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Correlations between ankle–foot impairments and dropped foot gait deviations among stroke survivors

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ABSTRACT

Background: The purpose of this paper is to 1) evaluate the relationship between ankle kinematics during gait and standardized measures of ankle impairments among sub-acute stroke survivors, and 2) compare the degree of stroke-related ankle impairment between individuals with and without dropped foot gait deviations.
Methods: Fifty-five independently ambulating stroke survivors participated in this study. Dropped foot was defined as decreased peak dorsiflexion during the swing phase and reduced ankle joint motion in stance. Standardized outcome measures included the Chedoke–McMaster Stroke Assessment (motor impairment), Modified Ashworth Scale (spasticity), Medical Research Council (muscle strength), passive and active range of motion, and isometric muscle force.
Findings: Foot impairment was not related to peak dorsiflexion during swing ($r = -0.17$, $P = 0.247$) and joint motion during stance ($r = 0.05$, $P = 0.735$). Active ($r = 0.45$, $P < 0.001$) and passive ($r = 0.48$, $P < 0.001$) range of motion was associated with stance phase joint motion. Peak dorsiflexion during swing was related to isometric dorsiflexor muscle force ($r = -0.32$, $P = 0.039$). Individuals with dropped foot demonstrated greater motor impairment, plantarflexor spasticity and ankle muscle weakness compared to those without dropped foot.
Interpretation: Our investigation suggests that ankle–foot impairments are related to ankle deviations during gait, as indicated by greater impairment among individuals with dropped foot. These findings contribute to a better understanding of gait-specific ankle deviations, and may lead to the development of a more effective clinical assessment of dropped foot impairment.

1. Introduction

Although it has been reported that 60% to 80% of stroke survivors are able to ambulate independently on discharge from rehabilitation (Jorgensen et al., 1995), many individuals still exhibit gait deviations contributing to limited functional mobility (Olney and Richards, 1996). Specifically previous research has demonstrated the contribution of impaired ankle–foot function to poor gait performance. Ankle muscle weakness among stroke survivors has been associated with low plantarflexor power for push-off, reduced swing phase dorsiflexion, and slow preferred gait velocity (Hsu et al., 2003; Olney and Richards, 1996; Olney et al., 1991). Greater isometric force production during a maximum voluntary contraction (MVC) of the ankle dorsiflexors has been positively related to temporal symmetry and increased gait velocity among stroke survivors (Lin et al., 2006). Ankle plantarflexor spasticity was the most important determinant of spatial and temporal asymmetry among stroke survivors and contributed to a slower gait velocity (Hsu et al., 2003; Lin et al., 2006). While these studies provide evidence linking ankle–foot impairments to gait dysfunction among stroke survivors, it remains unclear how standardized outcome measures of ankle–foot impairment relate to gait-specific problems at the ankle, such as dropped foot.

Dropped foot is commonly described by kinematic deviations at the ankle–foot including reduced ankle dorsiflexion during the swing phase of gait, and forefoot or flat foot initial contact leading to reduced stability during stance (Burridge et al., 1997; Olney and Richards, 1996).

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Lamontagne et al. reported reduced dorsiflexion during swing phase of the affected side in more than 50% of persons with stroke compared to healthy control values at natural and very slow speeds (Lamontagne et al., 2002). Stroke related ankle impairments causing inadequate dorsiflexion control during gait include weakness of dorsiflexors, spasticity of plantarflexors, passive stiffness of the plantarflexors, and abnormal muscle coactivation (Lamontagne et al., 2002). For stroke survivors with these ankle impairments, approximately 22% require an ankle–foot orthotic (AFO) at discharge from inpatient rehabilitation (Teasell et al., 2001). Stroke survivors using an AFO demonstrated greater motor impairment, reduced independence and poor balance at admission and discharge (Teasell et al., 2001). However, it is unknown how these impairment measures are related to specific dropped foot kinematic gait deviations that lead to an AFO prescription. As well, individuals with dropped foot gait may not receive a prescription at discharge due to difficulty donning/doffing independently, patient and clinician perceptions, financial cost, and other stroke-related impairments (Tyson and Thornton, 2001). A current systematic review highlights the need for specific investigation into clinical indications of stroke survivors that may benefit from an AFO prescription (Leung and Moseley, 2003).

The purpose of this study was to 1) determine the relationship between sagittal ankle kinematics during gait and ankle impairment measured at rest (Chedoke–McMaster Stroke Assessment, CMSA; Modified Ashworth Scale, MAS; Medical Research Council strength scale, MRC; joint range of motion, RoM; and isometric MVC) among sub-acute stroke survivors at discharge from inpatient rehabilitation, and 2) compare the degree of ankle impairment measures between individuals with and without dropped foot gait deviations. We hypothesize that sagittal ankle kinematics will be correlated with lower limb sensorimotor control, plantarflexor spasticity and dorsiflexor strength. Additionally, individuals with dropped foot will demonstrate a greater degree of ankle impairment in the clinical tests.

