DOI: http://dx.doi.org/10.12775/MBS.2016.028

Medical and Biological Sciences, 2016, 30/4, 5-11

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ASSESSMENT OF THE COGNITIVE FUNCTIONS IN KAYAKERS OF THE NATIONAL TEAM AFTER A TRAINING CYCLE COMBINED WITH WHOLE BODY CRYOTHERAPY

OCENA FUNKCJI POZNAWCZYCH U KAJAKARZY Z REPREZENTACJI NARODOWEJ PRZED I PO ZASTOSOWANIU KRIOTERAPII OGÓLNOUSTROJOWEJ

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Summary

Introduction. Using the Quick Mind Testing method, the efficiency of cognitive functions in kayakers after physical training combined with whole body cryotherapy was assessed.

Material and methods. The athletes (n = 17) performed the Quick Mind Testing on the first day and at the end of a 2-month training cycle, as well as before and after whole body cryotherapy conducted between the 5th and the 15th day of the cycle. Cryotherapy was administered twice a day, before and after training (20 sessions altogether). One cryotherapy session lasted 3 mins with the temperature gradually decreased from the initial -120^{o}C to the final -145^{o}C.

Results. After the training period, the kayakers committed approx. 2 times less incorrect Go and NoGo reactions, and approx. 12% more correct NoGo ($p < .004$) reactions, as well as gave more correct answers in the ATTENTION test ($p < .004$) than on the first day of training. After cryotherapy, as compared with the results obtained before the cryochamber stimulation, the kayakers gave more correct answers in the ATTENTION test.

Conclusions. Physical training combined with whole body cryotherapy increases the mental efficiency of kayakers, which may affect the efficiency of physical exercise.

Streszczenie

Wstęp. Uznaje się coraz powszechniej stosowanie kriostymulacji ogólnoustrojowej w medycynie sportowej tak w szeroko pojętej odnowie biologicznej jak w profilaktyce przetrenowania. Dotychczasowe badania wskazują, iż zastosowanie krioterapii w treningu sportowców może mieć korzystny wpływ na przebieg ich przygotowań do zawodów.

Celem badania była ocena sprawności funkcji poznawczych w zakresie szybkości psychomotorycznej oraz procesów uwagi przed krioterapią i po krioterapii w grupie kajakarzy, zawodników reprezentacji Polski.

Materiał i metody. Badaniami objęto grupę 17 kajakarzy, zawodników kadry olimpijskiej, którzy przebywali na zgrupowaniach szkoleniowych w Wałczu.

Badanie funkcji poznawczych przy zastosowaniu testu Quick Mind Testing zostało wykonane bezpośrednio przed cyklem krioterapii i bezpośrednio po jej zakończeniu.

Wyniki. Uzyskane rezultaty wskazują na istotną poprawę w zakresie poprawnych odpowiedzi we wszystkich trzech częściach testu UWAGA po krioterapii w porównaniu z wynikami przed krioterapią, co może wskazywać na korzystny wpływ tej metody na funkcje uwagowe, takie jak:

przeszukiwanie pola percepcyjnego oraz selektywność. Wnioski: Trening fizyczny w połączeniu z krioterapii ogólnoustrojowej zwiększa sprawność umysłową kajakarzy, która może wpłynąć na skuteczność ćwiczeń fizycznych.

Key words: whole body cryotherapy, cognitive processes, sport psychology
Słowa kluczowe: krioterapia ogólnoustrojowa, procesy poznawcze, psychologia sportu

INTRODUCTION

The aim of an athlete, a trainer and a sports medicine physician is a constant improvement of the results obtained by the former. Therefore new possibilities of increasing the abilities in performing exercise are constantly being sought. Recently, the role of psychiatry and psychology in sports has been emphasized. Apparently, the assessment of the effect of training on the attention functions in professional athletes is important for optimizing the results obtained by those athletes. The purposefulness of administering whole body cryotherapy in sports medicine, biological regeneration (in a broad sense) and overtraining prevention gains increasing acceptance. Studies conducted to date indicate that administering whole body cryotherapy as part of athlete training may have a beneficial effect on the course of the preparations for a sporting event.

In professional sports, a complex approach to the athlete training process prevails. Apart from an individually adapted training of technique and endurance, as well as psychophysical, psychomotor and psychophysiological abilities, medical support and psychological preparation are also emphasized. Improvement of particular features and mental abilities required in a given discipline, e.g., selected cognitive functions such as attention and reaction time, is an essential part of mental training [1, 2]. During the pre-event preparations, the training load is significant, which has been demonstrated multiple times in the studies of the effect of intense training on various physiological parameters [3, 4, 5, 6, 7]. Additionally, the deficit of time necessary for proper regeneration hinders the efforts to maintain good psychophysical condition. As a result, fitness reduction occurs, which makes various techniques of biological regeneration useful [8, 9].

