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Keywords

BlazePod, reaction speed, reaction time, cognitive abilities, mixed martial arts, MMA

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Article

Assessment of the reliability and validity of simple and complex reaction speed tests in mixed martial arts athletes using the BlazePod™ system

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1. Introduction

The measure of motor behavior quality, alongside movement accuracy, is reaction speed, which refers to the speed of response, or the rate at which we respond to a stimulus. The speed of motor responses to stimuli depends on reaction time (RT) and movement time (MT). The first parameter is the time interval between the occurrence of an unexpected stimulus and the initiation of the appropriate response. MT, on the other hand, signifies the time interval from the initiation to the completion of a specified movement [1].

Several factors influence athletes' reaction speed, such as gender, age, psychological state, stress, circadian rhythm, nutrition, substance intake, fatigue, genetic factors, and individual predispositions [2–9]. The efficiency of responses to stimuli is linked to the speed of information processing in the central nervous system (CNS), primarily dependent on the duration of the stimulus identification phase [10]. Simple reaction time (SRT), involving a response to a single stimulus, and choice reaction time (CRT), involving different responses to two or more stimuli, are distinguished [11]. The number of processed stimuli affects RT, following Hicks's law, which posits that increasing the number of choices logarithmically increases decision-making time [12].

Specific exercises performed during combat sports training contribute to improving reaction time. Studies among karate practitioners have demonstrated that advanced karate athletes have significantly shorter reaction times than beginners or non-practitioners of this martial art [13, 14]. Similar findings have been reported among boxers [15], where finalists in boxing tournaments exhibited significantly better reaction times than those who did not reach the finals. These studies highlight the positive impact of combat sports training on reaction speed, emphasizing the significance of this motor skill in the context of athletes' success.

Mixed martial arts (MMA) is a sport where quick reaction is fundamental, incorporating various fighting styles, and gaining increasing popularity worldwide [16]. MMA involves elements such as clinching, grappling, and striking exchanges, where rapid execution of appropriate offensive and defensive actions in response to the opponent's movements determines success in the sport. Visual stimuli play a crucial role in decision-making during fights, making tools that stimulate quick responses to visual stimuli valuable in training and assessing combat sports athletes. Computer technology, and even virtual reality, are increasingly used for this purpose [17].

In recent years, training and diagnostic systems have emerged to enhance cognitive abilities through stimulation for rapid motor responses to visual stimuli. These systems utilize a set of touch-sensitive wireless lights (lighted pods) that collaborate with a mobile control device, randomly lighting up or following a specific sequence and turning off upon user touch as quickly as possible. These systems, often referred to as Light Sport Training Systems (LSTS), are employed for training and assessing rapid reaction and coordination in various sports disciplines [18, 19]. Notable solutions in this category include the FitLight Trainer™ (FitLight Corp, Ontario, Canada) and the BlazePod™ system (Play Coyotta Ltd, Tel Aviv, Israel). As this technology develops, the conducted research indicates the significant potential of these solutions in both motor diagnostics [19–27] and in supporting the training process [28–31].

Of the mentioned technologies, the FitLight system is more well-known and better tested one due to its longer presence on the market [18]. BlazePod, on the other hand, is gaining popularity among coaches of various sports disciplines, particularly combat and team sports, due to its user-friendly interface, ease of use, and affordability. Depending on the number of available pods, BlazePod can be used for individual or group sessions, and even to introduce elements of competition. It allows for the adjustment of exercise parameters to athletes' abilities, making it applicable at different levels of athlete training. Such training can undoubtedly influence reaction speed by shaping the ability to initiate and execute purposeful motor actions in response to a light stimulus, engaging the whole body or its parts. Besides training applications, BlazePod also enables the assessment of reaction speed to both simple and complex stimuli during the execution of movement patterns characteristic of different combat sports. Therefore, it seems that this training tool can be applied in the training process of MMA athletes for diagnosing their motor fitness level and evaluating training progress, especially concerning coordination motor skills.

