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Can Anthropometric and Physiological Performance Measures Differentiate between Olympic Selected and Non-Selected Taekwondo Athletes?

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Abstract. This study examined whether anthropometric and physiological performance measures differentiate between Olympic selected and non-selected athletes. Height, body mass, skinfold thickness, strength (squat, bench press and bench pull), power (counter-movement jump, single leg counter-movement jump and 20 m sprint) and aerobic performance (shuttle test) from 10 national squad athletes was collected at the selection camp prior to the Olympic Games. Power, velocity and acceleration profiles during bench throw, bench pull and squat jump were also collected using a linear encoder. Results demonstrated that anthropometric, strength, power and aerobic performance measures could not differentiate between Olympic selected and non-selected athletes. Male Olympic selected athletes displayed a decreased power profile for bench pull and squat jump and only limited improvements in the bench throw compared to non-selected athletes. Power profiles for the bench pull and squat jump but not the bench throw could differentiate between female Olympic selected and non-selected athletes. It was concluded that anthropometric and physiological performance measures cannot consistently differentiate between Olympic selected and non-selected athletes.

Keywords: power monitoring, combat sport, performance assessment, strength, fitness

1. Introduction

Taekwondo is a popular Olympic fighting sport characterised by repeat efforts of high-intensity activity occurring during three 2 minute rounds with 1 minute recovery [1-3]. The fighting in taekwondo is kicking based with points awarded for body and head contact and matches won either by knockout or accumulated points [4]. The emphasis on kicking in taekwondo means that athletes are required to possess high levels of sport specific leg strength, power and endurance [3, 5, 6]. It is therefore important to understand how specific lower extremity qualities relate to performance in taekwondo. This is particularly pertinent for strength and conditioning coaches that aim to improve the functional capacity of high performance taekwondo athletes through training leg strength, power and endurance.

Previous research has examined the anthropometric and physiological profiles of high performance taekwondo athletes and found that higher level athletes display superior performance in counter movement jumping (CMJ), repeated jumping (15 s) and 20 m sprint [5]. In this study, 13 female Croatian taekwondo athletes who had won medals at major international tournaments were compared to those who had not won a medal. Markovic et al. [5] also found that higher level athletes displayed greater body body mass, standing height and lean body mass but lower percent body fat. Aerobic endurance (VO_2max), leg strength (1 RM back squat) and measures of upper body strength were shown not to differentiate between performance levels of female athletes. The findings from Markovic et al. [5] suggest that lower extremity power and speed are important functional capacities in determining taekwondo performance level.

It should be noted that the study conducted by Markovic et al. [5] was limited to female athletes so there is scope for research to investigate male high performance taekwondo athletes. Anthropometric and physiological profiles of male taekwondo athletes have been reported in the literature but has been limited to recreational adolescent athletes [7]. The implications of research involving recreational adolescent athletes are limited within a high performance context. It should also be noted that studies that have examined lower extremity functional capacity and the association with taekwondo performance have used simplified

measures [3, 5, 8]. For example, leg power has been assessed predominately through CMJ height [3, 5, 8]. Strength and condition coaches now have access to innovative technology (e.g. linear encoder systems) that provides greater depth of information when assessing jumping capacity [9]. There is a lack of published studies that have used novel technology to assess the functional capacity of high performance taekwondo athletes including Olympic selected athletes. Clearly, research using novel technology to provide a more comprehensive examination of high performance (including Olympic level) taekwondo athletes is warranted.

The aim of this study was to examine whether anthropometric and physiological measures can differentiate between taekwondo athletes selected for national representation at an Olympic games and those that were not selected for Olympic representation. The objectives consisted determining the difference in power, velocity and acceleration measures (collected through novel technology) between a training squad of taekwondo athletes and then to determine the differences between the two groups when divided into male and female athletes.

