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Blood indices and psychomotor skills demonstrated by elite male and female taekwondo performers during laboratory tasks of various intensity

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Summary

Introduction. The purpose of this study was twofold: (i) to examine time execution of kicks and the impact of kick during laboratory exertion simulating typical 3-round contests including kicks into a punching-bag, (ii) to determined of blood hormones changes and blood lactate responses to that exertion in males (M) and Females (F).

Material and methods. Two groups of taekwondo players: A (M=11, F=5) and B (M=4, F=1) underwent exertion of various intensities: Group A performed exertion of lower intensity (75 single blows) executed by left or right leg or a turning kick, group B 75 series consisting of 3 various blows that yielded 225 blows. Each type of action, single kick and 3-kick series were evoked by appropriate light signal in a randomized order. Serum cortisol (C) and testosterone (T) and blood lactate (LA) was determined during task performance.

Results. As expected, the hormonal (C and T), the metabolic (LA) and serum volume changes were higher in responses to Task B involving a more intensive exertion. Sex-related differences regarding C dynamic prior to task A and following it were observed as females demonstrated somewhat higher cortisolism. The mean impact adjusted to body mass was almost two times higher in males (47.8±9.1) than that in females (26.5±9.1N/kg), whereas the execution time was similar in the females (678.8±92.8) and males (794.3±86.0 m/sec).

Conclusions. The larger total number of blows executed during a contest, the stronger blood indices responses. Females demonstrated approximately similar execution time of blows as males, but considerably lower impact force.

Introduction

A single physical exercise brings about specific acute metabolic and hormonal changes, which are easy to detect in blood. These changes manifest themselves as a rise of blood concentration of several hormones for instance adrenaline, growth hormone, prolactin aldosterone, cortisol and many others, which are commonly considered as markers of physical stress or psychological stimuli. Post-exercise rise of blood lactate is an indicator of glycolysis rate induced by exertion. The magnitude of elevation of the above mentioned blood hormones are usually dependent on the intensity and duration of exertion and the level of physical fitness. In a consequence hormonal responses are modulated by type of training, (strength or endurance) and length of training period. End–exercise blood lactate is mainly dependent on exercise intensity and its peak is much higher following anaerobic than following aerobic exertion. In scientific studies or routine exercise examinations conducted among athletes, determination of blood indices is coupled with standardized, laboratory exercise and measures of various psychomotor parameters, such as work output, power output, strength, time reaction and so on. These measures are indicative of the current physical disposition and may reveal sport talent.

Among numerous sport events, combat sports often focus investigators attention. Taekwondo being a Korean, traditional martial arts was included into Olympic Games in 2004. For that reason, the knowledge on the biology of specific exertions is required for practitioners and their coaches. Some investigators focus their attention on anthropometric variables [1], personality profile [2-5], others – on head injury rate, mainly risk of concussion during competition [6-10]. Few studies were carried out on the physiology and ergonomics of taekwondo. It was found that Polish elite taekwondo players demonstrated better anaerobic capacity compared to kick-boxing athletes of the comparable sport class [11], but the laboratory test employed in that study (WINGATE) was not related to the psychomotor potential required for this martial art.

Few studies explored the two factors characterizing taekwondo kicks: execution time of motion and impact (maximal force of blow), and none of them was coupled with hormonal and metabolic observations during the specific task performance. Thus, the purpose of this investigation was twofold: (i) examination of psycho-motor skills during laboratory task simulating an official contest, (ii) determination of blood hormones and lactate in response to the above mentioned laboratory task in Polish elite taekwondo players.

