



## Neurocognitive Functioning of Sport Climbers

by

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*Sport climbing, included in the programme of the Tokyo 2020 Summer Olympic Games, is increasingly gaining in popularity as a method of physical and mental health enhancement. Studies show a positive relationship between climbing and improvement of neurocognitive functioning. The aim of this study was to determine the differences in neurocognitive indicators: time of testing, memory, and location between climbers and non-climbers. The sample comprised 30 sport climbers (15 males, 15 females; aged  $25 \pm 4$  years) practicing climbing regularly for five years, and 30 non-climbing age- and sex-matched controls. The Tactual Performance Test (Halstead-Reitan Test Battery) was used to measure neurocognitive functions (tactile-spatial functions, motion coordination, kinesthetic abilities, learning, memory). Significant differences were found between sport climbers and controls in reference to time, memory, and location ( $p < 0.05$ ). Climbers reached higher memory as well as location ratios and lower time ratios in comparison to controls. Different strategies used to complete the task between the two groups were observed. The neurocognitive functioning of sport climbers manifests itself in faster recognition and differentiation of tactile input and better spatial perception, tactile perception, and movement memory.*

**Key words:** neurocognitive functioning, sport climbing, Tactual Performance Test.

### Introduction

Visual-spatial functions such as creating non-verbal information that allows for orientation in space improve adaptation to environmental conditions. In addition, visual-spatial functions are the basic aspect of knowing the world by perceiving the surrounding space, mental rotation, spatial visualization and the ability to predict the position of a moving object in space (Bednarek, 2004; Hegarty, 2011; Magiera, et al. 2013). In order to correctly perform visual-spatial activities, they must refer to proper basic cognitive functions such as perception, attention, memory, thinking, cognitive control and language. In the visual-spatial function, both cerebral hemispheres are involved (Sendrecka, 2007). During visual-spatial activation, the temporal, the parietal and the frontal lobe, as well as the temporal and parietal cortex are active

(Buetti and Walsh, 2009). In addition, the cerebellum plays an important role in the regulation of visual-spatial functions associated with spatial orientation, mental rotation of objects, and spatial memory (Starowicz-Filip et al., 2013). Visual and visual-spatial perception are related to the efficient functioning of visual receptors and eye movements. Identifying, copying, and searching for similarities are used when performing visual-spatial tasks (Possin, 2010). Active stimulation, environmental analysis, and the ability to detect errors are also important during visual-spatial activities (Gomez-Pinilla and Hillman, 2013). Moreover, one of the basic ways of acquiring information about the surrounding objects is touch perception, which is an important aspect of everyday functioning since birth. It includes the perception of pain, temperature,

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proprioception, and perception of kinesthetic character (Fernandes and Albuquerque, 2012). Touch perception is also associated with the differentiation of texture and geometric shapes (Bergmann Tiest, 2010). In addition, vision and touch functions are automatically integrated for the perception of sequences of events (Bresciani et al., 2006).

Cognitive functions are weakened with progressive aging processes that are caused by neurodegenerative changes and cerebrovascular disease (Gottesman and Hillis, 2010; Querfurth and LaFerla, 2010). Disorders of visual-spatial orientation are present in Alzheimer's disease and may be its first symptoms (Possin, 2010; Weintraub et al., 2012). In mild cognitive impairments, visual-spatial abilities such as visual-motor coordination, psychomotor speed, visual synthesis, and structural praxis are decreased (Cho et al., 2015; Stegmayer et al., 2016; Wojtyńska, 2012). Changes in cognitive functioning also occur in terms of cognitive flexibility and planning, which are extremely important during visual-spatial tasks (Gardner et al., 2013).

For neuropsychological assessment of visual-spatial function, the Tactual Performance Test, the Benton Visual Retention Test (BVRT), the Rey-Osterrieth Complex Figure Test (ROCF), and the Ruff Figural Fluency Test (RFFT) are used (Kang et al., 2014; McIntyre et al., 2013; Steck, 2005). Clinical studies of tactile-spatial perception have so far focused on blind individuals (Postma et al., 2007), newborns and children with no linguistic features (Gallace and Spence, 2009), alcohol addicts (Charter, 2000) and healthy people considering sex as the differentiating variable (Heller et al., 2010). However, in the current literature, there is a lack of study of tactile-spatial perception in athletes.

