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COACHING

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Physical and physiological profile of young female taekwondo athletes during simulated combat

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Key words: match demands, athletic performance, combat sports

Abstract

Aim and Method. The purpose of this study was to describe the physical performance (acceleration, number of impacts, distance and maximum speed) and physiological response (heart rate and blood lactate) of young female taekwondo athletes during combat simulations.

Material. The sample consisted of seven girls (13.1 ± 1.1 years), who participated in a simulated taekwondo competition.

Results. The main results observed were: post match blood lactate = 4.19 ± 2.03 mmol.L^{-1}; peak heart rate = 201 ± 7 bpm; maximum acceleration = 9.68 ± 0.52 G; number of impacts = 148 ± 42; total distance = 203 ± 69 m; and maximum speed = 7.07 [6.7, 8.2] km/h. A lower mean heart rate ($P < 0.05$; $F = 8.333$) was found in the first round (163 ± 14 bpm) compared with the second (182 ± 9 bpm) and third rounds (185 ± 10 bpm).

Conclusions. The main findings of the present study are that young female taekwondo athletes presented with low blood lactate after the match, performed around 150 impacts during the match, which occurred each 1.37 m – given that the total displacement is around 200 m – with high acceleration, and the displacements were performed at moderate speeds. In addition the heart rate was lower in the first round compared to the other two rounds.

Introduction

Taekwondo is a combat sport that has evolved in scientific and technological aspects since its inclusion as an Olympic discipline, forcing countries to seek information from the different variables involved in the sport process to achieve international best results [Bridge *et al*., 2014]. Taekwondo is considered a high-intensity intermittent sport, making it difficult to assess the effort made by athletes during competition or simulated combat [Campos *et al*., 2012]. In this context, several studies have quantified the type and number of actions performed and some physiological responses, such as blood lactate measurements [Bridge *et al*., 2009; Lee *et al*., 2012; Tornello *et al*., 2013], heart rate [Capranica *et al*., 2011; Chiodo *et al*., 2011] and oxygen consumption [Campos *et al*., 2012] during taekwondo matches, with intention to better understand the physical and physiological demands of this discipline.

Furthermore, in young taekwondo athletes the number of studies is smaller, existing studies regard hormonal and physiological responses [Chiodo *et al*., 2011; Pilz-

Burstein *et al*., 2010], the immunological impact [Lee *et al*., 2012], the technical-tactical analysis [Casolino *et al*., 2012] and time motion during the combat [Tornello *et al*., 2013]. In addition to the above, both physical and physiological responses have been determined simultaneously in male young athletes during combat simulations [Herrera *et al*., 2014].

There is scarcity of studies related to the variables of acceleration, speed, number of impacts and distance traveled during the match [Herrera *et al*., 2014]. Even to the best of our knowledge, this is the first study to describe these variables in young female taekwondo athletes. Therefore, the aim of this study was to describe the physical (acceleration, number of impacts, distance and maximum speed) and physiological responses (heart rate and blood lactate) performed by female young taekwondo athletes during a combat simulation. Moreover, the correlations between the displacement, speed and acceleration and physiological responses were also analysed.

Methods and subjects

Experimental approach

The purpose of this study was to describe the physical and physiological variables during taekwondo match simulation. Anthropometrical measurements and information concerning taekwondo experience were obtained before the match simulation. The variables measured during taekwondo match were heart rate, speed, number of impacts, distance and acceleration. This data was obtained by GPS integrated to a heart rate monitor. One minute after the match the blood lactate concentration ([BL]) was measured by taking a fingertip blood sample.

Subjects

Seven young female taekwondo athletes, selected to train in Chile's Olympic Training Center (mean ± SD: Age: 13.1 ± 1.1 years; body mass: 43.2 ± 6.7 kg; height: 151.7 ± 9.8 cm; BMI: 18.7 ± 1.6 kg/m^2; practice time: 3.1 ± 0.7 years) volunteered to participate in this study and their parents gave written consent to their participation in this study after being informed about the procedures and risks associated. They were free from any injury and neuromuscular disorder during the period the study was conducted. The study was approved by the Institutional Ethics Committee of the Universidad San Sebastián (Chile).

Procedures

Figure 1 presents a schematic description of the study design.

Taekwondo match simulation. Taekwondo match simulation consisted of three 2-min rounds with a 1-min rest interval in-between. The athletes were paired according to their weight category and technical level.

