Age-related Differences in Reaction Time Responses under Simple- and Dual-task Conditions in Middle-aged Ski Marathon Amateur Males

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[Received August 13, 2012; Accepted February 28, 2013; Published online March 12, 2013]

The present study sought to examine age-related differences in reaction time responses under simple- and dual-task conditions in active middle-aged males. Fifty healthy males aged 42 to 64 years who took part in public marathon events in 2010 or 2011, and who had participated in ski marathon events for more than 2 years were assessed, and whole body reaction times (WBRTs) were measured by under simple-task and dual-task conditions. In the dual-task condition, participants performed WBRTs measurements while they counted backwards aloud to 1, starting from 100. Although reaction times in the simple-task condition were not associated with age (r = 0.21, p = 0.14), a significant positive correlation was found between age and reaction times in a dual-task task condition involving concurrent cognitive tasks (r = 0.45, p < 0.01). One-way analysis of variance revealed that older subjects (60 years and older) responded more slowly than two younger groups (aged <50 and 50-59 years) in dual-task conditions (F = 7.87, p < 0.01). However these age-related differences were not found in simple-task reaction times (F = 1.74, p = 0.19). The present findings suggest that attentional capacity assessed by reaction time in dual-task conditions declined with age in active middle-aged males.

Keywords: reaction time, dual-task, middle age

1. Introduction

Many studies have reported that increasing physical activity can have physical and cognitive health benefits (Buchman et al., 2012; Etgen et al., 2010; Larson et al., 2006; Nelson et al., 2007). A 25-year longitudinal study recently reported that a healthy lifestyle in midlife including high levels of physical activity was associated with a lower risk of dementia in later life among Japanese-American men (Gelber et al., 2012). Thus, a high level of physical activity in midlife may help to maintain cognitive health in later life.

Poor reaction time responses under conditions with cognitive demands are an important risk factor for health problems among older people, especially cognitive impairment. Attentional resources must be divided to perform multiple tasks simultaneously. The dual-task paradigm can be used to examine the extent of attentional resource sharing. Dual-task performance can be measured while a person performs two concurrent tasks, and reflects divided attention, which is considered to be an important executive function (Baddeley et al., 2001; Logie et al., 2004). In older adults, poor dual-tasking performance is thought to be an indicator of age-related changes in attentional capacity, and has been used as a predictor of the risk of falling (Makizako et al., 2010a; Woollacott and Shumway-Cook, 2002) and developing Alzheimer’s disease (AD) (Baddeley et al., 1991; MacPherson et al., 2007; Pettersson et al., 2005; Sala and Logie, 2001). However, no previous studies have examined whether reaction time response under a dual-task condition with cognitive...
demand is associated with age among middle-aged adults with a physically active lifestyle. Although a large number of studies reported that comparison of dual-task performance between younger and older adults (Fraser et al., 2007; Huxhold et al., 2006; Laessoe et al., 2008; Sparrow et al., 2002), and effects of dual-task performance on falls risk in older adults (Hauer et al., 2003; Makizako et al., 2010b; Shumway-Cook et al., 1997; Toullette et al., 2006), few data have showed age-related differences among middle-aged adults. Clarifying age-related differences on dual-task performance in active middle-aged adults may provide information to suggest age-related impact for the extent of attentional resource sharing in an early stage of ageing.

The aim of the present study was to examine age-related differences in reaction time responses under two conditions of cognitive demand of attentional resources: a low demand (simple-task) condition and a high demand (dual-task) condition, in active middle-aged males.

2. Methods

2.1. Participants

Fifty healthy men aged between 42 and 64 participated in this study (Table 1). Participants were recruited from the public ski marathon events in 2010 or 2011 to examine age-related differences in reaction time responses in active middle-aged amateurs. All participants in this study had participated in ski marathons for more than 2 years before the study. We confirmed whether each participant could understand our test protocols without serious cognitive impairment. All participants provided written informed consent.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>54.2 ± 6.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.3 ± 6.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.5 ± 9.3</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>22.7 ± 2.6</td>
</tr>
<tr>
<td>Experience of ski marathon (yrs)</td>
<td>10.8 ± 9.2</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± standard deviation.

