"IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology",
Vol. 14, no. 2 (2014), pp. 36–40
DOI: 10.14589/ido.14.2.5

Tomás Herrera Valenzuela [1,2(ABCDEFG)], Jorge Cancino López [3(ACDEF)], Emerson Franchini [4(CDEF)], Carlos Henríquez-Olguín [5(BEF)], Esteban Aedo Muñoz [2,6(EF)]

[1] Faculty of Sciences for Physical Activity, Universidad San Sebastián (Chile)
[2] Faculty of Medical Sciences, Universidad de Santiago de Chile (Chile)
[3] Faculty of Medicine, Universidad Mayor (Chile)
[4] School of Physical Education and Sport University of São Paulo (Brazil)
[5] Laboratory of Exercise Sciences, Clínica MEDS (Chile)
[6] Department of Physical Education, Sports and Recreation, Universidad Metropolitana de Ciencias de la Educación (Chile)
e-mail: tomasherreravalenzuela@gmail.com

Physiological and physical profile of taekwondo athletes of different age categories during simulated combat

Submission: 25.03.2014; acceptance: 2.05.2014

Key words: match demands, athletic performance, combat sports

Abstract:
The purpose of the present study was to compare the physiological responses and the actions performed by taekwondo athletes from three different age groups. The sample consisted of children (10.9 ± 1.6 years), cadets (14.7 ± 1.3 years) and adults (23.4 ± 3.1) male taekwondo athletes, who participated in simulated taekwondo competition. Higher values were found in blood lactate cadets (9.49 ± 3.52 mmol.L-1) versus children (5.87 ± 2.45 mmol.L-1;, n2 = 0.274, P = 0.01), lower displacement values in adults (166.7 ± 20.2 m) versus children (225.4 ± 39.6 m, n2 =0.265, P = 0.01). Maximum speed also differed among groups (F = 3.39; P = 0.048; η2 = 0.195), with lower values for children (1.89 ± 0.22) versus adults (2.19 ± 0.34, P = 0.041) and cadets (2.16 ± 0.34, P = 0.025). For peak heart rate (HRpeak) there was an effect of group (F = 4.14; P = 0.027; η2 = 0.24) and of round (F = 10.55; P = 0.001; η2 = 0.28). Cadets had a higher HRpeak compared to adults (P = 0.025). Independently of age group, round 1 resulted in lower HRpeak compared to both rounds 2 (P = 0.004) and 3 (P < 0.001). Blood lactate, displacement, maximum speed and HRpeak differed among age groups, with no difference in acceleration and number of impacts. HRpeak and HRmean differed among rounds. The time spent during match simulated differed among HRpeak zones.

Introduction

Taekwondo is a high-intensity intermittent combat sport [Bridge, Jones *et al*. 2009; Marcovic, Vucetic 2008; Santos, Franchini *et al*. 2011]. Due to this characteristic, the relative and absolute intensity performed by athletes during competition or training is difficult to be quantified [Campos, Bertuzzi *et al*. 2012]. Thus, some authors have been measured the type and number of actions [Bridge, Jones *et al*. 2009; Matsushige, Hartmann *et al*. 2009; Santos, Franchini *et al*. 2011], the energy absorbed by the electronic body protector during competitions [Del Vecchio, Franchini *et al*. 2011], or some physiological responses as blood lactate [Bridge, Jones *et al*. 2009; Marcovic, Vucetic 2008; Matsushige, Hartmann *et al*. 2009], heart rate [Capranica, Lupo *et al*. 2011; Chiodo, Tessitore *et al*. 2011] and oxygen consumption [Campos, Bertuzzi *et al*. 2012]. The control of these variables can help to understand the physical and physiological demand of Taekwondo to improve the training methods applied to achieve such demand. While some of these measurements can be easily conducted (e.g., time motion analysis, heart rate, blood lactate), others are impractical in the training setting (e.g., oxygen consumption). Additionally, only a few studies analyzed technique, tactics and physiological responses to taekwondo match simulation or competition in young athletes [Capranica, Lupo *et al*. 2011; Casolino, Lupo *et al*. 2012; Chiodo, Tessitore *et al*. 2011].

To the best of the authors' knowledge no studies have examined the physiological responses and the time-motion analysis in high-level taekwondo athletes from different age categories. This

Table 1: Descriptive characteristics from children, cadet and adult taekwondo athletes.