2. Methods

2.1. Participants

Fifty-five individuals who sustained a stroke (ischemic or hemorrhagic) and were inpatients at the Toronto Rehabilitation Institute participated in the study. Inclusion criteria were ability to walk 5 m independently with or without a gait aid and understand instructions. Participants were excluded if they had other neurological or musculoskeletal disorders limiting their walking function. This study was approved by the local university and hospital research ethics boards. All participants provided informed consent.

2.2. Clinical assessment

All hospital inpatients have a standardized clinical assessment performed by a trained physiotherapist at discharge from rehabilitation. The following information was obtained, when available, from their medical charts: demographic data, medical history, AFO prescription, CMSA leg and foot score, Berg Balance Scale (BBS) and Clinical Outcome Variables Scale (COVS). The CMSA measures severity of sensorimotor impairments at the leg and foot on a 7 point scale, with higher score indicating better motor recovery. The CMSA has been reported to have a high inter- ($r = 0.85$–0.96) and intra-rater ($r = 0.94$–0.98) reliability (Gowland et al., 1993). The BBS evaluates 14 tasks on a scale of 0 to 4 with a higher score indicating complete ability to perform the task. This scale has been validated in the stroke population, and has high inter- ($r = 0.95$–0.98) and intra-rater ($r = 0.97$) reliability (Berg et al., 1995). The level of spasticity in the ankle plantarflexors of the affected lower extremity was evaluated with the Modified Ashworth Scale (MAS) on a 5-point scale, with 0 representing no increase in muscle tone and 4 indicating a rigid contracture (Blackburn et al., 2002).

Passive and active RoM at the ankle joint was assessed using electrical goniometers following a standardized procedure (Clarkson, 2005). Participants were seated with their hip flexed to approximately 90° and knee extended with the lower leg supported. Each movement was performed twice to obtain an average RoM.

Maximal voluntary contractions (MVC) were used to evaluate isometric force of the ankle dorsiflexors and plantarflexors for both limbs. Participants were in a seated position with their knee at 90° and foot strapped to a load cell positioned at the metatarsal heads. A load cell (SSM-AJ-500N, Interface Inc., Scottsdale, AZ, USA) was mounted to a platform at a 10° angle with a strap fixed to measure muscle force. Instructions were to push/pull on the load cell and hold for 1 s. This procedure was repeated twice for each muscle group after 1 min of rest. Participants were also scored on the MRC Manual Muscle Test scale for both limbs, which is graded from 0 to 5 with the highest score indicating normal strength against manual resistance.

2.3. Gait protocol

Participants were asked to walk a distance of 7 m over a pressure sensitive mat (GaitRite® Electronic Walkway, CIR Systems Inc., Peekskill, NY, USA) with their regular footwear at their preferred speed. Participants were instructed to stand upright with equal weight between limbs starting 1 m before the mat and continued to walk 1 m after the mat. Gait aids permitted include wheeled walkers and single or quad point canes. Three trials were completed. Electrical goniometers were placed bilaterally with the axis inferior to the lateral malleoli to record sagittal ankle kinematics (Fig. 1). Participants were allowed to rest when needed.

2.4. Measurements tools

Custom made electrical goniometers were designed using a 10 kΩ potentiometer, 9 V battery and 5 mm thermoplastic to measure sagittal ankle movements (weight 105 g). A positive value from neutral (90° angle) indicates ankle plantarflexion and a negative value indicates ankle dorsiflexion. These signals were sampled at 1000 Hz and stored for offline analysis (Noraxon Telemyo System, Scottsdale, AZ, USA). The devices were calibrated with a mechanical goniometer and weights, respectively. Spatial–temporal gait parameters recorded using the pressure sensitive mat, which is 5.25 m in length, 0.88 m in width and contains a grid pattern of 48 by 288 sensors arranged at 1.27 cm on center.

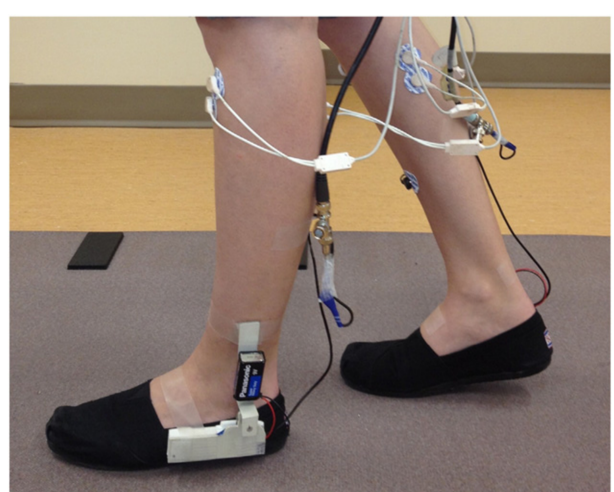

Fig. 1. A picture showing the setup of our goniometer devices on the participants.