How Is Attention in Soldiers Affected by Carrying Combat Equipment?

EVA ORANTES-GONZÁLEZ (meoragon@upo.es)
Pablo de Olavide University: Universidad Pablo de Olavide
JOSE HEREDIA-JIMENEZ
University of Granada: Universidad de Granada

Research

Keywords: arousal, exercise, military, perception

Posted Date: March 6th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-285884/v1

Abstract

Background: Load carriage is a common task in military contexts. This study analysed the influence of carrying different equipment during an obstacle course on perception and attention performance in soldiers belonging to the Spanish infantry.

Methods: Forty-six soldiers were evaluated before and after having completed a 1-km obstacle course carrying the combat equipment and carrying no additional load (control). The determination test was used to measure the stress tolerance and reaction abilities, while the divided attention test measured the alertness, vigilance and divided attention.

Results: A significant decrease was observed in the reaction time after the course compared to the pre-course in the control and combat conditions. In contrast, the correct and incorrect responses and number of reactions increased from the pre to post-obstacle test in the control and combat conditions.

Conclusion: Soldiers improved their arousal after having completed a moderate intensity obstacle test, answering more quickly than on a pre-obstacle test.

Introduction

The challenging nature of military duties requires personnel to operate at a high level in situations that require physical and cognitive challenges. Related to the cognitive performance, to be successful in missions or military duties, combatants need to maintain surveillance and selective attention during the task to achieve the set objective (Idiazábal Alecha et al., 2018). The strain-induced decrements in cognitive performance could produce fatal negative consequences in military contexts (Eddy et al., 2015) where the lives of soldiers are sometimes committed.

The effect of physical exercise on cognitive performance in military personnel has been analysed under combat simulations (Delgado-Moreno et al., 2019) and combined with sleep restriction or food deprivation (Lieberman et al., 2006). The results indicated that the simulation of combat situations produced an increase of somatic anxiety and had a negative effect on the working memory; the elements related to sight were the most remembered in soldiers after the mission (Delgado-Moreno et al., 2019).

In studies carried out with non-military personnel, the results indicated that physical activity seems to have a positive influence on attentional performance, decreasing the reaction time after practicing moderate physical activity (Rogerson & Barton, 2015) and during 20 minutes of cycling at different intensities (Davranche et al., 2015). The study by Davranche et al., (2015) concluded that cognitive control seems to be a robust cognitive function not affected by exercise constraints. The positive answer after physical activity could be explained by arousal theories, wherein physical exercise is accompanied by an increase in arousal working as an inverted-U (Kahneman, 1973; Yerkes & Dodson, 1908). Thus, as physiological arousal increases, performance increases towards an optimal performance point at moderate levels of arousal, although if that arousal continues to increase, a detriment to performance will appear (Yerkes & Dodson, 1908).

In addition to physical exercise, among the physical tasks that soldiers complete daily are activities in which they have to carry an extra load, including carrying protective ensembles (e.g., body armour, helmet) or combat specific equipment (e.g., weapon, ammunition, power sources, radio) (Carlton & Orr, 2014; Johnson et al., 1995). The effect of load carriage on attention performance has been analysed in a previous study where soldiers walked 2 hours on a treadmill carrying 40 kg while completing two cognitive tasks (auditory go/no go task and a visual target detection task) (Eddy et al., 2015). This study concluded that cognitive performance, especially executive control and response inhibition, was negatively affected by load carriage during prolonged exercise. In spite of the determinant role that load carriage seems to have in attention performance, no additional studies have been carried out.

In the military field, obstacle courses have been widely used in previous studies as a basis for a representation of the battlefield because of their basic and main military instructions (Dias et al., 2005). However, the combined effect of load and fatigue on soldiers' arousal after the completion of an obstacle course is still unknown. Therefore, our study analysed the influence of an obstacle course, together with the influence of carrying combat equipment, on perception and attention performance combined with the analysis of heart rate and performance in soldiers belonging to the Spanish infantry.

Methods

Participants

Forty-six male soldiers participated in this study. The average (standard deviation) age was 26.1 (4.5) years, height was 1.75 (0.62) m and weight was 80 (10.6) kg. All participants were volunteers and belonged to the Spanish infantry. They completed an informed consent form before their inclusion in the study. They did not have recent orthopaedic trauma, neurologic problems, or had any restrictions in relation to walking or load carriage. The Ethics Committee of the University of Granada approved this study.