	Children (n = 13)	Cadets (n = 13)	Adults (n = 5)
Age [years]	10.9 ± 1.6	14.7 ± 1.3	23.4 ± 3.1
Body mass [kg]	40.1 ± 8.2	56.0 ± 6.2	60.2 ± 5.4
Height [cm]	143.6 ± 10.4	165.3 ± 6.2	171.6 ± 3.2
BMI [kg/m^2]	19.21 ± 2.47	20.49 ± 2.13	20.41 ± 1.13

Data is shown as mean ± standard deviation.

knowledge can help coaches and sport scientists to understand better the training process in different ages, before the conducting of a longitudinal study to establish the process of competitive development more suitable for different age groups. Thus, the objective of the present study was to compare the physiological responses (heart rate and blood lactate) and the actions (accelerations, impacts generated, displacement and maximum velocity) performed by taekwondo athletes from three different age groups (child, cadets and adults). We hypothesized that the child group would present lower blood lactate and higher heart rate values compared to cadet and adult groups, while the adult group would present higher values of displacement, speed and acceleration during the match compared to child and cadet groups. Additionally, displacement, speed and acceleration would be correlated to physiological responses.

Materials and methods

Sample

Thirty-one high-level taekwondo athletes (5 adults, 13 cadets and 13 children) took part voluntarily in this experiment after giving their and their parents' (in the case of the subjects from the two under 18 year old groups) informed consent before their participation in the present study, which was approved by the local ethics committee. These athletes were previously selected to take part in the Chilean Olympic Training Center (CEO). Athletes injured or taking medications were not included in this sample. We comply with the human experimentation policy statement guidelines of the American College of Sport Medicine and in accordance with the Declaration of Helsinki. All athletes were evaluated in January and February 2012.

Study design

This is an observational descriptive study where the athletes were submitted to one experimental session. During the match simulation the athletes the following measurements were conducted: (a) physiological, blood lactate and heart rate; (b) time-motion analysis measurements, body displacements and accelerations.

Match simulation

The match consisted of three 2-min rounds with 1-min rest interval, reproducing the characteristics of a real taekwondo competition. Athletes were paired according to their body weight category and technical level.

Time-motion analysis

The body displacements, accelerations, number of impacts (i.e., the accelerations were measured in units of "G" force in the number of accelerations) and maximum speed were determined via a triaxial accelerometer EI SPi Elite (GPSports Systems, Australia) attached to each athlete. The acceleration generated by the three axis were registered 100 Hz. This equipment was previously validated [Edgecomb, Norton 2006] and has an overestimation of 4.8% for the total displacement.

Heart rate measurement

Heart rate was measured using the EI SPi Elite (GPSports Systems, Australia) integrated to a Polar sensor (Polar, Finland). This method presents a high correlation (R = 0.97-0.99) with the electrocardiographic measurements [Gameling, Berthoin *et al.* 2006]. We determined HRpeak and HRmean achieved during the match simulation.

Blood lactate measurement

Blood lactate was measured using a portable lactate analyzer (HP Cosmos, Germany). Blood sample was collected 1 minute after the exercise from a finger.

Statistical analysis

Data normality for heart rate, blood lactate, accelerations, speed and displacements were tested through the Kolmogorov-Smirnov test.

Table 2: Blood lactate, accelerations, number of impacts, displacements and maximum speed during a simulated taekwondo match in athletes from adult, cadet and child categories

	Children (n = 13)	Cadets (n = 13)	Adults (n = 5)
Blood lactate [mmol/L]	5.87 ± 2.45	9.49 ± 3.52[a]	6.90 ± 1.70
Acceleration [force G]*	9.7 (8.8; 10.4)	10.4 (9.5; 10.4)	10.1 (9.1; 10.4)
Number of impacts (over 1 G)	2736 ± 386	2695 ± 352	2426 ± 351
Displacement [m]	225.4 ± 39.6	208.1 ± 34.3	166.7 ± 20.2[a]
Maximum speed [m/s $^{-1}$]	1.89 ± 0.22	2.16 ± 0.34 [a]	2.19 ± 0.34 [a]

* = As data was not normally distributed, data are presented as median (25% and 75% percentile); a = different from child (P < 0.05).

Table 3: Peak and mean heart rate (bpm) during a simulated taekwondo match in athletes from adult, cadet and child categories

	Round 1[b]	Round 2	Round 3
Children [n = 13]			
HRpeak [bpm]	183 ± 29	192 ± 17	203 ± 7
HRmean [bpm]	166 ± 30	178 ± 20	185 ± 13
Cadets [n = 13]			
HRpeak [bpm]	188 ± 13 [a]	200 ± 8	201 ± 10
HRmean [bpm]	156 ± 16	184 ± 10	188 ± 13
Adults [n = 5]			
HRpeak [bpm]	173 ± 7	181 ± 8	182± 4
HRmean [bpm]	152 ± 13	166 ± 7	170 ± 5

a = different from adults (P < 0.05); b = different from rounds 2 and 3 for both HRpeak and HRmean (P < 0.01).