2.2. Tasks

Each participant’s whole body reaction time (WBRT) was measured in two conditions: simple- and dual-task. WBRTs were measured while participants jumped in response to a visual stimulus (a bright red light) presented using THP-15 (Sakai, Tokyo, Japan) (Miyatake et al., 2007). WBRTs were defined as the temporal interval between the presentation of a visual stimulus and the onset of a jumping response. Participants stood still, adopting a posture that could be rapidly changed, and concentrated their attention on the light. The experimenter (physical therapist) checked that participants were standing safely and quietly, then issued the verbal command "ready" as a starting signal before WBRT measurement. When the light turned on, participants jumped as quickly as possible. The time at which both legs left the floor was employed as the measure of WBRT. After WBRTs were measured in the simple-task condition, the dual-task condition was presented. In the dual-task condition, participants were asked to count backwards aloud to 1, starting from 100. Counting backwards requires both working memory and attention (Hittmair-Delazer et al., 1994). This dual-task condition was used to assess changes in performance between single and dual-tasks in previous studies (Allali et al., 2008; Beauchet et al., 2009; Montero-Odasso et al., 2009). Participants performed five WBRT trials in each condition. The fastest and slowest trials were excluded, and the average WBRT from the remaining three trials in each condition were included, recorded in milliseconds (ms).

2.3. Data analysis

All analysis was performed using SPSS Windows 19.0. Pearson correlation coefficients between WBRTs during simple- and dual-task conditions and age were calculated to evaluate age-related differences in reaction time. We classified participants into three age-groups (aged <50, 50-59, and ≥60 years), and group differences in body mass index and WBRTs were examined using one-way analysis of variance (ANOVA). Tukey’s post-hoc analysis was used to identify specific group differences. P-values <0.05 were considered statistically significant.
3. Results

Reaction times during simple-task conditions were not significantly associated with age ($r = 0.21, p = 0.14$). In contrast, a significant positive correlation was found between age and reaction times in dual-task task conditions with concurrent cognitive tasks ($r = 0.45, p < 0.01$) (Figure 1). There were no group differences in body mass index ($F = 0.88, p = 0.42$). The ANOVA revealed significant group differences in WBRT in the dual-task condition ($F = 7.87, p < 0.01$). The older group (60 years and older) demonstrated significantly slower WBRTs than the two younger groups (forties and fifties) in the dual-task condition ($<50$ vs. $50-59$: $p = 0.02$; aged $50-59$ vs. $\geq 60$: $p < 0.01$). However these age-related differences were not found in simple-task RTs ($F = 1.74, p = 0.19$) (Table 2).

4. Discussion

The current study revealed a significant positive correlation between age and reaction times while active middle-aged males who had participated in ski marathons for more than 2 years performed a dual-task condition involving concurrent cognitive tasks. However, reaction times in the simple-task condition were not associated with age. The older group (aged between 60 and 64 years) exhibited significantly slower reaction times than the two younger groups ($<50$ and $50-59$) in the dual-task condition.

A previous study testing large sample size (more than 7,000 participants) with an age range between 10 and 94 years reported that mean simple reaction time barely increased until people reached approximately 50 years of age, whereas mean choice reaction time increased throughout the adult age range (Der and Deary, 2006). Choice reaction time perfor-

![Figure 1](image.png)