Protocol

Each soldier was heighted and weighted with a scale and measuring rod (SECA769, Hamburg, Germany). From this point on, in each of the 2 experimental sessions, the participants completed the following three phases in a continuous way. The first phase was the application of two cognitive tests for attention analysis. The second phase was to complete, as fast as possible, an obstacle course that they used for training their combat skills in the military headquarters. The third and last phase was, again, the application of the cognitive test that was performed in the first phase.

In the control condition, soldiers completed the obstacle course wearing military socks and boots, a camouflage uniform, and light body armour. In the combat condition, soldiers had to wear the same equipment as the control condition, as well as a helmet, body armour with ammunition clip, battle rifle (HK-42) with 5 empty chargers, combat gloves, and joint protectors. They also carried a battle backpack containing spare clothes, a rigid 1-litre bottle of water, an American blanket, individual medical kit, and various survival accessories. The approximate weight of the equipment in the combat condition was 19 kg. Each experimental session was completed on different test days, and at least 48 hours of rest were allowed between conditions. Each soldier carried out each condition following a randomized order.

During the obstacle course, a Tomtom Runner 3 (TomTom international, Amsterdam, Holland) was used to measure the obstacle course competition time in minutes. A Zephyr BioHarness system at 100 Hz (Zephyr Technology, Auckland, New Zealand) was placed in the thorax of each participant to obtain the mean heart rate (HR) during the obstacle course with the software OmniSense 5.1 (Zephyr Tech. Corp., MD, USA).

Cognitive tests: the Determination Test (DT) and the Divided Attention Test (WAFG)

The DT is a complex, multi-stimuli reaction test involving the presentation of both coloured stimuli and acoustic signals. The respondent reacts by pressing the appropriate buttons on the response panel that assessed the divided attention (Gurd et al., 2010). The DT is used to measure reactive stress tolerance and the associated ability to react (Schuhfried, 2017). Stress tolerance refers to the individual's ability to resist the effect of the stimuli; that is, their ability to use modes of behaviour that enable them to cope as effectively as possible with the situation (Brickenkamp et al., 1986). The stress element of the DT arises from the need to sustain continuous, rapid and varying responses to rapidly changing stimuli (Schuhfried, 2017).

The DT form chosen was the "Rostock Form" that included colours and tones. The respondent's task was to react as quickly as possible to visual or acoustic stimuli. There were 5 visual stimulus colours (white, yellow, red, green and blue), which appeared in an upper and a lower row. The reaction buttons assigned to these five colours were arranged on the response panel in such a way that the respondent could use both hands. There were 2 additional acoustic stimuli (high and low tone) assigned to the "sound" buttons in the middle of the panel. The visual stimuli were presented on the screen and the acoustic stimuli via headphones. Each stimulus appeared when a correct response was made to the current one, so the speed of the stimulus presentation was determined by the respondent. The administration time was approximately 8 minutes.

In addition, after the DT, the divided attention of the perception functions were measured using the WAFG test. This test is based on the paradigm of Zomeren and Brouwer (1994), where according to this model, the central factors of attention include the distinguishing of intensity and selectivity aspects. The intensity aspect of attention integrated alertness and vigilance, while the selectivity aspect included the focused-selective and divided attention.

In the short form of the WAFG Test, the respondent received stimulus on a visual and auditory channel presented in a cross-modal way. They had to respond if the signal on the visual stimulus channel became brighter twice in succession or if that on the auditory stimulus channel became quieter twice in succession. For that, 85 stimuli (visual and auditory) were presented. The easy short form of the WAFG test was chosen, which takes approximately 8 minutes. The stimuli were presented for 1500 ms, while a change took place after 500 ms. There was an interstimulus interval of 1000 ms between stimuli.

Both tests were completed in a warm, quiet and light room before and after the obstacle course. The participants were comfortably seated, and the computer´s screen was adapted to each subject's eye level. In the test that required sound, the volume of the headphones was chosen by each participant. The instructions were provided at the start of the test and followed independently by the respondent on the screen. The 2 tests included a training mode before starting, completing a familiarization trial before the data collection. The researcher was not required to provide any further explanation. The variables analysed are presented in Table 1.

The Obstacle Course

The obstacle course was approximately 1 km from the start to the finish and returned with an altitude slope of 50 meters. The course included the following 6 obstacles:

1. Cargo net climb: soldiers climbed up and over a 4.5 meter vertical cargo net.
2. Balance log: soldiers had to traverse a balance log without touching the ground with their feet.
3. Low crawling: soldiers low-crawled across 15 meters underneath a barbed wire obstacle located 0.5 meters over the ground.

