



## Full Length Article

## Effects of arm weight on gait performance in healthy subjects

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## ABSTRACT

Previous studies have investigated how additional arm weights affect gait. Although light weights (0.45 kg) seemed to elicit performance improvements in Parkinsonian patients, it was not studied how light weights affect gait parameters in healthy individuals. It is important to understand normal responses in a healthy population so that clinical effects might be better understood. Therefore, the purpose of this study was to investigate the effects of arm weights on arm swing amplitude, gait performance, and muscle activity in healthy people. Twenty-two subjects walked overground at their preferred speed under different weight carriage conditions (C1: no weight; C2: unilateral arm weight; C3: bilateral arm weights; C4: waist weights). Gait speed increased in C2 ( $p = 0.018$ ) and C4 ( $p = 0.013$ ) when compared with C1 ( $C1: 1.21 \pm 0.08$ ;  $C2: 1.25 \pm 0.11$ ;  $C3: 1.24 \pm 0.11$ ;  $C4: 1.25 \pm 0.11$  m/s) with an increase in cadence during C2 ( $p < 0.001$ ), C3 ( $p = 0.008$ ), and C4 ( $p < 0.001$ ) ( $C1: 105.5 \pm 5.2$ ;  $C2: 108.5 \pm 5.6$ ;  $C3: 107.9 \pm 5.6$ ;  $C4: 108.5 \pm 5.3$  steps/min) and in tibialis anterior electromyographic activity on the unweighted side in C2 ( $p = 0.048$ ) ( $C1: 21.05 \pm 4.59$ ;  $C2: 25.10 \pm 6.10$ ;  $C3: 23.93 \pm 4.75$ ;  $C4: 24.33 \pm 6.32$   $\mu$ V). The results indicate that an additional sensory input with the application of the weights may result in an overcompensation with the whole body and facilitate faster walking speed when applied on one arm or around the waist. The locations of the weights and amount of the weights may elicit different responses. Various strategies of adding weights should be further investigated as a potential intervention to improve performance in individuals with various gait impairments. Although there is evidence for benefits of this intervention in Parkinsonian patients, further study is warranted in other patient populations, such as stroke patients, who might benefit from this intervention to improve gait performance.

## 1. Introduction

During normal human locomotor tasks, neuromotor control of the upper and lower limbs are interdependent (Ferris, Huang, & Kao, 2006; Meyns, Bruijn, & Duysens, 2013). The underlying mechanism responsible for the coordination between upper and lower limb movements has been called interlimb neural coupling, which is defined as a flexible, task-specific, physiologically meaningful linkage of the limbs during complex movements (Dietz & Schrafl-Altermatt, 2016). Researchers have reported a positive relationship between arm swing amplitude and stride length in healthy people during walking (Eke-Okoro, Gregoric, & Larsson, 1997; Yang,

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Atkins, Jensen, & James, 2015). Normally, as arm swing amplitude increases or decreases, stride length also increases or decreases (Eke-Okoro et al., 1997; Yang et al., 2015). Investigators demonstrated that greater upper limb muscle activation leads to increased lower limb muscle recruitment during recumbent stepping tasks using handles and pedals that are contralaterally coupled. Thus, upper limb motion can drive lower limb stepping motion of the contralateral side that allows the lower limb to passively go along for the ride (de Kam et al., 2013; Ferris et al., 2006; Kao & Ferris, 2005). Also, studies observed an increase in lower limb muscle recruitment with higher arm movement frequencies during recumbent stepping tasks (de Kam et al., 2013; Kao & Ferris, 2005). Related also is that contralateral upper and lower limb movement during tricycling conserved metabolic energy when compared with right and left arms moving in union, indicating that neural energy cost is lower when the preferred coordination is utilized (Meyns et al., 2014). Similarly, Kawashima et al. examined the effect of resting, passive, and active arm swing on lower limb muscle activation during passive locomotor-like leg movements (Kawashima, Nozaki, Abe, & Nakazawa, 2008). They found that passive or active arm swing increased locomotor-like soleus activation when compared with resting arm swing in patients who had incomplete cervical spinal cord injury, where there was no significant difference in the EMG amplitudes between the passive and active arm swings. This study suggests that it is not descending motor commands that affect the muscle activation of lower limb, but rather sensory afferent signals to the spinal cord induced by upper limb movements that affect the muscle activation of lower limb. Although lower limb activation can be enhanced by additional supraspinal descending motor commands, neural connections within the spinal cord seem to play a significant role in the coordination of upper and lower limb motion (Meyns et al., 2013). The spinospinal (proprio-spinal) tracts are a likely pathway for this neural coupling (Dietz, 2002; Zehr, Hundza, & Vasudevan, 2009).

