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A review on the effect of heat stresses on cognitive functions

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ABSTRACT

Introduction: Many studies have been done on the effects of heat stress on cognitive functions, but the results are inconsistent. This article aimed to review the effect of heat stress on cognitive functions.

Material and method: In this study, all English articles conducted on effect of heat stress on cognitive, perceptual, and psychomotor functions from 1970 to 2018 were reviewed. For this, articles with keywords such as heat strain, heat stress, cognitive function, memory, comprehension, psychomotor, reaction time, mental performance, mood, mental response, error, task performance, fatigue, alertness, hyperthermia, and heat exhaustion were searched in the Scopus, Web of Science, Science Direct, Pub Med, Springer, Wiley Online Library and ProQuest databases. Out of 157 retrieved articles, 39 articles were finally reviewed according to the inclusion criteria.

Results: Out of 157 retrieved articles related to the topic, according to the inclusion criteria, 39 articles were finally considered for review. Among this articles, 9 (%23) articles were published \ before 2000 and 30 (%77) after 2000. Two articles were in athletes, four articles (%10.2) in workers, four articles (%10.2) in students, four articles (%10.2) in military soldiers and twenty-five articles (%64.2) were conducted in ordinary people. Based on the results, heat stress was identified as a detrimental factor for decreased cognitive functions such as reading comprehension, memory, focus, mathematical processing, tracking test, reaction time, perception and decoding text and numeric messages, visual alertness, mental computing, text reading , hidden figures test and verbal fluency.

Conclusion: Based on the results of these studies, heat stress has been introduced as a detrimental factor for disrupting cognitive functions, but conclusion based on the results of studies is a systematic method is difficult because many confounding variables such as type of work, exposure time, skill and adaptation plays a big role.

Keywords:

Heat Stress, Heat strain, Cognitive Function, Psychomotor, Mental Function.

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1. Introduction

Physiological changes in warm environments is well documented, but cognitive changes are not well understood (1). Therefore, in mental works requiring cognitive demands, workers exposing to workplace heat should be barred from working before the heat stress of the workplace affects their cognitive function. A better understanding of cognitive functions under heat conditions, which reflects the state of human mental health, not only can be helpful in developing a permissible occupational exposure limit, but also it can be effective in improving the quality of social life as well as improving the work environment. In general, few studies have studied cognitive functions under heat working condition, and there is little knowledge in this area. Accordingly, many attempts have been made to create a permissible occupational exposure limit based on cognitive function and not only considering the physiological function (2). Therefore, this study was conducted to review the effects of heat stress on cognitive functions.

2. Material and Methods

In this review study, all articles published in English on the effect of heat stress on cognitive, perceptual, and psychomotor functions from 1970 to 2018 were reviewed. For this purpose, a systematic search using keywords including heat stress, cognitive function, memory, themal stress, perception, psychomotor, reaction time, mental function, mood, mental response, error, task performance, fatigue, awareness, hyperthermia and overheating were performed at Scopus, Web of Science, Science Direct, Pub Med, Springer, Wiley Online Library, and ProQuest databases. Studies that only examined the physiological effects of exposure to heat stress were also excluded. Animal studies have also been eliminated due to lack of similarity with human cognitive processes.

3. Results

Of the 157 recovered articles related to the topic, 39 articles were finally selected according to the inclusion criteria. Among them, 9 (23%) articles were published in the years before 2000 AD and 30 studies were published in the years after 2000 AD. A review of studies published before 2000 showed that all studies were performed in a laboratory setting. According to the results of these studies, heat stress is a detrimental factor for cognitive functions including comprehension, memory, concentration, mathematical calculations, tracking tests, reaction time, perception and decoding text and numerical messages, visual alertness, mental calculations, and reading text. The results of Table 1 showed that exposure to heat leads to a decrease in many aspects of cognitive functions. Studies in different groups, including the workforce, athletes, public volunteers, and students, showed that the effects of heat stress are not limited to one group, but all people under different conditions will be affected by this harmful agent, although these effects are more significant in occupational groups.