However, the research on the application of the BlazePod system for this purpose requires validation.

Considering the above considerations, the conducted research primarily aimed to assess the reliability of measurements of simple and complex reaction speed using the BlazePod system in MMA athletes. Additionally, the validity of the tested measurement tool was verified by comparing the obtained research results with the results of standard computer tests. Furthermore, a comparison of the reaction speed of the right and left hands of the examined athletes was performed.

2. Materials and methods

2.1. Study participants

The study involved 34 male professional MMA athletes (training experience 7.0±4.0 years, age 26.5±5.3 years, body mass 76.9±9.8 kg, height 178.5±5.7 cm). The vast majority of these athletes (30 individuals) were right-handed, while the remaining four individuals declared left-handedness. The inclusion criteria comprised good overall health, no physical limitations (e.g., injuries), no intense physical exertion within the 12 hours preceding the study, and no use of medications or substances that could affect reaction time. All athletes participated voluntarily, were informed about the purpose and procedure of the tests, and could withdraw from the study at any time without providing a reason. The research procedure was approved by the Research Ethics Committee of the Jerzy Kukuczka Academy of Physical Education in Katowice.

2.2. Research procedures

To conduct reaction speed tests, the BlazePod™ system (Play Coyotta Ltd, Tel Aviv, Israel) was used. This system is designed for monitoring and training reaction speed, consisting of pods equipped with LED lights and a mobile application for recording results. The pods, part of the system, can illuminate in various colors and are well-visible even in strong lighting conditions. The equipment is durable and resistant to strong impacts. The study involved assessing the simple and complex reaction speed of MMA athletes to a visual stimulus by performing a characteristic movement pattern – an arm extension. This pattern is associated with a boxing punch, an effective technique frequently executed by MMA athletes. Participants assumed a starting position in a boxing guard stance with symmetrically positioned arms and feet, without torso rotation. The task for the participants was to perform a dynamic extension of the upper limb and touch the pod, located 30 cm away at the chin level, upon the appearance of a light stimulus (illumination of the pod). A hit was counted when the hand touched the surface of the pod, triggering its deactivation. After performing the extension movement, the hand returned to the starting position. Participants conducted a trial run with three signals, followed by the main part of the experiment consisting of three attempts. Each attempt comprised 12 signals, with the analysis focusing on ten responses, excluding the smallest and largest values. The calculated averages were used to assess the reliability of the tests. Stimuli appeared randomly at intervals of 2–6 seconds. The simple reaction time test was conducted separately for the right and left upper limbs. In the case of the complex reaction test, athletes performed an extension with the right limb when the pod illuminated yellow and with the left limb when it appeared in blue (Fig. 1).

The accuracy of the reaction speed test using the BlazePod system was evaluated by comparing its results with classic computer tests [32]. The computer tests involved pressing corresponding keys on the computer keyboard upon the appearance of light stimuli (white squares) on the screen. The examination was conducted in a seated position. The simple reaction time test was performed separately for the right and left hands. Participants pressed the designated keyboard key with the index finger when the white square appeared in the middle of the screen. In the case of the complex reaction test, white squares could appear in three locations (left side, right side, or center of the screen) (Fig. 2).

Participants pressed the designated keyboard keys accordingly: the left or right index finger when the square appeared on the sides of the screen or any thumb on the spacebar when it appeared in the center. The research procedure for computer tests was the same as that used for tests with the BlazePod system.