**Figure 1** Relationship between reaction time during simple- and dual-task conditions and age. Figure 1(A) open circles indicate reaction times during the simple-task condition. Reaction times during the simple-task condition were not associated with age ($r = 0.21, p = 0.14$). Figure 1(B) filled circles indicate reaction times in the dual-task condition. A significant correlation was found between age and reaction times in the dual-task condition ($r = 0.45, p < 0.01$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1: aged &lt;50 (n = 14)</th>
<th>Group 2: aged 50-59 (n = 20)</th>
<th>Group 3: aged ≥ 60 (n = 16)</th>
<th>ANOVA F-value</th>
<th>Tukey's post-hoc comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index</td>
<td>23.1 ± 3.9</td>
<td>23.1 ± 2.0</td>
<td>22.0 ± 1.7</td>
<td>0.88</td>
<td>N/A</td>
</tr>
<tr>
<td>WBRT in simple-task</td>
<td>352.8 ± 31.5</td>
<td>355.3 ± 37.7</td>
<td>374.0 ± 34.5</td>
<td>1.74</td>
<td>N/A</td>
</tr>
<tr>
<td>WBRT in dual-task</td>
<td>379.5 ± 48.8</td>
<td>401.8 ± 45.6</td>
<td>448.7 ± 54.1</td>
<td>7.87**</td>
<td>Group 1 &lt; Group 3**, Group 2 &lt; Group 3*</td>
</tr>
</tbody>
</table>

* $p < 0.05$, ** $p < 0.01$.
Data are expressed as mean ± standard deviation, WBRT: whole body reaction time, ANOVA: analysis of variance, N/A: not applicable.
mance provides a measure of attentional resource sharing, and discriminates between fallers and non-fallers in older people (Woolley et al., 1997). In addition, previous studies have indicated that poor dual-task performance is associated with a greater risk of falling in older adults (Beauchet et al., 2009; Faulkner et al., 2007; Lundin-Olsson et al., 1997; Makizako et al., 2010b). A decrease in gait performance due to a simultaneously performed attention-demanding task to count backward aloud has been reported among older adults (Beauchet et al., 2005a; Beauchet et al., 2003; Beauchet et al., 2005b). In the present study using attention-demanding task to count backward aloud, although no age-related differences in WBRT were found in the simple-task condition, there was a significant association between slower WBRTs and age in the dual-task condition, even among active middle-aged males. These results indicate that age-related differences in attentional capacity may be observed earlier using the dual-task paradigm than the simple-task paradigm.

An association between dual-task performance deficits and cognitive impairments among older adults has been previously reported (Gillain et al., 2009; Houston et al., 2005). A recent study indicated an association between poor dual-task performance and white matter hyperintensities (WMHs) in older adults (Zheng et al., 2011). WMH refers to an abnormal signal in the white matter observed on T2 weighted magnetic resonance imaging. The extent of WMH is associated with increasing age (DeCarli et al., 2005), vascular risk factors (Jeerakathil et al., 2004), and cognitive impairment (Yoshita et al., 2006). In addition, it has been reported that WMHs are related to diminished cognitive function in middle-aged adults (Soriano-Raya et al., 2012). The maintenance of attentional resources involved in dual-task performance may be important for middle-aged as well as older adults.

Several limitations of this study should be considered. We used cross-sectional data, meaning that causal relationships could not be assessed. In addition, because of a lack of longitudinal measures of age-related changes, the current study could not examine the long-term characteristics age-related changes. Our sample included only middle-aged males who led active lives, such as participating in ski marathons for more than 2 years. However, no measure of daily activity levels was included. Moreover, we did not examine the medical condition of participants, or include measures of type II diabetes mellitus or hypertriglyceridemia. A previous study reported longer reaction times in subjects exhibiting metabolic syndromes (Miyatake et al., 2007), particularly type II diabetes (Richerson et al., 2005), and mild peripheral neuropathy may also cause a decline in reaction times. In addition, although we confirmed whether each participant could understand our test protocols without serious cognitive impairment, objective cognitive performance data were included in the present study. Further studies are required to further our knowledge of age-related changes in attentional capacity in the middle-aged population.

In summary, the present findings revealed that dual-task performance, as assessed by reaction time during a dual-task condition with cognitive demand, declined with age in active middle-aged males.

Acknowledgements

This work was supported in part by a grant from the National Agency for the Advancement of Sports and Health. We thank the Japan Health Promotion & Fitness Foundation for providing us the opportunity of measurement.

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