Influence of cell phone email use on characteristics of gait

著者	Demura Shinichi, Uchiyama Masanobu
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Original Article

INFLUENCE OF CELL PHONE EMAIL USAGE ON GAIT CHARACTERISTICS

Running head: INFLUENCE OF CELL PHONE USE ON GAIT

Shinichi Demura　　Masanobu Uchiyama

Key word: young adults, attention, obstacle

Abstract

Previously, gait had been considered an automatic and rhythmical movement which uses minimal attentional resources. The relationship between attention and gait has been revealed in recent research. However, particularly in the young adults, the influence of cell phone use which is frequently performed in daily life and considered to require high attentional demands on gait has not been demonstrated. This study examined the influence of mobile phone use on gait. Fifteen healthy college males and fifteen females walked through a normal straight course with or without an obstacle under two different walking conditions while either using the email function of the cell phone or walking without a cell phone. Subjects walked at a normal speed on a 10m-walkway. In walking conditions with an obstacle, an obstacle (17 cm in height) was set at the middle point of the walkway. Gait parameters were calculated for velocity (m/s) / leg length (cm), stride length (cm) / leg length (cm), stride width (cm), stance phase of one foot (just before an obstacle, one and two steps before the obstacle). Velocity and stride width decreases and stance phase increases during walking while operating cell phone. Stance phase just before an obstacle and stride length increase while operating cell phone when there is an obstacle. Gaze fixations and the high attention required in order to use the email function of the device may result in greatly disturbing gait.

Introduction

In Japan, the number of subscribers of cellular phones reached 100,000,000 at the end of 2008, i.e. nearly equivalent to 80% of the population of Japan (one hundred and twenty million). Cell phones include functions that permit email transmission and reception using the Internet in addition to its normal call function, and it has been utilized widely regardless of the generation because of its convenience. Recently, it was reported that the email functions of a cell phone is frequently used more than the call function (Abe, 1999; Kamibeppu and Sugiura, 2005). However, in spite of the convenience of the cell phone, problems may also occur with cell phone use.

It is widely known that operation of a cell phone along with the eye movements required to use it and making calls while driving cause a reduction in concentration and visual field, and can lead to auto accidents due to impeding traffic visibility (McKnight and McKnight, 1993; Alm and Nillson, 1994; Briem and Hedman, 1995). The mobile phone use during driving induces cognitive distraction (Harbluk et al., 2007), reduced peripheral visual fields (Langer et al., 2005) and longer reaction time (Regan, 2005). However, pedestrians are the largest group of road-users and they represent a large proportion of road casualties (Hatfield et al., 2007). Gaze transfer or cognitive distraction due to mobile phone email usage may also influence various physical activities as well as driving. Harbluk et al. (2007) reported that pedestrians walk slowly whilst using a mobile phone in order to compensate for the secondary task (mobile phone use) and to avoid tripping. Furthermore, they suggested that these distractions due to the usage of mobile phone induce not only such slower walking but also a possibility of greater exposure to risk (Harbluk et al., 2007). However, the impact of mobile phone email use on any form of transportation other than motor vehicle, for example walking, has not been examined.

While using the email function of a cell phone (character input, sending and receiving email), people need to maintain focus on the small screen of the handset held in their hand. Thus, visual information about the walking environment remarkably decreases because of the gaze fixation on the cell phone (Langer et al., 2005). Additionally, a high level of attention may be required because dexterity of the hands and fingers is needed while using the email function. Previously, postural control such as standing upright or gait control has been considered to be an automatic or reflex controlled task. This implies that postural control systems use minimal attentional resources (Woolacott and Shumway-Cook, 2002). However, recent research suggests that significant attentional demands are required for postural control (Woolacott and Shumway-Cook, 2002). For example, Ebersbach et al. (1995) reported that a significant change in gait pattern was induced by the various concurrent secondary tasks (memory retention, fine motor tasks, finger tapping, and a combination of the aforementioned tasks) in young adults (25 - 42 yrs). Similarly, in several previous studies using the dual task paradigm, the secondary tasks which require attentional resources results in various patterns of gait change (Lajoie et al., 1993; Ebesbach et al., 1995). Considering these findings, it was hypothesized that manipulating the email function of the cell phone, particularly by young adults, has a significant influence on gait in daily life, including level walking and obstacle approach and negotiation. If cell phone use decreases gait velocity of pedestrians during street crossing, it increases the amount of time the pedestrian’s body is exposed to risk. Additionally, the decrease in step length may negatively impact motion while stepping over an obstacle. Hence, analyzing the relationship between cell phone manipulation and gait has a great practical significance.