The aim of the study was the assessment of cognitive functions concerning psychomotor speed and attention processes during physical training combined with whole body cryotherapy in kayakers of the Polish national team during the preparations for a sporting event (world championship).

MATERIAL AND METHODS

Participants

The study involved 17 kayakers of the Polish national team gathered at a training camp in the Olympic Preparation Centre in Wałcz, Poland. The cognitive function tests were conducted on the first day and at the end of a 2-month training cycle, in which the athletes prepared for the world championships, as well as immediately before and after the whole body cryotherapy cycle which was run within 10 days, from the 5th until the 10th day of the training period. The training cycle involving procedures performed in a chamber of extremely low temperatures (Table 1) was conducted twice a day: in the morning, before the morning training, and in the afternoon, immediately after the completion of the afternoon training (20 procedures altogether). Each time, the kayakers remained in the cryochamber for 3 mins. Every consecutive day, according to the established protocol, the temperature was gradually decreased from -120^{o}C to -145^{o}C. In the morning and in the afternoon, the training programme followed the established principles of the training cycle.

Research has been conducted in an ethical and responsible manner, in full compliance with all relevant codes of experimentation and legislation. The study was approved by the Ethics Committee Nicolaus Copernicus University Collegium Medicum. All participants have given written consent to the inclusion of material pertaining to them, and that they acknowledge that they cannot be identified via the manuscript; and that authors have anonymised them and do not identify them in any way.

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Materials and Procedure

The cognitive functions were studied using a test battery, QMT – Quick Mind Testing (Wiłkość et al., 2009). The decision-making processes belong to complex cognitive processes. In demanding situations, psychomotor speed, related with the speed of information processing, as well as attention, allowing an adequate and quick assessment of stimuli and

circumstances, are of particular importance as the functions affecting the process of decision making. The attention functions encompass: selective attention, sustained attention (prolonged concentration), divided attention, set-shifting and vigilance. In the applied battery the following tests were performed:

1. Psychomotor speed test, in which the subject is asked to react as quickly as possible after exposure to a stimulus (time in milliseconds);

2. The Go-NoGo paradigm test for the assessment of selective attention and the processes of cognitive inhibition. The participant has to react to 4 stimuli out of 6 by clicking a button, while the reaction has to be avoided in the case of two stimuli;

3. A stimulus cancellation test based on the paradigm of the Bourdon figure cancellation test for vigilance and selective attention testing, thus also for the weighted search process testing. In a matrix of digits, letter and arrow codes, the participant has to find the "appropriate", sought stimuli.

Table 1. *Course of the training microcycle with cryostimulation*

Day of week	Hrs of cryostimulation	Hrs of training	TRAINING		
			Type	Duration (min)	Intensity range
Monday	R* - 9^{30}	R* - 10^{00}	Basketball, football, gym followed by stretching	110	I/II and I/II
	P* - 15^{30}	P* - 16^{00}	General training, kayak ergometer training + stretching	110	II/III
Tuesday	R* - 9^{30}	R* - 10^{00}	General and special endurance training	120	I/II
	P* - 15^{30}	P* - 16^{00}	General and special endurance training	120	I/II
Wednesday	R* - 9^{30}	R* - 10^{00}	General and maximum strength training + peripheral strength	90	I/II
	P* - 15^{30}	P* - 16^{00}	Basketball, football, special endurance	120	I/II
Thursday	R* - 9^{30}	R* - 10^{00}	General and specialized training performed in kayak or on ergometer	120	I/II
	P* - 15^{30}	P* - 16^{00}	General and special endurance training	120	II/II
Friday	R* - 9^{30}	R* - 10^{00}	Specialized training performed in kayak + strength training	120	I/II
	P* - 15^{30}	P* - 16^{00}	Strength and special strength training + stretching	90	I/II
Saturday	R* - 9^{30}	R* - 10^{00}	Running, swimming, team sports	120	I/II
	P* - 15^{30}	----------	Free time	---------	---------
Sunday	R* - 9^{30}	Day off training, cryotherapy according to the programme			
	P* - 15^{30}				

Note. R^* – morning; P^* – afternoon. Range I – training with lactate levels threshold up to 4 mmol · l^{-1}. Range II – training with lactate levels threshold up to 4–8 mmol · l^{-1}. Range III – training with lactate levels threshold at > 8 mmol l^{-1}

Table 2. *QMT test results – Quick Mind Testing performed in athletes at the beginning of the training cycle with cryotherapy and after two months of training*

