ORIGINAL ARTICLE

Usefulness of the psychomotor tests for distinguishing the skill levels among older and younger judo athletes

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Abstract

Background & Study Aim: Cognitive functions of combat sports contestants, such as visual perception, information processing, divisibility of attention and eye-limb coordination play an important role in solving the problems related to tactic and strategy during a fight. The purpose of this study was to answer the question: whether performance level of the two various psycho-motor tests is linked to the sport levels among male judo athletes.

Material & methods: The psychomotor studies involved four groups of male judo athletes. Two groups were composed of highly skilled senior members of the Judo National Team (HSS, n = 18, age 22.7±3.0) and junior members of the Judo National Team (HSJ, n = 24, age 17.8±0.9), who were more successful than the others and therefore were called up to the Polish National Team. Two other groups were less successful and possessed lower skills, i.e. seniors (LSS, n = 24, age 23.2±3.3) and juniors (LSJ, n = 26, age 18.8±0.6), who were not selected into the national teams. All groups were examined at rest state in the forenoon at the same period of the training season.

Results: The older groups (HSS+LSS) showed better performance of the psychomotor tests than the younger ones (HSJ+LSJ). Likewise, the highly skilled groups (HSS+HSJ) obtained better scores than the lower skilled ones (LSS+LSJ). Only highly skilled groups and the entire group showed significant correlations between age or training experience and psychomotor skills.

Conclusions: The psychomotor abilities were better among older athletes allowing to formulate two competing hypotheses suggesting that: (1) long-term judo training (assuming the similarity of the characteristics of all subjects before the start of the training) has a positive effect on the development of cognitive functions of a human, which translates both into high athletic performance and improvement of motor safety during daily physical activity; (2) high athletic performance in judo is conditioned by an optimal level of psychomotor abilities.

Key words: cognitive functions · psychomotor abilities · sport achievements · training experience

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Introduction

Reaction time (RT) – the interval of time that elapses from the sudden presentation of a stimulus to the beginning of a person's response [5]

Movement time (MT) – the interval of time that elapses from the beginning to the end of a movement [5]

Non-apparatus test – motor test (exercise endurance test) of the required reliability (accurate and reliable), which use does not require even the simplest instruments [66]

Quasi-apparatus test – test that can be conducted with simple instruments (a stopwatch, a ruler, a measuring tape, etc.) [66]

Motor safety – is a consciousness of a person attempting to solve a motor task or consciousness of the subject who has the right to encourage and even enforce from this person that would perform the motor activity, who is able to do it without the risk of the loss of life, injuries or other adverse health effects [67]

Sutemi (jap.) **–** the state of sacrificing one's all in a match, or executing a technique without thinking about the outcome [57]

Waza – a technique or movement which is based on a standard form and is used to challenge and defeat the opponent [57]

Boxing, fencing, judo, taekwondo (WTF) and wrestling constitute a group of Olympic combat sports. Athletes, who practise such sports, should have not only high physical capacity and technical skills but also particular, well-developed features of central nervous system (visual and sensory perception, fast information processing, correct decision-making process and fast realization of a task).

Scientists use various tests to assess human psychometric capacity, which may be based on electronic devices and computer programmes [1-6] or classified as quasi-apparatus or non-apparatus tests: e.g. *pen and paper* test, catching scale-bearing rod (psychomotor reaction index measured in centimetres – what matters is the distance from captured space on the rod to bottom of the hand converted to milliseconds according to the applicable formula [8]). Some scientists measure reaction abilities with the use of numerous tests only in millimetres without converting the result to milliseconds [9,10]. Athletes are usually examined in terms of response time, i.e. certain movement towards the goal performed with a hand (to a button) or leg (to a pedal) in response to light and sound stimuli generated irregularly by an electronic device [11-13].

