COACHING & KINESIOLOGY

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A comparative analysis of the short-term memory of martial arts' athletes of different level of sportsmanship

Abstract

Problem. The paper presents a comparative analysis of the short-term memory of martial arts players and involved 45 participants in the martial arts (*taekwondo, karate, judo, sambo*, Greco-Roman wrestling) with different levels of skill.

Material and Method. The 1st group included 17 male athletes, average age 16.88±0.48, who were general athletes and novice sportsmen. The 2nd group was 14 strong, aged 19.50±2.43, athletes of First Class Sportsman (regional champion) rank while the 3rd group of 14 was aged 19.57±0.40 and had a high degree of training and experience, being Candidate Masters of Sport (national rank) and Masters of Sport (national champion) rank. Their short-term memory was tested using the «TestSTMemory» computer application and their heart rate was monitored at the same time. To note the heart rate (HR) a BT4.0&ANT+ HR monitor was used.

Results. It was found that results depend on levels of skill. During the later stages of the test the HR of novice sportsmen was notably higher. In carrying out the test the First Class Sportsman athletes showed a lower number of accurate clicks. Masters athletes completed the test much faster, and the average duration of their attempts in the 3rd stage of testing was shorter. These athletes also made far fewer errors during the 1st/2nd stages of testing. A lower rate of average and minimum HR was found in Masters athletes as compared with the First Class Sportsman group. The Masters athletes carried out the test with increased efficiency, i.e. the amount of correct clicking was higher, than with novice sportsmen. During the 2nd/3rd phases they made significantly fewer errors. Masters athletes carried out the final stage of the test faster than the novice sportsmen. The reduction in the initial, average and minimum HR in Masters athletes displays how the organism is activated to promote economy and higher psychological stability. This hypothesis is confirmed by the HR results during the 2nd/3rd test phases.

Conclusions. The results obtained confirmed greater stress adaptation among novice sportsmen. Masters athletes had a higher level of short-term memory and a greater ability to process information rapidly. Masters athletes showed a higher degree of workability, and the best ability to mobilise and economise bodily functions.

1. Introduction

The psychophysiological features of an athlete's condition are a major element in ensuring their success. The testing of coordination, reaction rate, mental determination and refocusing, and also memory is applied in condition monitoring in various kinds of sports. Relations between psychophysiological measures and other criteria allow one to evaluate strength and mental training and predict increase in skill level.

Lopsan and Buduk-ool [2017] tested morphofunctional and psychophysiological measures of boys with differing physical activity skills. Short-term memory and concentration skills were examined when assess-

ing the quality of psychophysiological factors. It was concluded, that the level of physical activity and sport specialisation exert a significant impact on morphological, functional and psychophysiological factors. Cetin, Beyleroglu, Bagıs and Suna [2018] affirmed that there is a net effect of physical exercise on boxers' psychophysiological condition (coordination, concentration, equilibrioception status). Korobeynikov *et al.* [2017] studied the relationship between psychophysiological factors and state of motivation in well-trained *judo* athletes. It was concluded, that the high level of motivation to achieve success in well-trained *judo* athletes is provided by the activation of neurodynamic and cognitive functions and sufficient resistance to stress.

Sazonov [2017] estimated specific qualities of special working efficiency approving and higher nervous activity of qualified martial arts players. A correlation was established in the relationships between the special staying power of sportsmen, the degree of maturity of the complex hand-eye reaction, and the lability of the nerve process level. Ben Cheikh *et al.* [2017] studied the impact of sleep loss on forms of fitness of martial arts players. It was concluded that it had the most significant impact on the selective attention activation process and on maximum isometric force, which are key skills in martial arts.

Interest in the study of athletes' short-term memory is driven by the integral nature of this factor and its relationship with a range of factors important for estimating what state they are in Hudac *et al.* [2018] point out that working memory comprises the capacity to retain short-term information and to be integrated with high-order cognitive processing for planning and executing behaviour and critical skills both for effective cognitive and athletic activities. It has been suggested that short-term memory be used as a criterion in assessing the quality of athletes' physical therapy.

