Can Probe Reaction Time of the Lower Extremity be Predicted from that of the Upper Extremity?

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Abstract. [Purpose] The purpose of this study was to predict the Probe Reaction Time (P-RT) of the lower extremity from the upper extremity. [Subjects] Ten healthy young people (7 males, 3 females) with a mean age of 27.0 ± 7.5 years participated in this study. [Methods] Walking and tapping with the non-dominant hand in synchrony with beats of a metronome at 1 Hz and 4 Hz were tested for the subjects. P-RT of movements were measured continuously 10 times. The speed of walking was self-determined by the subjects. [Results] The results showed significant correlations between walking and tapping with the non-dominant hand at 1 Hz ($r=0.87$, $p<0.05$) and 4 Hz ($r=0.95$, $p<0.05$). [Conclusion] Regression analysis showed a high correlation so P-RT of the upper extremity predicts P-RT of the lower extremity. Therefore P-RT of the upper extremity can be considered as a substitute for the lower extremity. This will be useful in the clinical field, especially for patients who are not able to walk or stand, and weak people.

Key words: Probe Reaction Time, Upper extremity, Lower extremity

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INTRODUCTION

The primary function of the lower extremity is to support the weight of the body and to provide a stable foundation in standing, walking, and running, and it has become specialized for locomotion. The functional ability of the upper extremity focuses on subtle hand movements, whereas that of the lower extremity focuses on standing, walking and running. The lower extremity, although similar in structure in many respects to the upper extremity, has less freedom of movement¹⁾. The main purpose of the functional ability of the upper extremity, especially for the hand, is to place the hand in various positions to accomplish an inexhaustible number of activities, ranging from very simple to quite complex tasks. The difference of the

dominant side of upper extremity is more significant than that of the lower extremity.

In healthy people, positive and often significant relationships exist between the strengths of the upper extremity and lower extremities. Bahannon reported that all non- paretic muscle group strengths were significantly correlated at $p<0.01$ and 91.7% were significant correlated at $p<0.001$ ²⁾. Mender found that knee extension force increased when subjects grasped the sides of the testing chair in which they were seated^{3, 4)}. These results suggest that there is a significant correlation between the upper extremity and the lower extremity. In the report of Robert and Steven, they predicted throwing speed by using the predictor variables of shoulders, arm, legs, and grip strength⁵⁾. It is thought in psychology that there is a limitation in

capacity of processing information from the environment. For instance, when a movement task is going on, and another task is concurrently applied, work requiring for the two tasks at the same time is known as dual task. If the main task is comparatively simple, a comparatively large amount of attention can be allocated to the second task. This makes it possible to perform the second tasks comparative quickly. Thus, it is interpreted that there are a lot of attention resources allocation to the second task. So if the second task (simple reaction time) is demanded during movement task enforcement and the reaction time (RT) to the dual task is relatively short, it implies that the main task is performed automatically. This study method is called the probe reaction time (P-RT). Some studies have investigated the P-RT of the upper extremity and the lower extremity, but these papers did not mention a relationship between the upper extremity and the lower extremity, and no paper has used the upper extremity as a predictor for the lower extremity. A few studies have investigated the relationship between the upper extremity and the lower extremity from different aspects of motor performance, but so far, there has been no study reporting on the prediction of P-RT in movement of the lower extremity from that of the upper extremity.

Previously, measurements of RT and P-RT have been performed for risk assessment of falls, and also in order to find some method of prevention of falls. In most previous studies, the authors measured the movements of the lower extremity and the upper extremity, e.g. walking, obstacle walking, stepping, stance phase, depression of switches by the finger and foot, or a dual task were performed. Tapping with the dominant hand and non-dominant hand at different frequencies in synchrony with the beats of a metronome were reported for measuring control mechanisms in sequential movements, successive stresses and time intervals or the extent of hesitation on subjects or patients when they were interrupted at different intervals. In this study, the reason why we chose to examine the relationship between upper extremity and lower extremity P-RT, rather than simple reaction time, is that the reliability of the simple reaction time was not as good as that of the P-RT of the movement of tapping with the non-dominant hand in synchrony with the beats of a metronome at frequencies of 1 Hz and 4 Hz in a study of the correlation of P-RT with walking⁶⁾.

There might exist a relationship between P-RT of the upper extremity and the lower extremity. Hence, this study investigated the relationship of P-RT between the upper extremity and the lower extremity, following the interclass correlation coefficient (ICC) of measurement of the P-RT of tapping with the non-dominant hand in synchrony with the beats of a metronome at frequencies of 1 Hz and 4 Hz. It further tries to predict the P-RT of the lower extremity from that of the upper extremity. The clinical advantage of P-RT is that it is applicable to severely handicapped subjects, and P-RT can be measured as a substitute for other exercise tests if direct measurement poses a safety risk to the subject.

SUBJECTS AND METHODS

Subjects

Ten young healthy people with a mean age of 27.0 ± 7.5 years, a mean height of 170.8 ± 9.5 cm, and a mean body weight of 65.1 ± 11.1 kg were recruited for the study. All the subjects were able to perform activities of daily life, independently. All the subjects gave their consent to participate in this study.

Methods

We evaluated the P-RT of “walking” and “tapping with the non-dominant hand at 1 Hz” and “tapping with the non-dominant hand at 4 Hz” in synchrony with the beats of metronome. The speed of walking was self-determined. The P-RT was measured 10 times at each frequency.

Prior to the experiment, the subjects were told of what would be done in the experiment, and they performed trial exercises to familiarize themselves with the procedures. In the actual experiment the subjects were asked to respond to an auditory cue asking the subject to walk. The subject was asked to tap with non-dominant hand in synchrony with beats of metronome at the frequency of 1 Hz and 4 Hz. The speed of walking was self-determined by the subject. The P-RT was measured 10 times continuously in the repetitive movements. Data was recorded by a personal computer, and the DigionSound5 sound-processing software was used for the analysis.