If the instructions are to react to only one type of stimulus, simple reaction (response) time is measured. In case when a subject has to react to several types of stimuli generated irregularly and in random order, reaction (response) time with choice or complex reaction time are measured. Other types of psychometric tests include a series of consecutive the same or different stimuli generated in random order but with regular imposed frequency. In this case, an examined person is expected to respond correctly before next signal appears. Each delayed or inadequate response is treated as an error, whereas the sum of correct answers in a given series determines the level (quality) of test performance. This type of tests have various difficulty levels – the higher frequency of signals, the more difficult the test. So-called GO/NO GO tests are the most complex task. During such test electronic system generates randomly a series composed of various repeated types of stimuli including 'forbidden' signals that should be ignored by a tested person. Spontaneous response to forbidden signal as well as delayed or inadequate response to appropriate stimuli are considered as errors.

Scientific literature describes direct influence of different external factors on the level of cognitive-executive functions examined with various psychomotor tests including response time measurements. Considerable attention has been devoted to research on momentary changes in response time and activation of the sympathoadrenal response examined with the use of direct measurements after various physical efforts [14-26], after exposure to hard environmental conditions or lack of sleep [27-31]. Scientists have also determined the relationship between response time and age, physical activity and/or health [32-35] and in healthy subjects after administration of erogenic substance [36-38]. Numerous psychomotor tests have been conducted on competitive athletes, however judo competitors participated only in few [39-41].

Similarly to other sports, in judo basic principle of being selected to the national team (as well as regional team, sports club, etc.) embraces the result obtained in high-level competitions (international championships, national championship of senior or juniors, etc.). Medallists are appointed in a way obligatorily to the national team, whereas those who did not win any medals are appointed only in exceptional cases.

We have adopted four elementary assumptions in our study:

main characteristic of national team competitors is a cumulative effect of talent for sports judo with high level of training, while other athletes can be characterized with lower level of both factors or at least one;

there are four possible combinations of two factors: (a) a novice is extremely talented and despite short training experience achieves extraordinary sports results; (b) a novice is extremely talented but short training experience affects the level of sports education so that he does not achieve athletic performance adequate to innate predispositions; (c) a novice is not highly talented but long training experience translates into athletic performance useful in the national team; (d) a novice is not highly talented and despite long training experience he has not reached the training level that could be translated into satisfying athletic performance;

due to the fact that training experience is correlated with the age of an athlete (taking into account another assumption stating that each athlete is trained by highly qualified coach) highly talented and well-trained judo athletes achieve outstanding sports results;

on one hand, membership either to senior or junior national team of judo proves positive correlation of

talents and high level of training; on the other hand, judokas age is a sufficient criterion to separate both teams due to training level (therefore, age criterion of judokas and membership to national team or group of other active competitors form the basis of division and classification of tested people in this study).

The purpose of this study was to answer the question: whether performance level of the two various psychomotor tests is linked to the sport levels among male judo athletes.

Material and methods

Participants

The following four groups of male judo athletes have been tested in the study: highly skilled senior members of the Judo National Team (HSS, n = 18, age 22.7±3.0), junior members of the Judo National Team (HSJ, n = 24, age17.8±0.9), less skilled seniors (LSS, n = 24, age 23.2±3.3) and less skilled juniors (LSJ, n = 26, age 18.8±0.6). All groups were examined at rest state in the forenoon at the same period of the training season. The study was approved by the Local Ethics Committee.

Procedures

Using electronic device MRK433 competitors performed in a sequence the following psychomotor tests: Test-1 and Test-2.

Description of Test-1 (type of task GO/NO GO)

The device generates randomly four different signals, 3 light signals: yellow, red and green, and one sound signal. Tested person should press a button with preferred hand, when yellow signal appears, other light and sound stimuli are supposed to be ignored. A total of 30 various (light and sound) signals appear during the test, including 10 yellow stimuli. End result is a total time of response to yellow stimuli.

Description of Test-2 (visual and motor coordination of upper and lower limbs stimulated by light stimuli (three colours) and acoustic signal)

The task is to react with a movement of right hand to yellow stimulus, left hand to red stimulus, right leg to green stimulus and left leg to acoustic signal. Test result is an execution time of tests composed of 20 stimuli and the number of correct answers.