Verburgh *et al.* [2016] studied the relationship between daily physical activity and a wide range of neurocognitive functions. Sports activities brought about an improvement in short-term memory, working memory, concentration and speed of information processing. Suda *et al.* [2017] explored athletic training for competitions. The authors used short-term memory as a quality measure to demonstrate psychomotor function and physical efficiency.

The condition of short-term memory is used as a criterion in assessing the efficiency of fitness training [Huelsmann 2018]. Billaut *et al.* [2018] studied the relationship between diving training and neurocognitive functions. Short-term memory capacity was used as a criterion for assessing athletes' form or fitness. Shi Qing Hai *et al.* [2016] used short-term memory as a criterion for assessing the impact of hypoxia. The informativity and significance of this factor were confirmed. Consequently, the data available confirms the relevance of study of the state of short-term memory as a predictor of success in sport. On the basis of the foregoing, the target of the present study was a comparative analysis of the short-term memory of martial arts players with different levels of skill.

2. Materials and methods

2.1. Participants

The participants included 45 martial arts players (*taekwondo, karate, judo, sambo*, Greco-Roman wrestling) of which 1st group comprised 17 athletes with an average age of 16.88±0.48. They were general athletes and novice sportsmen. The 2nd group was 14 strong, aged 19.50±2.43, and was made up of athletes of First Class Sportsman (regional champion) rank while the 3rd group of 14 was aged 19.57±0.40 and had a high degree of training and experience, being of Candidate Masters of Sport (national rank) and Masters of Sport (national champion) rank. All participants signed informed consent before participating in the test which permitted use of personal data. The experiments reported in the manuscript were performed in accordance with the ethical standards of the Helsinki Declaration.

2.2. Organisation of the study

Short-term memory was tested using the «TestSTMemory» (Short-Term Memory) – computer application. The application is designed for devices with the iOS operating system. The device used was a fifth-generation iPad with a 9.7-inch screen, a tablet computer of the Apple company. The working field, on which the test was performed, was a net of 77 circles (11 on 7), 14 mm in size.

The test to detect the level of short-term visual memory includes 5 stages and 10 attempts at every stage. During the first five attempts in the first stage, the participants were required to react to a monochrome signal and tap on the relevant circle. During the next five attempts they were required to react to a colour signal. At each next stage the quantity of simultaneously emerging signals was increased by one. In the 5th stage they were required to remember the position of five signals and press the correct circles. The action period of the visual signals during the testing is 300 ms. Heart rate monitoring was carried out throughout the test, with initial values being recorded at the moment of reaction to the visual signal. A BT4.0&ANT+ Heart Rate Monitor was used to record the heart rate (HR).

The testing procedure permits the avoidance of response time failure values when incorrect clicking occurs and if the time limit for each stage was exceeded. In such cases the sportsman is allowed to retake the attempt.

The amounts of correct and incorrect clicking, percent of correct clicking and duration of test performance (s) were recorded (abc) during test processing. For each stage individually, the length of time it took to perform the test, the length of each attempt, and the percent error were recorded. Initial HR was estimated, also its maximum, minimum and average measure during the whole duration of the test, as well as the HR at each stage and attempt (min⁻¹).

2.3. Statistical analysis

Statistical analysis of the findings took place using ExCel, the licensed spreadsheet package. During the test the following measures of descriptive statistics were estimated: arithmetic mean (M), standard deviation (δ) and the mean quantity error (m). The density of comparative figures was estimated (M) and their error (m). The confidence of differences in groups was rated with Student's t-test (t) and the non-parametric Mann–Whitney–Wilcoxon U test (U), Rosenbaum's Q-test (Q) and the Wald – Wolfowitz model (r).

3. Results

Key results are listed in Table 1.

The data in Table 1 are indicative of how close together are the results obtained. At the same time the analysis conducted has enabled significant differences to be identified among the groups tested.

The novice sportsmen produced fewer errors while carrying out the test. The error density during the 1st, 2nd and 3rd stages of testing was greater among the First-Class Sportsman, consequently, (U=0, p<0,01; r=2, p<0,01), (U=65, p<0,05; r=8, p<0,01; Q=9, p<0,05), (r=10, p<0,05; Q=8, p<0,05). At the same time the HR during the 5th stage of the test was higher among the novice sportsmen, (r=10, p<0,05).

