Original Article

Effects of acute static stretching on visual search performance and mood state

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Abstract:

Static stretching appears to not only enhance flexibility, but also to improve mood state. However, little is known about how acute static stretching influences cognitive function. To elucidate this, we tested the hypothesis that alterations in mood state following static stretching would improve visual search performance. Sixteen participants were divided into stretching and control groups. In the stretching group, the participants answered questionnaires about mood state and performed a visual search task before and after 30 min of static stretching. In the control group, the participants rested instead of stretching. The questionnaires included items related to pleasantness, relaxation, anxiety, negative affect, positive engagement, and tranquility. We evaluated changes in cerebral hemodynamics and oxygenation during the visual search task via near-infrared spectroscopy. In the stretching group, reaction time in the visual search task decreased ($P < 0.05$), while response accuracy was not affected. This improvement in response speed was accompanied by increase in positive engagement ($P < 0.01$) and a decrease in anxiety ($P < 0.05$). Stretching did not modulate cerebral hemodynamics or oxygenation during the visual search task. Visual search performance was not altered in the control group. These results suggest that improved response speed is associated with an increase in positive engagement and a decrease in anxiety after static stretching.

Key words: static stretching, visual search, mood state, cerebral hemodynamics, oxygenation

Introduction

The relationship between acute exercise and cognitive function is the subject of increasing attention, as new evidence indicates that acute exercise improves cognitive function (Brisswalter, Collardeau, & Rene, 2002; Byun et al., 2014; Chang, Labban, Gapin, & Etnier, 2012; Lambourne & Tomporowski, 2010; McMorris, Sproule, Turner, & Hale, 2011). Cognitive functions are multifaceted, and include attention, memory, and decision-making, all of which are required in daily life. According to a recent review summarizing the relationship between cognitive function and exercise at various intensities, low to moderate intensity exercise leads to improved cognitive function (Chang et al., 2012). However, the way in which acute low intensity exercise affects cognitive function is unclear. In this study, we focused on static stretching, which is low intensity and thus applicable to a varied population. Characterization of the impact of acute static stretching may facilitate the design of low-intensity exercises that enhance cognitive function.

In a visual search task, participants selectively detect a target stimulus from visual stimuli presented in a large section of the visual field. Visual search tasks require selective attention as well as visual information processing (Fredrickson & Branigan, 2005; Ueda & Yoshikawa, 2012; Yoshikawa & Ueda, 2012). Thus, visual search task performance is thought to reflect one aspect of cognitive function. To date, several studies have reported that visual search performance is affected by mood state (Fredrickson & Branigan, 2005; Mikels, Reuter-Lorenz, Beyer, & Fredrickson, 2008). Additionally, participants tend to process information about large portions of the visual field when they are in a positive mood state, and process information about narrow areas when they are in a negative mood (Gasper, 2004; Gasper & Clore, 2002; Murakami, 2010). Since static stretching leads to improvements in mood state (Nagamatsu & Kai, 2014), it is possible that a static stretching-induced increase in positive mood state will affect performance in visual search task.

Therefore, the purpose of this study was to examine the effects of acute static stretching on visual search performance. Specifically, we tested the hypothesis that alterations in mood state following static stretching would improve visual search performance. In addition to mood state, we also examined alterations in cerebral hemodynamics and oxygenation via near-infrared spectroscopy (NIRS) to test whether physiological alterations in the prefrontal cortex were associated with alterations in visual search performance. We hoped to gain insights about the interactions among static stretching, mood state, and visual search performance.

Materials and Methods

Participants

Sixteen healthy male volunteers participated in this study. Participants were normotensive and free from cardiovascular, metabolic, or neurological diseases. They gave written informed consent prior to participation. This study was approved by the ethics committee of the Meiji Yasuda Life Foundation of Health and Welfare, Physical Fitness Research Institute (approval number: No. 26004), and was in accordance with the Declaration of Helsinki.