Material and methods

Six female and fifteen male Polish taekwondo competitors, varied by age (20-26y) and body mass (51-96 kg) were subjected to this study. They were randomly divided into two groups. Each of those group underwent of laboratory tasks simulating official 3-round (3 x 2min) contests including kicks into purpose-made punching bag. Group A, 5 females and 11 males, underwent Task A of lower intensity, which included 25 various single kicks performed during each round, that makes 75 kicks during the whole task. During that test, three different types of single blows were performed in a randomized order as follows: simple frontal blows with the left leg, by right leg, and turning kick performed by dominance leg (360 degrees). Each type of blow was evoked by an appropriate light signal. Group (B), consisting of one female and four males underwent exertion of higher intensity, Task B. That test included 25 series of blows/round. Each series consisted of of 3 various blows in randomized sequence: right leg-left leg-turning kicks, left leg-right leg-turning and turning-left leg-right leg. The total number of kicks in Task B (225) was 3 time higher than that in Task (75), thus we may assume that exertion intensity in Task B was also three time higher. Various series of kicks in Task B were also evoked by various types of appropriate light signals. Execution time of blows was the time passed from a the light signal occurrence to the registration of peak impact force. The peak force was expressed in N and execution time was expressed in ms. Serum cortisol and testosterone levels were assayed in capillary blood sampled as follows: in the morning, prior to the tasks (-3min), and at +3 and +30 min of post- exertion recovery. Blood lactate levels were determined prior to and following exertion (+3 min). Hormones were determined by ELISA kit (DRG-GERMANY). To estimate the post-exercise serum volume, shift haematocrit was determined in glass capillary tubes after blood centrifugation. Blood lactate levels were measured by DR LANGE KIT. The protocol of this study was approved by the Ethics Committee at the Institute of Sport. To estimate the differences between the means (one-way ANOVA) and linear correlations between the variables the program STATISTICA software, version 8.0 (StatSoft USA) was used.

Results

The results of the experiment carried out among taekwondo players of the group A are presented in Table 1 and 2. The results of the experiment carried out in group B are presented in Table 3. The matrix of correlations is presented in Table 4.

In males, the mean cortisol level before the task performance (C2) was significantly ($p<0.05$) lower than that in the morning (C1) and at +3 following the task (C3), however, some athletes (M2- M5) demonstrated somewhat higher C2 than C1. In females, mean cortisol level before the task (C2) was significantly ($p<0.05$) higher than that in the morning (C1). Thus, within the time interval from the morning hours to the moment preceding Task A in males C dropped according to its daily rhythm,

Tab. 1. Serum cortisol (nmol/L) levels in the morning (C1), prior to Task A (C2) and in the 3rd (C3) and 30th (C4) minute of post-exertion recovery. The psychomotor variables: impact force (IF) and execution time (ET)

Sex	Cortisol (nmol/L)				Psychomotor variables	
Females N=5 Males N=11	**C1** 8:00	**C2** -3min	**C3** + 3 min	**C4** +30 min	**IF** (N/kg)	**ET** (msec)
F1 (62.0kg)	331	414	442	345	29.1	685
F2 (52.5kg)	460	614	460	414	33.1	835
F3 (51.0kg)	304	580	662	524	27.8	652
F4 (59.0kg)	290	331	326	254	39.3	617
F5 (56.6kg)	414	497	386	304	39.9	605
Means±SD	**360 ±74**	**$487^{C1,C4}$ ±117**	**462^{C4} ±119**	**368 ±105**	**26.5^{M} ±13.7**	**678.8 ±92.8**
M1 (56.0kg)	326	179	174	331	52.1	874
M2 (72.1kg)	254	276	273	265	45.4	912
M3 (60.0kg)	524	552	580	455	65.5	715
M4 (78.0kg)	276	326	331	331	36.3	887
M5 (92.0kg)	229	276	326	290	43.8	872
M6 (78.0kg)	326	304	359	276	44.6	760
M7 (69.0kg)	414	326	483	442	46.9	804
M8 (67.5kg)	359	270	414	414	57.4	641
M9 (79.2kg)	483	359	455	414	47.0	706
M10 (85.1kg)	455	331	442	345	33.6	777
M11 (72.9kg)	317	132	290	317	53.3	780
Means±SD	**360 ±97**	**$303^{C1,C3}$ ±107***	**375 ±113**	**352 ±68**	**47.8 ±9.1**	**794.3 ±86.0**

and in the females C change was opposite to the daily rhythm. The tendency of somewhat higher cortisolism in females occured prior to- (-3 min) and following (3+min) exertion. In both sexes cortisol dropped throughout 0.5h post task recovery. Mean execution times of kicks in males and females participating in Task A were comparable, and the difference between these means (115.5 msec.) is hard to estimate because of the small sample size of the females. The mean impact force adjusted to body mass was almost two times higher in males than that in females, and that difference was significant.

