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Effects of arm swing on walking abilities in healthy adults restricted in the Wernicke-Mann's limb position

Akiyoshi Takami, PhD[1]), Shuit Cavan, MS[1, 2]), Misato Makino, PhD[1])

[1]) Hirosaki University Graduate School of Health Science: 66-1 Honcho, Hirosaki-shi, Aomori 036-8564, Japan
[2]) Ushioda Hospital, Japan

Abstract. [Purpose] Arm swing is seldom considered while designing clinical rehabilitation protocols for hemiplegic patients with upper or lower extremity disabilities, likely due to the unclear role that arm swinging plays in the ability to walk. We, therefore, aimed to investigate the effect of arm swinging on walking abilities. [Participants and Methods] The study enrolled 20 healthy adults who performed a 10 m walking test with normal gait, single-arm restricted gait, both-arms restricted gait, and maximum arm-swing gait with one arm fixed in the Wernicke-Mann's position. The walking time, number of steps taken, and pelvic fluctuation were measured for the four gaits. A fixed-trunk type arm sling was used for maintaining the Wernicke-Mann's position. [Results] Velocity and stride length decreased significantly while walking with the single-arm restricted gait and both-arms restricted gait in comparison to normal gait. The maximum arm-swing gait showed no significant differences from normal gait in terms of cadence, velocity, and stride. Pelvic fluctuations also had no significant differences among all gaits. [Conclusion] Restricting movement of one or both arms limited the walking speed and stride; however, in Wernicke-Mann's limb position, if the arm is intentionally swung, the walking speed and stride resembled that of normal gait.
Key words: Arm swing, Walking abilities, Hemiplegia cases

INTRODUCTION

Conventionally, walking involves arm-swinging and the movement of the upper limb increases walking efficiency by reducing the disturbance caused by its weight[1]. Furthermore, Umberger compared the arm-swinging of the upper limbs versus walking without arm-swinging and showed that the movement of the upper limbs can reduce the energy consumption during walking by 8%[2]. Murray et al. reported that the rotation of the shoulder girdle and counter rotation of the pelvis are indispensable for efficient walking[3] and Ferris et al. explained how rhythmic movement of the upper limbs promotes muscle strength of the lower limbs[4]. Thus, these studies elucidated how walking efficiency improves by the swinging movements of the upper limbs. However, while carrying or holding some items of considerable weight and walking simultaneously, both upper limbs or one of the upper limbs remains fixed near the waist or shoulder to perform both the actions efficiently. For patients with disabilities, clinical rehabilitation specialists design walking exercise-based interventions often considering the disabilities of the lower limbs and trunk with negligible attention to upper-limb movements. Particularly in hemiplegia following stroke, which is characterized by the disability to swing either one or both arms, the influence of the disability on walking has not been clarified. Therefore, in this study, we aimed to investigate the effects of different arm swings on the walking abilities. We hypothesized that inducing a swinging movement with both arms might improve the walking abilities more than the single-arm swing.

*Corresponding author. Akiyoshi Takami (E-mail: a-takami@hirosaki-u.ac.jp)

PARTICIPANTS AND METHODS

Twenty healthy adults (8 males, 12 females, age 28.1 ± 6.2 years, 164.1 ± 8.6 cm, 59.7 ± 15 kg) participated. All participants were informed in writing and agreed. Those who had orthopedic disorders or severe pain in the upper and lower limbs were excluded. This study was carried under the permission of the Hirosaki Stroke Rehabilitation Center Ethics Committee (approval number: 15B007).

The participants were asked to perform a 10-m walk test once for each of the following four conditions. a) normal gait, b) single-arm restricted gait as in a typical moderately hemiplegic patient, while the dominant hand was restricted with an arm sling, c) both arms restricted gait (Fig. 1) as in a hemiplegic patient who tries to maintain balance with non-paralyzed upper limbs, while the dominant hand was restricted with an arm sling and non-dominant arm was restricted with a strap, d) maximum arm swing gait similar to hemiplegic patients instructed to swing both arms as much as they could while the dominant arm was constricted with an arm sling. As regards the implementation of Wernicke-Mann's position[5], we created an arm sling with straps on both sides to fix the trunk and mounted it at an elbow joint of 90°.

We used an ankle-fixed short lower-limb orthosis on the corresponding side of the dominant hand while performing the steps (b) to (d). The participants were instructed to walk in the maximum speed during the 10-m walking test, while the time and number of steps were recorded. A multi-measurement device, Corpus (Inter Reha Inc.) was used to evaluate the range of motion, muscle strength, and acceleration in 3 axes. It was attached between the posterior superior iliac spines on both sides of the participants to analyze pelvic fluctuation. The item specifications used for the analysis included the sensor scale ± 4 g, a maximum number of measurements ≤ 800, sampling cycle 100 Hz, and pelvic fluctuation with the standard deviation of acceleration in 3 axes of the pelvis. After completing the test, the participants were instructed to answer a questionnaire (Fig. 2) regarding the experience.

