and AN were 0.80, 0.58, and 1.01, respectively.

indexes 1–9 were different between competitions (World Championship vs. Olympic Games) or between winners and losers. The Mann–Whitney *U* test was used also to compare medalists vs. nonmedalists in the Olympic Games, and gold and silver vs. bronze medalists in the World Championship. The comparison was performed between gold and silver and bronze medalists in the World Championship because all matches analyzed were semifinals and finals, so it was not possible to create a nonmedalist category as was done for the Olympic Games. Indexes 1–9 were also compared among weight divisions using a Kruskal–Wallis followed by a Mann–Whitney *U* test for localization of the differences. This analysis was performed separately for each competition. The differences among rounds were also determined using the Friedman and Wilcoxon tests. The level of significance was set at $p \leq 0.05$.

Table 7. Values (mean ± *SD*) for AT; ST; PT; total time of AT, ST, and PT, AN; ratio between AT and ST; and ratio between summed time of the AT + ST and PT in rounds 1–3 in the 2007 World Championship.*†

	Round 1 ($n = 22$)	Round 2 ($n = 22$)	Round 3 ($n = 21$)
AT (s)	1.3 ± 0.2‡	1.4 ± 0.3	1.4 ± 0.2
ST (s)	11.9 ± 5.3‡	10.6 ± 3.4‡§	7.7 ± 3.2
PT (s)	4.9 ± 4.0‡	7.4 ± 3.7§	8.8 ± 5.0
AT sum (s)	9.0 ± 4.6‡	9.3 ± 4.2‡	14.1 ± 6.7
ST sum (s)	109.6 ± 29.5‡	106.5 ± 10.7‡	98.8 ± 12.3
PT sum (s)	21.4 ± 20.0‡	34.8 ± 18.2‡§	59.8 ± 38.9
AN (times)	7.1 ± 2.8‡	6.7 ± 2.1‡	10.2 ± 3.8
AT/ST ratio	0.13 ± 0.06‡	0.14 ± 0.07‡§	0.21 ± 0.10
(AT + ST)/PT ratio	3.39 ± 2.05‡	1.89 ± 1.09‡§	1.37 ± 0.87

*AT = attack time; ST = skipping time; PT = pause time; AN = number of AT.
†Effect sizes for AT, ST, PT, AT sum, ST sum, PT sum, AT number, AT/ST ratio and AT + ST/PT ratio were 0.24, 0.44, 0.38, 0.44, 0.26, 0.61, 0.49, 0.44 and 0.66, respectively.
‡Significantly different from round 3.
§Significantly different from round 1 ($p \leq 0.05$).

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Results

Comparison among Competitions and Winners and Losers

Indexes 1–9 for the Olympic Games and World Championship are displayed in Table 1. The average ST and PT were significantly higher for the World Championship than for the Olympic Games. Additionally, the summed ST and PT values were also significantly higher for the World Championship. Consequently, the AT/ST ratio was significantly lower for the World Championship than for the Olympic Games.

Variables 1–9 did not differ between athletes who won and those who lost the match in both the World Championship and the Olympic Games (Table 2). Similarly, no differences were noted when gold and silver medalists were compared to bronze medalists in the World Championship (Table 3). Meanwhile, in the Olympic Games, no differences were found between medalists and nonmedalists for the AT, ST, PT, summed AT, AN, and AT/ST ratio (Table 3). However, medalists in the Olympic Games had a higher summed ST value and (AT + ST)/PT ratio and a lower summed PT value than nonmedalists (Table 3).

Comparison among Weight Divisions and Rounds during Olympic Games

The comparison of indexes 1–9 among weight divisions for the Olympic Games is displayed in Table 4. The AT was significantly higher in the ≥80-kg and 58- to 68-kg divisions than in other divisions. The ST was significantly lower in the 68- to 80-kg than in the 58- to 68-kg division, but no significant differences were found among other divisions. Greater PT values were determined for the 68- to 80-kg division compared to the 58- to 68-kg and ≥80-kg weight divisions. Meanwhile, the summed PT value was significantly higher in the 68- to 80-kg than in the 58- to 68-kg divisions. The ≤58-kg division had a higher AN than the 58- to 68-kg division had but did not differ significantly from the other divisions. The AT/ST ratio for the ≤58-kg division was lower than that of the ≥80-kg athletes but not different from that of the other divisions. The (AT + ST)/PT ratio for the 58- to 68-kg division was higher than that of the ≤58-kg and 68- to 80-kg divisions but not significantly different from that of the ≥80-kg athletes. The AT, summed AT, and summed ST were not different across weight divisions.