Much more prominent differences were established when comparing the results of the 2nd and 3rd groups. Masters of Sport athletes completed the test much more quickly and more precisely. They had better results with regard to the density of correct clicks (Q=6, p<0,05), click length at the 3rd stage (Q=6, p<0,05), error density in the 1st stage (U=26, p<0,01; Q=13, p<0,01; r=4, p<0,01), error density in the 2nd stage (r=5, p<0,01).

Table 1. The key results of short-term memory and heart rate testing in martial arts participants, (M±m)

Marker	1st group (n=17)	2nd group (n=14)	3rd group (n=14)
Total number of correct clicks (abc)	126.29±2.41	122.07±4.12	124.64±1.81
Total number of incorrect clicks (abc)	23.71±2.41	27.93±4.12	25.36±1.81
Density of correct clicking (%)	84.20±9.75	81.39±10.40	83.10±10.02
Duration of test (s)	154.29±6.62	156.64±9.15	142.57±4.76
Duration of 1st stage of test (s)	18.05±0.32	18.21±0.64	18.34±0.34
Duration of 2nd stage of test (s)	25.60±1.70	25.09±1.63	22.85±1.11
Duration of 3rd stage of test (s)	31.09±1.53	29.93±2.06	28.34±1.50
Duration of 4th stage of test (s)	37.64±2.28	41.51±4.63	33.39±1.66
Duration of 5th stage of test (s)	42.05±2.18	41.93±2.88	39.69±1.95
Duration of attempt at 1st stage of test (ms)	754.29±33.24	742.64±46.45	754.86±36.13
Duration of attempt at 2nd stage of test (ms)	564.76±25.99	535.93±24.48	535.00±27.30
Duration of attempt at 3rd stage of test (ms)	521.71±27.94	521.29±26.40	479.86±24.27
Duration of attempt at 4th stage of test (ms)	504.18±23.51	491.79±29.34	463.86±22.65
Duration of attempt at 5th stage of test (ms)	502.71±21.66	481.07±29.34	463.43±24.70
Error density in 1st stage of test (%)	0.00±0.00	1.43±3.17	0.71±2.25
Error density in 2nd stage of test (%)	4.12±5.31	6.43±6.55	1.43±3.17
Error density in 3rd stage of test (%)	12.14±8.73	14.53±9.42	10.96±8.35
Error density in 4th stage of test (%)	18.24±10.32	20.36±10.76	20.00±10.69
Error density in 5th stage of test (%)	23.88±11.40	28.00±12.00	27.43±11.92
Initial HR, min-1	96.24±3.56	92.43±4.88	83.64±4.10[1]
Maximum HR, min-1	103.00±4.62	101.00±4.46	91.86±4.36
Minimum HR, min-1	84.65±4.47	81.79±3.59[2]	71.43±2.70[1]
Average HR, min-1	92.59±4.70	91.38±3.94	81.23±3.39
HR in 1st stage of test, min -1	94.48±4.28	90.04±4.35	80.19±3.36[1]
HR in 2nd stage of test, min -1	93.50±5.08	92.02±4.05	75.79±3.19[1]
HR in 3rd stage of test, min -1	92.80±5.18	93.39±4.49[2]	81.86±3.35
HR in 4th stage of test, min -1	90.73±4.89	91.26±3.84	83.72±3.83
HR in 5th stage of test, min-1	91.44±4.67	90.19±3.71	84.55 ±4.21

Notes: 1 – Differences with 1st group are significant (p<0,05), 2 – differences with 3rd group are significant (p<0,05).

Athletes of the 3rd group also had better results with regard to HR measures. A lower average HR was noted (U=59, p<0,05), minimum HR (t=2.30, p<0,05; U=39, p<0,01; Q=6, p<0,05), HR during the 2nd stage (U=37, p<0,01; Q=8, p<0,05), HR during the 3rd stage (t=2.06, p<0,05; U=55, p<0,05).