Sport climbing, included in the programme of the Tokyo 2020 Summer Olympic Games, is increasingly gaining in popularity as a method of physical and mental health enhancement. Sport climbing improves overall physical fitness, muscle strength, visual-motor coordination, balance, muscle strength, endurance, sensory perception and mobility (Ginszt et al., 2017; Schnitzler, 2009; Voelcker-Rehage et al., 2011).

In addition, sport climbing improves the

ability to search for new solutions, orientation and manipulation (Orth et al., 2016). Unlike other sports (running, cycling), sport climbing engages the cognitive and emotional resources of the individual (Luttenberger et al., 2015). Planning and executing motion sequences is a very important training element during sport climbing (Schram Christensen et al., 2017). Moreover, individual body movements are constantly monitored and modified to affect the overall motion, that requires visual, spatial, and psychomotor capabilities (Seifert et al., 2017). Hence, it can be assumed that sports climbing may improve neurocognitive functioning. However, in the current literature, there are no publications confirming the above assumptions.

Therefore, the purpose of this study was to determine the differences in neurocognitive indicators: time of testing, memory, and location between climbers and non-climbers.

## Methods

The sample comprised 30 sport climbers (15 males, 15 females; aged  $25 \pm 4$  years) practising climbing regularly (3 to 5 training days per week) for five years. All sport climbers included in the study group reached the rock climbing difficulty level 7b, based on the self-reported most difficult boulder problem/route ever climbed graded in the Font scale for bouldering and the French/sport scale for lead climbing. The age- and sex-matched control group (15 males, 15 females; aged  $24 \pm 6$  years) consisted of individuals who did not practice sport in a targeted and systematic manner (they did not attend sports clubs, gyms, did not work with a coach). All participants ( $N = 60$ ) were right-handed (they declared themselves as right-handers and it corresponded to the hand they used to write).

All athletes and controls gave their informed consent to participate in the study. The study protocol was in accordance with the Declaration of Helsinki for Human Research.

The Tactual Performance Test (Halstead-Reitan Test Battery) was used to measure neurocognitive functions (time, memory, location). The testing tool used was a wooden board of dimensions  $45.5 \times 30.2 \times 2.1$  cm with 10 cut-out geometric holes for 10 matched objects: a cross, a triangle, a semicircle, a circle, a rectangle, a hexagon, a diamond, a star, an oval, and a

square (Figure 1). Each figure corresponded to one hole.

None of the participants saw the testing tool before or during the study. Prior to the measurement, all figures were randomized and distributed on a table. The first part of the study consisted of 3 trials. Just before the start of each task participants were informed what their specific task in that trial would be. In the first trial, the figures were to be placed in the appropriate test holes using the dominant hand (the right hand in our study). In the second attempt, the task was performed with the subordinate hand (in our study with the left hand). In the third attempt, the task was performed using both hands. After each test, the blocks were re-randomized.

The second part of the study was performed immediately after the first one under visual control. Participants were asked to draw on the paper all shapes of the figures that were memorized by touch in previous attempts. They were asked to draw the objects in their original layout. There were no time limits for this part of the test. In addition, there were no hints on the number, shape, and layout of the figures.

For the first part of the study, time of completion the task (in seconds) was the measure of performance. For the second part, the memory ratio corresponded to the number of correctly reconstructed figures on the paper by the participant (maximum of 10). The location ratio referred to the correct figure drawn on the card as close as possible to the board (maximum of 10).

IBM SPSS Statistics 21 software was used to perform statistical analysis. To compare the variables between the two groups, the Mann-Whitney U test and the Student's t test were used. The  $p$ -values  $< 0.05$  and  $< 0.01$  were considered statistically significant.

## Results

Significant differences were found between sport climbers and controls in reference to memory, location, and both hands time ratios ( $p < 0.01$ ) (Tables 1 and 2). A significant difference between the two groups was also found in the left-hand time ratio, right-hand time ratio, and total time ratio ( $p < 0.05$ ) (Table 1). Sport climbers achieved higher memory and location ratios and lower time ratios.