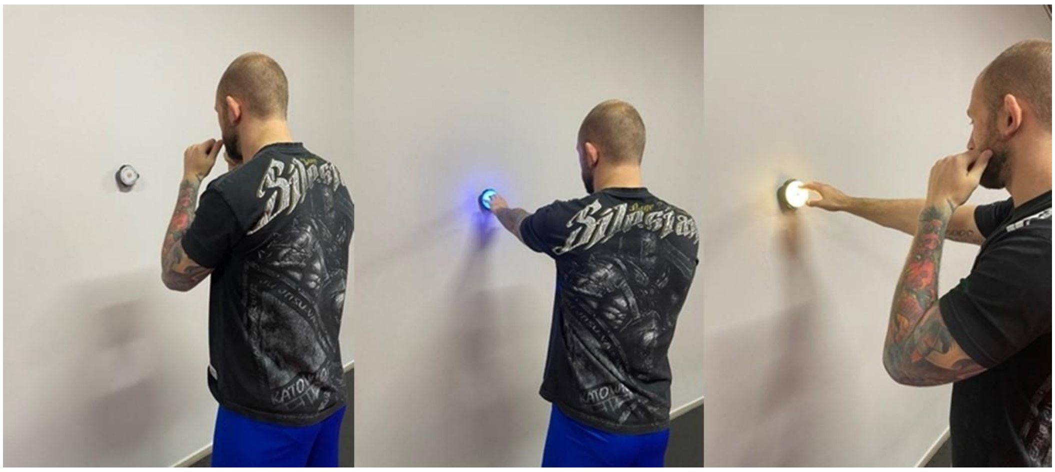

Figure 1. MMA athlete performing dynamic upper limb extensions during the complex reaction test using the BlazePod system

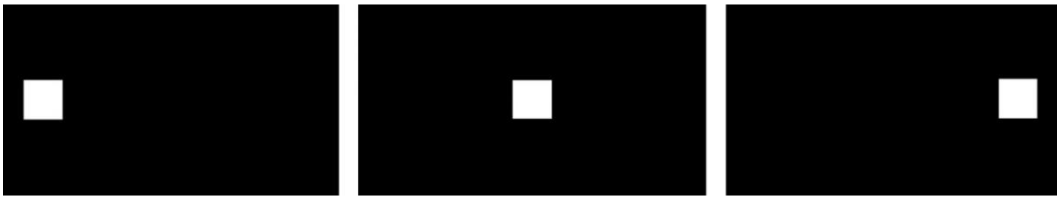

Figure 2. Visualization of light stimuli appearing on the screen during computer tests evaluating complex reaction

2.3. Statistical analysis

The reliability of measurements was estimated based on the Intraclass Correlation Coefficient (ICC) and its 95% confidence interval (CI) according to Koo & Li procedures (2016). A 2-factor model with mixed effects was applied, where object effects were random, position effects were fixed, and the type of intraclass correlation utilized the definition of absolute agreement. Reliability was assessed for a single measurement according to the formula:

$$\text{ICC (3,1)} = \frac{MS_R - MS_E}{MS_R + (k-1)MS_E + \frac{k}{n}(MS_C - MS_E)}$$

where:

MSR – mean square sum between objects

MSE – mean square sum of error

MSC – mean square sum between measurements

n – number of objects

k – number of repeated measurements for each object

The value of ICC was interpreted as follows: poor (< 0.5), moderate (0.5–0.75), good (0.75–0.9), and excellent (> 0.9) reliability [33]. The significance of ICCs was tested using the F test.

To assess the validity of tests conducted using the BlazePod system, Pearson correlation analysis was employed, comparing the results of tests for simple and complex reaction speed using the BlazePod system with computer-based tests. The results were interpreted according to the scale provided in Table 1.

Table 1. The scale of Pearson's Correlation Coefficient

Scale of correlation coefficient	Value
$0 < r \leq 0.19$	very low correlation
$0.2 \leq r \leq 0.39$	low correlation
$0.4 \leq r \leq 0.59$	moderate correlation
$0.6 \leq r \leq 0.79$	high correlation
$0.8 \leq r \leq 1.0$	very high correlation

To assess the significance of differences in the results of left and right upper limb reaction speed tests, the Student's t-test was utilized. The effect size was measured using Cohen's *d*. Normality of the distribution was assessed using the Shapiro-Wilk test. The study considered a significance level of $p < 0.05$. Statistical calculations were performed using IBM SPSS (IBM Corp., Armonk, NY) and Statistica (StatSoft, Inc., Tulsa, OK, USA).