4. Steel wire balance: soldiers maintained their balance crossing 7 meters of steel wire. The steel wire was placed 2 meters above the ground. Soldiers had another steel wire at the height of their head to pass the obstacle.
5. Underground tunnel: soldiers crawled through a 10-metre-long tunnel.
6. Climbing with cord: taking advantage of a natural slope of the terrain, a rope was attached. Soldiers had to climb up the 15-metre slope using that rope. The slope had a gradient of approximately 50º.

Soldiers completed the obstacle course under control and combat conditions as quickly as they could. Before the data collection, each soldier completed the course once by walking to ensure that the itinerary of the course was clear.

Statistical Analysis

SPSS software v.24 (IBM SPSS, Armonk, NY) was used for the data analysis. The variables of the 2 attentional tests were analysed with a repeated measured two-way ANOVA (equipment and fatigue). Tukey's post hoc test was used whenever significant differences were found. The Kolmogorov–Smirnov test was used to test data normality, and Levene's test was used to test the homogeneity of variance. Mauchly's test was used to assess sphericity. In addition, a dependent-samples Student's t test was used to analyse differences between the control and combat conditions in the obstacle course time and mean HR. The level of significance was set at $p<0.05$.

Results

From the ANOVA results of the WAFG test variables, non-significant differences were found for the effect of equipment, fatigue or their interaction (Table 2). On the other hand, the DT test showed a significant effect of fatigue for all the variables analysed ($p<0.001$) (Table 2). Non-significant differences were found for the equipment effect (control vs. combat) and for the interaction between equipment and fatigue (Table 2).

In the post-hoc comparisons of the DT variables, a significant decrease in median reaction times after the obstacle course (lower values indicated better results) compared to pre-obstacle course in the control and combat conditions was observed. In contrast, the correct and incorrect responses and number of reactions increased from pre to post-obstacle course in the control and combat conditions.

With respect to the time to complete the obstacle course and the mean HR, both showed significant differences between control and combat conditions (Figure 1).

Discussion

In a military context, strain-induced decrements in cognitive performance could have fatal consequences (Eddy et al., 2015). This study evaluated the effect of fatigue during a 1-km obstacle course and load carriage on perception and attention performance, a very common and useful task for combat simulation in soldiers. In our study, the results indicated that the physical effort and not the increased load produced a higher arousal response in soldiers, positively influencing the stress tolerance and the reaction ability, while the alertness and vigilance was not affected by the load carriage of the exercise fatigue.

In relation to the effect of equipment carriage and fatigue, although soldiers increased their physiological response, increasing the mean HR and needing a longer time to complete the test, the results of the WAFG test indicated that the alertness and vigilance were not compromised after an obstacle exercise carrying the military equipment. In contrast, in the study of Eddy et al. (2015), false alarms and reaction time increased after prolonged exercise when soldiers carried 40 kg compared to the unloaded condition. The lack of differences in stress tolerance, ability to react, alertness and vigilance in the combat condition found in our study could be due to the differences in the physical activity duration and load. In fact, in the study of Eddy et al. (2015), soldiers were walking for 2 hours, while in our study the activity was shorter (1 km) and the weight of the combat equipment was lower (approximately 20 kg vs. 40 kg).

The results of the DT test indicated that after the completion of the obstacle exercise, the reaction time decreased compared to the pre-obstacle test (lower values indicated better results), together with a higher number of reactions and correct and incorrect responses. That improvement in reaction time is supported by Davranche et al. (2015), where the reaction time was faster after 15 minutes of cycling. With respect to the correct and incorrect responses, in concordance with the results found in our study, the numbers of false alarms resulted also increased after 65 minutes of walking (Eddy et al., 2015).

The faster answering capacity (decreasing the reaction time), together with the increase in reactions and incorrect reactions after fatigue, seemed to be related to an increase of the soldiers´ arousal, decreasing the stress tolerance and increasing the reaction ability. Those results could support the conclusions of McMorris et al. (2011), where a dissociated effect after moderate intensity exercise was found: on the one hand, the brain seems to increase the concentrations of the neurotransmitters norepinephrine and dopamine, which would decrease the reaction time and increase the number of responses; on the other hand, that would produce a negative effect on accuracy. In this way, Yanagisawa et al. (2010), found an interaction between accuracy of processes and speed. Although the decrease in accuracy is not necessarily due to an increase of speed, McMorris et al. (2008) found this relationship during intermediate intensity exercise.

