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ORIGINAL ARTICLE

CHARACTERISTICS OF 3-MIN SELF-PACED TAPPING MOVEMENT OF THE INDEX FINGER AND ANKLE-TOE IN THE ELDERLY

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Abstract Objectives: We examined the effects of age on the speed and variability of continuous tapping movement of the hands and feet over 3 min.
Methods: Tapping speed and variability of tapping interval during 3-min self-paced tapping tasks for the index finger and ankle-toe were compared between groups of 20 young people and 20 active elderly people.
Results: No effect of age on tapping speed was found, but the variability of tapping interval decreased with age. Both groups showed no correlation between speed and variability, and the speed of the ankle-toe task was slower than that of the index finger task. There was a correlation between variability of the index finger task and that of the ankle-toe task in the elderly group. Movement speed was slower in the second half of the 3-min task time in both groups, but there was no difference in the degree of variability.
Conclusions: Variability in self-paced single-joint tapping movement of the hands and feet may reflect regressive changes in the mechanisms of internal rhythm formation. In addition, for clinical screening, it is sufficient to conduct the task for 1.5 min to evaluate any changes in movement speed and variability.

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Key words: elderly; self-paced tapping; speed; variability; cerebellum.

原　著

高齢者における示指と足部の３分間セルフペース・タッピング運動の特性

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抄録　研究目的：本研究の目的は，手と足の３分間の持続的タッピング運動のばらつきに及ぼす加齢の影響について明らかにすることである．
対象と方法：若年者群20人と活動的高齢者群20人において，セルフペースで示指と足部のタッピング課題を３分間行った時の，それぞれの運動速度とタッピング間隔のばらつきが比較検討された．
結果：タッピング速度に加齢の影響は認められなかったが，タッピング間隔のばらつきには加齢による低下が認められた．両群とも，速度とばらつきの相関は認められなかった他，足部課題の速度は示指課題の速度より遅かった．示指課題と足部課題のばらつきの相関が高齢者群において認められた．３分間の課題時間の後半で運動速度は延長するが，ばらつきの程度に変わりはなかった．
結語：セルフペースで行なう手足の単関節タッピング運動では，内部リズム形成機構の退行性変化を反映することが示唆された．また臨床的スクリーニングという点で運動速度やばらつきの変化を見極めるためには，1.5分間あれば十分と思われる．

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Introduction

Generally, patients with cerebellar diseases have temporospatial variability in limb movement[1-3], and tapping tasks of the index finger and ankle-toe are used as diagnostic tests for such signs[4]. However, movement variability in these tapping tasks has also been reported among elderly people without neurological disorders[5, 6]. The reason for this variability in the elderly is considered to be regressive changes in the muscles, nerves, and joints. These regressive changes trigger decreases in the accuracy of movement, and movement speed decreases to ensure precision, thus leading to variability in movement[7-11]. In addition, comparative studies of multi-joint movement of the upper limb in the elderly and in young people have reported that temporospatial variability of movement increases in the elderly because they cannot make smooth movements[10, 12].

However, the tapping tasks used in these previous studies have used multi-joint, complex movements that include the shoulders and elbows, or those that combine sight and hearing stimulation. The numbers of measurement repeats and measurement times have also been limited, with the number of repeats ranging from several[6] to about 30 times[2, 13-15] and the measurement times short (maximum of 1 min)[16]. Thus, these study results reflect only part of the regressive changes due to age. Considering that daily life is sustained by the repetition of simple movements such as those involved in breathing, chewing, and walking[17], it is important to investigate the variability of movement when simple movement tasks are conducted continuously for more than 1 min.

Our aim was to elucidate the effects of age on the variability of movement when tapping tasks with single-joint movements of the hands and feet were conducted continuously for 3 min.