2. Methods

2.1. Participants

The subjects consisted of 10 taekwondo national squad athletes. The sample included 4 athletes selected to represent the national team in taekwondo at the 2008 Beijing Olympic Games (height 1.74 ± 0.02 m, mass 68 ± 5.6 kg) and 6 athletes that were not selected to compete at the Olympics (height 1.74 ± 0.02 m, mass 67 ± 5.0 kg). The Olympic selected female athletes competed in the heavyweight category (over 67 kg) and the welterweight category (67 kg). The Olympic selected male athletes competed in the fly weight category (58 kg) and featherweight category (68 kg). The participants in this study were regarded as two groups to assess the profile of Olympic selected and non-selected national squad members. The Olympic athletes in this study successfully competed in the Beijing 2008 Olympics and won at least 1 bout at the games with the highest placed athlete competing in the repechage. Due to the low number of participants it was deemed appropriate to consider the athletes as two groups (Olympic selected and non-selected athletes). All Taekwondo national squad participants had more than 1 year strength and power training experience prior to the selection of the Olympic taekwondo team.

2.2. Study Design

Data was collected during the Olympic selection camp held prior to the 2008 Bejing Olympics. Athletes were selected to represent the national taekwondo team at the Olympics during this training camp. All testing was conducted in accordance with the National Sports Science Quality Assurance Scheme (NSSQA) National Protocols. Anthropometric and physiological testing was conducted during a national squad training camp. All testing was conducted with Institutional approval. Body mass, standing height and skinfolds (sum of 7 sites) were measured from each athlete and then used to calculate lean mass index (LMI) [10]. Skinfolds were measured with Harpenden calipers (West Sussex, England) from the tricep, subscapular, biceps, supraspinale, abdominal, front thigh and calf according to the International society for the Advancement of Kinanthropometry (ISAK) guidelines.

A multistage shuttle test [11] was used to calculate maximal oxygen uptake (VO_2max). Speed was assessed using a 20 m sprint test from a stationary start and measured using wireless infra-red timing lights (Speedlight, SA). Strength assessment consisted squat, bench press and bench pull at a load of 3 repetition maximum (3 RM). Lifts were performed in a continuous manner and no more than 2 secs was allowed between repetitions with full rest between tests. A minimum of 2.5 kg weight increments were used between each trial and the 3RM was found within 4 trials and deemed to be reached once either 3 repetitions were unable to be completed or technique had failed according to the judgement of the accredited strength coach.

The bench throw, bench pull and squat jump tests were weighted with 20 kg and athletes were instructed to perform at maximal effort over 1 repetition with full recovery between exercises. The power, velocity and acceleration variables for the concentric portion of each power exercise was recorded using a linear encoder (Gymaware, Kinetic, Canberra, Australia) with the linear transducer attached to the middle of the barbell. In the squat jump exercise, the barbell remained in contact with the body (positioned on the upper scapula region of the athlete) by the athlete placing their hands on the bar and pulling it into their body. Lower body power was also assessed through a 1 repetition counter movement jump test (bilateral and unilateral) with the Gymaware linear transducer secured to the middle of a wooden dowel rod that was positioned the same as the barbell during the jump squat.

The retraction tension of the linear position transducer was 5 N which was adjusted for calculating peak power, velocity and acceleration. Displacement time data was sampled at 29 Khz and down sampled to 50 hz with time stamping occurring every 35 microseconds [12]. Velocity was calculated as a differentiation of displacement-time data and acceleration was obtained through double differentiation. Power was calculated as work (mass (kg) x gravity ($m.s^{-2}$) x jump height (m)) divided by each time point. Peak power and mean power (W), peak velocity and mean velocity ($m.s^{-1}$) and peak and mean acceleration ($m.s^{-2}$) were calculated in addition to allometric mean and peak watts ($w.kg^{-0.67}$). Height of the squat jump (m) was also recorded.

2.3. Statistical Analysis

All data were analysed using PASW (Version 18.0 for Windows). Exploratory analysis demonstrated descriptive statistics were the most appropriate method of data analysis due to the sample size of the current study. Results were reported as mean ± SD as well as the percent difference in Olympic selected athletes compared to non-selected athletes (positive difference meant a greater value for Olympic selected athletes).

3. Results

Anthropometric data showed similar body mass and standing height values for Olympic selected and non-selected athletes (Table 1). Olympic selected athletes had slightly greater overall skinfold thickness compared to non-selected athletes (7.1 %) which was attributed primarily to an increase in front thigh (32.8 %) and calf measures (47.5 %). Despite this, Olympic selected athletes demonstrated a decrease in skinfold thickness at subscapular (-23.9 %) and supraspinale sites (-19.7 %) when compared to the non-selected athletes. The increase in skinfold thickness for Olympic athletes was not reflected in the lean mass index with similar values for both athlete groups.

