INTRODUCTION

The ability to maintain postural stability is the foundation of achieving independent standing and walking [1]. It is a result of an integration of vestibular, somatosensory, and visual systems to maintain the center of mass within the base of support [2-4]. Any deficit in these components will result in poor posture control, which is often associated with the risk of falling and has been identified as a major health problem [5]. Many physical and psychological factors can affect postural sway [6]. With a focus on psychological factors, we consider the impact of a state of anxiety, a state of mind, an attention, a cognitive task etc. Human postural stability might be negatively influenced by muscle fatigue [7-9], but it is still unclear whether or how is postural control affected by the cognitive fatigue.

Numerous studies investigated association between the postural control and the cognitive function using dual task designs in which subjects have performed cognitive and postural tasks simultaneously [10]. Cognitive task affects the characteristics of the neuromuscular response that underlie the control of reactive balance. The muscle activity decline while performing the secondary task that suggests that less attentional processing capacity is available for balance control during the dual-task paradigm. The decline of muscle activity when the secondary task is performed suggests that less attentional processing capacity is available for balance control during the dual-task paradigm. The dual-task activity has a greater impact on balance control in the older adults than in the young adults [11]. These studies indicate that the postural control and attentional resources are related. The
attention and cognitive load may influence the central processing of information required for the perception and the control of orientation [12]. There is possible causal links between vestibular dysfunction and cognitive performance. Previous literature suggests the inner ear vestibular system has a substantial impact on cognitive function. The strongest evidence exists in connecting vestibular function to the cognitive domain of visuospatial ability, which includes spatial memory, navigation, mental rotation, and mental representation of three-dimensional space. Substantial evidence also exists suggesting the vestibular system has an impact on attention and cognitive processing ability [13]. The static posturography could be a useful diagnostic tool of equilibrium for assessing beginning cognitive decline in men [14].

Not only dual-task exercise but also emotional-based factors such as a state of mind, a state of anxiety or an arousal can affect postural steadiness. The state anxiety, the physiological arousal and the balance efficacy are related to specific changes in postural performance with increased standing balance [15]. According to the theory of arousal, the relationship between activation and power follows the inverted U curve with the optimal degree of activation for each individual task. The more complex the task, the lower the level of activation required for optimum performance [16]. The cognitive load can arouse attentional resources and affect the postural control.

It is still unclear whether or how a cognitive load interacts with postural control during a quiet stance. The purposes of this study were to investigate the effects of cognitive load on changes in postural control induced by a cognitive load.

MATERIALS AND METHODS

Postural sway was measured in 18 healthy subjects (17 men, 1 woman), aged between 25 and 47 years old. The group consisted of pilots of jet airplanes and pilots of transport and combat helicopters. All of subjects participated voluntarily in this study.

A repeated measures design was employed, in which participants performed two trials of quiet, upright stance before and after cognitive load. Standing trials lasted 60 s, during which participants stood as still as possible on a force platform. COP was calculated separately for left (L COP) and right leg (R COP). Data were transferred wirelessly to a personal computer via Bluetooth. COP was calculated separately for left (L COP) and right leg (R COP).

The effect of cognitive load on postural stability was analysed using the Wilcoxon matched-pairs sign rank test; each parameter being evaluated separately. All statistical calculations were done with the “Statistica 13” statistical software.

Commonly used measures of COP and COG in the time and frequency domains (D, MV, EA) were used. EA covered by the trajectory of the COP with a 90% confidence interval, where the smaller the surface is, the better the performance is. MV represents the total distance covered by COP divided by the duration of the sampled period and constitutes a good index of the amount of activity required to maintain stability [20]. D is the total length travelled by the COP to reach the maximal distance – the smaller the distance, the better the postural stability [21]. The reliability and validity of these parameters are better reported for 95% confidence ellipse area of COP and sway velocity than other COP parameters [22-23].

RESULTS

Table 1: Summary of Wilcoxon Matched Pairs Test results (P values) for the effects of cognitive load on COG.

| Pair of Variables                        | Wilcoxon Matched Pairs Test (BEFORE_AFTER_COG) Marked Tests are Significant at p < 0.05000 |
|-----------------------------------------|------------------------------------------------------------------------------------------|
| Distance_eyes_open & Distance_eyes_close | Valid N  | T          | Z          | p-value         |
|                                         | 18     | 56        | 1.284735   | 0.198886       |
| MeanVel_eyes_open & MeanVel_eyes_open    | 18     | 56        | 1.284735   | 0.198886       |
| EllipseArea_eyes_open & EllipseArea_eyes_close | 18     | 31        | 2.373494   | 0.017621       |
| Distance_eyes_close & Distance_eyes_close | 18     | 80        | 0.239527   | 0.810697       |
| MeanVel_eyes_close & MeanVel_eyes_close  | 18     | 80        | 0.239527   | 0.810697       |
| EllipseArea_eyes_close & EllipseArea_eyes_close | 18     | 33        | 2.286394   | 0.022323       |
Table 2: Summary of Wilcoxon Matched Pairs Test Results (P values) for the effects of cognitive load on LCOP.