The purpose of this study is to examine the influence of using the email function of a cellular phone on gait characteristics while walking on a walkway with or without an obstacle.

Methods

Participants

Thirty healthy Japanese college students (15 Male [Age: mean = 20.3 yrs, SD = 0.9; height: mean = 172.1 cm, SD = 3.3; weight: mean = 67.7 kg, SD = 5.0], 15 Female [Age: mean = 19.4yrs; SD = 0.8; height: mean = 160.3cm, SD = 0.9; height: mean = 58.2 kg, SD = 7.3]) volunteered to participate in the randomized, single-blind study. Their physical characteristics were almost the same as the age-matched national standard value (Laboratory of Physical Education Tokyo Metropolitan University, 2000). Prior to the measurements, the outline of this study such as purpose, procedures and risks involved in this study was explained to all participants, and written informed consent was obtained.

Experimental protocol

On a smooth walkway or a walkway containing an obstacle, the following four walking conditions were selected to examine the influence of using the email function of a cell phone (from now on, "email usage") on walking movements on the walkway: 1. normal walk condition; 2. walk with obstacle condition; 3. normal walk + email usage condition; 4. walk with obstacle + email usage condition. Subjects performed walking with (conditions 3 and 4) and without holding a cell phone (conditions 1 and 2). The obstacle was set on a walkway in conditions 2 and 4.

In the latter two conditions involving email usage, subjects were asked one question described in Table 1 immediately before the start of the test. The question was selected at random for each subject. Subjects concurrently began keying their answers to the tester's questions into their cell phones and walking at the tester's starting signal. Each subject in this study was allowed to use their own personal cell phone. Although the fact that each subject is accustomed to using their own cell phone was confirmed verbally, any strict questionnaire asking about the duration of ownership of the telephone used, the number of texts made, calls and emails sent & received per week, etc, was not run. This is a methodological limitation in this study. Although the attentional demands associated with gait vary depending on the phases of the gait cycle (Lajoie et al., 1993), subjects performed the text input to answer the questions continuously over the gait cycle in this study. However, it is obvious that the influence of performing a task requiring some attentional resources on gait control varies depending on the timing of performing the task (Lajoie et al., 1993). Therefore, controlling the timing of the answer of each subject may enhance findings in this study. However, this study is conducted as a basic study for examining the influence of cell phone operation on gait, thus a simple experimental condition (without control or the timing was used.

The walkway length was 10 m. Subjects were asked to walk at normal pace. Their gait characteristics (gait speed, stride length, stride width and stance phase) were measured in the section between 2.5 to 7.5 m from the starting point. In two situations where an obstacle was present, a 19 cm obstacle (equal in height of a single typical step in the facilities of a Japanese university) was put at the midpoint of the walkway (position at 5 m ahead of starting line) and subjects were asked to walk toward and step over the obstacle. There are stairs which range height between 17 and 19 cm. In addition, according to Templer et al. (1985), stairs over 18 cm in height are associated with fall accidents. Hence, the height of 19 cm was selected for this study.

****** Table 1 near here ******

Measurement device and procedure

In all gait conditions, subjects walked on a laminated gait analysis system 5 m length (WalkWay MG-1000, ANIMA). This apparatus can record time and spatial information as digital signals sent to a personal computer when the bottom of a subject's foot contacts the sensing sheet. The sampling frequency of this device was set at 100 Hz. The WalkWay system was placed at an intermediate position of the 10 m walkway (a section from 2.5 m to 7.5 m after the start line).