Table 1: Difference (absolute (precent)) between anthropometry measures (mean ±SD) of Olympic selected (N = 4) compared to non-selected (N = 6) taekwondo athletes.

	Selected	Non-selected	Difference
Height (m)	1.74 ± 0.02	1.74 ± 0.07	0.01 (0.29 %)
Mass (kg)	68.1 ± 5.0	66.9 ± 5.6	1.15 (1.7 %)
Skinfolds			
Triceps (mm)	13.4 ± 5.5	14.3 ± 9.0	0.9 (6.9 %)
Subscapular (mm)	8.1 ± 0.4	10.6 ± 4.3	-2.4 (-23.9 %)
Bicep (mm)	5.1 ± 1.4	4.9 ± 1.6	0.2 (4.1 %)
Supraspinale (mm)	6.4 ± 0.2	8.0 ± 4.2	-1.6 (-19.7 %)
Abdominal (mm)	12.4 ± 2.6	13.3 ± 7.3	-0.9 (-6.7 %)
Front thigh (mm)	20.0 ± 13.9	15.1 ± 7.4	4.9 (32.8 %)
Calf (mm)	12.7 ± 9.3	8.6 ± 4.3	4.1 (47.5 %)
Skinfolds sum (mm)	79.0 ± 32.4	73.8 ± 73.8	5.3 (7.1 %)
Lean mass index	37.2 ± 4.3	36.8 ± 3.1	0.4 (1.2 %)

Table 2: Difference (absolute (precent)) between physiological test results (mean ±SD) for Olympic selected (N = 4) compared to non-selected (N = 6) taekwondo athletes.

	Selected	Non-selected	Difference
Strength			
3RM Squat (kg)	87.50 ± 6.45	91.25 ± 11.15	-3.75 (-4.1 %)
3RM Bench Press (kg)	55.63 ± 11.97	53.33 ± 6.65	2.30 (4.3 %)
3RM Bench Pull (kg)	60.63 ± 11.97	56.67 ± 8.47	3.96 (7.0 %)
Upper body relative	0.85 ± 0.14	0.83 ± 0.10	0.02 (3.3 %)
Lower body relative	0.92 ± 0.62	1.38 ± 0.21	-0.05 (-32.8 %)
Aerobic Performance			
Shuttle test (level)	10.8 ± 1.7	11.1 ± 0.6	-0.3 (-2.5 %)
VO2 max ($ml.min^{-1}.kg^{-1}$)	52.4 ± 6.0	54.4 ± 2.9	-2.1 (-3.5 %)
Power			
CMJ (m)	0.39 ± 0.04	0.43 ± 0.06	-0.04 (9.4 %)
Single leg CMJ – left (m)	0.26 ± 0.06	0.28 ± 0.05	-0.02 (-6.4 %)
Single leg CMJ – right (m)	0.30 ± 0.03	0.28 ± 0.01	0.02 (5.4 %)
20m sprint (s)	3.49 ± 0.36	3.21 ± 0.26	0.27 (8.6 %)

Strength measures showed that upper and lower relative values were similar between Olympic selected

and non-selected athletes (Table 2). Olympic selected athletes demonstrated slightly greater absolute upper body strength with the greatest increase observed in the 3 RM bench pull (7.0 %). Olympic selected athletes displayed a decrease in 3 RM squat strength compared to non-selected athletes (-4.1%). Further analysis observed comparable shuttle run (-2.5 %) and VO_2max levels (-3.5 %) for both groups of athletes. Similarly, CMJ measures did not clearly differentiate between Olympic selected and non-selected athletes. Speed showed the greatest percent difference between the two groups with Olympic selected athletes 0.28 s slower than non-selected athletes.

Table 3: Difference (absolute (percent)) between concentric power, velocity and acceleration during the bench throw (mean ±SD) for Olympic selected (N = 4) compared to non-selected (N = 6) taekwondo athletes.