3. Results

The values of Intraclass Correlation Coefficients (ICCs) for reaction speed tests performed by MMA athletes using the BlazePod system and classic computer-based tests are at a similar level. In the case of simple reaction tests during right and left upper limb extensions, ICCs were almost identical, with values of 0.826 (0.717–0.902) and 0.833 (0.717–0.909), respectively. For computer-based tests performed with the right hand, ICC was 0.786 (0.654–0.879), and with the left hand, it was 0.804 (0.679–0.890). Comparing ICCs for both complex reaction tests, higher values were observed in trials using the BlazePod system (ICC = 0.785 (0.659–0.877)) than in computer-based tests (ICC = 0.740 (0.596–0.849)) (Table 2). In reference to the interpretation of ICCs mentioned above [33], the reliability of simple and complex reaction speed tests using the BlazePod system can be considered good.

Table 2. Intraclass Correlation Coefficients (ICC) for computer-based tests and tests using the BlazePod system

Type of Test	ICC (95% CI)	*p*
Computer-based test – Simple reaction – Right hand	0.786 (0.654–0.879)	0.001
Computer-based test – Simple reaction – Left hand	0.804 (0.679–0.890)	0.001
Computer-based test – Complex reaction	0.740 (0.596–0.849)	0.001
BlazePod light set – Simple reaction – Right hand	0.826 (0.717–0.902)	0.001
BlazePod light set – Simple reaction – Left hand	0.833 (0.717–0.909)	0.001
BlazePod light set – Complex reaction	0.785 (0.659–0.877)	0.001

Legend: ICC – Intraclass Correlation Coefficient; CI – Confidence Interval; p – p value

The correlation between the results of tests using the BlazePod set and computer-based tests was high. The highest correlation coefficient was observed in the case of simple reaction speed tests performed with the right hand ($r = 0.703$; $p < 0.001$) (Fig. 3).

Comparing the results of tests performed with the left hand, the correlation was slightly lower ($r = 0.654$; $p < 0.001$) (Fig. 4). The correlation coefficient for complex reaction speed tests was at the level of $r = 0.640$; $p < 0.001$ (Fig. 5).

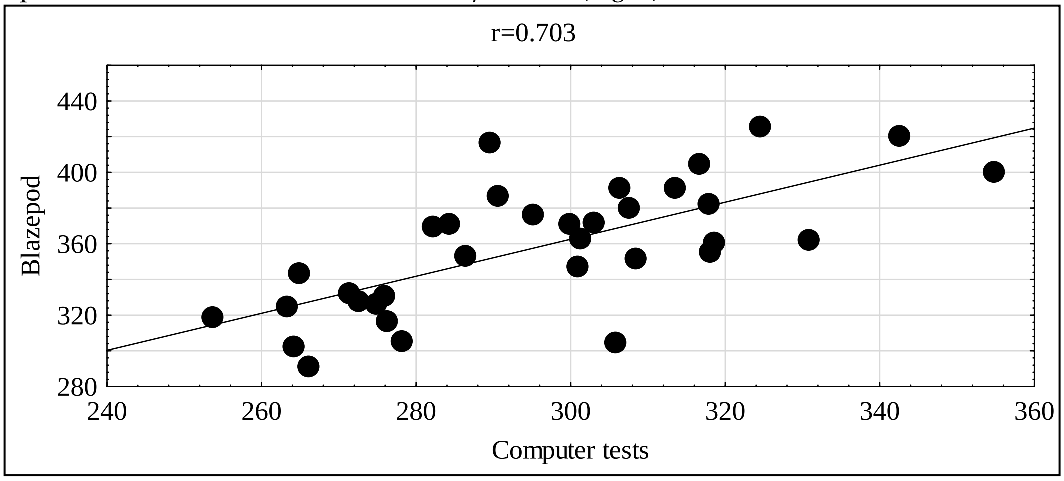

Figure 3. Correlation of results between computer-based tests and BlazePod light set tests – Simple reaction, right hand