Prior to the measurements, subjects gained sufficient rest by relaxing in a sitting position on a chair. In all experimental conditions, after the rest, subjects were instructed to stand at a start line with their feet together, and to begin at a normal pace a 10 m walk on a tester's word "go". In the walk with obstacle and the walk with obstacle + email usage conditions, they were asked to walk 10 m while stepping over an obstacle placed 5 m ahead from the start line.

Measurements under each condition were conducted three times based on our previous study (Demura and Uchiyama, 2007). Preliminarily, a tester ensured that each subject understood the movement required in the test by giving a demonstration. The first trial was a practice run and was intended to familiarize the subject with the test. The trial order was assigned to each subject using random digits. Because four experimental conditions were set, there were 12 sets of orders; patterns 1 to 12. Numbers from 1 to 12 were generated using the Rand function of MS Excel and were assigned to each subject. Trial order was assigned based on these numbers. The mean value of two trials except for the first trial was used for further statistical analysis.

Parameters

Gait velocity (mean gait velocity calculated from the 5 m section WalkWay system) (cm/s), stride length (the distance between heel positions in two stance phases of one leg and the opposite side leg) (cm), gait width (the mean distance between both heels on the frontal plane of each step) (cm), and stance phase (s) of Steps 1 - 3 (a time period during which one heel is landing in each step) are illustrated in Figure 1. Additionally, there is a possibility that the two parameters of gait velocity and stride length may be influenced by subjects' physical characteristics (Hillman et al., 2003). These parameters were used for further analysis after normalization by leg length. For example, Moyer et al. (2006) also used the step length normalized by leg length as a gait parameter.

****** Figure 1 near here ******

Statistical analysis

The sex-differences in each physique and gait parameters were tested by a non-paired t-test. Because sex-differences were hardly detectable in gait parameters, two-way repeated measure analysis of variance (email usage condition × obstacle condition) was used for the integrated data of males and females. Tukey's honestly significant difference (HSD) test was used for multiple comparison tests if ANOVA indicated a significant interaction. A significance level was set at 0.05 in this study.

Results

Table 2 shows the test results of sex differences for each parameter related to physique. All parameters were found to be significantly higher in males than females. There was no significant correlation in each stance phase of Steps 1 - 3. Table 3 shows the test results of sex differences of each gait parameter after dividing the gait velocity and stride length, which showed a significant correlation to some physique parameters, by a mean length of both legs.

A significant difference was found only in stride length in the walk with obstacle condition.

****** Tables 2 and 3 near here ******

Figure 2 shows the results of two-way ANOVA (email usage condition × obstacle condition) and multiple comparison tests for each gait parameter (Figure 1). No significant differences between obstacle conditions were found in stride length and stance phase of Step 2 in the experimental conditions without email usage and in stance phase of Step 3 in both email usage conditions. Significant differences between email usage conditions were found in gait parameters except for the case of step width. Gait velocity/leg length and stride length/leg length were significantly higher in the condition without email usage. Stance phases in Steps 1 - 3 were higher in the condition with email usage.

****** Figure 2 near here ******

Discussion

The influence of a email usage on subjects' gait was found in all gait parameters except for step width under both conditions of normal walk and walk with obstacle (Figure 2). People appear to walk with shortened step length and slowed pace while using the email function of a cell phone, because gait velocity and stance phases during walking (step 1: last step just before an obstacle, step 2: one step before the obstacle and step 3: two steps before the obstacle) significantly changed during email usage. Although it is well known that a phone conversation on a cell phone with another party induces a delay of reaction time in cognitive tasks (Strayer and Johnston, 2001), there is no report yet focusing on the use of the email function of the cell phone which has a higher level of difficulty than a phone conversation when performed while walking. Namely, traffic accidents may occur more during key operation of cell phone than during calling (Makishita, 2005). Thus, high attention may be required to use the email functions of a phone. In walking while operating an email function, it is necessary to keep gazing at the screen of the handset while entering and reading text on a cell phone or during email transmission and reception operations, which is not true during normal walking. Even if the gait is an automatically patterned movement due to spinal central pattern generators (CPG) (Grillner, 1981), the influence of these factors on the above stated gait parameters is considerably large.