It was concluded that there were significant differences between novice sportsmen and Masters of Sport athletes related to age (t=4.27, p<0,05). The athletes of the 3rd group were significantly older. Novice Sportsmen had the largest number of correct clicks (U=66, p<0,05). Participants in the 1st group didn't produce errors during the 1st stage of testing (U=17, p<0,01; r=2, p<0,01). At the same time Masters athletes completed the 5th stage of testing more rapidly (Q=7, p<0,05). Participants from the 3rd group therefore produced fewer errors during the 2nd and 3rd stages of the test (U=32, p<0,01; r=4, p<0,01), (r=8, p<0,05).

HR figures were also much better among the Masters athletes. It was concluded that there were significant differences between the figures for initial HR (t=2.32, p<0,05; U=71, p<0,05; Q=8, p<0,05), for average HR (Q=8, p<0,05), for minimum HR (t=2.53, p<0,05; U=67, p<0,05; Q=10, p<0,05), for HR in the 1st stage (t=2.63, p<0,05; U=70, p<0,05; Q=11, p<0,05), and for HR in the 2nd stage (t=2.95, p<0,05; U=57, p<0,05; Q=12, p<0,05).

4. Discussion

Predicting success in sports is mainly based on principles such as: a complex approach, consideration of the sports concerned, and a comparative analysis of martial arts practitioners with different levels of skill. An efficient and reasonable forecast can be prepared if these principles are taken into account.

Podrigalo, Galashko, Iermakov, Rovnaya & Bulashev [2017] developed the complex successfulness forecasting technique for arm-wrestling based on an analysis of morphological functional indicators.

The results obtained by Podrigalo, Volodchenko, Rovnaya & Stankiewicz [2017] affirm that the successfulness predictor in kick-boxing is associated with the condition of the motor apparatus. Increased skill is associated with an increase in movement amplitude in appendicular joints.

Korobeynikov and Myshko [2016] studied the specific character of the performance of neurodynamic characteristics in sport dance in sportsmen aged 14-15 years and its impact on their success. The presence of high mobility of neuronal processing and an increase in perceptual speed and information associated with a reduction in the level of psycho-emotional tension is the guarantee of success in sport dance.

These findings are based on a technique of simultaneously recording psychophysiological (short-term memory) and physiological (HR) parameters. Such an approach is very popular in sport. Yagotin *et al.* [2018] estimated psychophysiological state in equal measure by measuring psychomotor skills and the functional capabilities of the cardiorespiratory system. The most significant relationships are those defined between measures of motion skills and the psychomotor system parameters of participants. Van Biesen *et al.* [2016] note that cognitive and motor skills are related. However, the precise influence of cognitive deterioration on sports skills is unknown. Short-term memory is used as an integral part of the general cognitive test applied for classifying the sportsmen participating in the Paralympic Games.

Balestra and Germonpre [2016] used short-term memory to estimate the fitness of divers. It was concluded, that diving results in a certain decrease in short-term memory and much higher cognitive function, including visual motor skills. The use of heart rate as a criterion to measure load performance or for functional tests is also widely applied in sports. A similar design is used in Lum's [2019] work. *Judo* athletes had a special fitness-test. The measurement of heart rate illustrated reaction to load. It was concluded that, among the factors studied, average force showed a correlation. El-Ashker *et al.* [2018] used heart rate as an illustration of response when measuring performance in special tests on boxers. Bridge *et al.* [2018] studied physiological and hormonal reactions in a series of *taekwondo* fights. The HR dynamic allowed one to proactively manage the metabolic alterations in relation to the fight schedule, and helped to promote recovery between fights. Podrigalo, Volodchenko, Rovnaya, Ruban & Sokol [2017] studied and analysed the adaptive capability of the cardiovascular system in kickboxing athletes during a standard physical load and during recovery. The importance of HR monitoring in estimating athletes' fitness was confirmed.

The use of a computer application for testing has a number of advantages in the monitoring of an athletes' fitness. The version of test proposed is characterised by efficiency, mobility, availability and informative value. It is used in the research of Frolova *et al.* [2018]. The authors applied the computer application in tests on young basketball players. Visual cues were used for the measurements. These visual cues accelerated from the different points on the display.

