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Correlation between moderate daily physical activity and neurocognitive variability in healthy elderly people

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ABSTRACT

Recent studies have reported that moderate physical activity in daily life contributes to maintenance of a proper state of cognitive function in elderly individuals. The present study investigated the validity of correlations between moderate physical activity and cognitive function using more objective and detailed assessments of both physical activity and neurocognitive function. Participants comprised 72 healthy elderly individuals who wore an electronic accelerometer during waking hours for 3 months. This device recorded the number of steps per day as well as the duration of each intensity level in daily life; levels 1–3 were the equivalent of easy-paced walking (light activity), while levels 4–6 corresponded to brisk walking (moderate activity). To estimate executive cognitive ability in healthy elderly individuals, performance variability of executive control was examined with a task-switching reaction time (RT) test measuring intra-individual variability (IIV) in RTs. In 43 consenting participants, functional magnetic resonance imaging (fMRI) during the task-switching RT trial was analyzed to assess differences in brain activity patterns as a function of daily physical activity. Daily duration of level 4 physical activity correlated negatively with and significantly predicted IIV. Moreover, fMRI analysis confirmed that the higher physical activity group (duration of level 4 activity $\geq$ 26.4 min/day) showed significantly reduced age-related functional attenuation of prefrontal activations during the task-switching RT trial. The study discusses the possibility that enhancing the moderate daily physical activity could be helpful for lowering the rate of neurocognitive degradations in healthy elderly individuals.

1. Introduction

In developed countries, maintaining the health of elderly individuals who may have various chronic diseases such as obesity, diabetes, and dementia represents a serious problem for both society and medical providers. Recent health and exercise studies have contributed to improved prevention of these diseases in patients (Bopp and Fallon, 2008; Draper et al., 2010). However, exactly how exercise applications are able to prevent declines in cognition with aging and associated impairments remains unclear. In addition, few studies have focused on the quality and quantity of exercise that can favorably influence neurocognitive function in the elderly. Knowing what intensity and duration of exercise we need in daily life to prevent cognitive declines in the elderly is particularly important.

Epidemiological studies have reported that the intensity of daily physical activity might be an important factor in maintaining life-long cognition and preventing cognitive impairments (Tierney, Moineddin, Morra, Manson, & Blake, 2010; Weuve et al., 2004). In particular, the implication is that elderly individuals who habitually engage in moderate physical activity (i.e., brisk walking) might show delayed onset of age-related declines in cognitive function (Larson et al., 2006; Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001; Rovio et al., 2005; Weuve et al., 2004). Those reports thus suggest that to maintain cognitive health through physical activity or exercise, consideration of the amount of moderate physical activity in daily life is of utmost importance, rather than just light exercise or the total amount of physical activity. However, previous epidemiological studies have been inconclusive in discerning the amount and intensity of physical activity that might favorably influence cognitive function in the elderly. For example, studies have assessed daily physical activity using a simple questionnaire asking participants how much moderate or vigorous physical activity they perform during a typical week. Such subjective estimates offer only limited accuracy when assessing the volume and intensity of physical activity, and these problems are particularly great in older adults, many of whom have difficulties remembering their activities due to loss of cognition.

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The present study used an observational method that could objectively assess and quantify levels of daily physical activity using an electronic accelerometer, a small device attached to a waist belt. Accelerometers have recently been recommended to more accurately assess daily physical activity (Kumahara, Schutz, et al., 2004; Kumahara, Tanaka, & Schutz, 2004; Yasunaga et al., 2008). In this manner, the present study was also able to observe and assess the daily duration of moderate and light physical activity in detail. Generally, the range from 3 to 5 metabolic equivalents of task (METs; accepted as a standard value in which 1 MET is proportional to the energy expended while sitting quietly) is known to correspond to moderate physical activity. A previous study suggested that moderate physical activity in daily life can contribute to the maintenance of cognitive function. Between 3 and 5 METs of physical activity is thus predicted to correlate strongly with maintenance of proper cognitive status among the elderly. The present study was conducted to confirm previous reports regarding the impact of moderate physical activity on cognitive function by means of an observational survey of daily physical activity along with a cross-sectional assessment.