	Selected	Non-selected	Difference
Peak Power (W)	561.8 ± 117.7	525.2 ± 107.8	36.6 (7.0 %)
Mean Power (W)	276.6 ± 40.3	284.6 ± 46.2	-8.0 (-2.8 %)
Peak Velocity ($m.s^{-1}$)	2.10 ± 0.34	1.86 ± 0.43	0.24 (12.7 %)
Mean Velocity ($m.s^{-1}$)	1.34 ± 0.17	1.25 ± 0.26	0.09 (7.2 %)
Peak Watts ($W.kg^{-0.67}$)	12.32 ± 2.11	11.72 ± 1.76	0.61 (5.2 %)
Mean Watts ($W.kg^{-0.67}$)	5.84 ± 0.70	6.11 ± 0.90	-0.27 (-4.5 %)
Peak Acceleration ($m.s^{-2}$)	10.24 ± 1.15	12.60 ± 4.14	-2.36 (-18.7 %)
Mean Acceleration ($m.s^{-2}$)	0.52 ± 0.36	0.72 ± 0.18	-0.20 (-27.6 %)
Height (m)	0.25 ± 0.06	0.21 ± 0.05	0.05 (23.0 %)

Table 4: Difference (absolute (percent)) between concentric power, velocity and acceleration during the bench pull (mean ±SD) for Olympic selected (N = 4) compared to non-selected (N = 6) taekwondo athletes.

	Selected	Non-selected	Difference
Peak Power (W)	612.5 ± 109.9	606.1 ± 130.5	6.4 (1.1 %)
Mean Power (W)	388.8 ± 20.0	390.2 ± 469.9	-1.4 (-0.4 %)
Peak Velocity ($m.s^{-1}$)	2.17 ± 0.2	2.16 ± 0.3	0.01 (0.5 %)
Mean Velocity ($m.s^{-1}$)	1.41 ± 0.03	1.40 ± 0.10	0.01 (1.0 %)
Peak Watts ($W.kg^{-0.67}$)	13.44 ± 1.88	13.60 ± 2.80	-0.16 (-1.2 %)
Mean Watts ($W.kg^{-0.67}$)	8.29 ± 0.66	8.44 ± 1.38	-0.14 (-1.7 %)
Peak Acceleration ($m.s^{-2}$)	12.12 ± 0.57	11.65 ± 1.42	0.47 (4.0 %)
Mean Acceleration ($m.s^{-2}$)	1.63 ± 0.91	1.17 ± 0.71	0.46 (39.1 %)
Height (m)	0.51 ± 0.06	0.50 ± 0.06	0.01 (2.3 %)

Table 5: Difference (absolute (percent)) between concentric power, velocity and acceleration during the squat jump (mean ±SD) for Olympic selected (N = 4) compared to non-selected (N = 6) taekwondo athletes.

	Selected	Non-selected	Difference
Peak Power (W)	3618.0 ± 406.4	3587.7 ± 711.3	35.2 (1.0 %)
Mean Power (W)	1305.5 ± 128.0	1374.1 ± 170.2	-68.6 (-5.0 %)
Peak Velocity ($m.s^{-1}$)	2.48 ± 0.23	2.51 ± 0.28	-0.03 (-1.3 %)
Mean Velocity ($m.s^{-1}$)	1.35 ± 0.10	1.45 ± 0.15	-0.10 (-6.7 %)
Peak Watts ($W.kg^{-0.67}$)	79.67 ± 7.75	80.20 ± 14.01	-0.53 (-0.7 %)
Mean Watts ($W.kg^{-0.67}$)	42.84 ± 3.26	46.99 ± 7.64	-4.16 (-8.8 %)
Peak Acceleration ($m.s^{-2}$)	10.69 ± 1.45	11.21 ± 2.40	-0.52 (-4.6 %)
Mean Acceleration ($m.s^{-2}$)	1.51 ± 0.29	1.48 ± 0.25	0.03 (1.7 %)
Height (m)	0.28 ± 0.04	0.31 ± 0.06	-0.02 (-8.0 %)

Analysis of the concentric power, velocity and acceleration profiles during the bench throw, bench pull and squat jump showed a lack of consistent differentiation between Olympic selected and non-selected athletes. Peak power (7.0 %), peak velocity (12.7 %), mean velocity (7.2 %) and peak watts (5.2 %) were greater during the bench throw for Olympic selected athletes compared to non-selected athletes. Olympic athletes demonstrated a 23 % increase in the height of the bench throw compared to non-selected athletes, but this equated to a 0.05 m difference between the groups and this was within 1 standard deviation (0.25 ± 0.06 m) from the mean bench throw height for Olympic athletes (Table 3). The results for the bench pull showed that Olympic selected athletes displaying increased peak power (1.1 %), peak velocity (0.5 %), mean velocity (1.0 %), peak acceleration (4.0 %) (Table 4). The most pertinent difference was in mean acceleration where Olympic selected athletes displayed a 39.1 % increase compared to non-selected athletes, which equated to 0.46 $m.s^{-2}$ greater mean acceleration. A 2.3 % increase to bench pull height was observed but this represented only 0.01 m difference between the athlete groups. Further analysis demonstrated that Olympic