Procedure

The participants arrived at the laboratory at least 1 hour before the experiment. After they arrived, they abstained from exercise and remained seated until the cessation of the experiment. The participants were randomly assigned to either the control group (N=8) or the stretching exercise group (N=8). At the beginning of the experiment, we assessed the mood state of the participants in both groups via questionnaire. Then, the participants performed a visual search task. Following this, the participants in the stretching group completed a static stretching program. The program, which lasted 30 min, comprised stretches involving whole body muscles. The participants in the control group rested for 30 min instead of stretching. After the 30-min resting/stretching period, all participants answered another questionnaire about mood state and then performed the visual search task again. All participants refrained from using any electronic devices during the experiment.

Visual search task

The visual stimuli were controlled using a multi-pass image stimulation system (PTS-141, DKH). Visual stimuli were presented on a 23 inch monitor in a dimly illuminated room. Participants viewed the screen at a distance of 80 cm. Fig. 1 illustrates the time course of the visual search task. Each trial started with the presentation of a target stimulus (green 'T' or red 'X') for 1 sec, followed by the presentation of a search array. Two response buttons were located on a desk in front of the participants. When the target stimulus was included in the search array, the participants were instructed to respond by pressing the left button with their left index finger as rapidly and accurately as possible. In contrast, when the target stimulus was not included in the search array, the participants were asked to respond by pressing the right button with their right index finger. The search array disappeared from the screen once a response was made, or after 5 sec if no response was registered. After the search array disappeared, a white screen was presented for 1 sec before the next trial began. The visual search task consisted of 30 trials: 15 with and 15 without the target stimulus, which were presented in random order. We averaged the reaction time for each participant. Response accuracy (%) and reaction time (sec) was used to assess visual search performance.

Figure 1. Schematic illustration of time course of the visual search task.

Mood state measurement

We used the Mood Check List-short form 2 (MCL-S.2) and Waseda Affect Scale of Exercise and Durable Activity (WASEDA) to assess mood state. The MCL-S.2 scale included 12 items, which were classified into three subscales: four items measured 'pleasantness', four items measured relaxation, and four items measured anxiety. Each item was rated on a seven-point Likert scale from 1 "very much so" to 7 "not at all". We

evaluated pleasantness, relaxation, and anxiety by averaging the results from the corresponding subscales. The reliability of the MCL-S2 has been established (Cronbach's α coefficient=0.84) in a previous study (Hashimoto & Murakami, 2011). The WASEDA scale includes 12 items that assess negative affect, positive engagement, and tranquility (Arai, Takenaka, & Oka, 2003). Each item was rated on a five-point Likert scale from 1 "very much so" to 5 "not at all". We assessed negative affect, positive engagement, and tranquility based on the results of the corresponding subscale items.

NIRS measurement

We used a NIRS system (NIRO-200, Hamamatsu Photonics, Shizuoka, Japan) to monitor changes in oxy-hemoglobin (oxy-Hb), deoxy-hemoglobin (deoxy-hemoglobin), and the tissue oxygenation index (TOI) during the visual search task. A probe holder was attached at the left side of the forehead, and a black cloth was wrapped around the probe holder to shield it from ambient light. The principles of NIRS are described elsewhere (Ando et al., 2013). The TOI was expressed as $\text{oxy-Hb}/\text{total-H} \times 100$ (i.e., as a percentage). Despite several limitations inherent to NIRS measurements (Gervain et al., 2011; Perrey, 2008; Subudhi, Dimmen, & Roach, 2007), we were able to noninvasively and qualitatively measure hemoglobin concentrations and cerebral TOI. Before the first visual search task, we measured baseline hemoglobin concentrations for 30 s while participants were seated at rest. Hemoglobin concentrations and TOI during the visual search task are expressed relative to the baseline. We averaged oxy-Hb, deoxy-Hb, and TOI during the visual search task for further analysis.

Statistical analysis

We used a two-way repeated measures analysis of variance with Group (stretching group vs. control group) as a between-participants factor and Time Course (pre vs. post) as a within-participants factor for each dependent variable, followed by post-hoc analysis where appropriate. The degrees of freedom were corrected using the Huynh-Feldt Epsilon when the assumption of sphericity was violated. All data are expressed as mean $\pm$ SD. The significance level was set at $P < 0.05$. All statistical analyses were performed using IBM SPSS Statistics 21.0.