One problem in addressing this issue lies in determining the kind of cognitive ability that should be targeted. A recent meta-analysis found that executive cognitive function would be the most strongly affected by physical activity or exercise, compared with other cognitive aspects such as perception, attention, and memory functions (Colcombe and Kramer, 2003). Executive function is known to decrease with age and is impaired in most patients with dementia (Alvarez and Emory, 2006). For example, impairment of executive function decreases the ability to plan and execute tasks, such as washing, chopping, and boiling food to make a meal (Carlson et al., 1999). Individuals with impaired executive function cannot flexibly reconfigure the information processed between tasks. Task-switching RT test is thus considered an appropriate examination technique to evaluate executive function (Cepeda, Kramer, & Gonzalez de Sather, 2001; Davidson, Amso, Anderson, & Diamond, 2006; Kramer, Hahn, & Gopher, 1999). In this test, the subject is asked to sequentially execute two tasks in a block, with one task (switch condition) suddenly interrupted into several sequential presentations of another task (repeat condition). Generally, RTs under the switch condition are longer and show greater fluctuations in a task block than in the repeat condition. Recent reports have suggested the trial-to-trial variability of executive performance (i.e., variability of RTs) for an individual offers an important marker for predicting executive cognitive decline with aging or mild cognitive impairment (Dixon et al., 2007; Lovden, Li, Shing, & Lindenberger, 2007; MacDonald, Hultsch, & Dixon, 2003). Importantly, a previous study showed that executive performance variability was better than mean RT in predicting cognitive ability in healthy individuals (Dixon et al., 2007). The present study thus determined the level of executive cognitive function in individuals by focusing on the IIV in the RT of the task-switching test.

Furthermore, brain lesion and imaging studies have demonstrated a correlation between brain activation and IIV in executive control. For example, damage to the prefrontal cortex is a cause of increased IIV in executive performance (Stuss, Murphy, Binns, & Alexander, 2003). Among healthy elderly individuals, participants with less variability show task-relevant brain activation in memory retrieval tests, but participants with more variability shared no systematic associations with any relevant activation in the same tasks (MacDonald, Nyberg, Sandblom, Fischer, & Backman, 2008).

According to neurocognitive background and observational assessment of daily physical activity, the present study examined the hypotheses that: (1) a direct correlation exists between the amount of moderate physical activity in daily life and IIV in executive control; and (2) assuming this is so, brain activation linked to executive control can be characterized as a function of the amount of moderate physical activity.

2. Methods

2.1. Participants

This study was conducted in two institutions in Japan: Tokyo Denki University, in Inzai, Chiba Prefecture; and Bunka Gakuen University, in Kodaira in the Tokyo Metropolitan Area. The study recruited 80 elderly people who resided in either of these locations. On the basis of their annual medical examination, all participants were judged to be free of chronic conditions that might limit the ability to engage in physical activity. Data on cognitive performance and daily physical activity were collected in the laboratories of these institutions. We excluded 5 participants from data analysis because they had been regularly performing structured exercise, such as strength training, jogging, swimming, or dancing, within the previous 3 years. This was because the study mainly focused on the effects of walking-based (aerobic) daily physical activity. In addition, 3 participants were excluded after failing to meet the criterion of wearing the accelerometer for at least 50% of the days on which measurements were taken. Finally, we conducted behavioral analyses with 72 participants (38 male, 34 female; age range, 60–79 years). A total of 50 people residing in Inzai, Chiba prefecture were initially approached and asked to participate in an additional experiment involving fMRI at the High Tech Research Center at Tokyo Denki University. Of these, 43 provided informed consent and underwent the fMRI session. All study protocols were approved by the ethics committee of Tokyo Denki University. Subjects submitted written informed consent prior to participation in this study.

2.2. Measurement of physical activity

An electronic accelerometer with a storage capacity of 200 days (Kenz Lifecorder EX; Suzuken, Nagoya, Japan) was used to measure the number of steps taken and the intensity of physical activity every 4 s throughout each day. The monitor was attached to a waist belt. For 3 months (September through December), participants wore the accelerometer as much as possible during the day except for when bathing, dressing, and sleeping. Intensity of activity was categorized into 11 levels (0, 0.5, and 1–9), based on the pattern of the accelerometer signal. An intensity level of 0 meant no movement and that of 0.5 signified slight body or arm movement such as desk work. Intensity levels 1–3 indicated light physical activity such as easy-paced walking approximately corresponding to an energy expenditure of less than 3 METs, and intensity levels of 4–6 indicated moderate physical activity such as brisk walking, equivalent to an energy expenditure of more than 3 METs. Intensity levels of more than 6 corresponded to vigorous physical activity, such as jogging. The reliability of the correlation between accelerometric intensity levels and observational energy expenditure in physical activity was confirmed by Kumahara, Schutz, et al. (2004) and Kumahara, Tanaka et al. (2004).

Daily step counts were totaled and intensity categories were determined over each 24-h period from midnight to the following midnight. Parameters calculated were the daily number of steps and daily durations of each activity intensity level (levels 1–9); both were averaged over 3 months. We excluded 24-h data segments when an interval of more than 16 h was detected with no recorded movement, on the basis that the participant had been unable to wear the accelerometer for some reason. With this exclusion criterion for collection of accelerometer data, measurements were available for an average of 77% of the 90 days [standard