selected athletes tended not display greater concentric power, velocity or acceleration during the squat jump when compared to non-selected athletes (Table 5). Peak power (1.0 %) and mean acceleration (1.7 %) were the only measures that Olympic selected athletes achieved greater values than the non-selected athletes.

Results then examined the affect that gender had on the difference between Olympic selected and non-selected athletes. Anthropometry measures indicated that Olympic selected male and female athletes had greater skinfold thickness than their non-selected counterparts (Table 6). A 5 % (2.5 mm) increase was observed in Olympic selected males compared to non-selected males and 8.0 mm (8.3 %) increase in Olympic selected females compared to non-selected females. Olympic selected female athletes displayed considerably greater lower extremity skinfold thickness with increased front thigh (10.7 mm, 53.8 %) and calf (8.4 mm, 73.9 %) measures compared to non-selected athletes. Despite this, Olympic selected females displayed a considerable decrease in supscapular (-5.0 mm, -38.8 %), abdominal (-5.6 mm, -31.7 %) and supraspinale (-3.9 mm, -37.3%) skinfold measures.

Table 6: Anthropometry measures (mean ±SD) of Olympic selected male and female athletes compared to non-selected male and female athletes.

	Male		Female	
	Selected	Non-selected	Selected	Non-selected
Height (m)	1.75 ± 0.03	1.77 ± 0.08	1.73 ± 0.00	1.70 ± 0.03
Mass (kg)	69.5 ± 8.2	65.0 ± 7.3	66.6 ± 0.7	68.8 ± 3.6
Skinfolds				
Triceps (mm)	7.7 ± 0.5	8.9 ± 1.8	21.0 ± 8.3	17.9 ± 3.3
Subscapular (mm)	8.4 ± 0.5	8.3 ± 1.4	7.9 ± 0.2	12.9 ± 5.4
Bicep (mm)	3.9 ± 0.1	3.8 ± 0.6	6.4 ± 0.1	6.0 ± 1.5
Supraspinale (mm)	6.3 ± 0.1	5.5 ± 1.4	6.5 ± 0.1	10.4 ± 4.9
Abdominal (mm)	12.7 ± 3.9	8.8 ± 2.4	12.2 ± 2.1	17.8 ± 8.2
Front thigh (mm)	9.4 ± 0.3	10.2 ± 4.1	30.7 ± 11.1	19.7 ± 8.0
Calf (mm)	5.7 ± 0.6	5.9 ± 1.3	19.7 ± 8.0	11.3 ± 4.6
Skinfolds sum (mm)	53.9 ± 2.7	51.3 ± 12.2	104.2 ± 24.8	96.2 ± 31.2
Lean mass index	40.1 ± 4.7	37.7 ± 4.6	34.4 ± 0.94.3	35.9 ± 0.7

Strength measures were shown not to differentiate Olympic selected and non-selected female athletes (Table 7). The bench press and bench pull was greater in Olympic selected male athletes compared to non-selected male athletes. Similar shuttle run scores were observed in the male athletes but Olympic selected females achieved a poorer shuttle run level than non-selected female athletes (-1.2 level, -11.1 %). Overall Olympic selected male and female athletes could not jump as high in the CMJ as the non-selected male (-0.05 m, -10.8 %) and female (-0.03 m, - 7.7 %) athletes, respectively. Olympic selected male athletes showed a right leg dominance with a higher jump height when compared to non-selected athletes (0.04 m, 12.5 %). Both Olympic selected male (0.30 s, 10 %) and female (0.25 s, 7.3 %) athletes were slower during speed testing when compared to non-selected athletes.

Table 7: Physiological test results (mean ±SD) for Olympic selected male and female athletes compared to non-selected male and female athletes.