Results

Participant characteristics

We found no differences in age (Stretching: 23.9 ± 2.3 yr., Control: 23.8 ± 2.1 yr.), height (Stretching: 1.75 ± 0.03 m, Control: 1.72 ± 0.04 m), or body weight (Stretching: 69.6 ± 5.5 kg, Control: 68.7 ± 6.3 yr.) between the stretching and control groups.

Visual search performance

Fig. 2 shows the results of the visual search task. We found no significant main effects of Group ($P=0.573$) or Time course ($P = 0.566$) on response accuracy. These results indicate that stretching did not affect the accuracy of the visual search task. In contrast, we observed a significant interaction ($P = 0.031$) between Group and Time course on reaction time. Further analysis revealed that reaction time was significantly shorter in the stretching group ($P = 0.023$). Reaction time did not change between measurements in the control group ($P = 0.612$). These results demonstrate that response speed improved after stretching, without impairing response accuracy.

Figure 2. The accuracy (A) and reaction time (B) in the Visual Search task. White circle indicates the Control group. Black circle indicates the Stretching group. * $p < 0.05$. vs. Pre in the Stretching group.

Mood state

Fig. 3A summarizes the results of the MCL-S.2. We found no significant main effects of Group ($P = 0.589$) or Time course ($P = 0.233$) on pleasantness, indicating that pleasantness was not affected in either group. There was a significant main effect of Time course on relaxation ($P = 0.007$), indicating that the degree of relaxation increased irrespective of the stretching intervention. We also observed a significant main effect of Time course on anxiety ($P = 0.018$), as well as a significant interaction between Group and Time course ($P = 0.018$). Further analysis indicated that anxiety significantly decreased over time in the stretching group only ($P = 0.002$).

A: MCL-S.2 **B: WASEDA**

Figure 3. Alterations in mood state assessed by Mood Check List-short form 2 (MCL-S.2, A) and Waseda affect scale of exercise and durable activity (WASEDA, B). White circle indicates the Control group. Black circle indicates the Stretching group. * $p < 0.05$, vs. Pre in the Stretching group.

Fig. 3B summarizes the results of the WASEDA. Main effects of Group ($P = 0.080$) and Time course ($P = 0.056$) on negative affect failed to reach statistical significance. In contrast, we found a significant main effect of Time course on positive engagement ($P = 0.008$). We also observed a significant interaction between Group and Time course ($P = 0.027$). Further analysis indicated that positive engagement significantly increased after the stretching program ($P < 0.001$). A main effect of Time course on tranquility was also significant ($P = 0.002$), indicating that tranquility increased as time elapsed.

Cerebral hemodynamics during the visual search task

Table 1 summarizes changes in cerebral hemodynamics and oxygenation observed during the visual search task. For oxy-Hb, we found no significant main effects of Group ($P = 0.326$) or Time course ($P = 0.064$). Similarly, for deoxy-Hb, we found no significant main effects of Group ($P = 0.516$) or Time course ($P = 0.549$). Finally, we found no significant main effects of Group ($P = 0.287$) or Time course ($P = 0.101$) on TOI. These results indicate that stretching did not affect hemoglobin or oxygenation in the prefrontal cortex during the visual search task.

Table 1 Oxy-Hb, deoxy-Hb, and TOI during the visual search task.

Variable	Group	Pre	Post
Δ oxy-Hb, a.u.	Stretching	0.20 ± 1.60	-0.82 ± 0.59
	Control	0.51 ± 2.04	-0.53 ± 1.20
Δ deoxy-Hb, a.u.	Stretching	0.39 ± 0.80	0.01 ± 0.88
	Control	-0.56 ± 0.84	0.00 ± 0.77
TOI, %	Stretching	-0.41 ± 1.74	-0.53 ± 0.49
	Control	0.27 ± -0.36	-0.36 ± 1.44

Discussion

Static stretching is used in sporting activities and exercise interventions to enhance flexibility and increase the range of joint motion. However, the ways in which psychological and physiological alterations induced by acute static stretching affect cognitive function are unclear. Our working hypothesis was that alterations in mood state following static stretching would improve visual search performance.