Test n = 17	First day of training (1) M ± SD	Before cryotherapy (A) M ± SD	After cryotherapy completion (B) M ± SD	End of training cycle (2) M ± SD	training1/training2 p	(A)pre-cryo/(B)post-cryo p
GoNoGo test						
No. of incorrect Go reactions	19.00 ± 8.38	11.76 ± 2.46	13.92 ± 4.17	9.60 ± 3.86	.004	.087
No. of incorrect No Go reactions	4.75 ± 2.09	4.0 ± 3.6	2.23 ± 2.39	2.40 ± 0.97	.004	.138
No. of correct No Go reactions	20.25 ± 2.09	21.0 ± 3.61	22.77 ± 2.39	22.60 ± 0.97	.004	.138
ATTENTION test						
% correct responses 1	62.00 ± 10.41	66.82 ± 10.51	77.33 ± 17.08	77.20 ± 11.63	.004	.047
% correct responses 2	63.33 ± 11.65	64.71 ± 9.30	74.36 ± 10.11	76.67 ± 10.10	.010	.011
% correct responses 3	33.92± 9.53	35.14 ± 6.56	44.21 ± 10.25	43.70± 17.20	.097	.006

The following tests were performed: the psychomotor speed test, the Go-NoGo test for the assessment of selective attention and cognitive inhibition, the ATTENTION test for the assessment of visual field search and selective attention.

Tests assessing basic cognitive functions, e.g., visual perception, attention and memory, were used in this study. In these tests, visual stimuli presented on a computer screen are used. The task of the participants is to give responses to the appearing stimuli. Computer keyboard and mouse were used by the participants for giving responses. During the experiment, reaction time and the correctness of the response were measured. Breaks were allowed during the experiment so that the participant may rest. The number and duration of breaks depended on the participant's mood. The duration of the experiment was approx. 25 mins.

Research has been conducted in an ethical and responsible manner, in full compliance with all relevant codes of experimentation and legislation. The study was approved by the Ethics Committee Nicolaus Copernicus University Collegium Medicum. All participants have given written consent to the inclusion of material pertaining to themselves, and that they acknowledge that they cannot be identified via the manuscript; and that authors have anonymised them and do not identify them in any way.

Statistical analysis

Statistical analysis was conducted using the ANOVA test with post hoc analysis (Tukey's range test) (*STATISTICA v.* 9.1). A hypothesis of the equality of two means was tested. Differences at a significance level $p < .05$ were assumed as statistically significant.

RESULTS

The assessed results of the Go-NoGo test demonstrated that after the completion of the training cycle the kayakers committed approx. 2 times less incorrect Go and NoGo reactions ($p = .004$), and approx. 12% more correct NoGo ($p < .004$) reactions than on the first day of the training cycle (Table 2). No statistically significant differences were demonstrated by comparing the results of the Go-NoGo test performed immediately before the initiation of whole body cryotherapy and after 10 days of stimulation with extremely low temperatures.

However, a statistically significant difference was found in the correct responses given in two parts of the ATTENTION test (Table 2). The participants after the completion of the two-month training cycle gave significantly more correct responses as compared with the results obtained on the first day of training. Comparing the number of correct responses in part 1, the increase was approx. 27% ($p = .002$), while in part 2 the increase was approx. 23% ($p = .006$).

By assessing the effect of whole body cryotherapy, a statistically significant improvement was found in the number of correct responses in all three parts of the test ATTENTION. The participants gave significantly more correct responses in the results obtained after the whole body cryotherapy cycle, as compared with the results obtained before the cryochamber stimulation, and the increase was approx. 16% ($p = .047$), 15% ($p = .011$) and 26% ($p = .006$), respectively.

DISCUSSION

For many years, whole body cryotherapy has been used as an efficient form of treatment of rheumatological and degenerative disorders, injuries, burns, muscle spasticity and bone disorders [10]. Positive changes observed in the organism after whole body cryotherapy introduction encouraged its use as a biological regeneration procedure in sports [11, 12, 13]. In her work, Chwalbińska-Moneta [14] presented the results obtained in rowers, in whom the use of whole body cryotherapy resulted in an improvement in the circulatory and metabolic tolerance to physical exercise, the increasing fatigue during muscle engagement slowed down, while stress reactions to the progressive fatigue during muscle engagement slowed down. Moreover, a significant increase in the ability of performing long-lasting exercise of high intensity was observed, i.e. a significant increase in threshold power, comparable with that occurring as a result of a few weeks of endurance training. The article by Hausswirth et al. [15] described positive effects of administering whole body cryotherapy after training inducing muscle damage in runners, as compared with other methods used in the biological regeneration of athletes. Other studied demonstrated a positive effect of whole body cryotherapy on the antioxidant enzyme barrier in peripheral blood [16, 17], improvement in neural transduction, increased pain tolerance and threshold [18], as well as static and dynamic balance after ankle

injuries [19]. Lubkowska et al. [20] have reported an increase in body's immunity, associated with a decrease in total oxidative status and inflammatory response after repeated WBC sessions (10 to 20 sessions). In a pilot study, improvement in mental condition after whole body cryotherapy administration was also documented [21].