| Pair of Variables                        | Wilcoxon Matched Pairs Test (BEFORE_AFTER_COG) Marked tests are significant at p < 0.05000 |
|-----------------------------------------|------------------------------------------------------------------------------------------|
|                                         | Valid N  | T   | Z      | p-value                |
| Distance_eyes_open & Distance_eyes_open | 18       | 34  | 2.242843 | 0.024908               |
| MeanVel_eyes_open & MeanVel_eyes_open   | 18       | 34  | 2.242843 | 0.024908               |
| EllipseArea_eyes_open & EllipseArea_eyes_open | 18   | 47  | 1.676689 | 0.093604               |
| Distance_eyes_close & Distance_eyes_close | 18     | 57  | 1.241185 | 0.214538               |
| MeanVel_eyes_close & MeanVel_eyes_close | 18       | 57  | 1.241185 | 0.214538               |
| EllipseArea_eyes_close & EllipseArea_eyes_close | 18   | 69  | 0.718581 | 0.4724                 |

Table 3: Summary of Wilcoxon Matched Pairs Test results (P values) for the effects of cognitive load on RCOP.

| Pair of Variables                        | Wilcoxon Matched Pairs Test (BEFORE_AFTER_COG) Marked tests are significant at p < 0.05000 |
|-----------------------------------------|------------------------------------------------------------------------------------------|
|                                         | Valid N  | T   | Z      | p-value                |
| Distance_eyes_open & Distance_eyes_open | 18       | 72  | 0.58793 | 0.55658                |
| MeanVel_eyes_open & MeanVel_eyes_open   | 18       | 72  | 0.58793 | 0.55658                |
| EllipseArea_eyes_open & EllipseArea_eyes_open | 18   | 72  | 0.58793 | 0.55658                |
| Distance_eyes_close & Distance_eyes_close | 18     | 74  | 0.500829 | 0.616492               |
| MeanVel_eyes_close & MeanVel_eyes_close | 18       | 74  | 0.500829 | 0.616492               |
| EllipseArea_eyes_close & EllipseArea_eyes_close | 18   | 50  | 1.546038 | 0.122096               |

Acute effect of cognitive load was observed across all dependant variables in an open eye measurement. Significant effect of cognitive load was found among parameters of COG and COP, specifically in ellipse area. In a trial with eyes open, CL caused a significant difference (p < 0.05) in EA of COG (decreased by 25%), in D of L COP (decreased by 28%) and in MV of L COP (decreased by 28%). In a close-eye experiment, EA of COG also significantly fell (decreased by 29%) (See Chyba! Nenalezen zdroj odkazů., Chyba! Nenalezen zdroj odkazů., (Table 1-3) for a summary of Wilcoxon Pairs Test results with statistically significant variables).

Data concerning differences in postural sway are summarized in boxplots (Figure 1-4). The most substantial effects of COG were evident in a trial with eyes close with a 29% decrease in EA of COG. In contrast, no significant increasing of COG and COP were found across all measurements. Decreases in variables of COP and COG to be tended to improve postural stability while subject’s postural characteristics improved after cognitive load compared with a default situation. The cognitive load had a positive effect on postural stability.

![Figure 1](image.jpg) Figure 1: Mean values of Ellipse Area of COG before and after cognitive load in a open-eyes trial.
Figure 2: Mean values of Velocity of LCOP before and after cognitive load in an open-eyes trial.

Figure 3: Mean values of Distance of LCOP before and after cognitive load in an open-eyes trial.

Figure 4: Mean values of Ellipse Area of COG before and after cognitive load in a close-eyes trial.
DISCUSSION

The purposes of this study were to investigate the effects of cognitive load induced by cognitive tests while listening a recording of a crying baby on changes in postural control. A repeated measures design was employed, in which participants performed multiple trials of quiet, upright stance before and after cognitive load including tests of spatial abilities while listening a highly stressful recording of a crying baby. The postural sway was assessed using force platforms, participants being in static position with eyes open and eyes closed. Standing trials lasted 60 s. Main effect of cognitive load was observed at EA of COG (in both trials), in D of L COP (in a trial with eyes open) and in MV of L COP (in a trial with eyes open) consistent with hypothesized changes in postural control after cognitive load. The results of this study demonstrated that control of posture is influenced by the cognitive load while the cognitive load may arouse attentional resources and have a positive effect on individual’s postural stability. The generalizability of the current results is limited by some issues. The sample size is relatively small, while more accurately results may be gained by involving many participants. Another issue needs to be further investigated by considering cognitive and emotional factors separately with the emphasis of assessment the relationship between vestibular system and cognitive function. Results of this study may facilitate the development of strategies to improve acute postural stability of pilots.

CONCLUSION

We assert that cognitive load induced by spatial skills tests and disruptive recording may improve performance in postural stability during quiet standing in airborne units of Czech army. As previously mentioned, postural stability is a complex task that requires coordination of visual, vestibular, and somatosensory inputs, and numerous investigations have been performed to elucidate varied factors affecting the maintenance of stability. In this study, various parameters that quantify postural stability have been reviewed. Cognitive load led to improved postural stability performance, but it is still not clear which specific aspects of cognitive stress caused it. These results suggest that there is a possible relationship between the performance and the arousal. Increased arousal can help improve performance but only up to a certain point. At the point when arousal becomes excessive, performance diminishes. Load induced cognitive tests and emotional stress was probably not large enough to lead to a reduction in performance in postural stability. Soldiers are trained to deal with stressful situations during training involving extreme endurance training, sleep deficit and psychic stress. Their mental and physical resilience is therefore at a very high level; it may be difficult to evoke an appropriate psychological stress. We can also consider connections between cognitive functions, especially spatial abilities, and postural stability. Further research is needed to identify what aspects of cognitive load caused improvements in postural stability parameters.

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