The precision of the measurements made during the testing demonstrates the importance of short-term memory for success in the martial arts. Athletes not only need a fast reaction, but also precise performance in their work which can be estimated through short-term memory. A comparative analysis of the results between the groups confirms that skill in sports is dependent on this. During the test the novice-sportsmen produce fewer errors, than the First Class Sportsmen martial arts specialists. However, their HR was significantly higher

during the last stage of the testing. This attests to the fact that there is greater tension during adaption among novice-sportsmen. In other words, they perform the test more accurately, but get the result through heavy physically demanding force.

An analysis of how the athletes of the 2nd and 3rd groups performed in the test demonstrates how the results are correlated with skill in sport. The First Class Sportsmen athletes had a lower number of correct clicks while performing the test. At the same time the Masters athletes completed the test much more rapidly, the duration of the 5th stage of the test was shorter. They produced a smaller number of mistakes in the 1st and 2nd stages of the test. This demonstrates better results during training, and confirms the greater capacity of Masters athletes to mobilise.

A parallel analysis of HR enables one to estimate the dynamics of the athletes' functional state during the performance of standard tasks. In particular the analysis of data on their average, minimum and maximum HR allows one to obtain a more precise estimate of the athletes' adaptive capabilities. Such a procedure is very popular in sport. Cortell-Tormo et al. [2017] applied HR as a reflection of physiological reactions to specific tasks in Choy Li Fut. It determined that data on HR in a state of rest, under average conditions and the maximum are sufficient to evaluate athletes' metabolic changes.

The review by Slimani et al. [2018] is dedicated to studying the HR reaction in martial arts competitions. Average HR and maximum HR were demonstrated to be highly informative in monitoring the state of fitness of taekwondo athletes, boxers and kickboxers. Masters martial arts players were demonstrated to have lower values of average and minimum HR than First Class Sportsmen athletes. This confirms once again the theory that athletes with a higher skill level are able to economise on their body functions.

It is interesting that HR was significantly lower in the 2nd and 3rd stages of the test than seen in First Class Sportsmen athletes. In other words, the Masters athletes not only showed better results and are faster in starting to show improvement, but they also keep the optimal functional state longer while doing the test and they are also more resistant to stress factors.

The same results were obtained by Tornero-Aguilera, Robles-Perez and Clemente-Suarez [2017]. The authors analysed the impact of combating physiological stress on the psychophysiological reactions of soldiers with different levels of skill. This study concluded that HR was highly informative. Hormeno-Holgado, Perez-Martinez, and Clemente-Suarez [2019] simulated means of combating physiological stress among military employees. The authors confirmed the normativity of HR measurements while monitoring the participants' condition.

The most interesting feature was seen in a comparison between the results of novice sportsmen and Masters athletes. This case established the prominent impact of skill level on the psychophysiological and physical state of athletes. The increase in the average age demonstrates the increase in length of training and is a logical presentation of a much higher skill level in sport. The Masters athletes completed the test more efficiently, with a larger number of correct clicks. This confirms the higher skill level with regard to short-term memory. Similar results were obtained by Donath et al. [2015]. The authors note that the learning of technical skills, which are very important for sporting success, depends on skill levels for short-term coordination memory. The same data was established by Howard, Wolpert, and Franklin [2015]. The authors confirm the importance of short-term memory during the learning of technical skills associated with working with a ball.

The precision of the test results was estimated by error density. In the 1st stage the novice sportsmen did not make any mistakes, their results were better than the Masters martial arts players. In the following stages of the test the accuracy of performance in the test was higher than the Masters athletes. In the 2nd and 3rd stages they made significantly fewer mistakes. This confirms once again the link with better mobilisation found in Masters athletes.

In the last stage of the test, the Masters athletes completed the test faster than the novice sportsmen. This could be taken as proof of better mobilisation, a higher capacity for processing operational information. The decrease of initial, average and minimum HR in those athletes with a high skill level demonstrates an ability to economise body functions and better psychological stability. The 1st and 2nd stage measurements of HR confirm this link. The Masters athletes achieve this through reduced psychological tension. Bromley et al. [2018] put special emphasis on HR being a very important factor in monitoring training tasks in judo. They estimated the average, maximum and minimum value. It was established that there exist correlations between these factors, lactate concentration, and mental capacity. Similar results were obtained by Villar et al. [2018]. HR was used as a criterion in a special model run of the test in Brazilian ju-jitsu. This confirmed the existence of correlations between HR and the test results, lactate concentration in the blood, and accommodation to tasks.