For each condition, a multiple comparison test was performed on velocity, stride, cadence, and pelvic fluctuation. The questionnaire results were calculated by simple tabulation. SPSS for Windows Ver 16.0 J was used for statistical analysis with significance level set at >5%.

RESULTS

In comparison with normal gait, velocity of arm swinging was significantly decreased while performing walking exercises with a restricted gait using one arm ($p<0.05$) and no arm movement ($p<0.05$). Whereas, the stride length decreased significantly during single-arm restricted gait ($p<0.05$) and both arms restricted gait ($p<0.05$). No significant differences were observed in the cadence (Table 1), whereas the pelvic fluctuation decreased the order of maximum arm swing, normal gait, both arms restricted gait, and single-arm restricted gait but no significant differences were observed (Table 2). In the questionnaire, 65% of individuals answered that gait with both arms restricted was the most difficult condition, while 60% considered a maximum arm swing gait as the easiest condition.

Fig. 1. Both arms restricted.

Fig. 2. Questionnaire.

Table 1. Average value of walking parameters under 4 conditions (n=20)

	Velocity (m/min)	Stride length (m)	Cadence (steps/min)
Normal gait	128.4 ± 18.2*	0.76 ± 0.05†	168.6 ± 20.5
Single arm restricted gait	113.4 ± 16.2*	0.71 ± 0.05†	159.2 ± 20.4
Both arms restricted gait	112.8 ± 17.6*	0.71 ± 0.06†	159.5 ± 20.9
Maximum arm swing gait††	115.5 ± 17.0	0.73 ± 0.05	159.6 ± 23.3

Average ± standard deviation.
*Velocity: Normal gait vs. Single arm restricted gait & Both arms restricted gait ($p<0.05$).
†Stride length: Normal gait vs. Single arm restricted gait & Both arms restricted gait ($p<0.05$).
††Maximum arm swing gait: Swing both arms to the maximum while being fixed in the Wernicke-man's position.

Table 2. Standard deviation of pelvic fluctuation under 4 conditions (n=20)

	Acceleration (m/s^2)		
	x-axis	y-axis	z-axis
Normal gait	± 0.37	± 0.54	± 0.52
Single arm restricted gait	± 0.32	± 0.52	± 0.45
Both arms restricted gait	± 0.29	± 0.52	± 0.47
Maximum arm swing gait*	± 0.34	± 0.58	± 0.51

No significant differences.
*Swing both arms to the maximum while being fixed in the Wernicke-mann's position.

DISCUSSION

Our hypothesis was supported by the observation that during single-arm restricted gait with an arm sling, swinging both arms showed similarity with normal gait, supporting our hypothesis. The velocity showed significant differences between normal gait with single arm restricted and both arms restricted gait. The rotation of the trunk was abrupted due to the restricted upper limb causing instability when walking. A previous study reported that stability is secured by lowering the velocity[6]. Furthermore, Abiko et al. reported a decrease in velocity and stride when the arm swing was restricted[7]. Ferris et al. showed that rhythmic upper-limb movement promotes lower-limb muscle strength,[4] which they suggested might promote the muscular strength and reflex of the lower limbs, thus improving the propulsive power and the stability of the swinging period and causing the stride length to increase. Conversely, the participants who performed the maximum arm swing gait (with one arm restricted in the Wernicke-Mann's position) had no significant differences between velocity, stride, and cadence with normal walking. Eke-Okoro reported an increase in stride length and velocity with increasing upper-limb swing width[8], which was different from the results of this study. Unlike normal gait, the maximum arm-swing gait had non-significant differences between single-arm restricted gait and both arms restricted gait, suggesting that maximum arm swing gait may deviate from normal gait. Murray reported that rotation of the shoulder band and counter rotation of the pelvis are indispensable for efficient walking[3]. However, our study results showed no difference in the pelvic fluctuation between the conditions, which could be attributed to the decreases in velocity and stride length having mutual influence on the decrease of pelvic oscillation.

One limitations of this study was that even after instructing the participants to walk in the maximum speed during the test, decreases of walking speed or number of steps could have occurred unconsciously. Hence, further study should consider using a treadmill for controlling the walking speed.

Compared to a normal gait, the single-arm restricted and both arms restricted gaits had significantly decreased velocity and stride length, while the maximum arm-swing gait showed no significant difference in the velocity, stride, and cadence compared to normal gait. However, velocity and stride were improved when the single-arm restricted gait was compared with both arms restricted gait, suggesting that even one-arm swinging could improve the walking ability. When walking, I thought that it would be easier to walk if the arm sling was firmly fixed, but it was suggested that swinging both hands would allow faster walking. It may be applied even in stroke depending on the case.

Conflict of interest
No conflicts of interest to disclose.

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