Physical measurement. 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 SPi Elite (GPSports Systems, Australia) attached to each athlete. The acceleration generated by the three axis was registered at 100 Hz. This equipment was previously validated [Edgecomb and Norton 2006] and had an overestimation of 4.8% for the total displacement. The impact classification system used in this study was based on methods used in

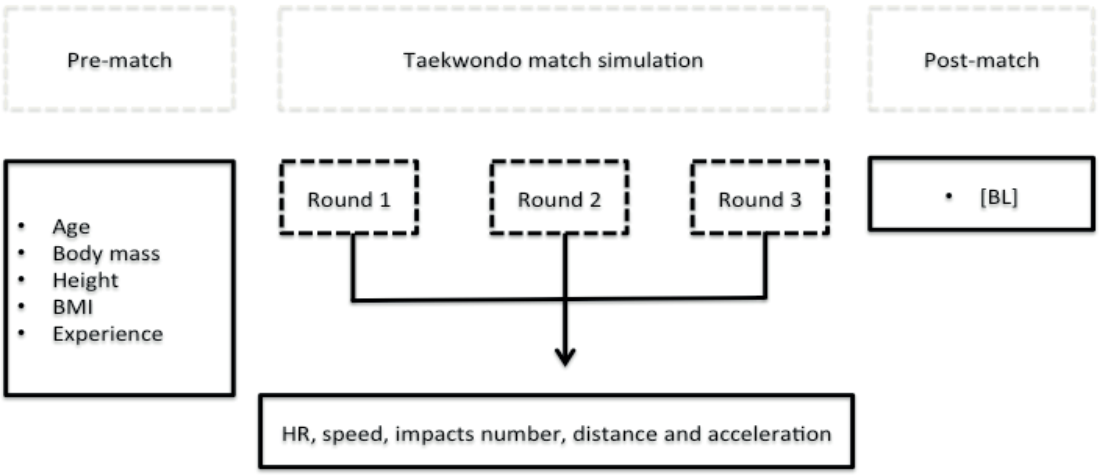

Figure 1. Schematic representation of the study design.
BMI: body mass index; HR: heart rate; [BL]: blood lactate measurements.

Table I. Blood lactate concentration post-match and acceleration, number of impacts, displacement and maximal speed during match n = 7 (data are presented as mean ± standard deviation).

Variables	Results
Blood lactate [mmol/L]	4.2 ± 2.0
Acceleration [G-force]	9.7 ± 0.5
Number of impacts [<5 G]	148.4 ± 42.0
Displacement [m]	203.3 ± 68.5
Maximum speed [k/h]*	7.1 (6.7; 8.3)

* Non-parametric variables are presented in percentiles (percentile 25%; percentile 75%).

Table II. Heart rate, number of impacts, displacement and maximum speed during each round of younger female taekwondo athletes during simulated combat.

Variables	N	Mean	SD	SE	95% confidence interval for the mean		Min.	
					Lower limit	Upper limit		
HRpeak (bmp)								
Round 1	7	192.6	9.1	3.4	184.2	201	181	205
Round 2	7	196	8.2	3.1	188.4	203.6	189	212
Round 3	7	199.3	7.7	2.9	192.2	206.4	192	213
Mean	7	196	8.4	1.8	192.1	199.8	181	213
HRmean (bpm)								
Round 1	7	163.3	13.6	5.1	150.7	175.9	141	180
Round 2	7	181.9	8.5	3.2	174	189.7	173	195
Round 3	7	185	9.5	3.6	176.2	193.8	173	200
Mean	7	176.7	14.2	3.1	170.3	183.2	141	200
Number of Impacts								
Round 1	7	45.9	11.5	4.4	35.2	56.5	26	60
Round 2	7	47.4	17.6	6.7	31.1	63.8	18	67
Round 3	7	44.6	10.5	4	34.8	54.3	34	61
Mean	7	46	13	2.9	40.1	51.9	18	67
Displacement (m)								
Round 1	7	70.3	26.7	10.1	45.6	95	41.4	109.6
Round 2	7	57.8	15.4	5.8	43.5	72.1	39.7	80.2
Round 3	7	55.3	25.7	9.7	31.5	79.1	34.4	107
Mean	7	61.1	23	5	50.7	71.6	34.4	109.6
Maximum speed (Km/h)								
Round 1	7	6.2	1	0.39	5.2	7.2	5.2	8.3
Round 2	7	6.2	0.85	0.32	5.4	7	4.4	6.8
Round 3	7	5.9	1.2	0.44	4.8	6.9	4.4	8
Mean	7	6.1	0.98	0.21	5.6	6.5	4.4	8.3

SD= standard deviation; SE= standard error

other sports [Cunniffe et al., 2009] and manufacturer guidelines (GPSports): (zone 1) 5-6 G, (zone 2) 6.1-6.5 G, (zone 3) 6.6-7 G, (zone 4) 7.1-8 G, (zone 5) 8.1-10 G, (zone 6) >10 G.