Statistical analysis

The Shapiro-Wilk test has been used to verify the normality of empirical data on each group. Non-parametric tests have been applied to analyze empirical data due to lack of normal distributions. The Mann-Whitney test has been used to investigate mean differences between two compared groups. Statistically significant differences were adopted to be $p<0.05$. Linear correlations between variables were tested with the use of Spearman's correlation coefficients. Intergroup comparison of results obtained on the basis of tests performed for groups HSS vs. LSS, HSJ vs. LSJ, HSS vs. HSJ, LSS vs. LSJ.

In addition, competitors were grouped according to the following criteria: *age*: older competitors, i.e. seniors (HSS+LSS, n = 42); younger competitors, i.e. juniors (HSJ+LSJ, n = 50); *training experience*: members of the National Judo Team (HSS+HSJ, n = 42); other active judokas (LSS+LSJ, n = 50).

The results obtained in two combined groups have been compared: between seniors (HSS+LSS) and juniors (HSJ+LSJ), and national team competitors (HSS+HSJ) and other judokas (LSS+LSJ).

Results

Judo athletes with the longest training experience (HSS) obtained higher average results in tests (shorter time of task execution and higher number of correct responses) than other examined judokas (Table 1). Except for the results obtained in Test-2, lower value of standard deviation indicates that HSS judokas are more similar in terms of measured physical properties than other examined subjects. HSS and LSS senior groups did not significantly differ in age ($p = 0.684$), whereas differences in training experience were statistically significant ($p<0.05$). Junior members of the national team (HSJ) and other juniors (LSJ) significantly differed in age and training experience ($p<0.001$).

Table1. Characteristics of the groups and their psychomotor abilities expressed as the scores of the Test-1, Test -2 and number of correct responses (CR) in the Test -2

Group	Age [years]	Training experience [years]	Test-1 [sec]	Test-2	
				[sec]	(CR)
HSS (n = 18)	22.7 ±3.0	11.0 ±2.6	2.86 ±0.22	12.57 ±1.59	16.78 ±1.83
HSJ (n = 24)	17.8 ±0.9	8.3 ±1.7	3.20 ±0.29	13.86 ±1.70	15.15 ±2.76
LSS (n = 24)	23.2 ±3.3	8.9 ±2.5	3.14 ±0.25	13.8 ±1.50	15.63 ±2.50
LSJ (n = 26)	18.8 ±0.6	3.6 ±1.2	3.36 ±0.40	14.1 ±2.00	14.21 ±3.32

The result of Test-1 proves that in general sense (taking into account mean scores and standard deviation) competitors from groups comprising senior and junior members of the national team (HSS+HSJ) react faster to light stimuli and sound stimulus than athletes who are not members of the national team (LSS+LSJ) and, moreover, are less diversified in this respect from other judokas (Table 2). Similar relationships can be observed in results of Test-2 (HSS+HSJ react faster with the limbs to visual stimuli, generate greater number of correct motor responses and are less diversified in terms of measured ratios than LSS+LSJ). However, taking into account the criterion of *training experience*, only the result of Test-1 indicates higher (statistically significant) level of adaptation of senior and junior members of the national team (HSS+HSJ) in comparison to other judokas from both age groups (Table 2).

The criterion of age favours seniors who treated as an entire group (HSS+LSS) not only have reacted faster to the stimuli and had more correct responses but also were less diversified in this respect when compared to juniors (HSJ+LSJ). Among seniors (HSS vs. LSS) higher training level was manifested by faster reaction to stimuli in laboratory conditions (T-1 $p<0.001$, T-2 $p<0.05$). Such relationship does not occur among juniors from the national team and other juniors (Table 2).

Spearman correlation coefficients indicate the strongest correlation of response time to stimuli and correctness of motor responses during Test-2 (Table 3, column T-2 [sec/CR]). All correlations are significant ($p<0.01$) and negative, what proves that judo athletes who had the greatest number of correct motor responses could also be characterized by shorter response time to stimuli generated in laboratory conditions. Qualitative diversification of this relation is, however, significant. Coefficient of determination (r^2) expressed in % accounts for 45% in seniors from the national team (HSS) and 79% in juniors (HSJ). In case of seniors and juniors who are not members of the national team it amounted respectively to 56% and 71% (Table 3).