In males, mean testosterone levels at +30 min post task recovery (T4) was significantly ($p<0.05$) lower compared to those recorded in the morning (T1) and at +3min (T3). T1 in the males was somewhat higher (by 6%) than T2, but the difference was insignificant, hence T1, T2, and T3 were similar. Despite that fact, analysis of individual data similarities showed within-subject fluctuations of testosterone levels between the above mentioned time points. The majority of male athletes demonstrated either lowered T2 compared to T1 or lack of differences, but in two of eleven players, (M7 and M11), a marked rise of T was noted prior to the task. Task B was characterized by higher end-exercise lactate level, and, in particular, a much greater clear plasma volume shift. In females, the level of plasma testosterone prior to Task A tended to increase, however, because of the small sample size (n=4), that rise was not significant. Unexpected very high individual levels of T2, T3, and T4 were noted in female F3. All these values exceeded the upper physiological limit of plasma serum testosterone level in healthy females amounting to 4.2 nmol/L.

Blood lactate after warm-up and at +3 min following Task A did not vary between genders and within the whole group (n=16) they ranged from 1.2 to 2.8 mmol/L, and from 1.8 to 3.3 mmol/L before and after the task respectively.

Task B was characterized by higher intensity, manifested by a markedly higher end-exercise lactate level. Blood lactate after warm-up to Task B ranged from 1.8 to 3.1 mmol/L, and following exertion as follows: F6 -7.0 mmol/L, and in males, M1-M4: 10.4, 18.6, 12.9 and 9.9 mmol/L respectively.

Contrary to Task A, Task B induced rise of plasma testosterone in males by 27%. However, it is worth to note that post exertion decrement of serum volume affects post-task changes in testosterone level. Considering the lowered post task plasma volume, the relative total amount of testosterone in circulation increased by only 9.6%. Comparing cortisol dynamics during the recoveries, it is easy to notice the delayed post-task peak of the level in Task B (+30 min), whereas maximal post Task A cortisol level was noted at +3 min.

As C or T levels, measured at various time points are dependent variables, appropriate correlations are useless from diagnostic point of view and should be excluded. The only interesting finding is the relationships between hormones and execution time, and between body mass and relative impact force.

Discussion

As expected, the females demonstrated much more lower relative impact force of kicks than the males did. Likewise, similar sex-related differences in explosive strength among strength-velocity trained athletes, weightlifters [12-14], and track and field sportsmen (performance of countermovement vertical jumps) with respect to their blood testosterone [15] were reported. In our study, the male athletes (n=11) examined during Task A performance, demonstrated a decreased relative impact force for their body mass. That relationship, expressed as a significant negative linear correlation coefficient between body mass and relative impact force (r=-0.709) was in accor-

Tab. 2. Serum testosterone (T) (nmol/L) levels: in the morning (T1), prior to Task A (T2) and in the 3rd(T3) and 30th (T4) minute of post-exertion recovery. Relative post-exertion decrements of serum volume (ΔPV%)

Sex	Testosterone (nmol/L)				Serum volume change (%)	
Females (N=5) Males (N=11) (age y.)	**T1** 8:00	**T2** -3min	**T3** +3 min	**T4** +30 min	**1ΔPV** +3 min	**2ΔPV** +30 min
F1 (20.1)	1.28	1.04	1.04	0.97	+1.4	-0.6
F2 (17.0)	2.19	1.49	1.56	1.18	+1.9	-1.1
F3 (18.0)	*3.0*	*8.00*	*6.88*	*5.02*	+1.8	-0.9
F4 (17.2)	1.74	1.56	1.49	1.56	+1.7	-0.4
F5 (16.9)	2.95	3.64	3.12	2.60	+1.2	-1.0
Means±SD (excluded F3)	**1.74 ±0.45**	**1.93 ±1.16**	**1.80 ±0.90**	**1.58 ±0.72**	**1.6 ±0.3**	**-0.8 ±0.3**
M1 (17.3)	20.8	12.8	13.9	12.4	+1.4	-0.5
M2 (20.5)	19.1	21.9	21.9	18.4	+1.2	-0.4
M3 (20.2)	17.4	13.9	14.9	13.7	+1.6	-0.3
M4 (17.5)	15.6	12.1	14.6	13.9	+ 1.4	-1.0
M5 (20.0)	9.9	8.7	10.1	9.7	+1.6	-0.7
M6 (17.6)	18.4	15.6	13.9	11.8	+1.2	-0.6
M7 (17.4)	20.8	31.3	21.9	21.2	+0.9	-0.8
M8 (18.7)	22.9	19.1	19.8	18.2	+1.1	-0.6
M9 (20.3)	14.9	11.8	12.1	11.9	+1.6	-0.5
M10 (19.3)	19.8	14.6	17.3	14.2	+1.4	-0.6
M11 (24.6)	17.7	22.9	22.9	21.9	+1.7	-0.5
Means ±SD	**17.9 ±3.5**	**16.8 ±6.5**	**16.7 ±4.4**	**$15.2^{T1, T3}$ ±4.1**	**+1.4 ±0.3**	**-0.7 ±0.2**