Table 4: Time (percentage of total) spent in different heart rate zones during a simulated taekwondo match in child, cadet and adult athletes

	<80% HRpeak	80-84% HRpeak [a]	85-89% HRpeak [b]	90-94% HRpeak	>95% HRpeak
Children	31.10±25.07	8.87 ± 4.00	11.53±5.55	21.97±11.36	26.53±14.04
Cadets	23.99 ± 12.11	9.79 ±5.43	18.10 ±6.41	28.80 ± 6.31	19.39±14.67
Adult	16.22 ±10.47	12.02±3.52	18.86 ±3.28	29.62 ± 7.90	23.32±19.89

a = different from all other intensities (P < 0.05); b = different from 90-94% HRpeak (P < 0.001)

Only acceleration did not achieve the normality criteria. The variables normally distributed were presented as mean and standard deviation and compared through a one-way or two-way analysis of variance, followed by the Tukey test. Acceleration was presented as median, 25% and 75% percentile and compared through a Kruskal-Wallis test, followed by the Dunn's test. Effect sizes were calculated for all results. The relationship between variables was calculated through Pearson correlation coefficient. The significance level was set at 5% (P < 0.05).

Results

Table 2 shows blood lactate, accelerations, number of impacts, displacements and maximum speed during a taekwondo match simulation.

Blood lactate differed among age groups (F = 5.27; P = 0.011; η^2 = 0.274), cadet group shown higher blood lactate concentration compared to the child group (9.49 ± 3.52 vs. 5.87 ± 2.45, P<0.01). On the other hand, we observed statistical differences in the distance between study groups (F = 5.05; P = 0.014; η^2 = 0.265), adult group shows lower values in comparison to the child group (P<0.01). Maximum speed during the match also differed among groups (F = 3.39; P = 0.048; η^2 = 0.195), with lower velocity in children compared to adults (P = 0.041) and cadets (P = 0.025).

Heart rate response to exercise is shown in table 3, statistical differences were found in HRpeak between age groups (F = 4.14; P = 0.027; η^2 = 0.24) and of round (F = 10.55; P = 0.001; η^2 = 0.28). Cadets had a higher HRpeak compared to adults (P = 0.025), but no other difference was found between age groups. Independently of age group, round 1 resulted in lower HRpeak compared to both rounds 2 (P = 0.004) and 3 (P < 0.001).

For HRmean there was only an effect of round (F = 29.83; P < 0.001; η^2 = 0.61), with lower values in round 1 compared to rounds 2 and 3 (P < 0.001 for both comparisons).

Table 4 presents the time spent in different heart rate zones during the taekwondo match simulation by the different age groups.

For time spent in different heart rate zones there was only an effect of intensity ($F = 6.38$; $P < 0.001$; $\eta^2 = 0.19$), with lower time spent in the 80-84% HRpeak zone compared to <80% zone ($P = 0.020$), to 85-89% HRpeak ($P < 0.001$), to 90-94% HRpeak ($P < 0.001$) and to >95% HRpeak ($P = 0.010$). Additionally, a lower time was spent in zone 85-89% HRpeak compared to 90-94% HRpeak ($P < 0.001$).

When all age groups were considered together the main significant ($P < 0.05$) correlations found between physiological and mechanical variables were: HRpeak during the match and impacts during the match ($r = 0.45$); HRpeak during the match and displacements during the match ($r = 0.38$).

Discussion

The main results from this study confirmed our hypothesis that higher blood lactate and lower HRpeak in adult compared to child taekwondo athletes. However, only displacement and maximum speed were higher in the adult group compared to child and cadet groups. Low to moderate correlations was found between HRpeak during the match and impacts and displacements during the match. Other important result was that HRpeak and HRmean during the match simulation were lower during the first round compared to rounds 2 and 3. Additionally, the time spent 80-84%HRpeak was smaller than other HR intensity zones, and a lower time was spent in zone 85-89%HRpeak compared to 90-94% HRpeak, but no difference was found among age groups.

Although no study compared taekwondo athletes from different age groups concerning blood lactate response to match competition or match simulation, investigations conducted with anaerobic tests normally reported higher blood lactate concentrations in adults compared to children [Van Praagh, Doré 2002]. However, it is possible that the small simple size in our adult group limited the test power [Zar 1999]. Another possible explanation for this result is that the adult group presented a smaller displacement during the match when compared to the child group. Thus, although this group could have a higher anaerobic capacity than the younger group, the tactics used by adults seem to be to avoid unnecessary displacements. Additionally, lower anaerobic power from the child group may affect the maximum speed achieved by the athletes from this group, which was lower than the achieved by the other two groups.