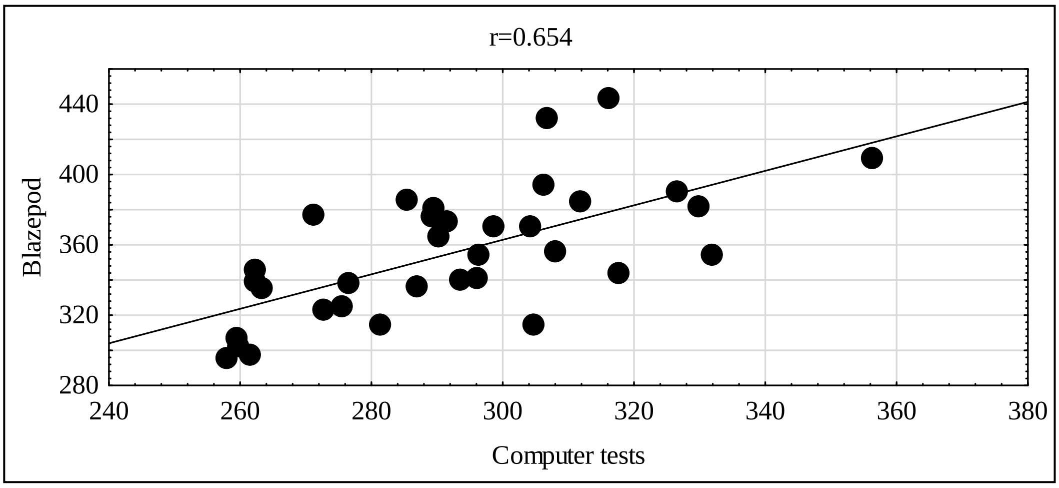

Figure 4. Correlation of results between computer-based tests and BlazePod light set tests – Simple reaction, left hand

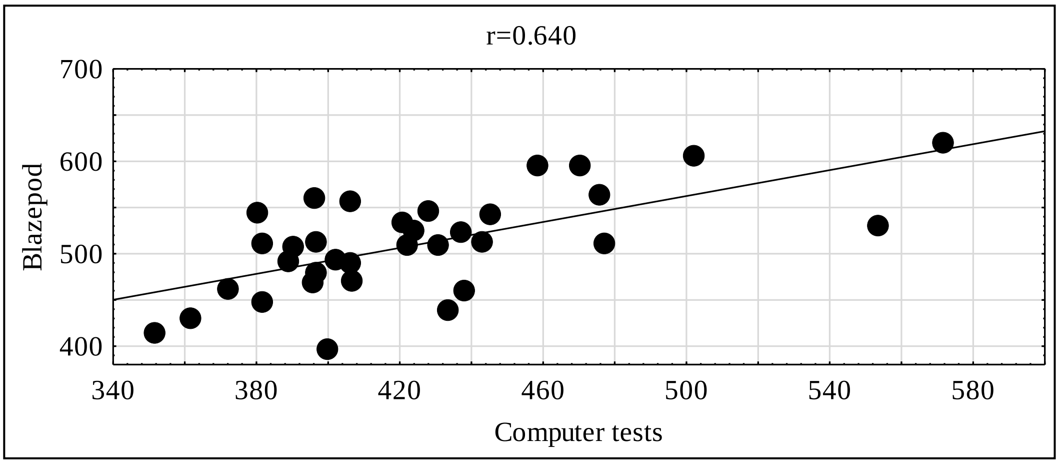

Figure 5. Correlation of results between computer-based tests and BlazePod light set tests – Complex reaction