The role of psychology in sports became an area of interest in 1920s [22]. Since then, it has been proven multiple times that the course of every cognitive process, i.e. attention, thinking, decision making and reaction time, has a significant effect on the results obtained in sports [2, 23]. The ability of focusing one's attention is crucial for the quality of actions taken, i.e. the speed and efficiency of movements exerted to obtain the planned goals. Attention affects the process of learning proper technique and the precision of the exerted movements during training and sporting events [2, 24, 25]. The latest studies by Wang et al. [26] and Andersen [2] demonstrated that tennis players are characterized by shorter stop-signal reaction times as compared with swimmers and a control group. Cognitive inhibition that is the ability to abstain from performing improper actions or ignore unnecessary information is a crucial skill in the selected disciplines, in which many processes enabling an athlete to score or lose points take place within a fraction of a second. The above mentioned papers also demonstrate that sport activities improve the ability of cognitive inhibition. In tasks requiring focused attention on visual stimuli and inhibition of the responses to certain stimuli with concurrent quick reactions to other stimuli, athletes are characterized by a shorter reaction time and commit fewer mistakes when required to abstain from reacting, as compared with a control group [26]. In their study, Vestberg, Gustafson, Maurex, Ingvar & Petrovic [23] revealed a correlation between the results of tests employing executive cognitive functions and the number of goals scored in football matches played by the studied group of players. The results of the study clearly demonstrated that a smooth course of cognitive processes determines success in ball sports. If the decision making process is efficient, the player quickly and adequately analyses the situation and knows how to properly select the information received during a match, while the effectiveness of the athlete's actions is high and increases the probability of scoring a point. Knowing that the course of cognitive processes is of key importance in sports regardless of discipline [2, 23, 26], while whole body cryotherapy has been administered as a tool of medical support for athletes for many years [11, 12, 27], the aim of this study was to verify a potential novel correlation between these two phenomena. No observations have been made, that would confirm the effect of changing the cognitive functions in high-ranked athletes as a result of physical training combined with whole body cryotherapy. By using the own experimental tool Quick Mind Testing [28], psychomotor speed, selective attention and cognitive inhibition were tested, along with vigilance and sustained attention. The obtained results indicate a significant improvement in the number of correct responses in all three parts of the ATTENTION test performed after whole body cryotherapy administration, as compared with the results obtained before the stimulation with extremely low temperatures, which may indicate a beneficial effect of the method on the attention functions, such as perception field search and selective attention. Statistically significant differences in visual field search, selective attention and cognitive inhibition before and after whole body cryotherapy administration were demonstrated. The studied athletes after extremely low temperature therapy committed fewer mistakes in tasks requiring abstinence from reacting and reacted more quickly in tasks requiring a response to a stimulus. A positive effect of whole body cryotherapy was also observed for each of the attention properties, i.e. perception field search and selective attention. What is significant, the improvement in the course of the cognitive processes of interest did not change 1.5 months after the completion of whole body cryotherapy.

The obtained results permit us to hypothesize that the proposed method of supporting athletes regeneration in the pre-event period is a good idea not only because of biochemical, physiological and physiotherapeutic benefits, but first of all as an additional tool supporting the psychological preparation of the kayakers of the national team. The small size of the study group provides no methodological grounds for generalizing the observed benefits onto other athlete groups; however, the obtained results encouraged us to take further actions. Yet it should be noted that in the case of the national team, the size of the group is limited on purpose. It is because these are prominent athletes selected from a large group of young people training their disciplines, who meet the technique and endurance criteria. It may

therefore seem that expanding the experiments onto other disciplines will enable us to obtain a broader image of the observed correlations. Comparing the *per se* effects of training, whole body cryotherapy and training combined with procedures performed in a chamber with an extremely low temperature.

The results of the presented study confirm that physical training combined with whole body cryotherapy increases the mental capabilities of kayakers. The increased mental potential in athletes may beneficially affect the effectiveness and quality of the obtained results.

The results provide a basis for believing that the proposed method of supporting the regeneration of players during contest is fortuitous idea not only because of the biochemical, physiological and physiotherapy benefits, but primarily as an additional tool to assist psychological training national team kayakers. Few large group of research may not give methodological basis for generalization of the benefits observed for other sports groups, but the results tend to undertake further research. However, it should be noted that at the level of the national team it is not accidental small size of the group. For they are outstanding athletes, elect a large group of trainees young people meet the technical and strength criteria. It seems, therefore, that the extension of the research to other disciplines will get a more complete picture of the observed relationships.

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Received: 8.09.2016
Accepted for publication: 16.12.2016