HRpeak differed among groups and seems to be related to an age effect as the two youngest groups presented higher values compared to the adult group, which is a common observation and many equations created to predict maximum heart rate use age as an independent variable [Robergs, Landwehr 2002]. While no difference was found between adult and child groups, cadets presented higher values compared to children.

HRpeak and HRmean increased from round 1 to rounds 2 and 3, a similar result observed in other studies [Campos, Bertuzzi *et al.* 2012; Capranica, Lupo *et al.* 2011]. Subjects from our group spent more time in the <80%HRpeak than previously reported by Capranica *et al.* [2011] in a study analyzing 10.4 ± 0.2 years-old children disputing an official taekwondo match. However, this profile were similar to that reported by Campos *et al.* [2012] in a study using adult taekwondo athletes submitted to one match simulation.

Only peak heart rate was low to moderately correlated to mechanical measurements, suggesting that physiological markers are not related to actions performed by the athletes during taekwondo matches. This result is similar to other results published previously, which indicated no significant correlation between physiological responses and technical actions performed during taekwondo matches [Bridge, Jones *et al.* 2009; Campos, Bertuzzi *et al.* 2012; Matsushige, Hartmann *et al.* 2009]. Thus, although physiological responses are important to training monitoring, coaches should also include time-motion analyses to obtain more detailed information about the training stimulus given to taekwondo athletes.

Conclusions

The main results from this study were: (1) physiological responses - higher blood lactate and HRpeak in cadet group compared to child and adults taekwondo athletes (respectively), and lower HRpeak and HRmean during the first round compared to rounds 2 and 3. Time spent at 80-84%HRpeak was smaller to that spent in all other HR intensity zones, with a lower time was spent at 85-89% HRpeak zone compared to 90-94% HRpeak, with no difference was found among age groups; (2) mechanical variables - the maximum speed were lower in the child group compared to cadet and adult groups, however the displacement were higher in the child group compared to adult group; (3) correlations - low to moderate correlations were found between HRpeak and impacts and displacements during the match.

References

1. Bridge C.A., Jones M.A., Drust B. (2009), *Physiological responses and perceived exertion during international Taekwondo competition*, "Int. J. Sports Physiol. Perform", vol. 4, no. 4, pp. 485-493.
2. Campos F.A., Bertuzzi R., Dourado A.C., Santos V.G., Franchini E. (2012), *Energy demands in taekwondo athletes during combat simulated*, "Eur. J. Appl. Phisiol", vol. 112, no. 4, pp.1221-1228.
3. Capranica L., Lupo C., Cortis C., Chiodo S., Cibelli G., Tessitore A. (2011), *Salivary cortisol and alpha-amylase reactivity to taekwondo competition in children*, "Eur. J. Appl. Physiol", vol. 112, no. 2, pp. 647-652.
4. Casolino E., Lupo C., Cortis C., Chiodo S., Minganti C., Capranica L., Tessitore A. (2012), *Technical and tactical analysis of youth taekwondo performance*, "J. Strength Cond. Res", vol. 26, no. 6, pp. 1489-1495.
5. Chiodo S., Tessitore A., Cortis C., Cibelli G., Lupo C., Ammendolia A., De Rosas M., Capranica L. (2011), *Stress-related hormonal and psychological changes to official youth Taekwondo competitions*, "Scand. J. Med. Sci. Sports", vol. 21, no. 1, pp. 111-119.
6. Del Vecchio F.B., Franchini E., Del Vecchio A.H.M., Pieter W. (2011), *Energy absorbed by electronic body protectors from kicks in a taekwondo competition*, "Biol. Sport", vol. 28, no. 1, pp. 75-78.
7. Edgecomb S.J., Norton K.I. (2006), *Comparasion of global positioning and computer-based tracking systems for measuring player movement distance during Australian Football*, "J. Sci. Med. Sport", vol. 9, no. 1-2, pp. 25-32.
8. Gameling F.X., Berthoin S., Bosquet L. (2006), *Validity of the polar S810 heart rate monitor to measure R-R intervals at rest*, "Med. Sci. Sports Exerc", vol. 38, no. 5, pp. 887-893.
9. Marcovic G., Vucetic V., Cardinale M. (2008), *Heart Rate and lactate responses to taekwondo fight in elite women performers*, "Biol. Sport", vol. 25, no. 1, pp. 135-146.
10. Matsushige K.A., Hartmann K., Franchini E. (2009), *Taekwondo: physiological response and match analysis*, "J. Strength Cond. Res", vol. 23, no. 4, pp. 1112-1117.
11. Robergs R.A., Landwehr R. (2002), *The surprising history of the "HRmax=220-age" equation*, "JEPonline", vol. 5, no. 2, pp. 1-10.
12. Santos V.G., Franchini E., Lima-Silva A.E. (2011), *Relationship between attack and skipping in Taekwondo contests*, "J. Stength Cond. Res", vol. 25, no. 6, pp. 1743-1751.
13. Van Praagh E., Doré E. (2002), *Short-term muscle power during growth and maturation*, "Sports Med", vol. 32, no. 11, pp. 701-728.
14. Zar J. (1999), *Biostatistical analysis*, Prentice Hall, New Jersey.