The increase in the skill level in the sports demonstrates the short-term optimisation of memory that is caused by a decrease in the frequency of mistakes. Masters athletes mobilise much more efficiently, they are capable of supporting the required momentum to complete the test over a long period. The differences in the distribution of performance were also established. The athletes with a higher skill level have a more rapid speed of efficiency and sufficiently longer period of high and sustainable performance.

5. Conclusions

The results that were obtained during testing confirmed greater tension over adaptation in novice sportsmen; the results of the First Class Sportsman athletes are better than those of the beginners, but worse than those shown by the 3rd group of participants. The Masters athletes had a greater capacity for short-term memory and a higher capacity in processing operational information. The Masters athletes showed a better level of improvement in their results during the test, better skill in mobilisation and an economising of body functions.

The use of a short-term memory test with parallel measurement of HR could be used to monitor the functional state of martial arts practitioners. The availability, financial viability, objectivity and informativity of a given test determine its.

This research received no external funding. The authors declare no conflict of interest.

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Analiza porównawcza krótkotrwałej pamięci zawodników sztuk walki na różnym poziomie zaawansowania sportowego

Abstrakt

Problem. W pracy przedstawiono analizę porównawczą pamięci krótkotrwałej zawodników sztuk walki, w której wzięło udział 45 uczestników sztuk walki (taekwondo, karate, judo, sambo, zapasy grecko-rzymskie) o różnym poziomie umiejętności. Materiał i metoda. W pierwszej grupie znalazło się 17 sportowców, średnia wieku 16,88±0,48 lat, którzy byli sportowcami na średnim poziomie zaawansowania i początkującymi. Druga grupa liczyła 14 bardziej zaawansowanych zawodników w wieku 19,50±2,43 lat i składała się z zawodników I klasy (mistrz regionu), natomiast trzecia grupa liczyła 14 zawodników w wieku 19,57±0,40 lat, posiadających wysoki stopień wyszkolenia i doświadczenia, będących *Candidate Masters of Sport* (ranga krajowa) i *Masters of Sport* (mistrz kraju). Ich pamięć krótkotrwała była badana za pomocą aplikacji komputerowej "TestSTMemory", jednocześnie monitorowane było tętno. Do pomiaru tętna (HR) wykorzystano monitor BT4.0&ANT+ Wyniki. Stwierdzono, że wyniki zależą od poziomu umiejętności. Na późniejszych etapach testu tętno początkujących sportowców było znacznie wyższe. W trakcie przeprowadzania testu sportowcy pierwszej klasy wykazywali mniejszą liczbę poprawnych wyborów. Zawodnicy klasy Masters ukończyli test znacznie szybciej, średni czas trwania prób w 3 etapie testu był krótszy. Zawodnicy ci popełniali również znacznie mniej błędów podczas 1 i 2 etapu testów. Mniejszy wskaźnik średniego i minimalnego tętna został stwierdzony u zawodników Masters w porównaniu do Sportowców Pierwszej Klasy. Zawodnicy Masters przeprowadzili test z większą wydajnością, tzn. ilość poprawnych kliknięć była większa niż u początkujących sportowców. Podczas fazy 2 i 3 popełnili znacznie mniej błędów. Zawodnicy Masters przeprowadzili ostatnią fazę testu szybciej niż początkujący sportowcy. Zmniejszenie początkowego, średniego i minimalnego tętna u sportowców Masters pokazuje jak organizm jest aktywowany w celu promowania wydajności i wyższej stabilności psychicznej. Hipoteza ta jest potwierdzona przez wyniki tętna podczas 2/3 fazy testu. Wnioski. Uzyskane wyniki potwierdziły większy stres adaptacyjny wśród początkujących sportowców. Mistrzowie sportowi mieli wyższy poziom pamięci krótkotrwałej i większą zdolność do szybkiego przetwarzania informacji. Zawodnicy Masters wykazali się wyższym stopień sprawności intelektualnej oraz najlepszą zdolnością do mobilizowania i oszczędzania funkcji organizmu.