The risk factors in the fall accidents of the elderly include some environmental factors such as obstacles and bumps (Kikuchi and Toba, 2005). Hence, especially in outdoor environments, high attention is required during walking (Ikeda, 2001). In this study, the combined factor of the existence of an obstacle and email usage influenced stride length and stance phase (Step 2) due to an obstacle being placed on a walkway. In short, when using the email function of a cell phone, the stride length significantly increased and the stance phase (Step 2) decreased due to the presence of an obstacle. An increase in stride length due to an obstacle was reported by Weerdesteyn et al. (2005) and Den Otter AR et al. (2005). Furthermore, an interaction effect from both experimental conditions was found in the stance phase (Step 1). It is shown that one leg stance phase just before an obstacle is extended due to the placed obstacle and the degree is increased because of email usage. Recently, the contribution of visual cognition to gait performance during walking on a level walkway approaching and stepping over an obstacle has been clarified by a series of reports by Patla et al. (1991, 1993, 1997, and 2002). During locomotion on a walkway with an obstacle, it may be necessary to recognize the form of the obstacle and the distance between the obstacle and oneself and to act depending on the outside environment perceived. If the obstacle on the walkway is small enough to step over, people are required to step over it rather than change their direction of locomotion and circumventing it (Patla, 1998). In this study, it was not possible to measure subjects' eye direction. However, according to previous studies (Patla and Rietdyk, 1993; Patla et al., 1996; Patla and Vickers, 1997), young adults do not gaze at an obstacle during locomotion two steps prior to stepping over it. Namely they look it during approaching process before then. Based on visual information, the trajectory of motion of the legs while stepping over an object is planned in advance (Patla et al., 1996; Patla, 1998; Patla et al., 2002; Mohagheghi et al., 2004). No visual perception at the moment of stepping over the obstacle is used for this feedforward control (Patla et al., 2002). In this study, subjects were instructed to start manipulating their cell phone as they began walking, namely 5 m before the obstacle. Thus, subjects might concurrently require both eye movement for cell phone manipulation and for recognizing the obstacle during the approach process three or more steps prior to stepping over it. The feedforward control for stepping over the obstacle might be influenced by eye-movement required to manipulate a cell phone.

Additionally, when consider from another perspective, the present results can be explained as follows: Gait is not a completely automated and reflexive task, as reported by Lajoie et al. (1993). They examined the attentional demands associated with gait using a dual task paradigm and reported that auditory reaction times were slower in the single support phase of the gait cycle when compared with the double support phase. In particular, the experimental condition in which subjects step over an obstacle used in this study may have more voluntary components than the condition in which the subject walks on a flat walkway. Hence, it is possible that the increase of stance in phase of Step 1 (immediately before the obstacle) during cell phone manipulation observed in this study may indicate the interference between the processes of controlling the two tasks (gait and manipulation of the cell phone). Whether the changes observed during cell phone manipulation were due to the limitation of visual information before stepping over an obstacle or due to the fact that subjects were performing dual tasks is difficult to determine from the present results. However, whatever the case, the changes in gait pattern by cell phone manipulation are significant findings. Further examination focusing on the visual behaviour has an important role.

According to Higuchi et al.'s study (Higuchi et al., 2003) on gait properties and their related factors in community-dwelling elderly people, a significant negative relationship between gait velocity and stride length was found. In short, the elderly with inferior physical mobility as a result of decreased muscle strength have low gait velocities and short strides (Shumway-Cook and Woollacott, 2000; Hoshino et al., 2002; Kurz and Stergiou, 2006) also reported that their self-paced gait speed was 0.8 m/s, being slower than speed (1.1 m/s) of young adults. In this study, gait velocity before leg length normalization was 1.29 m/s, 1.07 m/s while using a phone's email functions, and decreased further to 1.01 m/s (78 % of normal walk) by setting an obstacle on the walkway. The gait velocity results present here are slightly faster than Kurz and Stergiou's (2006) report (1. 1 m/s in young adults), but the decrement ratio (%) is similar. Chamberlin et al. (2005) also reported that elderly having a fear of fall accidents show a slower gait velocity than the elderly without this fear. Mobile email usage during walking compels even young adults to display similar walking characteristics to the elderly that have inferior physical mobility.