In the stretching group, we observed that reaction time in the visual search task decreased without sacrificing response accuracy. In contrast, reaction time was unchanged in the control group. These results suggest that improvements in response speed are likely to be ascribed to alterations induced by static stretching. Previous studies have suggested that static stretching for 30 min or less has a minimal effect on physiological state owing to the low physical demand (Bacurau et al., 2009; Behm, 2004). Thus, we can assume that the physiological changes induced by static stretching had a minimal effect on visual search performance in the present study.

Visual search refers to the process that occurs from the appearance of a visual stimulus to the detection of a target. In the present visual search task, participants were asked to report whether a target stimulus was included in a search array that contained interference stimuli. This type of task is thought to involve sequential searching, and hence, eye movements appear to play an important role in task performance (Kowler, Anderson, Doshier, & Blaser, 1995). Previous studies have suggested that a positive mood state enhances the processing of information that is contained in a large area of the visual field (Gasper, 2004; Gasper & Clore, 2002; Murakami, 2010). Furthermore, a recent study indicated that an increase in positive emotion leads to decrease in reaction time (Ueda & Yoshikawa, 2012), and a follow-up study revealed that decreases in reaction time can be attributable to a decrease in the retention times of eye movements (Yoshikawa & Ueda, 2012). These findings suggest that positive mood state has a beneficial effect on visual search performance. Hence, in the present study, alterations in mood state may account for the observed improvements in visual search performance. We found that participants exhibited an increase in positive engagement as well as a decrease in anxiety after static stretching. These alterations were not observed in the control group. Therefore, the improvement in response speed appears to be associated with an increase in positive engagement and a decrease in anxiety after stretching.

However, we observed an increase in relaxation and a decrease in negative affect in both groups, suggesting that relaxation and negative affect were similarly altered as time elapsed in all participants. This indicates that increased relaxation and decreased negative affect may not have been directly associated with the improvements in response speed observed in the present study. Given the scarcity of data concerning the relationships between static stretching, mood state, and visual search performance, further studies are clearly warranted.

In the present study, we used NIRS to detect changes in cerebral hemodynamics and oxygenation during a visual search task. Prefrontal increases in oxy-Hb have been observed during cognitive tasks executed after acute exercise (Byun et al., 2014; Endo et al., 2013; Hyodo et al., 2012; Yanagisawa et al., 2010). However, we found no changes in hemodynamics or oxygenation during the visual search task after stretching. It is possible that the physical demands of the stretching program were not sufficient to induce alterations in cerebral hemodynamics during the task, as discussed above. Alternatively, this inconsistency may be related to the visual search task that we used, which was different from the cognitive tasks used in previous studies. Thus, differences in the task demands may account for the observed lack of change in oxy-Hb. NIRS enabled us to measure cerebral hemodynamics and oxygenation in discrete brain areas. However, NIRS measurements are limited to the superficial layers of the cerebral cortex (e.g., prefrontal cortex). Given that mood state may be associated with activation in deep brain areas, alterations in cerebral hemodynamics and oxygenation reflecting the observed altered mood states may not have detected in this study.

The present study has several limitations. First, we divided the participants into two groups. Hence, we cannot rule out the possibility that inter-individual differences influenced the present results. Future studies may benefit from a crossover design. Second, response accuracy in the present study was higher than expected, indicating that the task was not sufficiently demanding. As the task demand is a key factor affecting visual search performance, the effects of stretching on visual search performance should be further investigated with a demanding visual search task. Third, we assessed mood state via questionnaire only, and thus did not have an objective measure. Together with additional measures of mood state, biological markers would be beneficial in exploring the association between mood state and improved visual search performance.

Conclusion

We examined the effects of acute static stretching on visual search performance. Specifically, we tested the hypothesis that alterations in mood state following static stretching would lead to improved visual search performance. After static stretching, reaction time in a visual search task decreased, while response accuracy was unaffected. The improved response speed was accompanied by an increase in positive engagement and a decrease in anxiety. These results suggest that improved response speed may be associated with increased positive engagement and decreased anxiety after stretching.

Conflicts of interest - There are no conflicts of interest to declare.

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