In computer-based tests, the average response time to stimuli for the right hand was 295.847±24.252 ms, slightly longer than for the left hand (292.463± ms). However, this difference was not statistically significant (p = 0.127; Cohen's d = 0.268). In the case of upper limb extension tests using the BlazePod set, response times to stimuli were longer, amounting to 358.223±35.837 ms for the right hand and 355.501±36.356 ms for the left hand. The observed difference in results was also not statistically significant (p = 0.500; Cohen's d = 0.117) (Table 3). The reaction speed of MMA athletes in complex tests in computer-based tests was at the level of 425.010±49.098 ms, while in tests performed using the BlazePod set, the average response time to stimuli was 509.814±53.851 ms.

Table 3. Comparison of the reaction speed of the right and left upper limbs of MMA athletes in computer-based tests and using the BlazePod light set

Type of Test	Right hand		Left hand		d	Effect size	p
	$\bar{x}$	SD	$\bar{x}$	SD			
Computer-based test [ms]	295.847	24.252	292.463	24.221	3.384	0.268	0.127
BlazePod light set [ms]	358.223	35.837	355.501	36.356	2.722	0.117	0.500

4. Discussion

The conducted research indicates that the tests of simple and complex reaction speed performed with the use of the BlazePod set by MMA athletes can be considered reliable. This is supported by relatively high ICC values, which were at a similar level to classic computer tests and even slightly higher. Until now, only a few authors have attempted to validate the BlazePod set in terms of measurement reliability [19,34]. However, these studies focused on different movement patterns and participant groups, utilizing distinct research procedures.

For instance, de-Oliveira et al. [34] assessed the reliability of BlazePod technology by evaluating the response time of 24 young active adults. They employed a performance test that involved tapping on floor-based pods arranged in a square formation. Participants performed the task for 30 seconds, standing in the middle of the square on their dominant leg and aiming to touch and extinguish illuminated pods in random order. This task, known as the "One-Leg Balance Activity" (OLBA), assessed not only reaction speed but also balancing ability. The ICCs calculated for the total number of pod strikes (ICC = 0.81) and the average response time to light stimuli (ICC = 0.82) were very similar to the results obtained in our study. de-Oliveira et al. [34] suggested that the BlazePod technology could provide valuable information for monitoring cognitive training performance and evaluating the effects of training interventions.

Similar studies using BlazePod and OLBA were conducted by Flôres et al. [19] on young soccer players, showing ICC values ranging from 0.785 to 0.906 for the number of pod strikes and 0.436 to 0.926 for average response time to light stimuli. Additionally, Hoffman [22] examined the agility of young soccer players using three BlazePod-based tests, demonstrating high measurement reliability (ICC ranging from 0.833 to 0.884).

In our study, the high correlation observed between BlazePod results and those of similar classic computer tests further emphasizes the potential of the BlazePod technology. Both simple and complex reaction speed tests demonstrated not only good reliability but also validity. This is corroborated by Hoffman's [22] investigation, which compared BlazePod agility test results with coach-assessed player agility, confirming construct validity.

Our research also compared the results of simple reaction tests performed with the right and left hands. Regardless of the test type, no statistically significant differences in reaction speed were observed between the tested hands. Notably, both in computer-based tests and those utilizing the BlazePod set, MMA athletes responded faster to stimuli when using the left hand, despite the majority being right-handed. This finding aligns with the asymmetrical positioning during sports combat, where the left hand of right-handed athletes plays a crucial role in initiating attacks and controlling distance, potentially influencing reaction speed.

Various methods assess reaction speed to stimuli, such as internet-based applications like Human Benchmark and Hit-the-dots Reaction Test [35,36]. While easy to implement, these methods may lack accuracy due to internet data transmission delays. The Red and Green Light test is also commonly used, involving reacting or refraining from reacting based on the color of the generated light. Additionally, laboratory-based computer tests evaluating reaction to visual and auditory stimuli are widely employed [37, 38, 39. 40].