Limitations of this study are that only males were evaluated, and the obstacle course was not carried out under real combat situations where soldiers could have highly compromised their attention or stress. Future studies could relate the physiological stress component with the variables of the attentional tests.

Conclusions

Completing a moderate intensity obstacle test improved the soldiers´ arousal, and they were able to answer question more quickly (decreasing their reaction times). Although their accuracy also decreased, alertness and vigilance were not influenced. With respect to the combat equipment carriage, a non-negative effect on perception and attention was observed in the soldiers' performance.

Lay Summary

Completing a moderate intensity obstacle test increased the soldiers´ arousal, decreasing their accuracy. So, for tasks where soldiers need to maintain the attention performance, such as checking point or similar, to practice moderate intensity activity previous to that, is not recommended.

Declarations

- Ethical Approval and Consent to participate: All of the participants have completed an informed consent form before their inclusion in the study. The Ethics Committee of the University of Granada approved this study.

- Consent for publication: This manuscript has been read and approved by all the listed co-authors. Besides, it is original and not previously published in any form including on preprint servers.

- Availability of data and materials: Not applicable

- Competing interests: None

- Funding: This project was funded by CEMIX: University of Granada and Command for Training and Doctrine (MADOC) ref. PIN 21/18, with funds of Santander Bank.

- Authors' contributions: JHJ has participated in the writing of the manuscript, data collection and statistical analysis. EOG was involved in the writing, data collection and interpretation of results. Both authors have reviewed the information included here.

- Acknowledgements: The authors thank all of the participants and military personnel of the Tercio Duque de Alba 2° de La Legión and Grupo de Regulares n° 54 (Ceuta) that took part in this study.

- Authors' information: JHJ is a full professor in the Department of Physical Education and Sports, in the University of Granada and head of the HubemaLab. EOG is an assistant professor in the University of Pablo de Olavide and a member of HubemaLab.

References

1. Brickenkamp, R., Angermeier, W. F., Barakowki, D., Becker-Carus, C., Bednorz, P., Galley, N., Grundlach, H., Hajos, A., Herff, W., Hopmann, G., Karl, G. A., Kisser, R., Krafack, A., Ludwig, L., Pieper, W., Traxel, W., Vaughan, C., Wahler, R., & Zschuppe, U. (1986). *Handbuch apparativer Verfahren in der Psychologie* (pp. 174-177).
2. Carlton, S. D., & Orr, R. M. (2014). The impact of occupational load carriage on carrier mobility : A critical review of the literature. *International Journal of Occupational Safety and Ergonomics*, *20*(1), 33-41. https://doi.org/10.1080/10803548.2014.11077025
3. Davranche, K., Brisswalter, J., & Radel, R. (2015). Where are the limits of the effects of exercise intensity on cognitive control? *Journal of Sport and Health Science*, *4*(1), 56-63. https://doi.org/10.1016/j.jshs.2014.08.004
4. Delgado-Moreno, R., Robles-Pérez, J. J., Aznar-Laín, S., & Clemente-Suárez, V. J. (2019). Effect of Experience and Psychophysiological Modification by Combat Stress in Soldier's Memory. *Journal of Medical Systems*, *43*(6). https://doi.org/10.1007/s10916-019-1261-1
5. Dias, C., Dantas, E. H. M., Moreira, S. B., & Furtado, V. (2005). Relationship between the level of the aerobic conditioning , performance on an obstacle course , and outcome in a shooting test. *Rev Bras Med Esporte*, *11*(21), 310-314. https://doi.org/10.1590/S1517-86922005000600007
6. Eddy, M. D., Hasselquist, L., Giles, G., Hayes, J. F., Howe, J., Rourke, J., Coyne, M., O'Donovan, M., Batty, J., Brunyé, T. T., & Mahoney, C. R. (2015). The effects of load carriage and physical fatigue on cognitive performance. *PLoS ONE*, *10*(7). https://doi.org/10.1371/journal.pone.0130817
7. Gurd, J. M., Kischka, U., & Marshall, J. C. (2010). The Handbook of Clinical Neuropsychology. En *The Handbook of Clinical Neuropsychology*. https://doi.org/10.1093/acprof:oso/9780199234110.001.0001