Methods

1. Subjects

The subjects were 20 elderly people who were participating in local exercise classes and could reach their classroom on foot or by bicycle or car (mean age 72.9 years, SD 7.0). The control group consisted of 20 young people who were students at Tsukuba International University and had applied as volunteers (mean age 21.6 years, SD 1.6). Any subject with a history of neuromuscular disease, circulatory disease, or cerebral stroke was excluded from participation. Cognitive function in the elderly was assessed with the Mini-Mental State Examination[18], and all subjects were found to have no problems. All subjects were determined to be right-handed from the results of the Edinburgh handedness test[19] and Chapman footedness test[20].

This study was approved by the ethics committees of Tsukuba International University and Hirosaki University Graduate School of Medicine and was conducted after we had obtained informed consent from all participants.

2. Tapping task and measurement method

The tapping tasks were repetitive bending and extension of the metacarpophalangeal joint of the right index finger (index finger tapping) and repetitive bending and extension of the right ankle joint (ankle-toe tapping). Subjects conducted these task movements at their own pace (self-paced), aiming to keep at a constant interval for 3 min, and the tapping interval and number of taps were measured. The order of tasks was randomized in each subject. We selected tapping with single-joint movement because it is easy, requires no practice, and reflects a person's ability to adjust basic movements. We chose self-paced continuous movement for 3 min because these conditions have never been covered by previous studies. Moreover, we hypothesized that these conditions would better reflect the mechanisms of autonomous rhythm formation, including the effects of fatigue and movement habituation.

(1) Measurement of index finger tapping

The subject sat on a standard chair in a quiet location and placed the forearm of the dominant hand on the table, with the elbow joint in a slightly bent position and the forearm pronated. To minimize the effect of the force of tapping[21], a pen tablet (Bamboo Fun pen tablet; Wacom, Tokyo) connected to a personal computer (EeePC X101CH notebook-type personal computer; ASUS) was used as a measurement device. The subject tapped the touch pad on the desk with the index finger of the dominant hand.

(2) Measurement of ankle-toe tapping

The subject sat on a standard chair in a quiet location and with both the ankle and the knee joint in a slightly bent position. A wireless touch pad button (TP500; Logicool) was placed on the floor for easy tapping as the measurement device. The subject tapped the button of the wireless touch pad on the floor with the base of the toe of the dominant foot (Fig. 1).

(3) Data recording

The tapping interval and number of taps during the index finger tapping and ankle-toe tapping tasks were measured for 3 min at a sampling frequency of 1000 Hz by using a measurement program prepared with a programming tool called Hot Soup Processor[22].

3. Data analysis

As a measure of the variability of the self-paced index finger/ankle-toe tapping interval in the younger and elderly groups, the coefficient of variation (CV) was calculated by formula of $(SD / Mean) \times 100$. The frequency (Hz) obtained by dividing the number of taps in 3 min by 180 s was called the "tapping speed." The first 10 taps of each tapping task were not included in the analysis; data in the 3 min from the 11th tap onward was analyzed.

For statistical analysis of data, we conducted a comparative investigation of tapping speed and variability in tapping interval in the younger group and the elderly group by using two-way repeated measures ANOVA. In addition, to investigate the effect of fatigue on the performance of each task, the 3 min of tapping was divided into a first half and a second half to compare differences in tapping speed and variability in tapping interval. Furthermore, the relationship between tapping speed and variability of tapping interval for each task was investigated by using Spearman's rank correlation coefficient. The first 10 taps measured were excluded from the analysis of variability of tapping intervals. The significance level was set at below 5%, and all analyses were conducted with SPSS15.0.