The data were analyzed using SPSS Ver.12.0 for Windows. Analysis of variance was used to examine the experimental times of the movements.

Table 1. The mean and SD of measurement of 1 Hz and 4 Hz tapping and walking (n=10)

Subjects	Tapping at 1 Hz (msec.)	Tapping at 4 Hz (msec.)	Measurement of Walking (msec.)
1	288.1 ± 33.8	291.4 ± 34.9	279.2 ± 14.9
2	305.7 ± 31.8	251.9 ± 42.7	221.7 ± 11.2
3	487.8 ± 32.0	343.6 ± 48.9	394.8 ± 36.5
4	352.5 ± 48.4	333.3 ± 31.5	357.6 ± 37.2
5	490.3 ± 40.9	398.8 ± 56.4	395.3 ± 48.9
6	305.7 ± 30.8	296.3 ± 27.0	305.7 ± 28.4
7	281.3 ± 29.9	284.1 ± 23.9	265.3 ± 48.1
8	299.6 ± 49.9	311.3 ± 41.5	337.1 ± 83.0
9	228.1 ± 30.3	236.4 ± 19.3	225.5 ± 10.1
10	253.1 ± 34.8	231.1 ± 34.7	220.9 ± 36.4
Mean ± SD	329.2 ± 36.3	297.8 ± 36.1	300.3 ± 35.5

Note: values are mean ± standard deviation.

To determine the correlation between each movement, Pearson's correlation coefficient was calculated. Regression was used to verify the relationship of P-RT in movement between the upper and lower extremities. The level of probability accepted as the criterion for statistical significance was $p < 0.05$.

RESULTS

The measurement results of P-RT of walking while tapping with the non-dominant hand in synchrony with metronome beats at frequencies of 1 Hz and 4 Hz are presented in Table 1. The relationship between the upper and lower extremities was estimated by Pearson's correlation coefficients. The coefficient between tapping at 1 Hz and walking was $r = 0.87$, $p < 0.01$ (Fig. 1). Pearson's correlation coefficient between tapping at 4 Hz and walking was $r = 0.95$, $p < 0.01$ (Fig. 2). A high correlation was found between the upper and lower extremities.

DISCUSSION

The significant reliability of P-RT in different types of repetitive movement was verified in a previous study. The reliability of the P-RT in walking (ICC=0.92), tapping with the non-dominant hand at 1 Hz (ICC=0.92) and 4 Hz (ICC=0.90) showed high ICCs. The purpose of this study was to try to predict the P-RT of lower extremity from that of the upper extremity while

Fig. 1. Relationship of tapping at 1 Hz and walking. **Fig. 2.** Relationship of tapping at 4 Hz and walking.

walking and tapping with the non-dominant hand during the experiment.

Kauranen and Vanharanta showed low correlation ($r = 0.40$ to 0.62) of simple reaction time, choice reaction time and tapping between the upper and lower extremities. The upper extremity showed higher correlation between movements of the dominant and non-dominant hands ($r = 0.71$ to 0.80 , $p < 0.001$). And the lower extremity showed a higher correlation between the left and right feet ($r = 0.57$ to 0.88 , $p < 0.001$)⁷. Atsushi Isagoda and Ruichi Nakamura reported only the rhythmic movement of

reaction time on the arm and foot were significant⁸⁾. Whereas, in the present study, the significant correlation of P-RT represents a high correlation coefficient between walking and tapping with the non-dominant hand at 1 Hz (Fig. 1) and 4 Hz (Fig. 2). Pearson analysis showed significant correlation in both sides of the lower extremity relative to walking, and tapping with the non-dominant hand at 1 Hz and 4 Hz ($r=0.88$, $p<0.01$). However, a higher significant correlation was shown when subjects tapped with the non-dominant hand at 4 Hz in synchrony with beats of metronome.

P-RT has been used in psychological tests, fall risk assessments and prevention, and also as intervention in the treatment of patients. After regression analysis, significant correlations were shown between walking and tapping with the non-dominant hand at 1 Hz ($r=0.87$, $p<0.01$), and also between walking and tapping with the non-dominant hand at 4 Hz ($r=0.95$, $p<0.01$). We further verified a significant relationship between P-RT of the upper extremity and P-RT of the lower extremity (Figs. 1, 2). Hence, the significant correlation between tapping with the non-dominant hand and walking could be explained by the P-RT of the lower extremity being predictable from that of the upper extremity.

As another reason for this study, we wanted to find which types of movement of the upper extremity are the best substitute movements, when the participants cannot perform a movement in the lower extremities. We would recommend substitution with tapping with non-dominant hand in synchrony with metronome beats at the frequency of 1 Hz because of the high reliability of tapping with the non-dominant hand at 1 Hz in synchrony with beats of a metronome, and also because tapping with the non-dominant hand at 1 Hz in synchrony with beats of a metronome showed a significant correlation with the lower extremities.

The highest correlation and ICC were found between the simple tests, while lower correlations were seen between more difficult and complex tasks. Therefore, we deduced that P-RT in lower extremity movements could be replaced by the P-RT of tapping with the non-dominant hand at 1 Hz in synchrony with beats of a metronome, a result that is highly reproducible. Furthermore, it is useful in the clinical setting, especially for patients who cannot walk or stand and weak people, that tapping with the non-dominant hand in synchrony with beats of 1 Hz frequency could be used as a substitute for movement of the lower extremities if direct measurement of that movement is considered risk to the patient.

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