Heart rate. Heart rate was monitored through SPi Elite (GPSports Systems, Canberra, Australia) integrated to a heart rate monitor (Polar Electro, Kempele, Finland). According to the literature [Chiodo *et al.* 2011; Capranica *et al.* 2011] five categories of intensity of efforts were used to indicate the physiological load imposed on athletes during their competitions: (1) >95% HRpeak, (2) 90–94% HRpeak, (3) 85–89% HRpeak, (4) 80–84% HRpeak, and (5) <80% HRpeak. Then, the frequency of occurrence (%) of each activity category was calculated.

Blood lactate concentration. Blood lactate concentration was measured only post match (lactometer HP

Table III. Maximum heart rate zones of young female taekwondo athletes during simulated combat.

HRmax	N	Mean	SD	SE	95% confidence interval for the mean		Min.	
					Lower limit	Upper limit		
<80% HRmax	7	25	13.8	5.2	12.2	37.8	3.6	41.8
80-84% HRmax	7	10.5	5.5	2.1	5.5	15.5	2.8	17.5
85-89% HRmax	7	19.9	11.7	4.4	9.1	30.7	7.9	37.2
90-94% HRmax	7	25.4	9.4	3.5	16.7	34.1	13.2	38
>95% HRmax	7	19.2	16.2	6.1	4.2	34.2	0.6	42.8
Total	35	20	12.5	2.1	15.7	24.3	0.6	42.8

SD= standard deviation; SE= standard error

Table IV. Results of the comparison of speed median values (km/h)

X^2 =15,429; p =0,001 (***) gl.= 3; Median= 1,75 * significant**		<6 km/h	6–7 km/h	7–8 km/h*	
Km/h	> Median	7	5	1	1
	<= Median	0	2	6	6

Table V. Results of the comparison of G-force median values (G)

X^2 =27,007; p =0,001 (***) gl.= 3; Median = 18,0		(%)					
		5-6 G	6–6.5 G	6.5-7 G	7-8 G	8-10 G	>10 G
G-force values	> Median	7	7	2	2	1	0
	<= Median	0	0	5	5	6	7

*****= significant.**

Table VI. Results of the regression equation, adjusted coefficient of determination, adjusted regression coefficient and standard deviation of the values of the dependent variable (y) on the regression curve.

Regression equation	r^2 (aj,)	r (aj.)	S and.x
HRpeak (bpm) = 209.7 - 0.2994 Number of impacts	**0.171**	**0.4135 (*)**	**7.65**
HRpeak (bpm) = 189.7 + 0.1016 Displacement (m)	**0.029**	**0.1703 ns**	**8.28**
HRpeak (bpm) = 183.8 + 1.998 Maximum Speed (km/h)	**0.050**	**0.2236 ns**	**8.39**
HRmean (bpm) = 188.4 - 0.2536 Number of Impacts	**0.040**	**0.2000 ns**	**14.13**
HRmean (bpm) = 167.5 + 0.1513 Displacement (m)	**0.011**	**0.1049 ns**	**14.08**
HRmean (bpm) = 141.7 + 5.663 Maximum Speed (Km/h)	**0.076**	**0.2757 ns**	**13.6122**

Cosmos Sirius, Nussdorf-Traunstein, Germany) from a fingertip blood sample.

Statistical Analysis

Main results were firstly analysed according to Shapiro-Wilk normality test and homoscedasticity (homogeneity of variance) among compared groups. Then, descriptive statistics of each analysed variable was calculated. The groups' data with normality and homogeneity of variance were compared through a one-way ANOVA. Moreover, Tukey's test was followed for determining the order of analysed means and F-test associated to ANOVA was used for checking analysed results. In those cases where mentioned conditions were not achieved, the groups were compared with the use of the median test. Moreover, the regression equation, the coefficient of determination (r^2), the correlation coefficient (r), the significance of this coefficient by Student's t-distribution and the standard deviation of the regression curve (S and x) were estimated. The significance level was set at $\alpha \leq 0.05$ in all cases.

Results

Descriptive statistics, mean and standard deviation, for the physical (acceleration, number of impacts, displacement, and maximum speed) and physiological variables (blood lactate) are presented in Table I.