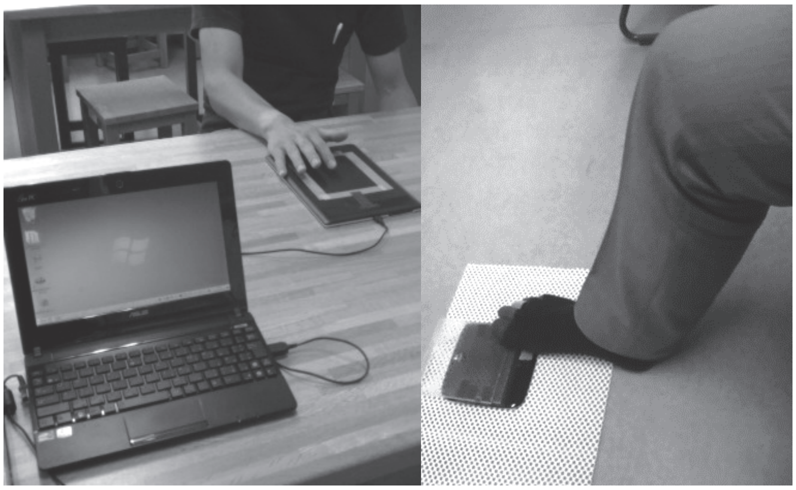
Results

1. Tapping speed (Table 1)

The mean index finger tapping speed was 2.13 Hz [SD 0.68] in the younger group and 2.09 Hz [SD 0.58] in the elderly group; no significant difference was found. There was no significant difference in mean ankle-toe tapping speed between the younger group (1.86 Hz [SD 0.57]) and the elderly group (1.86 Hz [SD 0.36]). Index finger tapping speed was significantly higher than ankle-toe tapping speed in both the younger group and the elderly group (both $P < 0.01$).

2. Variability of tapping interval (Table 1)

The mean variability of the index finger tapping interval in the younger group was 6.21 [SD 1.78], whereas that in the elderly group was 9.75 [SD 5.34]; the variability in the elderly group was significantly higher. A significant difference



Index finger Ankle-toe

Fig. 1 Tapping tasks.

Table 1 Tapping speed and variability of tapping interval

Mean (SD)

		Younger		Elderly	
Tapping speed (Hz)	Index Finger	2.13 (0.68)	** (Index Finger vs Ankle-toe)	2.09 (0.58)	** (Index Finger vs Ankle-toe)
	Ankle-toe	1.86 (0.57)		1.86 (0.36)	
Variability of tapping interval (CV)	Index Finger	6.21 (1.78)	** (Younger vs Elderly)	9.75 (5.34)	
	Ankle-toe	6.56 (2.29)	** (Younger vs Elderly)	9.16 (5.72)	

(CV: Coefficient of variation) $^{**}P < 0.01$

in mean variability of ankle-toe tapping interval was also found between the younger group (6.56 [SD 2.29]) and the elderly group (9.16 [SD 5.72]); the variability in the elderly group was higher. There was no significant difference between the variabilities of the index finger tapping interval and ankle-toe tapping interval in the younger group or the elderly group.

3. Comparison of tapping speed and variability of tapping interval between the first and second 90-s periods (Table 2)

The index finger or ankle-toe tapping speed and variability of tapping interval were compared between the first and second 90-s periods. The mean index finger tapping speed of the younger group was 2.19 Hz [SD 0.63] in the first half and 2.10 Hz [SD 1.70] in the second half; a significant decrease was found ($P < 0.01$). The index finger tapping speed in the elderly group also decreased significantly between the first half (mean 2.16 Hz [SD 0.48]) and the second half (mean 2.05 Hz [SD 0.71]) ($P < 0.01$). This pattern was also confirmed for the ankle-toe tapping speed: in the second half of the 3-min task there was a significant decrease in speed in both the younger group (first half: mean 1.90 Hz [SD 0.56]; second half: mean 1.82 Hz [SD 0.57]) and the elderly group (first half: mean 1.94 Hz [SD 0.36]; second half: mean 1.80 Hz [SD 0.35]).

In contrast, variability in either task did not

Table 2 Comparison of tapping speed and variability of tapping interval between the first and second halves of the tapping tasks

Mean (SD)

Index Finger		Younger	Elderly	Ankle-toe		Younger	Elderly
Tapping speed (Hz)	first half	2.19 (0.63) **	2.16 (0.48) **	Tapping speed (Hz)	first half	1.90 (0.56) **	1.94 (0.36) **
	second half	2.10 (1.70)	2.05 (0.71)		second half	1.82 (0.57)	1.80 (0.35)
Variability of tapping interval (CV)	first half	5.71 (0.57)	8.81 (4.56)	Variability of tapping interval (CV)	first half	6.12 (2.55)	7.99 (5.08)
	second half	5.92 (1.88)	9.62 (5.96)		second half	6.43 (2.58)	8.40 (5.79)

