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Original Article

Using crutches during walking possibly reduces gait imagery accuracy among healthy young and older adults

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Abstract. [Purpose] Although crutches are widely used in the field of rehabilitation to improve gait performance, patients usually have difficulties using them, and this may increase their risks for falls. This study aimed to define the accuracy of gait imagery during walking with and without crutches, in healthy young and older adults, using the mental chronometry method. [Participants and Methods] Overall, 99 healthy young (mean age, 20.2 ± 1.0 years) and 39 healthy older adults (mean age, 71.3 ± 2.9 years) performed the imagery and execution tasks, which involved walking through a distance of 10 meters both with and without crutches. Using the mental chronometry method, the accuracy of the motor imagery was defined as the difference between the imagery time and the actual execution time. Two-way analysis of variance and one-sample t-tests were performed to evaluate the accuracy of the gait imagery. [Results] Both the young and older adults significantly overestimated their gait speeds when using crutches; the overestimation was larger among the older adults. [Conclusion] The overestimations indicate that participants estimated their gait speeds with crutches to be faster than their actual speeds. Therefore, using crutches decreased the accuracy of gait imagery and might therefore increase an individual's risk of falling during walking.
Key words: Crutches, Gait imagery, Mental chronometry

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INTRODUCTION

Accurate imagery of one's movements is important when performing the activities of daily living. The image of motor performance is called motor imagery, defined as a dynamic state during which the representation of a given motor act is internally rehearsed within the working memory without any overt motor output[1)]. The accuracy of motor imagery is related to motor function. Previous studies have reported that older adults and patients with disorders were not able to accurately perceive their motor performances. For example, Fiorio et al.[2)] examined the accuracy of motor imagery in patients with idiopathic cervical dystonia using the mental rotation method and found that the direction that was more difficult to perform due to pain had longer reaction times. Other studies investigated the accuracy of motor imagery for the maximum forward reach distance in older adults and found that these patients overestimated their reach distance[3, 4)]. These results indicate that older adults and those in pain have inaccurate motor imagery, suggesting that the accuracy of motor imagery is related to physical function.

The mental chronometry (MC) method, which was designed by Decety et al.[5)] assesses the accuracy of motor imagery. It investigates the differences between imagery time and execution time for a task. Healthy, young adults typically require the same amount of time to perform an imagery task as they do to perform an execution task[5)]. Thus, the temporal incongruence between imagery and execution times may indicate the poor physical function or cognitive abilities.

Recent studies on the accuracy of motor imagery in older adults and patients with disorders, for example, Saimpont et al.[6)] found that older adults showed a larger difference in time between imagery and execution performance rather than the

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young adults, indicating a decline in the motor imagery accuracy. Nakano et al.[7] examined that the time difference between the imagery and execution walking by the mental chronometry method for the older adults using long-term care insurance services in Japan, resulting that the older adults who had high-risk falls showed the overestimation for their gait speed. Greiner et al.[8] also showed that the older adults who had a fear of falling decreased motor imagery for walking, that was, large time difference between the imagery and execution walking. Other previous studies also reported a decreased motor imagery accuracy for patients with stroke[9, 10], and individuals with cerebral palsy[11]. These studies involving patients with stroke or cerebral palsy revealed an overestimation of gait speed by the patients[9–11]. Beauchet et al.[12] examined the motor imagery accuracy of the timed up and go test (TUG), which is used to evaluate gait and balance performance, in older individuals with cognitive impairments. Their results showed that fewer individuals with poor TUG imagery had healthy cognitive function[12]. Since the accuracy of motor imagery has been shown the relation between physical function and falls, the mental chronometry method, which deals with the time difference between the imagery and execution time, may be useful as a method to clarify the risk of falls.

Assistive devices, which are often used by many patients in rehabilitation, has significant benefits for postural stability[13], gait performance[14], and reducing falls[15]. Although the use of assistive devices improves gait performance and postural stability, previous researches have reported its disadvantages. Bateni and Maki[16] showed that older adults did not use assistive devices even when the devices were prescribed and that they found it difficult and risky. The reason for these findings may be the challenge of dual-task walking (performing gait and using the assistive device). Wright and Kemp[17] examined the attentional demands during walking with or without assistive devices in healthy, young adults using the voice reaction time. The voice reaction time was longer when the participants walked with the rolling walker and standard walker than when they walked with no assistive devices. Moreover, Wellmon et al.[18] examined the attentional demands during walking with assistive devices (a rolling walker or a straight cane) in healthy, older adults using the voice reaction time. The voice reaction time was longer when participants used an assistive device than when they did not. A similar study of older adults with Alzheimer's disease showed that the walking time and the number of steps increased when using assistive devices[19]. Thus, using assistive devices requires attention during walking. Furthermore, while the use of assistive devices has many benefits for postural and gait performance, it also increases the attentional demand and risk for falls during walking.