Fizjologiczne i fizyczne profile zawodników taekwondo w różnych kategoriach wiekowych podczas symulowanej walki

Słowa kluczowe: wymagania sportowe, wyniki sportowe, sporty walki

Streszczenie

Taekwondo jest sportem walki o wysokiej intensywności. Ze względu na tę cechę, intensywność względna i bezwzględna wysiłku wykonywanego przez sportowców czasie treningu lub zawodów jest trudna do określenia ilościowego. Stąd niektórzy autorzy mierzyli rodzaj i ilość działań, energię pochłoniętą przez elektroniczny protektor ciała podczas zawodów lub niektóre fizjologiczne reakcje np. wytwarzanie się mleczanu we krwi, tętno lub zużycie tlenu. Analiza zmiennych może pomóc zrozumieć wymagania fizyczne i fizjologiczne *taekwondo* oraz doprowadzić do poprawy metod szkoleniowych.

Celem niniejszej pracy było porównanie reakcji fizjologicznych oraz czynności wykonywanych przez zawodników *taekwondo* z trzech różnych grup wiekowych. Próba składała się z dzieci (10,9 ± 1,6 lat), kadetów (14,7 ± 1,3 lat) i dorosłych (23,4 ± 3,1) zawodników *taekwondo*, którzy wzięli udział w symulowanej konkurencji *taekwondo*.

Walka składała się z trzech 2-minutowych rund z 1 minutową przerwą, odtwarzając charakterystykę rzeczywistej konkurencji *taekwondo*. Sportowcy zostali sparowani w zależności od ich masy ciała i poziomu technicznego.

Przemieszczenia ciała, przyspieszenie, liczba uderzeń (np. przyspieszenia były mierzone w jednostkach siły „G") i prędkości maksymalne zostały określone przez trójosiowy akcelerometr, który posiadał na sobie każdy sportowiec. Tętno zostało zmierzone za pomocą EI SPI Elite (GPSports Systems, Australia) zintegrowanego z czujnikiem polarnym (Polar, Finlandia).

Wyższe wartości mleczanu we krwi znaleziono u kadetów (9,49 ± 3,52 mmol.L^{-1}) w porównaniu z dziećmi (5,87 ± 2,45 mmol.L^{-1}; n^2 = 0,274 , P= 0,01), niższe wartości odchyłowe u dorosłych (166,7 ± 20,2 m) w porównaniu do dzieci (225,4 ± 39,6 m, n^2 = 0,265, P = 0,01). Różnica w maksymalnej prędkości między grupami wynosiła (F = 3,39, P = 0,048; η^2 = 0,195), przy niższych wartościach dla dzieci (1,89 ± 0,22) w porównaniu do osób dorosłych (2,19±0,34, P=0,041) i kadetów (2,16±0,34, P=0,025).

Dla szczytowej akcji serca (HRpeak) rezultat dla grupy wynosił (F = 4,14, P = 0,027; η^2 = 0,24) i całościowy (F = 10,55, P = 0,001 ; η^2 = 0,28). HRpeak dla kadetów miał wyższą wartość w porównaniu do osób dorosłych (P =0,025). Niezależnie od grupy wiekowej, w rundzie 1 uzyskano niższą wartość HRpeak w porównaniu do obu rund 2 (P = 0,004) i 3 (P <0,001). Zawartość mleczanu we krwi, wartości odchyłek, prędkość maksymalna i HRpeak różniły się w grupach wiekowych, bez różnicy w przyspieszeniu i liczby uderzeń. HRpeak i HRmean różniły między rundami. Czas spędzony podczas symulowanej walki różnił się między strefami HRpeak.