(CV: Coefficient of variation) $^{**}P < 0.01$

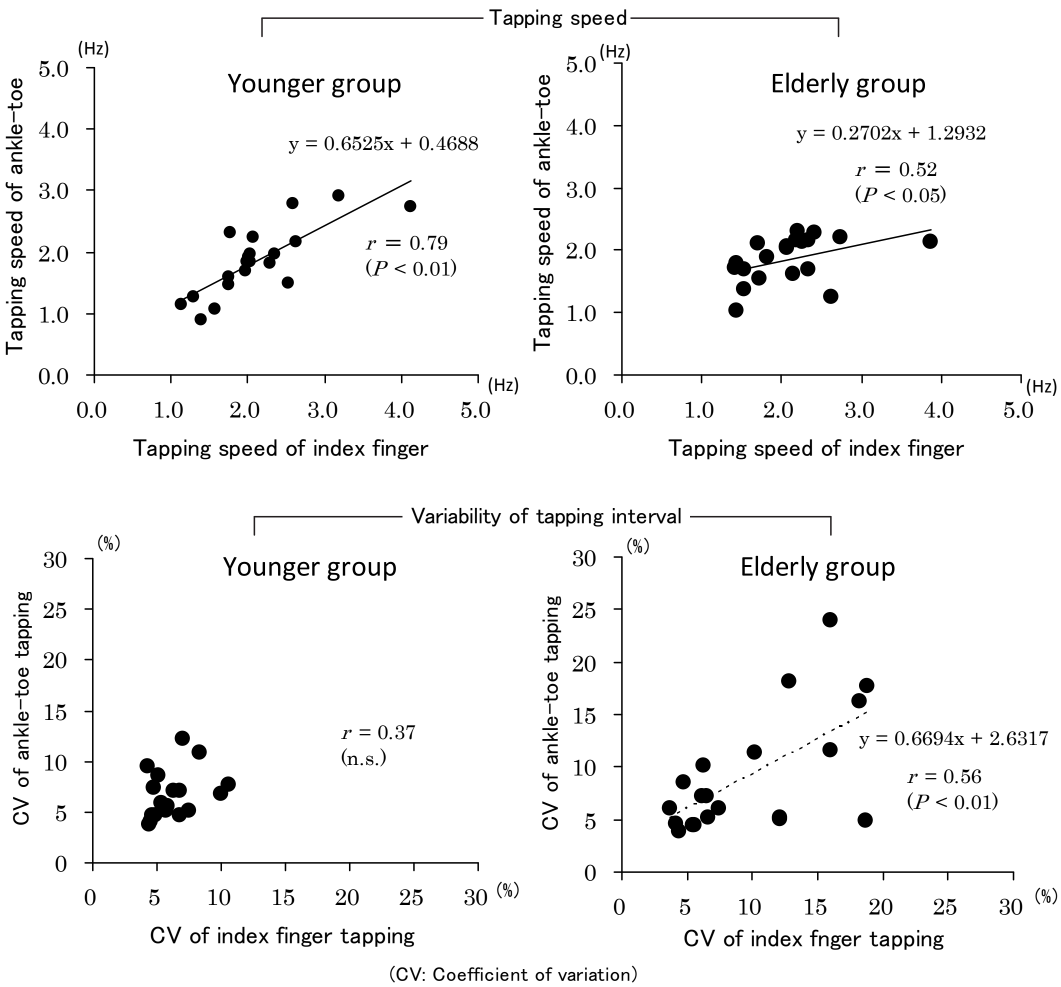


Fig. 2 Relationships between the index finger task and the ankle-toe task.

differ significantly between the first half and second half of the task in either the younger or the elderly group.

4. Relationship between index finger tapping and ankle-toe tapping (Fig. 2)

The relationship between index finger tapping speed and ankle-toe tapping speed was investigated with Spearman's correlation coefficient; a significant positive correlation was found in both the younger group (r = 0.79, P < 0.01) and the elderly group (r = 0.52, P < 0.05).