	Male		Female	
	Selected	Non-selected	Selected	Non-selected
Strength				
3RM Squat (kg)	92.50 ± 3.54	95.00 ± 5.00	82.50 ± 15.61	87.50 ± 15.61
3RM Bench Press (kg)	65.00 ± 7.07	56.67 ± 7.64	46.25 ± 5.30	50.00 ± 4.33
3RM Bench Pull (kg)	70.00 ± 7.07	62.50 ± 8.66	51.25 ± 5.30	50.83 ± 1.44
Upper body relative	0.97 ± 0.01	0.91 ± 0.05	0.74 ± 0.08	0.74 ± 0.04
Lower body relative	0.60 ± 0.84	1.46 ± 0.13	1.25 ± 0.05	1.29 ± 0.27
Aerobic Performance				
Shuttle test (level)	12.05 ± 1.39	11.41 ± 0.58	9.52 ± 0.70	10.71 ± 0.59
VO2 max ($ml.min^{-1}.kg^{-1}$)	57.09 ± 3.89	56.61 ± 1.73	47.63 ± 2.19	52.38 ± 2.21
Power				
CMJ (m)	0.43 ± 0.01	0.48 ± 0.03	0.36 ± 0.03	0.39 ± 0.06
Single leg CMJ – left (m)	0.29 ± 0.06	0.28 ± 0.08	0.23 ± 0.05	0.27 ± 0.03
Single leg CMJ – right (m)	0.32 ± 0.02	0.28 ± 0.02	0.28 ± 0.02	0.28 ± 0.01
20m sprint (s)	3.30 ± 0.49	3.00 ± 0.09	3.67 ± 0.00	3.42 ± 0.18

Power measures showed some differentiation between Olympic selected and non-selected male athletes

in the bench throw but not the bench pull or squat jump (Table 8). Peak power (77.48 W, 13.5 %), peak velocity (0.49 $m.s^{-1}$, 25.9 %), mean velocity (0.23 $m.s^{-1}$, 18.6 %), peak watts (1.00 $W.kg^{-0.67}$, 7.7 %) and height (0.12m, 18.1 %) were greater during the bench throw for Olympic selected male compared to non-selected male athletes. In contrast, Olympic selected male athletes achieved poorer results for concentric power, velocity and acceleration during the bench pull and squat jump. Similar poor results were observed for the Olympic selected female athletes in the bench throw compared to non-selected female athletes (Table 9). However, all measures of power, velocity and acceleration were greater during the bench pull (range 4.3 to 96.8 %) and squat jump (range 3.7 to 20.4 %) for Olympic selected female athletes compared to non-selected female athletes.

Table 8: Difference (absolute (percent)) between concentric power, velocity and acceleration during the bench throw, bench press and squat jump for Olympic selected compared to non-selected male athletes.

	Bench throw	Bench pull	Squat Jump
Peak Power (W)	77.48 (13.5 %)	-9.04 (-1.3 %)	-417.8 (-10.4 %)
Mean Power (W)	-5.31 (-1.7 %)	-29.87(-7.0 %)	-180.51 (-12.2 %)
Peak Velocity ($m.s^{-1}$)	0.49 (25.9 %)	-0.08 (-3.3 %)	-0.37 (-13.3 %)
Mean Velocity ($m.s^{-1}$)	0.23 (18.6 %)	-0.07 (-5.0 %)	-0.25 (-15.9 %)
Peak Watts ($W.kg^{-0.67}$)	1.00 (7.7 %)	-1.13 (-7.1 %)	-15.13 (-16.6 %)
Mean Watts ($W.kg^{-0.67}$)	-0.49 (-7.2 %)	-1.23 (-13.0 %)	-11.77 (-22.5 %)
Peak Acceleration ($m.s^{-2}$)	-0.69 (-6.4 %)	-0.04 (-0.4 %)	-1.58 (-13.2 %)
Mean Acceleration ($m.s^{-2}$)	-0.36 (-57.1 %)	-0.09 (-6.5 %)	-0.26 (-15.9 %)
Height (m)	0.12 (18.1 %)	-0.01 (-2.2%)	-0.15 (-20.3 %)

Table 9: Difference (absolute (percent)) between concentric power, velocity and acceleration during the bench throw, bench press and squat jump for Olympic selected compared to non-selected female athletes.