Table II shows that standard deviations are high due to the scarcity of data in each round and analysed variable, among other reasons. There were no significant differences ($p>0.05$) in F-test statistic (associated

to ANOVA) in all the comparisons among the analysed variables. Tukey's test presents the same results, except for the comparison of the rounds related with the HRmean (bpm) variable, which achieved a high significance ($p=0.003$; $F = 8.333$). In this case, when Tukey's test was applied, two groups of means were found: the first group is composed by the mean of the first round and it differs significantly from the second group ($p<0.05$), composed by the means of the second and third round.

Table III shows the estimate of descriptive statistics results in the %HRmax variable. Means are not significantly different between them, while standard deviations and standard error are high in some of these groups.

Table IV shows the results from the comparison of the speed median values (km/h). Results are higher than the global median values in groups <6 km/h and 6–7 km/h. The rest of the groups show the opposite results.

G-force variable shows the same pattern. Intervals of the first two groups comprise most of the values of this variable being higher than the global median (Table V). So, the first two groups of this variable present higher values.

Finally, Table VI shows the estimates of the regression equation, considering HRpeak (bpm) and HRmean (bpm) as dependent variables and the rest analysed variables as independent ones. The only equation presenting a significant result was the HRpeak (bpm) dependent variable with the number of impacts independent variable. The value of the coefficient of determination was 0.171 what it means that 17.1% of the total variation found in the dependent variable can be explained by the number of impacts. The coefficient of correlation is relatively low, but it is the equation with the lower dispersion of all the analysed ones.

Discussion

The main findings of the present study were that young female taekwondo athletes presented with low blood lactate after the match, performed around 150 impacts during the match, which occurred each 1.37 m - given that the total displacement is around 200 m - with high acceleration, and that the displacements were performed at moderate speeds. In addition the heart rate was lower in the first round compared to the other two rounds. This data is consistent with that found in young male taekwondo athletes [Herrera *et al*., 2014].

As in other studies [Campos *et al*., 2012; Herrera *et al*., 2014] the HR mean during the first round was lower when compared to rounds 2 and 3, which has been identified as a consequence of cumulative effort during the match and the short interval between rounds. This assumption of cumulative effort and short intervals contributing to the HR increase across the rounds is confirmed by the fact that no differences were observed in the distance covered, number of impacts performed or maximum speed achieved during the three rounds. These results demonstrate that cardiovascular demand is elevated during a taekwondo match, suggesting that coaches should consider improving the taekwondo-specific aerobic fitness of their athletes to allow them to deal properly with this physiological demand [Campos et al., 2012]. Additionally, the stability of distance covered, the number of impacts and maximum speed during the different rounds seem to indicate that athletes probably adopt a pacing strategy to maintain their ability to deal with the demands of the match.

Most of the distance covered during the match is done at low speed (i.e., less than 6 km/h), confirming previous reports concerning the time taken while stepping in taekwondo matches [Santos *et al*., 2011] and the high-intensity to low-intensity ratio [Bridge *et al*., 2009; Matsushigue *et al*., 2009]. Our findings add important information to these previous observations, as the number of impacts is around 150, resulting in one impact each 1.37 m displacements. This information can be useful to improve the training plan because coaches can create training activities taking into account that high-intensity actions are preceded by low-intensity stepping in a small space. Thus, taekwondo athletes should be trained to accelerate from slow speeds and to achieve the target positioned in a short distance.

It is probable that the high frequency of impacts performed by the athletes, HR kinetics, i.e., cumulative effort, and the short intervals between actions resulted in HR increases and those athletes who covered longer distances presented a higher HR peak during the match. However, as the scoring technique actions are powerful and short duration (1-2s) movements and the typical interval or low-intensity phases are 6 to 8 times higher, the blood lactate response presented by the athletes was low. This result confirms the observation made by Campos *et al.* [2012], who reported that a taekwondo match is mainly aerobic (66%), although the determinant actions are maintained by the anaerobic alactic system (30%), while the anaerobic lactic contribution is low (4%). As the taekwondo scoring system is based on minimum impact on the body protectors, athletes seem to avoid spending energy on conducting extremely intense efforts, which is confirmed by the lower number of impacts higher than 8 G. Displacements of young female taekwondo athletes under 7 km/h may be caused by the size of the combat area and the short distance to the opponent.