In comparison, the BlazePod system, as part of the LSTS, offers a relatively simple solution for designing tests assessing the motor response speed related to sports techniques. The BlazePod tool appears versatile, applicable not only for MMA training but also for various sports training processes. It serves as a valuable measurement method for evaluating both simple and complex reaction speed, as well as a complementary tool for traditional training with engaging and useful coordination exercises. BlazePod allows the creation of diverse training programs by composing different sequences and combinations of light stimuli, offering flexibility in programming color, duration, intervals, and the order of pod illumination.

Furthermore, BlazePod can measure the reaction speed in various movement patterns, ranging from local (small motor skills) to global (involving large muscle groups) ones. It allows the evaluation of upper and lower limbs' reaction speed and even complex motor actions. The system's data recording and storage capabilities enable continuous monitoring and analysis of athlete results. This versatility and utility position the BlazePod set as a more universal research tool compared to conventional motor and computer tests, with our study demonstrating relatively high reliability and validity of this system.

5. Conclusions

In recent times, various tools based on light systems have been employed in the training process of athletes from different disciplines to shape and assess their reaction speed. However, many of them have not yet been validated in terms of the reliability and validity of measurements, especially concerning specific sports disciplines. Therefore, the presented research should be considered among the first of its kind, focusing on combat sports.

The ICC analysis indicates that simple and complex reaction speed tests performed by MMA athletes using the BlazePod set exhibit reliability similar to classic computer tests. Furthermore, the correlation between the results of both types of test tasks is relatively high. Thus, the BlazePod system can be considered a measurement tool enabling a reliable and accurate assessment of simple and complex reaction speed. Due to the numerous configuration possibilities of the BlazePod set and the fact that tests created with it can be based on movement tasks characteristic of those practicing combat sports, this measurement system seems more useful in MMA training than typical computer tests. It can be applied not only for assessing and diagnosing athletes' reaction speed but also for training this motor skill.

6. Practical implications

In the context of sports practice, the results of this study have potential implications for coaches, sports psychologists, and judo athletes. It appears that EEG-biofeedback training, focused on regulating Beta and Theta waves, could be an effective tool in improving reaction times. The application of this type of training may be particularly beneficial for sports where a quick reaction to stimuli is crucial, such as judo. Coaches may consider integrating neurofeedback training into training programs to enhance the psychological effectiveness of their athletes. However, due to individual differences among athletes, it is essential to tailor training to the specific needs of each athlete.

7. Study limitations

Regarding the limitations of the conducted research, it seems that one limitation could be that athletes touched the surface of the pod with their bare hands in response to a light stimulus. This might have slowed down the movement of the upper limb extension in its final phase due to athletes' concern about sudden contact with the rigid and relatively hard element. In the future, conducting the test with boxing gloves, which absorb impact, could be considered. This may lead athletes to perform the task more dynamically, without fearing injury upon striking the pod. Additionally, using boxing gloves would create measurement conditions more closely resembling situations during training or sports competition, as athletes are accustomed to striking with gloves.

8. Directions for future research

Many previous studies assessing reaction speed utilized computer-based tests focusing on fine motor skills. These tests often involved simple motor tasks, such as pressing a button in response to a stimulus, which deviate from movement patterns characteristic of specific sports disciplines. Therefore, it is reasonable to evaluate reactions to stimuli by performing more global movements based on specific movement patterns used by athletes during sports competition. The BlazePod technology offers this possibility, particularly in the context of combat sports. Hence, further research should aim to assess specific movement patterns performed by athletes during training and sports competitions. In combat sports, these may include various types of strikes and kicks. Evaluating these motor actions could provide information about athletes' actual training levels and progress, potentially translating into sports success.

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