4. Discussion and conclusions

In general, simple functions such as reaction time have been shown to be less affected by heats tresses, while more complex functions such as alertness, tracking, and multi-tasking are more affected (3). Hancock stated that operators who are more adapted to heat have a greater ability to withstand the effects of heat (4). Prolonged exposure to heat stress is expected to reduce cognitive function, although short-term exposure to up to 18 minutes may improve performance in dual tasks (5). Pepler et al. stated that having high motivation as well as specialized knowledge along with encouragement to improve performance can improve people's performance in thermal conditions (6). Conclusively, it can be acknowledged that increasing the exposure to heat stresses leads to a decrease in cognitive functions, especially in occupations that have some degree of cognitive load.

5. References

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Table 1. Methodology and results of studies published after 2000 AD

Authors	understudy groups	understudy environment	Temperature range in the each set of articles	Understudy variables in the each set of articles	The results obtained from the each set of classified articles
Cian et al, Gaoua et al, Cheuvront et al, Witterseh et al, Morley et al, D'anci et al, Færevik et al, Gaoua et al, Serwah et al, Mcmorris et al, Ganio et al, Schlader et al, Racinais et al, Simmons et al, Gaoua et al.	Public volunteers	Laboratory study	The temperature range in these studies was from 3 °C to 50 °C.	Long-term and short-term memory, perceptions of distraction, reaction time, tracking, matching, visual, visual Vigilance, information processing test, spatial span, pattern recognition memory, logic and grammatical reasoning, fatigue, accuracy, concentration, Difficulty in thinking, mathematical processing, mood states, pattern recognition and performance	- Working memory is disturbed by heat while attention remain unchanged due to the use of cooling caps. - Decrease in concentration and performance and 56% increase in error rate. - Increased irritability. - Loss of consciousness. - Decreased performance in complex tasks, while it remain unchanged in simple tasks. - In less than 90 minutes of activity, the selected reaction time was not affected by heat. - Heat stress had a detrimental effect on the performance of central executive tasks and perception of mood. - Increased anxiety and fatigue. - Increasing of the reaction speed and reducing of the accuracy.

Hocking et al, Radakovic et al, Lieberman et al, Amos et al.	Militaries	Laboratory and field study	WBGT in the range of 16 to 29 (tropical regions)	Verbal learning, attention and focus, working Memory, information processing speed, motor function, rapid visual information processing, reaction time, Matching-to-Sample Test, logic and grammatical reasoning, anxiety questionnaire	- Disruption in working memory, information processing speed and data recovery. - Increasing the number of wrong answers and delays in answering. - Disruption in consciousness, reaction time, attention, memory and reasoning. - Disruption in people's moods including fatigue, confusion, depression and tension. - Decreased cognitive function in adapted soldiers.
Taber et al, Hygge et al,(31) Edmonds et al.	students	Laboratory study	WBGT in the range of 22 to 34	Skill performance, Attention, problem solving, long-term memory, short-term memory, arithmetic calculations, visual attention, auditory discrimination, unstable tracking, mood.	- Decreased performance in the first 90 minutes of piloting simulation test. - Interactive effect of noise and heat stress on long-term memory. - Increasing cognitive function following supplemental water intake and lowering body temperature.
Furtado et al, Chen et al, Berg et al, Mazlomi et al.	People working in different workplaces	Field study	WBGT in the range of 16 to 36	Attaching and detaching nuts and washers, putting on and taking off insulators, mental fatigue and reaction time, cognitive stress, precision and accuracy.	- Productivity is higher when people wear cooling clothes. - Heat stress can significantly affect productivity. - More mental fatigue and cognitive stress in those who work in hot environments. - Increased distraction in surgeons.
Sunderland et al, Bandelow et al,	Athletes	Laboratory and field study	30-46 ^{o}C	Skill testing, visual sensitivity, speed, visual-auditory performance, memory.	- Reduce the skill performance of hockey players in a warm environment. - Mild to moderate dehydration following heat exposure and in turn disruption of cognitive functions in the football players.