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Full Length Article

Errors in the ankle plantarflexor force production are related to the gait deficits of individuals with multiple sclerosis

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ABSTRACT

Background: Individuals with multiple sclerosis (MS) often have limited mobility that is thought to be due to the neuromuscular impairments of the ankle. Greater isometric motor control of the ankle has been associated with better standing postural balance but its relationship to mobility is less understood. The objectives of this investigation were to quantify the motor control of the ankle plantarflexors of individuals with MS during a dynamic isometric motor task, and explore the relationship between the ankle force control and gait alterations.
Methods: Fifteen individuals with MS and 15 healthy adults participated in both a dynamic isometric ankle plantarflexion force matching task and a biomechanical gait analysis.
Findings: Our results displayed that the subjects with MS had a greater amount of error in their dynamic isometric force production, were weaker, walked with altered spatiotemporal kinematics, and had reduced maximal ankle moment at toe-off than the control group. The greater amount of error in the dynamic force production was related to the decreases in strength, step length, walking velocity, and maximal ankle moment during walking.
Interpretation: Altogether these results imply that errors in the ankle plantarflexion force production may be a limiting factor in the mobility of individuals with MS.

1. Introduction

Multiple sclerosis (MS) is a demyelinating disease that affects about 570,000 individuals in the United States (Campbell et al., 2014). These individuals often face motor impairments that result from muscular weakness, latent muscular activity, spasticity, and muscular fatigue (Cameron, Horak, Herndon, & Bourdette, 2008; Lambert, Archer, & Evans, 2001; Ponichtera, Rodgers, Glaser, Mathews, & Camaione, 1992; Scheidegger, Kamm, Humpert, & Rosler, 2012; Sosnoff, Gappmaier, Frame, & Motl, 2011; Steens, Heersema, Maurits, Renken, & Zijdewind, 2012; Wagner, Kremer, Van Dillen, & Naismith, 2014). As a result of these motor deficits, individuals with MS often have balance limitations which make them highly susceptible to falling. It has been suggested that individuals with MS may compensate for their balance limitations by walking with shorter step lengths, slower walking velocities, slower cadences, and an increased amount of time spent in double support (Benedetti et al., 1999; Kelleher, Spence, Solomonidis, & Apatsidis, 2010; Martin et al., 2006). It has been speculated that the neuromuscular impairments in the ankle plantarflexor musculature, such as increased muscle weakness or poor motor

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control, have major effects on the mobility; however, this notion has not been well explored (Huisinga, Schmid, Filipi, & Stergiou, 2013; Kelleher et al., 2010; Martin et al., 2006; Sosnoff et al., 2011; Wagner et al., 2014).

Control of the ankle plantarflexor musculature can be quantified by the amount of variability or error that occurs in a submaximal isometric force matching task (Kouzaki & Shinohara, 2010). Previous investigations have used both continuous and dynamic isometric force matching tasks to explore the motor control of the lower extremities (Carville, Perry, Rutherford, Smith, & Newham, 2007; Christou & Carlton, 2001, 2002; Seynnes et al., 2005). During a continuous isometric task, subjects attempt to generate and sustain a force that matches a static target force value, while for a dynamic isometric task subjects attempt to ramp up and down their isometric force production to match a target force that often has a parabolic shape. While it is normal for a force trajectory to display a small amount of variability or error in its pattern, an increased amount of error is thought to reflect an inaccurate control of the muscular force production. Additionally, it is common for a more dynamic isometric motor task to display a higher amount of variability or error than a continuous isometric contraction. This has been speculated to be due to the higher rate of force production or that the motor command must be constantly altered during a dynamic motor task (Christou & Carlton, 2001).

Prior investigations have shown that a greater amount of variability in a submaximal continuous isometric contraction performed with the ankle plantarflexors is related to decreases in standing postural stability (Kouzaki & Shinohara, 2010; Mello, Magalhaes, & Kohn, 2013). Additionally, in our previous investigation, we displayed that a heightened amount of variability in the continuous isometric ankle plantarflexor force production was related with the degree of upright postural balance impairments seen in individuals with MS (Davies et al., 2015). Furthermore, a reduction in the amount of variability in the isometric plantarflexion force production seen after individuals with MS undergo physical therapy was related to the degree of improvements seen in their standing postural control. However, the reduction in the variability of the continuous isometric plantarflexion force production was not related to the improvements in walking ability. Other prior investigations have also struggled to find a relationship between the variability within a continuous isometric contraction and functional abilities such as walking or climbing stairs (Carville et al., 2007; Manini, Cook, Ordway, Ploutz-Snyder, & Ploutz-Snyder, 2005; Seynnes et al., 2005). Potentially, this is due to the dynamic nature of the ankle motor control during these functional tasks. Therefore, the use of a submaximal, dynamic isometric force matching task may be more useful in identifying the motor control deficits of the ankle musculature that may limit walking ability.

The primary purpose of this study was to evaluate the variability of the ankle plantarflexor musculature of individuals with MS while completing a dynamic isometric target matching task. Secondarily, we sought to determine whether the amount of variability or errors in the dynamic ankle plantarflexion force production is related to the alterations in the gait patterns that typically occur with MS. Our overarching hypothesis was that individuals with MS would have more errors in their dynamic ankle isometric force production, and that these errors would be directly related to the mobility impairments of individuals with MS.

2. Methods

Fifteen individuals with either relapsing-remitting or secondary progressive MS (Mean Age: 53.1 ± 7.6 years; 10 female; EDSS: 4.4 ± 1.0; see Table 1 for subject characteristics) and 15 healthy, age and gender matched adults (Mean Age: 53.5 ± 7.4 years; 10 female) participated in this research study. All experimental procedures were reviewed and approved by the University of Nebraska Medical Center Institutional Review Board. Additionally, all subjects provided written informed consent before participating in the experimental procedures. All experimental procedures were performed barefoot by the subjects without the use of any assistive devices (i.e., canes, ankle-foot orthoses, wheeled walkers).

Table 1
Subject demographics for the MS group.

Subject	Age	Gender	MS Diagnosis	Years with MS	EDSS	Assistive Device for Community Ambulation
1	57	F	RR	19	4.0	Cane
2	48	M	SP	12	5.5	Cane
3	50	F	RR	12	3.5	None
4	57	F	RR	12	4.0	None
5	55	M	SP	4	4.5	None
6	53	M	RR	15	4.0	None
7	58	F	RR	33	6.0	Cane/Walker
8	36	F	SP	14	6.5	Walker
9	57	M	RR	16	4.0	None
10	72	F	RR	34	4.0	Cane
11	53	F	RR	20	5.0	Walker
12	50	F	RR	23	3.0	None
13	53	M	RR	14	3.0	None
14	48	F	RR	20	4.0	Cane
15	50	F	RR	15	4.5	Cane

Abbreviations. MS, multiple sclerosis; RR, relapsing-remitting multiple sclerosis; SP, secondary progressive multiple sclerosis.