Test-1 has diversified to greater extent examined groups in terms of the relationship between response time to stimuli and other empirical variables. In case of Test-2 this property is displayed in higher degree by CR ratio than response time to stimuli. The highest number of significant correlations between pairs of analyzed empirical variables can be applied to seniors (Table 3, line HSS + HSJ) and secondly to the results generalized for all examined subjects (line Total).

Table 2. Comparison of the test performance between the senior group (S), junior group (J), the national teams (highly skilled-HS) and other judokas (lower skilled-LS)

Groups and tested relationships		Results (mean scores and standard deviation: z = standard score * p = significance level)		
		Test-1 [sec]	Test-2	
			[sec]	Correct responses to 20 signals (CR)
Criterion of training level				
national teams S+J	HSS+HSJ	3.06±0.32	13.33±1.76	15.81±2.54
other judokas S+J	LSS+LSJ	3.25±0.35	13.98±1.78	14.85±2.95
skill-related differences (HSS+HSJ) vs. (LSL+LSJ)		**z = –2.59 p = 0.009**	z = –1.68 p = 0.094	z = 1.57 p = 0.115
Criterion of age				
seniors	HSS+LSS	3.02±0.28	13.28±1.64	16.12±2.29
juniors	HSJ+LSJ	3.28±0.36	13.99±1.83	14.64±3.00
age-related differences (HSS+LSS) vs. (HSJ+LSJ)		**z = –3.49 p=0.000**	**z = –2.02 p = 0.043**	**z = 2.36 p = 0.018**
differences between seniors HSS vs. LSS		**z = –3.29 p = 0.001**	**z = –2.287 p= 0.022**	z = 1.45 p = 0.151
differences between juniors HSJ vs. LSJ		z = –1.495 p = 0.135	z = –0.669 p = 0.503	z = 1.204 p = 0.229

*the value of 'z' is interpreted here as deviation from unit normal curve [42]

Table 3. Matrix of correlation coefficients between age, training experience, Test-1 (T-1), Test-2 (T-2) and the number of correct responses (CR) observed within various groups

Group	Age [years]			Training experience [years]			T-1/T-2 [sec]	T-2 [sec/CR]
	T-1 [sec]	T-2		T-1 [sec]	T-2			
		[sec]	CR		[sec]	CR		
HSS (n = 18)	**–.579***	–.365	.433	–.221	–.305	.378	**.482***	**–.670****
HSJ (n = 24)	–.275	–.100	.207	–.299	–.020	.139	.222	**–.890****
LSS (n = 24)	–.055	–.089	.243	–.147	–.190	.322	.356	**–.749****
LSJ (n = 26)	–.042	.041	.108	–.197	.003	.007	.306	**–.841****
HSS + LSS (n = 42)	–.06	–.09	**.364***	–.187	–.247	**.395****	**.358***	**–.720****
HSJ + LSJ (n = 50)	–.196	.043	.109	–.199	.003	.008	**.345***	**–.883****
HSS + HSJ (n = 42)	**–.589****	–.365	**.433****	–.221	**–.307***	**.378***	**.482****	**–.828****
LSS + LSJ (n = 50)	**–.275***	–.100	.207	**–.299****	–.018	.139	.221	**–.811****
Total (n = 92)	**–.384****	–.186	**.283****	**–.314****	–.182	**.282****	**.364****	**–.835****

*p<0.05 ** p<0.05

Discussion

One of the most significant research on the reaction time combat sports athletes was conducted by Zbigniew Borysiuk [11, 12]. He found out [12] that novice fencers achieve better results than advanced fencers in terms of movement time (MT: 62.53 ms, advanced fencers 69 ms) who in turn achieve better results than novice athletes in terms of reaction time (RT: 160.93 ms, novice athletes 183.2 ms). Differences between advanced fencers and novice fencers are the most distinct when comparing MT and RT in spatial anticipation test (RT of advanced fencers amounted to 117.16 while novice fencers to 156.73, MT respectively: 44.25, 56.2) and also in choice reaction test (RT of advanced fencers amounted to 238.33 while novice fencers to 299.47, MT respectively: 99.217, 103.09).