In the rehabilitation field, assistive devices, such as crutches, are often prescribed and used in gait training. Independence in walking with the use of an assistive device is one of the criteria for discharge from the hospital. However, the effects of using the crutches on gait imagery are unclear. In particular, older adults may have difficulty using the crutches because of their inaccurate motor imagery compared to young adults, and it is not clear whether the use of crutches during walking affects the accuracy of gait imagery. Therefore, understanding the characteristics of the accuracy of gait imagery when using crutches in older adults might provide useful information for therapeutic teaching in rehabilitation. The aim of the present study was to define the accuracy of gait imagery with and without crutches in healthy young and older adults. We used the MC method to measure the accuracy of gait imagery. We hypothesized that the accuracy of gait imagery is worsened when crutches are used compared to when they are not used. This hypothesis was based on the fact that using assistive devices increases attentional demands, resulting in difficulty in paying attention to gait. The effects of using assistive devices on the accuracy of gait imagery are likely to be greater in older adults who have poor physical function than in young adults.

PARTICIPANTS AND METHODS

Ninety-nine healthy, young adults (60 males and 39 females; mean age, 20.2 ± 1.0 years) and 39 healthy, older adults (26 males and 13 females; mean age, 71.3 ± 2.9 years), recruited in the local community, participated in this study. The participants had no musculoskeletal, neurological or cognitive (Mini-mental State Examination score <24) disorders that would influence their gait or use of assistive devices. They also had no experience using crutches or other assistive devices. Each participant was right-handed and footed. Since the sample size of 33 participants for each group was required by the G-power analysis (a power of 80%, with an α error of 5% and effect size of 0.25), we recruited a sufficient sample size beyond that. This study was approved by the Local Ethics Committee of the International University of Health and Welfare (15-Io-16 and 17-Io-140) and conducted in agreement with the Declaration of Helsinki. All participants provided informed consent.

In this study, MC method was used to measure the accuracy of gait imagery for walking and crutch walking task. The participants were asked to walk 10 meters at a comfortable speed under the following two gait conditions: with and without the use of crutches. The length of the crutches was adjusted according to the height of each participant. When using the crutches, participants were asked to walk 10 meters while loading approximately 30% of their body weight on the right (the dominant) lower limb, to mimic a right lower limb injury. Previous clinical studies measured the accuracy of partial weight bearing after surgery for lower limb fractures and showed that the young and older adults tend to exceed the amount of load applied to the lower limb than what is prescribed[20]. Solomon et al.[21] have shown that even a small amount of load could cause displacement of fracture fragments in the early stage of tibial plateau fracture. It is therefore very important to achieve a partial weight-bearing gait by appropriately manipulating the crutches. The participants were asked to walk with their toe touching the floor, which is often suggested in clinical practice when patients have a lower limb injury. When using the crutches, participants first put both the crutches forward at the same distance as one step; then, they put their right toe forward while supporting approximately 70% of their body weight with the crutches. Finally, participants moved their left lower limb forward. All the participants practiced manipulating the crutches in at least a 3-meter walking path before the experimental trials. When a physiotherapist judged that they could walk with the crutches safely and independently, the participants performed the experimental trials.

Participants were asked to perform an imagery task followed by an execution task to avoid the effect of experiencing the actual gait on the imagery accuracy (Fig. 1). Both tasks were performed in duplicate, and the average time required for each task was calculated.

In the imagery task, each participant was instructed to imagine himself or herself performing the 10-m walk with or without crutches at a comfortable speed. A start signal ("ready-go") was provided by the experimenter, and the participants were asked to say "stop" when they imagined that they had arrived at the goal position. The motor imagery time was defined as the time between "ready-go" and "stop" and was measured using a stopwatch. In the execution task, participants performed a 10-m walk with and without crutches at a comfortable speed as the imagined time. The time required to walk 10 m was measured using a stopwatch. The imagery and execution tasks were performed two times each with and without the use of crutches conditions.

In the MC method, the accuracy of the motor imagery is defined as the difference between the imagery and actual execution times. In this study, the average times of the imagery and execution tasks were determined, and the difference between the motor imagery and execution times was calculated. Furthermore, the time difference was normalized to the execution time using the following formula:

$$\text{MC value} = (\text{execution time} - \text{imagery time}) / \text{execution time}$$

The MC value was normalized to the execution time to eliminate the difference in the performance time between the young and older adults[10, 22]. The closer the MC value is to zero, the more accurate the gait imagery. A positive MC value indicates an overestimation of gait speed, while a negative MC value indicates an underestimation of gait speed.

A two-way analysis of variance (ANOVA) was performed on the motor imagery MC values, with group (young and older adults) and crutch condition (no-crutch and crutch-use conditions) as variables. One-sample t-test was used to analyze the significance of the participants' over- or underestimation of their gait speed. Statistical significance was set at $p<0.05$. All analyses were performed using SPSS ver. 25 (IBM, Tokyo, Japan).