8. Idiazábal Alecha, M. Á., Sebastián Guerrero, M. V., Navascués Sanagustín, M. A., Arcos Sánchez, C., Arana Aritméndiz, M. V., Ruiz López, C., & Iso Pérez, J. M. (2018). Estudio cortical de la atención en tests de simulación militar. *Revista de Neurología*, *66*(10), 331. https://doi.org/10.33588/rn.6610.2017478
9. Johnson, R. F., Knapik, J. J., & Merullo., D. J. (1995). Symptoms during load carrying: Effects of mass and load distribution during a 20-km road march. *Perceptual and Motor Skills*, *81*, 331-338.
10. Kahneman, D. (1973). Attention and effort. Englewood Cliffs, NJ. En *Prentice-Hall, Inc*.
11. Lieberman, H. R., Niro, P., Tharion, W. J., Nindl, B. C., Castellani, J. W., & Montain, S. J. (2006). Cognition during sustained operations: Comparison of a laboratory simulation to field studies. *Aviation Space and Environmental Medicine*, *77*(9), 929-935.
12. McMorris, T., Collard, K., Corbett, J., Dicks, M., & Swain, J. P. (2008). A test of the catecholamines hypothesis for an acute exercise-cognition interaction. *Pharmacology Biochemistry and Behavior*, *89*(1), 106-115. https://doi.org/10.1016/j.pbb.2007.11.007
13. McMorris, Terry, Sproule, J., Turner, A., & Hale, B. J. (2011). Acute, intermediate intensity exercise, and speed and accuracy in working memory tasks: A meta-analytical comparison of effects. *Physiology and Behavior*, *102*(3-4), 421-428. https://doi.org/10.1016/j.physbeh.2010.12.007
14. Rogerson, M., & Barton, J. (2015). Effects of the visual exercise environments on cognitive directed attention, energy expenditure and perceived exertion. *International Journal of Environmental Research and Public Health*, *12*(7), 7321-7336. https://doi.org/10.3390/ijerph120707321
15. Schuhfried, G. (2017). *Vienna Manual Test System: Perception and Attention Functions*.
16. Van Zomeren, A. H., & Brouwer, W. H. (1994). *Clinical neuropsychology of attention.* Oxford University Press.
17. Yanagisawa, H., Dan, I., Tsuzuki, D., Kato, M., Okamoto, M., Kyutoku, Y., & Soya, H. (2010). Acute moderate exercise elicits increased dorsolateral prefrontal activation and improves cognitive performance with Stroop test. *NeuroImage*, *50*(4), 1702-1710. https://doi.org/10.1016/j.neuroimage.2009.12.023
18. Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459-482. https://doi.org/10.1002/cne.920180503

Tables

Table 1. Variables analysed in the Determination Test (DT) and the divided attention and perception test (WAFG). *Variables obtained for visual and acoustic stimulus.

Test	Variable	Description
DT	Median Reaction Time	Median of time between the stimulus appears and press the button (s)
	Correct Reactions	The number of accurate reactions
	Incorrect Reactions	Each inappropriate reaction to a stimulus
	Reactions	The total number of correct and incorrect responses
WAFG Test	Mean Reaction Time*	Mean of the individual reaction times (ms)
	Dispersion of Reaction Time*	The exponent of the standard deviation of reaction times (ms)
	Number of missed reactions*	Number of stimuli with no response within 1500 ms
	Number of false alarms	Number of reactions not preceded by a stimulus

Table 2. Mean (standard deviation) of the WAFG variables including in the crossmodal, visual and acoustic stimulus. Besides, the ANOVA results (F value and p value) as equipment and fatigue effects and its interaction. RT: Reaction time.