In conclusion, gait velocity, stride length and stance phase while walking are largely affected due to using a cell phone's email function even in young adults. Walking on a walkway with an obstacle present while using the email function of a cell phone causes the stance phase and stride length to increase just before the obstacle . Gaze transfers or gaze fixations and the high attention required in order to use the email function of a phone may induce large changes in the gait properties.

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Captions for figures

Figure 1 A schematic view of parameters for assessing gait characteristics

A gait analysis system Walkway MG - 1000 (ANIMA, JAPAN) was placed in the middle of a 10 m length walkway (a section from 2.5 to 7.5 m from the start line). An obstacle was set at the midpoint of the walkway (at 5 m from the start line) in both walk with obstacle and walk with obstacle + mail usage conditions.

Figure 2 Results of two-way ANOVA (mail usage × obstacle) and multiple comparisons for each gait parameter (n = 30)

*: $p < 0.05$. A significant difference between both obstacle conditions. †: $p < 0.05$. A significant difference between both mail usage conditions. Step 1-3: See Fig. 1"A schematic view of paraemters for assignment gait characteristics".

Figure 1

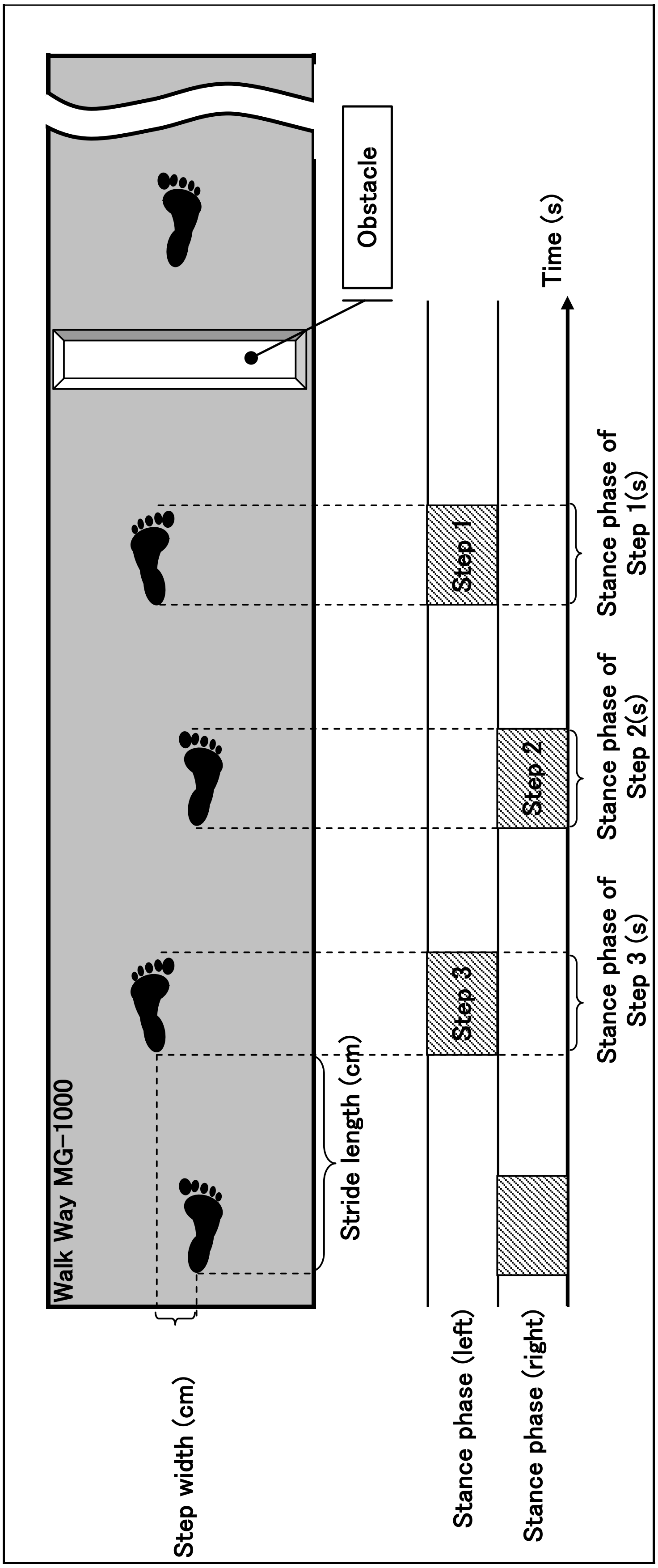
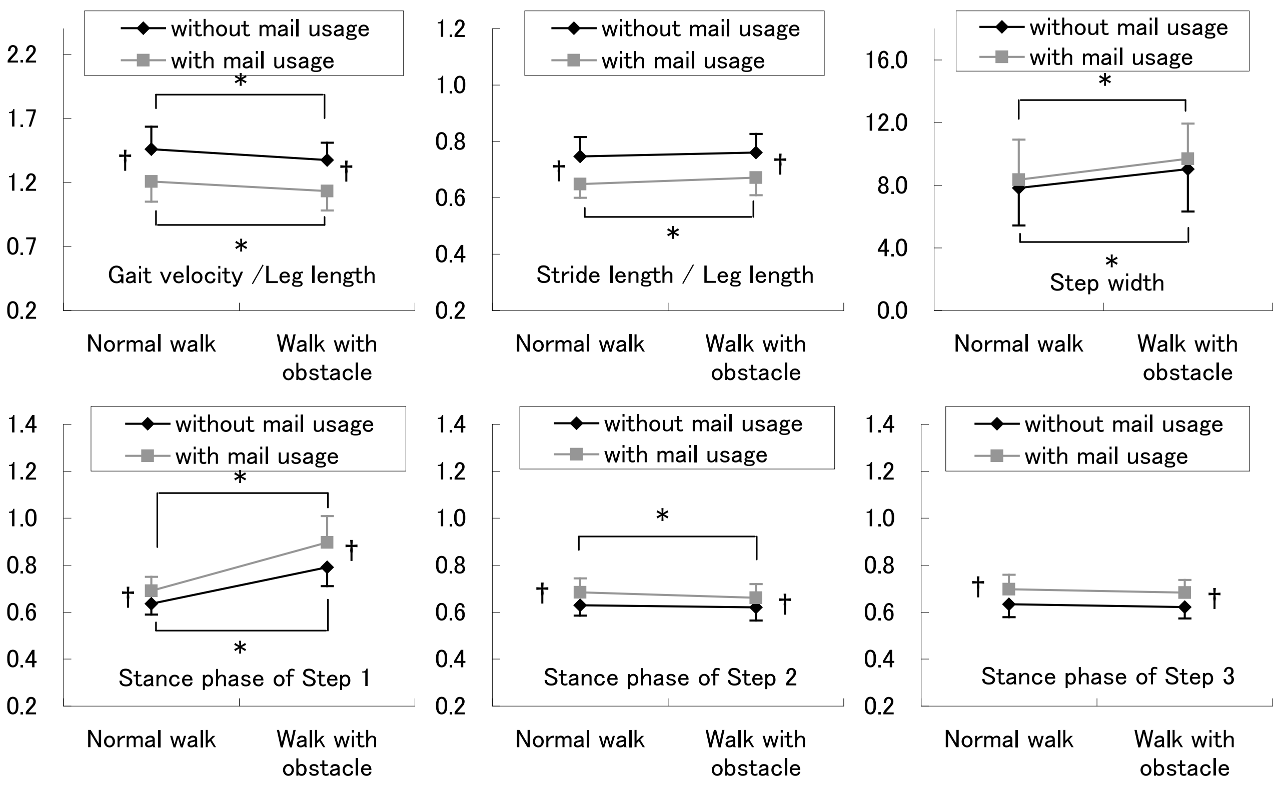