RESULTS

Table 1 shows the mean MC value for each group under each condition. The mean MC value of the crutch-use condition was significantly greater than that of the no-crutch condition ($F=149.1$; $p<0.05$, $\eta2=0.52$), as indicated by the two-way ANOVA test. The main effect on the young and older groups was not significant ($F=1.8$; $p=0.2$, $\eta2=0.01$). Therefore, the mean MC values were not significantly different between the young and older participants. The interaction between the two

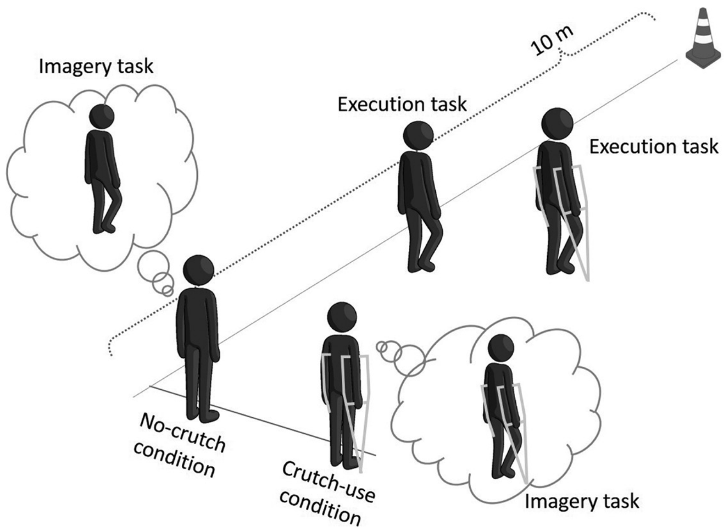

Fig. 1. Imagery and execution tasks.
The imagery task was performed at the starting line. Participants imagined how long it would take them to reach the goal (10 m away) walking or using crutches at a comfortable speed, and the time to imagine the completed task was recorded. For the execution task, the participants walked or used crutches at a comfortable speed, from the starting line to the goal line, and the time to complete the task was recorded. Each task was performed in duplicate.

Table 1. The mean MC value of mental chronometry

	No-crutch condition	Crutch-use condition
Young group*	0.03 ± 0.15 §	0.14 ± 0.22 †
Older group*	−0.24 ± 0.36 †	0.32 ± 0.27 †

[execution time−imagery time(s)/ execution time(s)]
*: significant difference between no-crutch and crutch-use condition (2-way ANOVA).
§: significant difference between young group and older group (2-way ANOVA).
†: significant overestination/underestimation (one-sample t-test).
MC: mental chronometry.

variables (age group and crutch condition) was significant ($F=67.9$; $p<0.05$, $\eta2=0.33$). The mean MC value of the crutch-use condition was significantly greater than that of the no-crutch condition in the young group ($p<0.05$). In the older group, the mean MC value of the crutch-use condition was significantly greater than that of the no-crutch condition ($p<0.05$). Moreover, the mean MC value for the older group was significantly lesser than that of the young group for the no-crutch condition ($p<0.05$). The mean MC value for the young group was significantly lesser than that of the older group for the crutch-use condition ($p<0.05$).

The mean MC value of the no-crutch condition indicated significant underestimation for the older group ($p<0.05$) but not for the young group ($p=0.05$), as determined by the one-sample t-test. The mean MC values when using crutches were significantly overestimated for both groups ($p<0.05$).

DISCUSSION

The accuracy of motor imagery when using crutches was worse than that when not using crutches. Both the young and older groups significantly overestimated the time required when using crutches, indicating that participants estimated their gait speed with crutches faster than their actual speed. Therefore, the accuracy of motor imagery may be negatively affected by the use of crutches during walking. The overestimation of gait speed while using crutches may be a risk factor for falls and accidents when performing activities of daily living. For example, patients may miscalculate the time required to cross a street when using crutches.

The overestimation of gait speed while using crutches was significantly greater in older adults than in young adults. Previous studies have indicated that the motor imagery of older adults is inaccurate compared with that of young adults[3, 4, 22]. For example, Butler and Lord[3] and Gabbard and Cordova[4] found that older adults overestimate the distance of the forward reach test more than young adults do. Moreover, decreased accuracy of gait imagery has been reported to be associated with fear of falling[8] and risk of falls[7]. The overestimation of gait speed in the present study may have been due to the events related to falls. Therefore, the risks of the overestimation of gait speed are especially serious in older adults.

In this study, the older participants underestimated their gait speed without crutches (they believed their gait speed was slower than it actually was). This underestimation may be a safety margin. Healthy individuals generally have a safety margin for their gait speed. A previous study indicated that healthy individuals estimated longer gait times than the actual gait times when judging the amount of time required to cross a street[23]. This underestimation plays an important role in safely crossing the street. Similar safety margins have been found for step length estimations during walking[24–26] and obstacle crossing[27], which are important for safe walking in daily life.

This study included healthy individuals, and all participants were able to walk independently. The results of the accuracy of gait imagery were significantly different between the young and older groups in both gait conditions. The older participants overestimated their gait speed more than the younger participants did when using crutches, suggesting the difference in the effects of using assistive devices on participants of different ages. The accuracy of gait imagery may be a useful tool in assessing the use of assistive devices as patients age.

The present study was not able to clarify why the accuracy of gait imagery when using crutches was poor. Future studies need to clarify the factors that cause poor gait imagery when using crutches from the perspective of attentional demands and physical function.

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Conflict of interest

The authors declare that there is no conflict of interest.

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