	Bench throw	Bench pull	Squat Jump
Peak Power (W)	-4.38 (-0.9 %)	21.79 (4.3 %)	488.39 (15.6 %)
Mean Power (W)	-10.79 (-4.2 %)	27.04 (7.7 %)	43.29 (3.4 %)
Peak Velocity ($m.s^{-1}$)	-0.01 (-0.6 %)	0.10 (5.2 %)	0.30 (13.0%)
Mean Velocity ($m.s^{-1}$)	-0.05 (-3.8 %)	0.10 (7.6 %)	0.05 (3.7 %)
Peak Watts ($W.kg^{-0.67}$)	0.21 (2.0%)	0.81 (7.2%)	14.07 (20.4 %)
Mean Watts ($W.kg^{-0.67}$)	-0.05 (-1.0 %)	0.94 (12.7 %)	3.45 (8.3 %)
Peak Acceleration ($m.s^{-2}$)	-4.03 (-28.0 %)	0.99 (9.1 %)	0.54 (5.2 %)
Mean Acceleration ($m.s^{-2}$)	-0.04 (-4.7 %)	1.00 (96.8 %)	0.31 (23.8 %)
Height (m)	0.01 (1.6 %)	0.04 (8.8 %)	0.08 (13.8 %)

4. Discussion

This study examined whether anthropometric and physiological measures differentiate between Olympic selected and non-selected taekwondo athletes. The findings indicated that power, velocity and acceleration measures (collected through linear encoder) could not differentiate adequately between a training squad of taekwondo athletes during an Olympic selection camp. Similarly, this study observed limited and inconsistent differences between the two groups when divided into male and female athletes. This study documents the anthropometric and physiological qualities of taekwondo athletes and represents the first paper to report findings regarding Olympic male athletes and also the use of a linear encoder system to compare the power profiles of Olympic selected and non-selected taekwondo athletes.

The lack of variation in anthropometric measures between Olympic selected and non-selected athletes suggests that height, body mass and lean body mass may not be a determinant of Olympic selection in a relatively homogenous sample of athletes. It should be noted that Olympic selected athletes did display a higher percentage skinfold thickness in the lower extremity which could relate to the body impacts that occur frequently to this area during fighting bouts. A higher adiposity in selected areas (such as the lower extremity) no doubt provides a greater capability to absorb the forces related to body contact such as kicking. This is supported by previous research in the football codes that has explored the change in athlete anthropometry depending on whether their sport is characterised by body impacts (contact / collision) between players [13]. Contact / collision sport athletes tend to display a greater percent adiposity than athletes whose sport does not have this performance requirement. To add to this, it has been shown that within the same contact / collision sport that athletes who are involved more frequently in body impacts display a greater percent adiposity than

athletes who are involved less frequently in this activity [14].

The female athletes observed in the current study were taller, heavier and leaner when compared to high level Taekwondo athletes from Croatia [5]. The male athletes were shorter, lighter and leaner than their counterparts from the Czech Republic [3]. Building on previous research, it was shown that anthropometric variables provide little differentiation between male Olympic selected and non-selected athletes. Olympic male athletes displayed a 5 % increase in skinfold thickness which equated to a 2.6 mm change and is questionable whether this difference is meanginful. In contrast, female Olympic selected athletes displayed a 36 % and 43 % increase in front thigh and calf skinfold thickness when compared to non-selected athletes. The difference in lower extremity skinfold thickness represents a meaningful difference between the female selected and non-selected athlete groups. The increase in lower extremity skinfold thickness observed in Olympic athletes could explain the 3 kg mean increase in body mass for this group when compared to the non-selected athletes. It would be expected that greater lower extremity mass (associated with additional adipose tissue) would increase the limbs momentum when kicking and could result in a more forceful impact when striking opponents. It is recommended that further research examine the association between greater lower extremity mass through increased skinfold thickness and the force-time profile of taekwondo kicking strategies.

Measures associated with an athlete's physiological capacity (strength, power and aerobic performance) were unable to consistently differentiate between Olympic selected and non-selected athletes in the current study. Olympic selected athletes were stronger in upper body strength assessment when compared to non-selected athletes but not stronger in the lower extremity. This finding is contrary to previous research that observed higher achieving athletes displayed greater upper and lower body 3 RM strength levels [5]. The poorer lower extremity strength levels observed of Olympic selected athletes in the current study could suggest that this measure may not be a determinant of success in the taekwondo. Alternatively, lower extremity strength levels could be an area for performance improvement in the sampled Olympic athlete cohort given the focus on kicking strategies in taekwondo.