Walk Way MG-1000
Obstacle
Time (s)
Step 1
Step 2
Step 3
Stance phase of Step 1(s)
Stance phase of Step 2(s)
Stance phase of Step 3 (s)
Stride length (cm)
Step width (cm)
Stance phase (left)
Stance phase (right)

Figure 2



without mail usage
with mail usage
Gait velocity /Leg length
Stride length / Leg length
Step width
Stance phase of Step 1
Stance phase of Step 2
Stance phase of Step 3
Normal walk
Walk with obstacle
*
†
2.2
1.7
1.2
0.7
0.2
1.4
1.2
1.0
0.8
0.6
0.4
16.0
12.0
8.0
4.0
0.0

Tables with captions

Table 1

Questions for mail usage task in noamal walk and walk with obstacle + mail usage conditions

Items	Contents
1	What did you eat for lunch?
2	What is your primary recent concern?
3	What do you first do in the morning after getting up?
4	What is your biggest mistake to date?
5	Please express your character using a single word.
6	What enrichment lessons have you had just before now?

Subjects were asked one question in this table before beginning the normal walk and walk with obstacle + mail usage conditions. After the beginning of each gait measurement, they walked while entering their answers to the question.

Table 2
Characteristics of subjects' physique

		Men (n = 15)		Women (n = 15)				
		Mean	SD	Mean	SD	t		ES
Age	yrs	20.3	0.98	19.4	0.83	2.82	*	1.03
Height	cm	172.1	3.43	160.3	5.92	6.64	*	2.43
Weight	kg	67.7	5.13	58.2	7.57	4.02	*	1.47
Left leg length	cm	92.1	3.71	85.4	4.12	4.69	*	1.71
Right leg length	cm	91.8	3.67	85.5	3.82	4.61	*	1.68
Mean leg length	cm	91.9	3.58	85.4	3.90	4.76	*	1.74
Left lower leg length	cm	41.0	1.39	38.2	2.15	4.15	*	1.52
Right lower leg length	cm	41.1	1.51	38.0	2.27	4.35	*	1.59
Mean lower leg length	cm	41.0	1.37	38.1	2.09	4.50	*	1.64

*: $p < 0.05$.   ES: effect size

Table 3
Results of tests of sex differences for each gait parameter

Gait parameters	Conditions	Male (n = 15)		Female (n = 15)		t	p		ES
		Mean	SD	Mean	SD				
Gait velocity / Leg length	Normal	1.47	0.21	1.45	0.14	0.26	0.80		
	Obstacle	1.38	0.14	1.37	0.13	0.19	0.85		
	Normal + Mail	1.22	0.20	1.21	0.12	0.17	0.87		
	Obstacle + Mail	1.15	0.17	1.13	0.14	0.27	0.79		
Stride length / Leg length	Normal	0.77	0.08	0.73	0.06	1.44	0.16		
	Obstacle	0.79	0.07	0.74	0.05	2.10	0.04	*	0.77
	Normal + Mail	0.66	0.06	0.65	0.04	0.62	0.54		
	Obstacle + Mail	0.69	0.07	0.66	0.06	1.57	0.13		
Step width	Normal	7.09	2.86	8.20	2.27	-1.19	0.25		
	Obstacle	8.53	3.25	9.29	2.25	-0.75	0.46		
	Normal + Mail	7.95	3.08	8.40	2.45	-0.44	0.66		
	Obstacle + Mail	9.92	2.66	9.16	2.12	0.87	0.39		

Note *: $p < 0.05$; ES: effect size.
Conditions: "Normal" means "Normal walk condition", "Obstacle" means "Walk with obstacle condition", "Normal + Mail" means "Normal walk + mail usage condition", "Obstacle + Mail" means "Walk with obstacle + mail usage condition".
*: $p < 0.05$. ES: effect size