The comparison of variables among rounds for the Olympic Games is displayed in Table 5. The average AT was not significantly different among rounds, although all other variables were significantly different between round 3 and the 2 other rounds. In addition, the summed ST in round 2 was significantly different from the ST in round 1. The duration of round 4 was 87.5 ± 51.7 seconds. The values derived from the time–motion analysis for round 4 were AT = 1.1 ± 0.1 seconds, ST = 8.7 ± 2.1 seconds, PT = 2.8 ± 2.4 seconds, AN = 4.8 ± 2.4 times, AT/ST ratio = 0.14 ± 0.05, and (AT + ST)/PT ratio = 2.32 ± 0.14. However, round 4 was not compared to other rounds because it had a lower duration and low frequency (only in 6 matches) and is disputed only when the match is even until the end of round 3.

Comparison among Weight Divisions and Rounds during World Championship

The comparison of variables 1–9 among weight divisions for the World Championship is displayed in Table 6. There were several differences across the weight divisions. Briefly, the heavier weight division (>78 kg) exhibited a lower AT and a higher ST than lighter weight divisions did (<58 kg, Figure 1). Similarly, the heavier weight division had a lower total AT and AN than lighter weight divisions had. However, a well-defined pattern of differences between weights divisions was not found for PT, total PT and ST, and the AT/ST ratio (Table 6). Meanwhile, a higher (AT + ST)/PT ratio was found in the heavier than in the lighter weight division (Table 6).

The comparison of all variables among rounds for the World Championship is displayed in Table 7. They were all significantly different between rounds 3 and 1. Similarly, there were differences between rounds 3 and 2 for all variables except AT and PT. There were also significant differences between rounds 1 and 2 for ST, PT, total PT, and the AT/ST and (AT + ST)/PT ratios. The duration of round 4 was 37.9 ± 37.4 seconds, and the values derived from the time–motion analysis for this round were AT = 1.1 ± 0.5 seconds, ST = 7.5 ± 4.3 seconds, PT = 3.3 ± 3.0 seconds, AN = 2.7 ± 2.1 times, AT/ST ratio = 0.26 ± 0.22, and (AT + ST)/PT ratio = 1.51 ± 1.13. Similar to the Olympic Games, round 4 was not compared to the others because it had a lower duration and a low frequency (only in 2 matches).

Discussion

This study found that matches during the Taekwondo World Championship had a greater ST and PT than the Olympic Games. Consequently, the AT/ST ratio was lower for the World Championship than for the Olympic Games. When compared to lighter weight divisions in the World Championship, the heavier division had a lower AN, a lower AT, and a greater ST. Additionally, round 3 had a lower ST and a higher AN than the first round values in both championships. Finally, no differences were noted between winners and nonwinners for any variable investigated for both the World Championship and the Olympic Games.

In this study, the pooled data for the AT/ST ratio were 0.18 ± 0.12 (Table 1), corresponding to an effort/pause ratio of ~1:7. This is very similar to the results of Matsushigue et al. (6), who reported that the ratio of the duration of high-intensity movements to low-intensity movements or inactivity is >1:6. Slightly different values (1:3 and 1:4) were observed by Heller et al. (4) during match simulations from the TDK-International Taekwondo Federation for athletes from the Czech National Team. This means that in national and international high-level taekwondo competitions, as in the contests analyzed here and by others (4), effort is often interrupted by low-intensity movements or inactivity. Therefore, athletes in these competitions spend more time

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studying, approaching, and preparing a new attack on their opponents than on executing attacks.

A significant difference in the ST and the referee-determined PT was noted between competitions, with higher values for the World Championship than for the Olympic Games. As a result, the World Championship had a lower AT/ST ratio than the Olympic Games, implying that the matches in the Olympic Games were less cadenced and more intense. One possible reason for these results may be the guidelines put forth by the World Taekwondo Federation (WTF), which state that referees in the Olympic Games should wait less time before applying penalty for avoidance (excessive pausing). Another possible explanation is that the selection procedure is more rigorous for the Olympic Games since the number of competitors is limited, leading to a higher level of competition than at the World Championship and thus a time-structure difference.

In the Olympic Games, a well-defined pattern of differences between weight divisions for AT and ST was not identified. In contrast, in the World Championship, the weight divisions >78 kg had a lower AT and higher ST than the division <58 kg. The heavier weight division also exhibited a lower AN, indicating that in taekwondo, matches in the heavier weight division are more cadenced than those in the lighter weight division. These results are partially supported by the findings of Butios and Tasika (2), who demonstrated that the light- and middle-weight divisions (≤68 kg and between 68 and 80 kg, respectively) showed high blood lactate levels in round 2, whereas the heavy-weight division (≥80 kg) reached elevated levels only in round 3. However, the statistical significance of these differences is unclear..In any case, it seems reasonable to hypothesize that heavier athletes expend more energy in executing kicks and punches because of a higher mass in their arms and legs, which can cause heavier athletes to fight more slowly.