Similar to the neural coupling observed between upper and lower limbs (non-homologous limbs), neural coupling may exist between right and left arms (homologous limbs). Donker et al. found in healthy people that carrying 1.8 kg on one arm increased arm swing amplitude on the opposite unweighted arm while decreasing arm swing amplitude of the weighted arm (Donker, Mulder, Nienhuis, & Duysens, 2002). The additional weight carriage condition resulted in a significant EMG activity increase at the deltoid muscles on the unweighted side, as well as the weighted side (Donker et al., 2002). However, the additional weight did not affect the relative frequency between the arms and legs when compared with walking without weights. The increased EMG signal might be explained by interlimb neural coupling, where a weighted arm required more force to move. Here, a strong motor command seemed to be sent to both arms leading to increased neural drive to and consequently arm swing amplitude of the unweighted arm (Donker et al., 2002). Additionally, the deltoid muscles of the weighted arm exhibited the greatest muscle activation. It is, therefore, plausible that loading an arm could decrease its movement amplitude but increase its muscle activity.

Applying additional weights to the body could be a possible intervention to facilitate improvements in gait performance via an interlimb neural coupling mechanism. In addition to the increased muscle activation observed in homologous limbs (Donker et al., 2002), a previous study in Parkinsonian patients reported that walking with light arm weights (0.45 kg each) resulted in increased arm swing amplitude leading to improved gait performance that included an increase in cadence, walking speed, stride length, and swing phase time (Yoon et al., 2015). Several possible reasons may explain the different adaptive response between the two studies such as different weights, gait speeds, and populations. Adding heavy weights to the arms may result in a decreased arm swing amplitude because of the greater inertial characteristics of the weighted arms. However, light weights may facilitate arm swing. Yoon et al. postulated that light weights could act as an additional sensory input and affect the perception to activate the motor cortex during walking especially in Parkinsonian patients (Yoon et al., 2015).

Previous research has investigated the effects of heavy weights on gait parameters during walking in healthy subjects (Donker et al., 2002). Light weights have been used to improve gait in Parkinsonian patients (Yoon et al., 2015). However, it is not clear how light weights affect gait parameters in healthy individuals. Additional knowledge about the effects of adding weight to the body, especially the arms, could provide information needed to facilitate developing new intervention strategies for improving gait performance in patient populations that have neuromuscular recruitment and control impairments. However, to better understand how a weight carriage intervention might affect a patient population, it is necessary to first understand how weight carriage affects healthy individuals. Therefore, the purpose of this study was to investigate the effects of adding weights to the arms on arm swing amplitude, gait performance, and muscle activity in healthy subjects. It was hypothesized that walking with arm weights would increase muscle activation in the upper and lower limbs and improve gait performance due to the interlimb neural coupling mechanism. Additionally, it was hypothesized that weights placed close to the center of mass of the body would not improve gait performance due to the failure of activation of the interlimb neural coupling mechanism.

## 2. Methods

### 2.1. Subjects

Twenty-two healthy subjects (10 male, 12 female;  $M \pm SD$  age:  $23.5 \pm 2.1$  years, height:  $1.71 \pm 0.07$  m, mass:  $67.8 \pm 10.9$  kg, BMI:  $23.0 \pm 3.1$ ) participated in the study. Volunteers were excluded from participation in the study if they had: 1) a history of shoulder subluxation, 2) a history of any major upper or lower limb joint pathology such as peripheral neurological, rheumatic, orthopedic or cardiovascular conditions that could interfere with walking, and 3) obesity (body mass index  $> 30$ ). Prior to participation, all subjects signed an informed consent form approved by the Institutional Review Board at the affiliated university.

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