**Table 1**  
*Differences between sport climbers and the control group in the completion time of the Tactual Performance Test (s) (Student's t test, Mann-Whitney U test)*

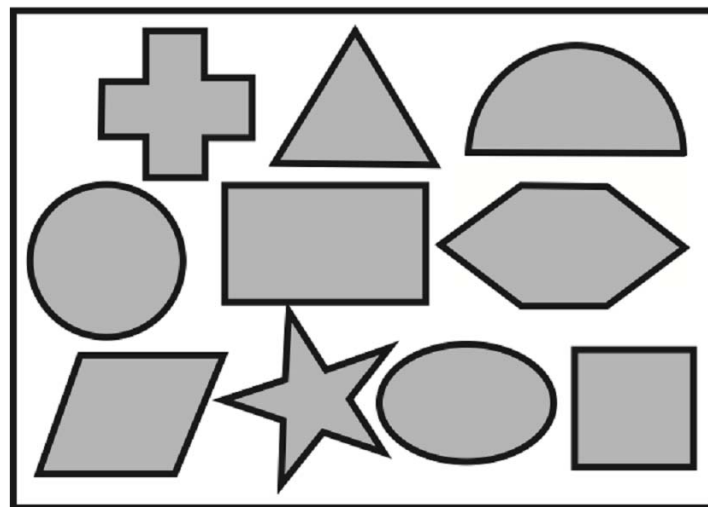
	Sport climbers		Control group		t / Z	p
	M	SD	M	SD		
Right hand	230.10	69.85	282.76	98.75	-1.996*	0.046
Left hand	184.70	53.55	218.83	73.59	-2.054*	0.045
Both hands	120.13	30.21	151.83	57.16	-2.685**	0.010
Total time	534.93	139.78	653.43	207.31	-2.596*	0.012

\*  $p < 0.05$ ; \*\*  $p < 0.01$

**Table 2**  
Differences between sport climbers and the control group in memory,  
and location ratios of the Tactual Performance Test (s) (Mann-Whitney U test)

	Sport climbers		Control group		Z	p
	M	SD	M	SD		
Memory	8.37	0.85	7.77	0.74	-2.654**	0.008
Location	7.67	1.241	7.00	0.78	-2.727**	0.006

\*\*  $p < 0.01$



**Figure 1**

A schematic drawing of the objects and the board of the Tactual Performance Test according to van Dijk et al. (2013)

## Discussion

Most people in the day-to-day routine prefer visual perception of the subject rather than touch perception (Newell et al., 2001). However, based on our results, sport climbers present a tendency

to receive stimuli with activated both visual and tactile perception. This can be explained by the fact that sport climbers have more experience in the field of tactile and spatial perception of objects than non-climbers. Moreover, the Tactual

Performance Test may be affected by coordination and memory skills, which is the indicator of the training effect between the individual tests (Steuden, 1994). To the best of our knowledge, this is the first report on neurocognitive indicators: time of testing, memory, and location not only in sport climbing, but also throughout themed sport activity.

In the present study, sport climbers achieved lower time ratios in comparison to non-climbers. The results obtained in the Tactual Performance Test may be due to the ability of touch sensing and the ability to discriminate dispersive stimuli, which in sport climbers was at a higher level. The speed of performance by sport climbers can also be increased by the development of skills related to the search for new solutions (Orth et al., 2016). Among the studied groups, the use of different strategies during the Tactual Performance Test was observed, which may be the result of the level of neurocognitive functioning. Moreover, sport climbers achieved higher memory and location ratios in comparison to non-climbers. These results may prove better tactile-spatial perception in sport climbers. In addition, memory and location reconstruction of figures on a sheet of paper was dependent on the ability to recognize figures by touch, which indicates better tactile perception in sport climbers. Although a large and rapidly increasing number of studies have investigated physiological aspects of sport

climbing, there is a lack of studies on neurocognitive functioning of sport climbers.

Sport climbing is used as a form of support for orthopedic, neurological, and psychological rehabilitation (Luttenberger et al., 2015). Climbing is also recommended for improving muscle stability and visual-motor coordination (Voelcker-Rehage et al., 2011). According to our results, it can also be assumed that sport climbing may assist in developing cognitive reserves in young people. Further research is recommended to determine whether climbing can be used as a method to support neuropsychological rehabilitation in patients with cognitive impairment. In future studies, it is also necessary to determine which features of climbing training have an influence on visual and spatial functioning in both healthy and cognitively impaired individuals.

## Conclusions

The neurocognitive functioning of sport climbers manifests itself in faster recognition and differentiation of tactile input and better spatial perception, tactile perception, and movement memory. Further research is recommended to determine whether climbing can be used as a method to support neuropsychological rehabilitation in patients with cognitive impairment.

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