In both competitions, ST was shortened and AN was increased in round 3, increasing the AT/ST ratio. This finding may be because of the decisive characteristics of round 3. One explanation for the intensification of the match in round 3 is that the losing athletes increase the match rhythm in an attempt to reverse the score. This action diminishes the ST and increases the AN and thus the AT. On the other hand, winning athletes may also increase the match rhythm in an attempt to rapidly finish the combat. However, it is noteworthy that the reduction observed in the AT/ST ratio from rounds 1 to 3 (from ~1:8 to 1:5) may not be sufficient to significantly alter the proportion between adenosine triphosphate–phosphocreatine (ATP–PCr) and glycogenolysis. In fact, Butios and Tasika (2) showed that despite the same duration of the rounds, taekwondo athletes exhibited significantly lower blood lactate levels than boxers did. The authors suggested that this result may be because of fewer mean scoring attempts per round. Because of the technical and tactical demands of taekwondo, the number of offensive and defensive attempts generally does not exceed 15–20 kicks and punches per round. Meanwhile, in boxing, 80 punches in 1 round are quite common. Accordingly, we found that despite the increase in AN from rounds 1 to 3, the value did not exceed 15 attacks per round. This suggests that in taekwondo, effort is very high-intensity but discontinuous, and that the intervals between attempts keep blood lactate levels low. Conversely, Boulhel et al. (1) reported a continuous increase in blood lactate across the 3 rounds of a taekwondo match and suggested that this was because of an increase in glycolysis. However, based on the data of that study, the change in blood lactate was likely the same across rounds, suggesting a constant glycolysis level throughout the match (1).

In this study, we found no difference between winning and losing athletes for all 9 variables investigated. On the other hand, medalists in the Olympic Games had a higher summed ST than nonmedalists. A past study conducted by our group showed that winners generally perform fewer techniques and high-intensity methods per match during a Songahm Taekwondo competition than the losing athletes (6). In conjunct, these findings suggest that matches may be slightly more cadenced by better athletes, who seem to attack only when there is a fair chance of scoring.

The results of this study have important practical implications for taekwondo training sessions. For example, lighter athletes should undergo more dynamic routine training than heavier athletes should. The specific exercise sequence should be executed intermittently and the effort/-pause ratio should be altered over the course of training to mirror competition sequences. During competition, the performance of elite taekwondo athletes depends on their stress level, motivation, tactics, and competitiveness, and the level of their opponent (1). The athletes are required to react during each time interval (1 attack every 8–10 seconds) and to execute less than about 15 attacks per round. This information should be taken into account during planning of specific exercise training programs for taekwondo athletes.

In conclusion, our data show that during international high-level taekwondo tournaments, the AT/ST ratio is ~1:7. Matches in the Olympic Games appear to be less cadenced than in the World Championship, perhaps because of the guidelines put forth by the WTF for referees in the Olympic Games or because of varying competitiveness. Matches also seem more cadenced in heavier than in lighter weight divisions. Finally, the ST is reduced, and the AN is increased in round 3, but it is unlikely that this sufficiently alters the role of anaerobic processes because PCr stores may be a main source of energy during these action phases (1–5 seconds). Meanwhile, aerobic metabolism may be responsible for energy supply during the intervals between 2 high-intensity actions.

Practical Applications

The findings presented here suggest that coaches need to structure taekwondo training not only around the technical

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needs of the practitioners but also in a manner that ensures a work/pause ratio mirroring the physical demand imposed during competition. An important finding was the ~1:7 AT/ST ratio, with approximately 7–10 attacks per round. Thus, coaches should emphasize high-intensity interval training with a similar time structure to that of an official match. More specifically, high-intensity, short-duration (1–2 seconds) specific taekwondo techniques interspersed with skipping movements (~7 seconds), performed mostly in the range from 7 to 10 repetitions, should prepare the athlete to handle the metabolic and physiologic demands of the match. However, it is also important that the coach considers the range and frequency of occurrence for the variables considered in this study to create more specific circuit-training protocols. Additionally, ST was decreased and AN was increased during round 3, suggesting that coaches should prepare athletes to intensify the match during the last and decisive round. Finally, lighter athletes should have a more dynamic routine training than heavier athletes since their AT is shorter and ST is longer.

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