Tab. 3. Serum cortisol (C), testosterone (T) in nmol/L, and relative decrements of serum volume (Delta PV%), and psychomotor variables: impact force (IP) and execution time of kicks (ET) during Task B

Subjects (body mass)	Cortisol (nmol/L)				Serum volume change (%)	
	C1 8:00	**C2** -3min	**C3** +3 min	**C4** +30 min	**1ΔPV** +3min	**2Δ PV** +30 min
F1 (77kg)	317	331	442	400	+11.4	-1.1
M1 (96.1kg)	539	304	326	497	+9.9	-0.5
M2 (71.0kg)	483	524	580	662	+14.8	-1.1
M3 (66.0kg)	276	442	497	607	+12.4	-0.7
M4 (83.0kg)	483	483	480	552	+12.8	-0.9
Means ±SD	**445 ±116**	**438 ±96**	**470 ±106**	**580 ±71**	**+12.9 ±1.4**	**-0.8 ±0.3**
	Testosterone (nmol/L)				Psychomotor variables	
Subjects (age y)	**T1** 8:00	**T2** -3min	**T3** +3 min	**T4** +30 min	**IF** (N/kg)	**ET** (msec)
F1 (26.2)	2.8	1.7	1.9	1.6	20.9	795
M1 (20.2)	17.4	14.9	19.8	17.4	32.8	687
M2 (23.4)	26.0	17.4	19.1	16.3	55.5	888
M3 (22.9)	31.2	26.0	34.7	22.9	30.3	909
M4 (19.9)	27.8	16.3	19.8	14.9	23.3	671
Means ±SD Exluded F6	**25.6 ±5.8**	**18.5 ±5.1**	**23.3 ±7.6**	**17.9 ±3.5**	**35.5 ±13.9**	**789 ±127**

Tab. 4. The matrix of coefficients of correlation among the blood variables (hormones), the indices of psycho-motor skills, impact force (IF), execution time (ET), age and body mass (BM) obtained from the data of 11males performing Task A

	C1	C2	C3	C4	T1	T2	T3	T4	IF	ET	age	BM
C1	-	0.66	0.80	0.80	0.26	0.00	-0.00	-0.00	0.33	-0.68*	0.00	-0.28
C2		-	0.83	0.57	0.02	0.12	-0.00	0.05	0.22	-0.349	-0.22	-0.07
C3			-	0.78	0.02	0.12	-0.01	0.03	0.25	-0.66*	-0.03	0.02
C4				-	0.26	0.22	0.08	0.19	0.50	-.0.65*	-0.12	-0.42
T1					-	0.58	0.64	0.56	0.24	-0.31	-0.26	-0.64*
T2						-	0.89	0.91	0.15	-0.05	0.11	-0.31
T3							-	0.97	0.15	-0.04	0.33	-0.32
T4								-	-0.21	-0.08	0.36	-0.31
IF									-	-0.50	0.27	-0.71*
ET										-	-0.10	0.15
age											-	0.15
BM												-

dance with appropriate relationships (body mass- peak power output and body mass-total work output) revealed earlier among the male and female judoists undergoing anaerobic exertion (WINGATE) [16]. The only study on execution time and impact force of kicks in taekwondo players, the experienced and novice ones, was carried out by Falco and co-workers [17]. The authors showed that those two groups differed with regard to the way of using their body mass to achieve maximal impact force of kicks. The other study revealed a beneficial effect of elastic resistance trainings for improving the velocity of turning kicks. [18]. The time measured from the start to impacting the target improved by 7% following 4-week period of elastic resistance training. That relative small change is important as, based on our observation, turning kicks are considered an effective but technically difficult motion, and its execution time is longer compared to simple kicks.

Two studies explored physiological parameters, such as aerobic capacity like VO2 max. That mean variable ranged from 49.8 [19] in elite national Croatian female players to 51.8 ml/kg/min in elite Turkish national team including 11 males and 11 females [20]. The above mentioned anaerobic capacity is an important factor, particularly during a tournament with several fights, for better capacity, a higher rate of post-contest recovery prior to successive exertions. Moreover, aerobic capacity modulates hormonal and metabolic responses to maximal exertion and should be taken into consideration in the interpretation of the obtained blood indices.