Conclusion

The main results from this study are that no differences are observed in the distance covered, number of impacts performed or maximum speed achieved during the three rounds. The high-speed movements and high-accelera-

tion actions are less performed than low-intensity actions, although these actions are considered important to score during the match. Typically, the high-intensity actions are performed after a low-intensity stepping action and after a small displacement, suggesting that training activities directed to acceleration improvement should be considered in the taekwondo training programmes. As the high-intensity to low-intensity ratio is low, the match anaerobic lactic contribution is small. However, the accumulative effort and the short interval between rounds result in HR increase from round 1 to rounds 2 and 3, achieving values considered elevated, indicating the need to cardiovascular training for dealing with the taekwondo match demand.

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Fizyczny i fizjologiczny profil młodych zawodniczek uprawiających *taekwondo* podczas symulowanej walki

Słowa kluczowe: wymagania meczowe, wyniki sportowe, sporty walki

Abstrakt

Wstęp. *Taekwondo* to sport walki, który ewoluował w aspektach naukowych i technicznych od czasu włączenia go do grona dyscyplin olimpijskich, zmuszając poszczególne kraje do poszukiwania informacji z różnych źródeł – instytucji zaangażowanych w proces osiągania wyników sportowych na poziomie międzynarodowym. *Taekwondo* jest uważane za sport o przerywanej wysokiej intensywności, przez co trudno jest ocenić wysiłek sportowców podczas zawodów lub w symulowanej walce. Celem niniejszej pracy jest przedstawienie fizycznych i fizjologicznych reakcji młodych zawodniczek *taekwondo* podczas symulacji walki.

Metody. Zmienne mierzone podczas walki *taekwondo* obejmowały: tętno, prędkość, liczbę uderzeń, odległość i przyspieszenie. Dane te zostały uzyskane przy użyciu GPS zintegrowanego z monitorem pracy serca. Minutę po meczu zmierzono stężenie mleczanu we krwi ([BL]), po pobraniu próbki krwi z palca. Siedem młodych zawodniczek *taekwondo* zostało wybranych na szkolenia w Olympic Training Center w Chile (średnia ± SD: wiek: 13,1 ± 1,1 lat, masa ciała: 43,2 ± 6,7 kg, wzrost: 151,7 ± 9,8 cm; BMI: 18,7 ± 1,6 kg / m^2; czas praktyki: 3,1 ± 0,7 lat). Udział w tym badaniu był dobrowolny, a rodzice zawodniczek wyrazili pisemną zgodę na ich udział po uzyskaniu informacji na temat procedur i ewentualnych zagrożeń.

Wyniki. Główne zaobserwowane rezultaty były następujące: mleczan we krwi po meczu = 4,19 ± 2,03 mmol.L^{-1}; szczytowe tętno = 201 ± 7 uderzeń na minutę; maksymalne przyspieszenie = 9,68 ± 0,52 G; liczba uderzeń = 148 ± 42; całkowita odległość = 203 ± 69 m; maksymalna prędkość = 7,07 [6.7, 8.2] km/h. Częstość akcji serca ($p < 0,05$; $F = 8,333$) stwierdzona w pierwszej rundzie (163 ± 14 bpm) była niższa w porównaniu z drugą (182 ± 9 rund BPM) i trzecią rundą (185 ± 10 BPM). Maksymalna osiągnięta prędkość wyniosła ok. 6 km/h oraz 6-7 km/h i jest wyższa od średniej światowej, a dla przyspieszenia, liczba uderzeń w obrębie 5-6 G i 6-6,5 G jest także wyższa niż średnia światowa.

Dyskusja. Ponieważ system punktacji *taekwondo* opiera się na minimalnym kontakcie cielesnym (zastosowanie ochraniaczy), sportowcy wydają się uniknąć wydatków energii wymagających bardzo intensywnych wysiłków, co jest potwierdzone przez mniejszą liczbę uderzeń o wartości wyższych niż 8 G. Przemieszczenia się młodych zawodniczek *taekwondo* poniżej 7 km/h jest prawdopodobnie spowodowane przez wielkość obszaru walki i krótką odległość od przeciwnika.

Wnioski. Główne ustalenia niniejszego badania wskazują, że młode zawodniczki *taekwondo* miały niski poziom mleczanu we krwi po meczu, wykonano około 150 uderzeń w trakcie walki, które wystąpiły co 1,37 m – biorąc pod uwagę, że całkowite przemieszczenie wyniosło około 200 m – z dużym przyspieszeniem i że to przemieszczenie nastąpiło przy umiarkowanych prędkościach. Ponadto, częstość akcji serca była mniejsza w pierwszej rundzie w stosunku do pozostałych dwóch rund.