The Olympic selected athletes in the current study were considerably stronger for both bench press and squat when compared to the equivalent athletes observed by Markovic et al. [5]. It should be noted that the study conducted by Markovic et al. [5] was limited to observations of only female high level taekwondo athletes, whereas the current study involved both male and female athletes. The female Olympic selected athletes in the current study were weaker for squat and bench press strength than an equivalent cohort observed in previous research [5]. In contrast, the Olympic non-selected athletes were considerably stronger for the same strength measures than their equivalent counterparts in Croatia and similar to athletes that had recently won a medal at European Championships, World Championships or Olympics [5]. This adds weight to the notion that strength measures provide a poor means of differentiation between Olympic selected and non-selected athletes and that this lack of differentiation is particularly apparent with female athletes.

Measures of power used in the current study were also shown not to accurately differentiate between Olympic selected and non-selected athletes. The power capacity for both Olympic selected and non-selected athletes was greater than previously reported values for elite / high performance taekwondo athletes [3, 5] but not recreational athletes [7]. This suggests that lower extremity power is a poor predictor of taekwondo performance. The lack of differentiation between performance levels based on power was maintained when dividing the athlete cohort into male and female athletes. Olympic selected male and female athletes in the current study tended to display poorer power levels than non-selected athletes, which was supported by similar findings by Markovic et al. [5]. Furthermore, the male Olympic selected athletes performed considerably worse at the counter-movement jump test than recreational athletes observed by Noorul et al. [7]. Similarly, the female Olympic athletes in the current study performed only slightly better at the counter-movement jump test than recreational athletes [7]. Clearly, measures of power including counter-movement jumps and short sprints cannot differentiate between the performance levels of taekwondo athletes.

The linear encoder allowed a broad range of performance measures (associated with power profiles) during the bench throw, bench pull and squat jump assessments to be collected and was expected to provide a more precise means to differentiate between Olympic selected and non-selected athletes. Alternatively, power profiles demonstrated an inability to highlight consistently the differences between Olympic selected and non-selected athletes. Moreover, male Olympic selected athletes displayed a decrease in all performance measures for the bench pull and squat jump when compared to non-selected athletes. Peak power, peak velocity, mean velocity and peak watts during the bench throw were higher for male Olympic selected athletes, but it is questionable whether these variables when associated with a bench throw movement would

result in enhanced performance during a taekwondo fight. This is supported by the lack of difference observed previously in absolute bench press, relative bench press and maximum number of push-ups in 60 s between athlete performance levels in Croatia [5].

Power profiles were able to differentiate between female Olympic selected and non-selected athletes in the current study. This method of athlete assessment seemed to differentiate between performance levels only during the bench pull and squat jump test, with Olympic athletes demonstrating greater performance capacity across all measures. This finding is supported by previous research that reported taekwondo training improved measures of peak power and relative peak power [15]. It is proposed that power profiles measured through linear encoders provide a means to differentiate between female Olympic selected and non-selected athletes in the bench pull and squat jump only. The performance measures (power profiles) collected using a linear encoder during bench pull and squat jump assessments represent an appropriate selection tool for high level female taekwondo and seem appropriate for implementation in future talent identification programs for female athletes.

5. Conclusion

The current study demonstrated that anthropometric and physiological performance measures do not differentiate between Olympic selected and non-selected taekwondo athletes. Differences between athletes were not apparent when the participants were divided into male and female Olympic selected and non-selected athletes. The power profiles collected using linear encoders during the bench throw, bench pull and squat jump assessments provided an inconsistent method to differentiate between Olympic selected and non-selected athletes. Power profiles tended to highlight differences between male Olympic selected and non-selected athletes during only the bench throw, but these differences were not consistent across all performance measures. Power profiles most effectively differentiated between female Olympic selected and non-selected athletes and during only the bench pull and squat jump tests. The findings of the current study highlight the need for performance assessments of taekwondo athletes to be specific to gender groups due to the tactical, technical and physiological characteristics of the fighting sport that result in considerable adaptive variations between male and female athletes. It is recommended that research examines further the use of novel technology as a means to differentiate between performance levels of athletes and give specific consideration to developing a specific testing protocol for both female and male athletes.

6. References

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