In our study aerobic capacity was not investigated and was unknown for us. Comparing changes in blood indices following Task A and Task B, it is easy to conclude that 3 times higher intensity (number of kicks) resulted in higher rises of cortisol and testosterone levels in males and blood lactate levels in both sexes. In Task B, anaerobic glycolysis, expressed as end-exertion mean blood lactate level (11.8 mmol/L n=5), was approximately similar to the mean value recorded following the official 3-round taekwondo contest (11.7 mmol/L) when the mean numbers of kicks were 7.9, 9.9 and 14.3 during the1st, 2nd and 3rd round respectively [19]. The similar results of lactate responses to taekwondo fighting (two times 2 min) times, La 11.4 mmol/L reported by other researchers [21, however, unexpectedly decreased lactate levels (3.35 mmol/L) were recorded during simulated competition among elite Korean players [22]. Despite that, we may assume, that Task B represents the level intensity of exercise typical for competition boats. Despite large lactic acidosis, recorded following Task B we did not observe poorer execution time of blows in comparison to those following Task A. That indicates good adaptation of the examined athletes to anaerobic exertion, in contrast to that observed in untrained subjects who were subjected to graded exercise. The relation between time reaction and lactate level recorded in selected time points of that test represented U curve with minimal reaction time when the lactate concentration was of 5.5 mmol/L. [23,24].

Higher post- end pre-task cortisol levels were found during more intensive trials, which is a well known phenomenon reported by numerous investigators. As for the post-task change of testosterone concentration, (among males only) its mean rise was noted only following Task B, but not following Task A. Acute and temporary higher secretion of testosterone from the testes following exercise is mediated by appropriate secretion of adrenaline, as was reported by Jezová and coworkers [25]. Hence, we may assume, that the higher exercise stress after Task A induced higher adrenaline levels and consequently, an increase in testosterone levels. However, strong anticipation of any task may also be the reason for the pre-event rise in testosterone via adrenaline secretion, that is noted in some cases (in M7 and M11) prior to Task A. Probably, in our experiment, this pre-task rise in testosterone levels (in males), being a positive difference between morning and pre-task levels is blunted and masked by physiological diurnal rhythm of testosterone, i. e. natural drop of T at daytime that occurs in neutral conditions. Post-task testosterone levels tended to be higher in older males, however, because of relatively small samples, coefficients of correlation between age and the post-task androgen levels at +3 min (r=0.326) and +30 min of recovery (r=0.360) were not statistically significant. That tendency is in accordance with the results obtained by other authors [26], who noted significantly higher end-exercise testosterone levels in older males as compared to younger ones. Some authors point out, that the larger extent of post-exercise decrements in plasma volume has to be taken into consideration when relatively small changes in blood indices are small, and the deliberations, whether the observed rise in these parameters resulted in secretion or lowered metabolic clearance rate or haemoconcentration are unavoidable [27]. Changes in metabolism rate are hard to evaluate, but plasma volume shift is easy to estimate due to haematocrit measures in blood samples. Thus, the elevation of the levels of several blood indices, like endogenous proteins (albumin, transferrin, SHBG) as well as testosterone recorded in males following two different high-intensity exertions might be elicited by haemoconcentration, [28]. In contrast to that, an anaerobic exercise lasting 1h did not affect plasma volume shift [29]. In our study, Task B induced mean plasma volume of 12.9%, which was similar (12.3%) to that induced by 30-s maximal exertion (WINGATE-TEST) [30]. As mentioned earlier, mean relative blood testosterone increment after Task B in males was almost three times lower when adjusted to haemoconcentration, Moreover, the contribution of possible metabolism inhibition to the hormone accumulation in blood is unknown. In summary, psycho-motor task in laboratory conditions, coupled with determination of blood indices, seems to be a useful tool for estimation of physiological profiles in taekwondo players. It seems, however, that winning in this sport is not simple product of physical capacity or short time reaction, thus, additional predictors of success have to be searched by coaches and investigators.

Conclusions

1. This study highlights that intensity of the exertion involving 225 different blows into punching -bag represents intensity of boats typical for an official contest.
2. Capillary blood sampling for selected parameters allows to determinate real biological cost of the exertion.
3. The tendency of higher blood cortisol in females, examined prior the Task A and following it, may suggests higher pre- and post-task overall stress.

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