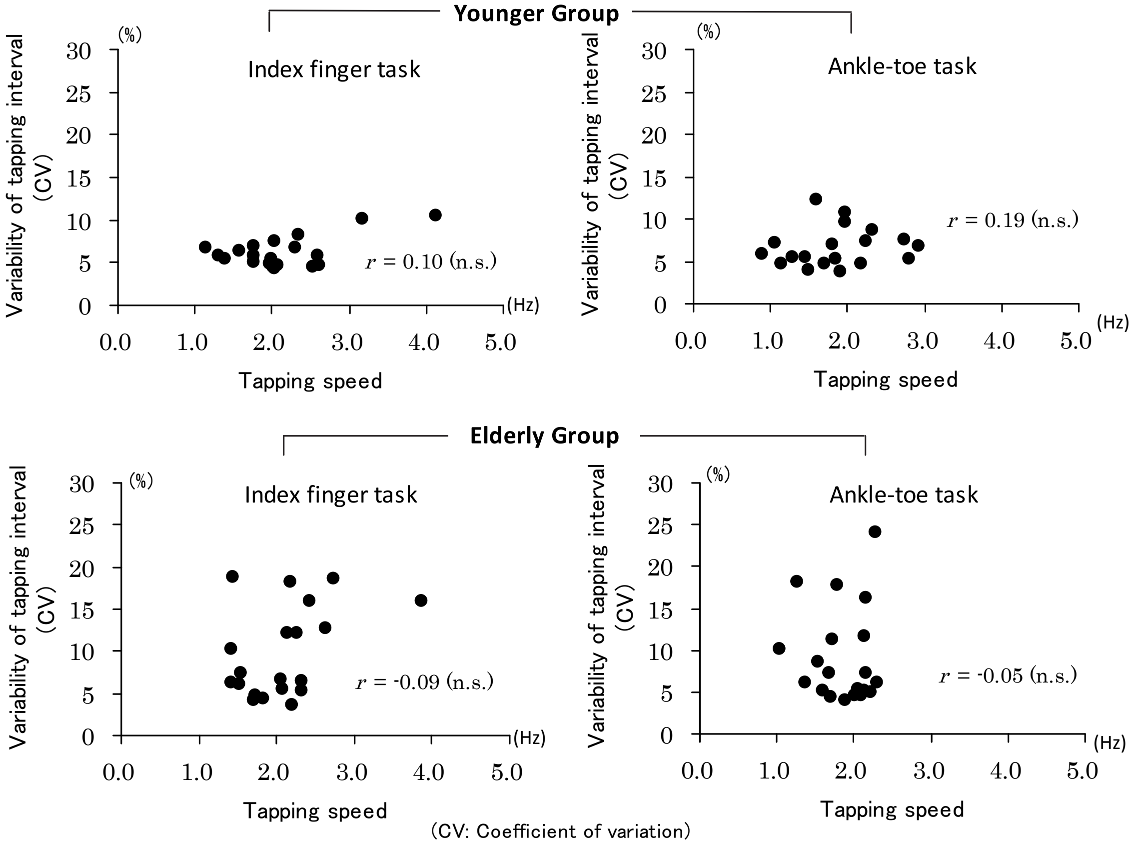


Fig. 3 Relationships between tapping speed and variability of tapping interval.

The variabilities of the index finger tapping interval and the ankle-toe tapping interval were significantly positively correlated only in the elderly group ($r = 0.56$, $P < 0.01$).

5. Relationship between tapping speed and variability of tapping interval

No significant correlations were found between tapping speed and variability of tapping interval in either the younger group or the elderly group in the index finger tapping or the ankle-toe tapping test (Fig. 3).

