Chapter 6
Arm Swing during Human Gait Studied by EMG of Upper Limb Muscles

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ABSTRACT

Arm swing during human gait has both passive and active components. The chapter presents a study conducted with normal subjects using electromyography (EMG) to describe patterns of arm and shoulder muscle activity in different gait conditions. These included normal forward walking, walking with immobilized arms, backward walking, power walking with accentuated arm swing, running, and load carriage. Complementary kinematic data are presented, too. Rhythmic muscle activity persists to some extent when both arms are immobilized during walking. Forward and backward walking involve dissimilar patterns of muscle activity, although the limb movements are very similar in both conditions. Likewise, power walking and running are characterized by different curves of EMG activity. Unimanual load carriage during walking affects muscle activities of both the loaded and the non-loaded arm. Research on normal arm swing provides a basis for clinical investigations of gait disorders.

INTRODUCTION

Arm swing is a typical, though not obligatory, feature of normal human gait. Since arm swing has no direct function for propulsion, it is unclear why this movement occurs (Meyns, Bruijn, & Duysens 2013); suggested reasons include improvement of stability, reduction of energy consumption, neuronal coupling of upper and lower limbs, and passive induction of arm swing by trunk movements, gravity, and inertia. Compared to the extensive research on leg muscle activity, EMG of upper
arm and shoulder muscles during different modes of human gait in healthy volunteers. We aimed to gain insight into neurophysiological mechanisms of gait (leg-arm coupling, adaptation of motor synergies to changing conditions) and to provide physiological EMG data, which might be useful for studies in patients with gait disorders, e.g. in Parkinson’s disease.

The frequency of arm swing and the phase coupling between upper and lower limbs depend on the walking velocity (Wagenaar & van Emmerik, 2000). During slow walking (<0.8 m/s), both arms tend to swing back and forth together rather than alternately, at twice the stride frequency of the legs. During normal and fast walking and running, both arms swing in alternation and in phase with the contralateral legs, so the left arm swings forward along with the right leg and vice versa (Webb, Tuttle, & Baksh, 1994).

In their seminal EMG study, Ballesteros, Buchthal, and Rosenfalck (1965) concluded that swinging the arm from back to forth (forward arm swing) during walking is actuated by contractions of internal rotators of the upper arm (latissimus dorsi), while the posterior part of the deltoid muscle and the teres major are responsible for backswing. Others argued that forward arm swing is a passive movement (Hinrichs, 1990; Hogue, 1969). Possibly due to methodical limitations, the aforementioned studies found no EMG activity of upper arm muscles (triceps, biceps) during walking, whereas recent research detected such activity (Ivanenko, Cappellini, Poppele, & Lacquaniti, 2008; Kuhtz-Buschbeck & Jing, 2012). Possibly due to methodical limitations, the aforementioned studies found no EMG activity of upper arm muscles (triceps, biceps) during walking, whereas recent research detected such activity (Ivanenko, Cappellini, Poppele, & Lacquaniti, 2008; Kuhtz-Buschbeck & Jing, 2012).

In brief, it has been shown that arm swing is not an entirely passive pendular movement, but the extent to which upper limb muscles actively drive arm swing during walking and running is not yet completely understood.

This chapter presents novel EMG data to characterize the activity of shoulder and arm muscles in normal subjects during various gait conditions. Activity of one paravertebral trunk muscle (erector spinae) was recorded, too. First, normal forward walking (control condition) is described together with corresponding kinematic data of arm swing. In line with the concept that arm and leg muscle activations are coupled by a central motor program (Dietz, 2002; Nielsen, 2003), it was then hypothesized that some EMG activity of upper limb muscles would persist when both arms are immobilized during walking. We also examined whether deliberate suppression of persisting EMG signals is possible. Next, we compare EMG data of forward and backward walking. Although the limb movement trajectories are remarkably similar in both conditions (Thorstensson, 1986), we expected dissimilar patterns of upper limb muscle activity. Reciprocal arm swing was deliberately accentuated during power walking, which is a popular alternative to Nordic pole walking. Here it was hypothesized that rhythmical shoulder and upper arm muscle activations would increase above control values. However, since the basic biomechanical features of walking are preserved during power walking, we anticipated no major change in the activation profile of the erector spinae muscle. By contrast, we expected the EMG curves of both, upper limb and paravertebral muscles, to differ between walking and running. Furthermore we studied the EMG during treadmill walking with unimanual and bimanual load carriage (10% body weight). Here we anticipated differences between unimanual and bimanual carriage and a possible involvement of the non-loaded arm during unilateral load carriage.

Taken together, the current EMG data have been collected in twenty normal subjects to outline the profiles of arm and shoulder muscle activity for different modes of gait on a treadmill (forward walking, walking with immobilized arms, backward walking, power walking, running, load carriage). The current data complement two previous related studies, which had been performed in the same laboratory, but with other subjects and other gait conditions (Kuhtz-Buschbeck, Brockmann, Gilster, Koch, & Stolze, 2008; Kuhtz-Buschbeck & Jing, 2012).