In his previous monograph [11], Borysiuk has published the results of the study on fencing (n = 27), karate kyokushinkai (n =25) and taekwondo WTF (n = 22) athletes, who differ within each sport in age, training experience and level of athletic performance. Groups qualified for specialist phase of training included only athletes with master or first sports class (n = 12; 11; 10 respectively) and their average age amounted to 22.1 years, whereas average training experience was 8.3 years. In groups that participated in preliminary phase of training (n = 12; 11; 10 respectively) the average age amounted to 14.7 years, whereas average training experience was 2.8 years. All members of this group have already had experience of participation in regional and national sport competitions in relevant age categories. In his conclusion Borysiuk states that significant differences in response time to tactile and visual stimuli emerged in profiles of athletes who participated in specialist and preliminary phase, whereas differences were not significant in case of responses to acoustic stimuli. He concludes that responses to tactile and visual stimulation can be trained to the highest degree. He further states that the characteristic similarity trend was related to motor aspect of sensorimotor responses to three types of stimuli. These observations are interpreted as follows: predispositions to perform fast movements become apparent in the early phase of training and are only slightly subjected to further development; type of stimulation, in contrast to response time (RT), does not influence the variability of movement time (MT) rates [11].

Borysiuk examined combat sport athletes who specialize in delivering and avoiding blows – karate and taekwondo athletes deliver blows with their limbs to the competitor's body and avoid blows directed by the

competitor at them (domination of visual stimuli), whereas motor specialization of fencers is asymmetric, hence limited to manipulate only one armed arm and very frequently the attack is preceded by 'weapon-weapon' contact (tactile stimuli occur). In judo both the distance between fighting athletes and the type of motor response to stimuli generated by a competitor are clearly determined by the necessity to grasp each other clothes (domination of tactile stimuli). Moreover, when throwing a competitor off balance simultaneously using hands and supporting leg (*o soto gari* throw, *o uch gari* throw, etc.), direct contact of the bodies is significantly larger than in preparatory stages for a throw. This contact is even more extensive during *gosni waza* throws and some *sutemi waza* throws. Therefore, tactile stimuli play a special role for judo athletes and it should be expected that they will obtain better results (in qualitative sense) in laboratory tests than athletes specializing in other combat sports. The results should, however, be compared using the same research methodology and, in addition, using more sophisticated tools.

Perhaps, this methodological aspect determines the fact that observations made by Borysiuk and conclusion drawn from them are only partially confirmed by the results of our study. Borysiuk's hypothesis, that "responses to tactile and visual stimulation can be trained to the highest degree" is confirmed in our research – paradoxically with an accent on visual aspect, what follows from used research tools – by the following three results: seniors treated as the entire group reacted faster to the stimuli and generated larger number of correct responses than juniors (HSS+LSS vs. HSJ+LSJ); higher training level was manifested by faster response to stimuli in laboratory conditions among seniors (HSS vs. LSS); such relationship does not occur among juniors (HSJ vs. LSJ).

On the basis of the results of our study it is difficult to verify the correctness of the conclusion made by Borysiuk that "characteristic similarity trend was related to motor aspect of sensorimotor responses to three types of stimuli".

We believe that two combining aspects are relevant in discussion of the research result (both ours and other authors') concerning reaction abilities. The first one refers to specificity of combat environment. The second relates to critical assessment of research methodology used, including adequacy of research tools (is this specificity aptly described?).

In theory of combat sports it is accurate to divide those sports into three groups according to the criterion of "permissible method to influence directly the competitor's body during a fight" i.e.: *using weapons* (fencing, kendo etc.), *blows* (boxing, karate, kick-boxing, taekwondo, etc.), *throws and holds restraining a competitor* (judo, sumo, wrestling, etc.) [43]. The relevance is mainly confirmed by specific differences in body build of people training various combat sports (disregarding important factors such as: sex, weapon type in fencing, weight categories in particular combat sport) regardless of detailed research methodology adopted by individual scientists: Katarzyna Sterkowicz-Przybycień et al. bases on the set of commonly used anthropological indicators [44-46], whereas Władysław Jagiełło et al. additionally used Perkal's method [47, 48], which is little-known in Anglo-Saxon literature; also in study on women practicing modern pentathlon where fencing (as a combat sport) is only one fifth of the competition [49].