			Control Condition		Combat Condition		ANOVA Results					
			Pre-course	**Post-course**	**Pre-course**	**Post-course**	Equipment		Fatigue		Interaction	
			Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F	Sig.	F	Sig.	F	Sig.
WAFG TEST	**Crossmodal**	Mean RT (s)	479.2 (110.8)	455.2 (112.5)	472.3 (116.9)	463.3 (118.5)	0.03	0.85	2.22	0.14	1.19	0.28
		Dispersion RT (ms)	1.4 (0.1)	1.4 (0.1)	1.4 (0.1)	1.4 (0.1)	0.03	0.86	2.29	0.14	2.75	0.11
		No. missed reactions	2.3 (2.4)	3.2 (3.1)	3.2 (3.5)	3.1 (3)	1.08	0.30	1.49	0.23	3.01	0.09
		No. false alarms	3.8 (6.1)	4.4 (7.3)	4.6 (7.1)	4.4 (6.5)	0.58	0.45	0.70	0.42	1.89	0.18
	Visual	Mean RT (s)	453.1 (128.3)	447.9 (123.1)	449.6 (106.8)	442 (131.5)	0.08	0.78	0.10	0.75	0.02	0.89
		Dispersion RT (ms)	1.3 (0.1)	1.3 (0.8)	1.3 (0.1)	1.4 (0.2)	0.47	0.50	2.36	0.13	0.11	0.72
		No. missed reactions	0.9 (1.4)	1.1 (1.8)	1.2 (1.6)	1.1 (1.3)	0.89	0.35	0.02	0.97	0.78	0.38
	Acoustic	Mean RT (s)	511.6 (108.8)	465.9 (113.4)	507.1 (154.8)	492.2 (134.5)	0.81	0.37	3.58	0.06	2.41	0.13
		Dispersion RT (ms)	1.4 (0.2)	1.4 (0.2)	1.4 (0.2)	1.4 (0.2)	1.37	0.25	1.59	0.25	2.09	0.16
		No. missed reactions	1.4 (1.6)	2.1 (1.8)	1.9 (2.3)	1.9 (2.2)	0.72	0.40	2.92	0.10	3.48	0.08
DT TEST		Median RT (s)	0.70 (0.1)	0.64 (0.1)	0.71 (0.1)	0.64 (0.1)	0.22	0.64	336.9	**<0.001**	2.20	0.15
		No. Correct reactions	332.5 (34.5)	361.7 (36.9)	327.4 (28.3)	360.8 (32.9)	0.72	0.40	223.6	**<0.001**	1.50	0.23
		No. Incorrect reactions	6.5 (5.8)	9.3 (8.9)	6.33 (4.8)	9.67 (7.1)	0.02	0.89	22.53	**<0.001**	0.29	0.60
		No. Reactions	339.1 (36.1)	370.8 (39.1)	333.8 (29.6)	370.5 (34.5)	0.52	0.47	242.1	**<0.001**	1.79	0.19

Figures

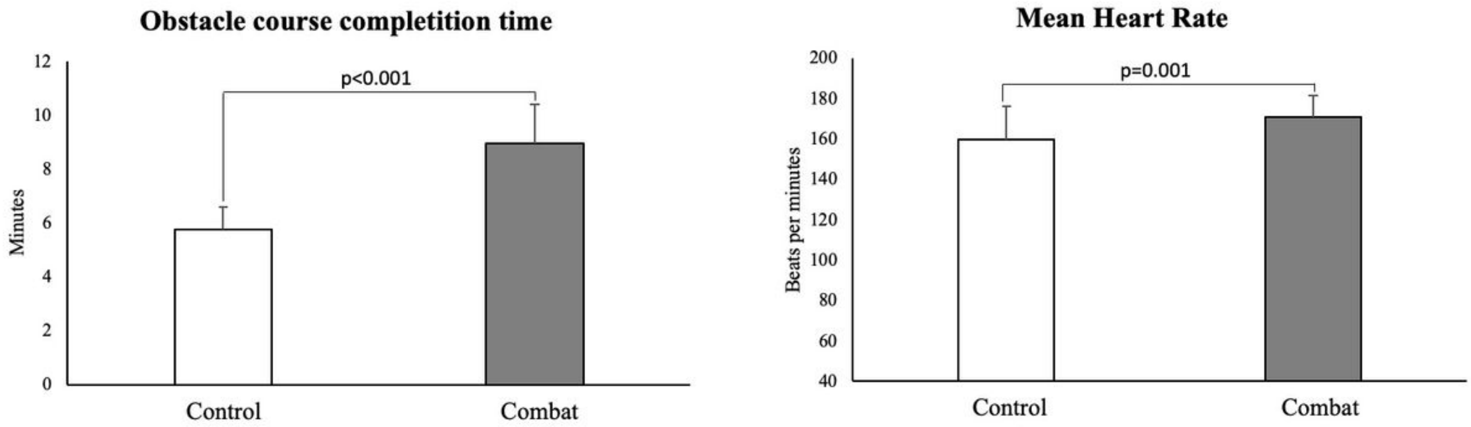

Figure 1

Mean and standard deviation (as error bars) of competition obstacle course time (seconds) and heart rate (bpm) between control (white color) and combat condition (grey color).