Discussion

There was no difference in self-paced tapping speed between the younger group and the elderly group. The elderly group showed no decrease in tapping speed, and the results in the two groups were approximately equal, with a mean of approximately 2.1 Hz for the index finger task and 1.86 for the ankle-toe task. In contrast, there was a significant difference in the variability of the tapping interval between the younger group and the elderly group; the variability was higher in the elderly group in both the index finger task and the ankle-toe task. For self-paced tapping, there was no effect of age on speed, but it was clear that variability was affected by age. Previous studies have shown that movement speed decreases in the elderly when maximum performance using external stimulation such as a metronome is required[6, 9], but there no differences in tapping speed between younger and elderly groups have been found in self-paced studies[23]. The speed of the tapping task closely reflects the functional status of peripheral structures such as the musculoskeletal system, but because the self-paced tapping used here required only basic levels of movement the effect of age may not have been apparent.

In contrast, as described in the Introduction, the functional status of the central nervous system, including the cerebellum, affects the variability of the tapping interval, and we found that age had a significant effect. The cerebellum plays an important role in coordination and timing of movement[5, 24, 25], and it makes adjustments to movement according to input from the outside[26]. In addition, the cerebellum makes timing adjustments, even in the case of self-paced tapping, in which there is little information from the outside[27, 28]. Recent neuroimaging studies have reported shrinkage of the parenchyma of the cerebellum and a decrease in Purkinje cell numbers with age[29-31]. Thus regressive change in the central nervous system—mainly in the cerebellum—likely caused variability in the tapping interval among our elderly subjects. These results suggest that tapping speed and variability in self-paced tapping are each affected by different factors in the elderly. This concept is supported by our finding that there was no correlation between tapping speed and variability in either group.

Tapping speed was slower in the ankle-toe task than in the index finger task. This was true in both groups and is thus not an effect of age but of the structural and functional characteristics of the feet: the ankle-toe task requires more gross movements than does the index finger task. In contrast, there was no difference in the variability of the tapping interval between the index finger task and the ankle-toe task. Additionally, in our elderly group there was a positive correlation between the variabilities of the two tasks. Keele and Pokorny[15] found that the tapping performance of the fingers and feet was correlated. Considering the neural mechanism proposed by Yamanishi et al.[13] and Semjen and Ivry[32] for the formation of internal rhythm, the timing for index finger tapping and ankle-toe tapping likely comes from the same neural mechanism that forms rhythm.

This study focused on the variability of movement during a continuous tapping task over 3 min, a period longer than the maximum of 1 min used in previous studies. When we divided the 3-min task time into first and second halves, we found that both groups had a decrease in tapping speed in the second half. However, there was no change in the variability of the tapping interval between the two halves, regardless of the age group. The effect of age was therefore negligible. Self-paced tapping tasks continuing for over 1 min may result in decreased movement speed because of habituation to the task, along with fatigue, but the rhythm of tapping is maintained by the internal rhythm formation mechanism.

A limit of this study was that our elderly subjects were healthy and active. Moreover, our discussion of the role of the central nervous system was limited to indirect validation based on the performance of tapping. We did not test joint excursion or muscle strength as part of our evaluation of movement function, but to confirm changes in peripheral structures due to age it is important that these functional evaluations be conducted. These are issues for future research, which we anticipate will include studies of the weakened elderly and brain imaging.

Conclusions

We focused here on the effect of age on tapping movements. Notably, our experiment used three conditions that have never been used simultaneously, namely, single-joint movement of the hands and feet with the exclusion of proximal joints; a self-paced format; and movement tasks that exceeded 1 min. Our findings revealed that the effect of age was more apparent in terms of variability than of movement speed in self-paced, single-joint tapping movement of the hands and feet. We suggest that this type of tapping reflects regressive changes in the mechanism of internal rhythm formation. Although there is a difference between the tapping performances of the hands and feet, there is no difference between the two in terms of the effect of age or reflection of the mechanism of internal rhythm formation. The task (either hands or feet) may be therefore be chosen to suit the subject's condition in clinical screening. It is sufficient to conduct the task for 1.5 min to evaluate any changes in movement speed and variability. The above findings may help to elucidate the mechanisms of tapping in not only the elderly but also patients with central nervous system diseases.

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