Numerous studies confirm a regularity that an increase in training experience usually results in general rise of energetic, motor (technical) capabilities of combat sport athletes, described with various indices [50-55].

There are, however, less recommendations concerning reaction abilities of combat sports athletes. Coaches obviously expect tools from scientists that will allow to estimate the probability of success in particular sports competition as well as predict the course of sporting career in a longer perspective. Therefore, based on the results of our study it would be risky to state that if Test-1 differentiated more examined groups of judo athletes created among others on the basis of sports achievements, GO/NO GO task corresponds to a greater extent with specificity of reaction abilities of judo fight than the execution of response with a choice to each stimulus (Test-2). Greater usefulness of Test-2 is proven, in our opinion, by two arguments based on empirical data.

The first, most significant one is that both rates of Test-2 (sec and CR – the last column in Table 3) are negatively correlated with each other, what means that athletes who reacted faster to the stimulus are also more accurate (make less mistakes). Due to the fact that both rates are the most closely correlated in a group comprising junior members of the national team (HSJ) and the least correlated in senior members of the national team (HSS), in initial phase of training all reaction abilities accurately provide information on high predispositions to achieve great results in judo. Decrease in the correlation as well as obtaining more training experience and experience resulting from numerous participation in championships

constitute an empirical proof that in later sporting career other factors have greater influence on success (certainly such as tactical and technical preparation, anticipation abilities and other intellectual properties as well as muscle strength and endurance [56]).

The second argument is as follows. Both rates used in Test-2 (sec and CR) are the only pair of results (in combination of created groups this only applied to HSS+HSJ) that are statistically significantly correlated with the criterion of age and criterion of training experience – sec negatively and CR positively. This means that senior judokas having more training experience, who represent the highest athletic performance in the population, reacted faster and were more precise. Therefore, both rates are susceptible to the influence of training but they probably interact with other important factors determining predispositions to judo, if the relationship between sec and CR is not a property of all judo athletes (line Total in Table 3).

An open issue is the need to develop a coherent system of monitoring morphofunctional capabilities of people training sports, especially those of great importance for adaptation of a human to solve the most difficult motor tasks also beyond sport. From the perspective of health care of global population, the second aspect is of greater importance. Combat sports, especially judo (with the exception of Japan [57, 58]) are not used to enhance motor safety of people. Paradoxically, many people after reading the newest review of Pocecco et al. [59] on injuries in judo would not recommend this type of physical activity as a sport of life. Nevertheless, the results of our study show the benefits of judo in development of reaction abilities, which play a significant role in motor safety of a human. Moreover, basic element of judo education is learning safe falling technique [57, 58] Based on judo methodology the safe falling technique is the most effective way to prevent injuries due to fall, whereas educational effects are not limited by age, sex, weight, physical fitness or even disability degree provided that a coach is highly qualified [60-62].

Moreover, on the other hand growing popularity of extreme forms of physical activity [63] and on the other escalation of interpersonal aggression [64] show in a different light the benefits of judo training in widely understood therapy. Seemingly, such basic motor activity as walk, especially in a sport form of *nordic walking* (each professional sport is also an extreme form of physical activity [63]) may constitute a threat of injury due to sudden fall [65]. The awareness that judo teaches safe falling technique as well as stimulates the reaction abilities and develops optimal motor responses to tactile stimuli (all those benefits are crucial for motor safety) opens a broad perspective for effective combination of judo and other forms of physical activity in modern health-relation training.

Conclusions

The psychomotor abilities were better among older athletes allowing to formulate two competing hypotheses suggesting that: (1) long-term judo training (assuming the similarity of the characteristics of all subjects before the start of the training) has a positive effect on the development of cognitive functions of a human, which translates both into high athletic performance and improvement of motor safety during daily physical activity; (2) high athletic performance in judo is conditioned by an optimal level of psychomotor abilities.

Competing interests

The authors declare they have no competing interests.

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