Lower Extremity Muscle Activation During Functional Exercises in Patients With and Without Chronic Ankle Instability

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Objective: To determine whether individuals with chronic ankle instability (CAI) exhibit altered neuromuscular control as demonstrated by surface electromyography (EMG) amplitudes compared with healthy controls during single-limb eyes-closed balance, Star Excursion Balance Test, forward lunge, and lateral hop exercises.
Design: A cross-sectional laboratory study.
Setting: A research laboratory.
Participants: Fifteen young adults with CAI and 15 healthy controls.
Interventions: The subjects performed functional exercises while surface EMG signals were recorded from the tibialis anterior, peroneus longus, lateral gastrocnemius, rectus femoris, biceps femoris, and gluteus medius.
Main Outcome Measurements: Surface EMG amplitudes (root mean square area) for each muscle, muscles of the shank (distal 3 muscles), muscles of the thigh (proximal 3 muscles), and total muscle activity (all 6 muscles) of the lower extremity were analyzed and compared between the groups.
Results: Individuals with CAI demonstrated significantly less EMG activity in the muscles of the lower extremity during all 4 functional exercises. Effect sizes for significant differences between groups ranged from −0.75 to −1.08, none of which had 95% confidence intervals that crossed zero, which indicates moderate to large decreases in muscle activity in patients with CAI compared with healthy controls.
Conclusions: Patients with CAI demonstrated decreased muscle activity of ankle, knee, and hip musculature during common functional rehabilitative tasks. Clinicians may benefit from implementing functional exercises for patients with CAI that target both distal and proximal muscles of the lower extremity.

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INTRODUCTION

Ankle sprains account for 15%-23% of athletic injuries in the high school and collegiate settings [1,2]. Furthermore, ankle sprains are the most common site for recurrent injury and account for 25% of all recurrent injuries [3], and recurrent ankle sprains account for 15% of all ankle sprains [4]. Recurrent ankle sprains are often associated with residual symptoms such as pain, subjective instability, and decreased self-reported function [5,6]. A recent position statement indicates that a history of at least 1 significant ankle sprain, a subsequent history of the ankle "giving way," and self-reported functional limitations are defining characteristics of a heterogeneous condition known as chronic ankle instability (CAI) [7].

Sensory, reflexive, and motor control deficits may contribute to CAI [8]. Visual inspection of motor control patterns in patients with CAI is difficult in practice; however, adaptations have been reported with laboratory measures. Patients with CAI have demonstrated altered motor control indicated by surface EMG (sEMG) during walking and drop landing [9-11]. During walking, patients with CAI activate their peroneus longus (PL) before initial contact (IC), whereas healthy controls do so after IC [9,10]. An opposite relationship exists during drop landing, in which patients with CAI have less anticipatory muscle activity compared with healthy individuals [12]. Altered motor control patterns also

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have been identified in proximal joint muscles, including decreased gluteus maximus muscle activity during a rotational squat exercise in patients with CAI [13]. During the transition from a bipedal to a unipedal stance, a slower onset of muscle activity and less anticipatory muscle activation in the ankle, knee, and hip muscles were seen in patients with CAI, which indicates a reliance on feedback, rather than feedforward, motor control to complete the postural transition [14].

Balance and coordination training are effective intervention strategies for reducing the risk of ankle sprains, especially in patients who have a history of ankle sprain but who have not developed CAI [15], but the efficacy of such exercises at reducing the risk of recurrent sprains in patients with CAI is uncertain [15]. Altered motor control patterns have been identified in muscles that act on the ankle, knee, and hip during gait [9-11] and isolated functional exercises [12-14,16] in patients with CAI; however, there has not previously been a comprehensive analysis of the EMG activity of both distal and proximal lower extremity muscles during common functional exercises used for rehabilitation in patients with CAI. An understanding of how patients with CAI activate muscles to complete functional rehabilitative exercises can give insight into how rehabilitation can be tailored to specifically target and improve patient outcomes. Our purpose was to compare the sEMG root mean square (RMS) area during common functional exercises, including lunges, single limb balance, the Star Excursion Balance Test (SEBT), and lateral hopping exercises to test the hypothesis that patients with CAI would have decreased sEMG amplitudes of ankle, knee, and hip musculature during all tasks compared with healthy counterparts.

METHODS

Design

We performed a cross-sectional laboratory study in which the independent variable was the group (CAI, healthy control) and the dependent variables were sEMG RMS area for the tibialis anterior (TA), PL, lateral gastrocnemius, rectus femoris (RF), biceps femoris, and gluteus medius during single-limb eyes-closed balance, SEBT reach directions (anterior, posterior medial, and posterior lateral), forward lunges, and lateral hops. We also summed the normalized sEMG amplitudes for individual muscles to analyze segmental muscle activity for the distal musculature (TA, PL, lateral gastrocnemius), proximal musculature (RF, biceps femoris, gluteus medius), and total lower extremity musculature (all 6 muscles) between groups.

Subjects

Fifteen young adults with CAI and 15 healthy controls volunteered (Table 1). This study was part of a larger study, and the same cohorts have previously been reported in another article that investigated EMG differences during gait [9]. Briefly, the control group was self-reported to be healthy and to have no history of ankle sprain to either ankle. The CAI group had a history of more than 1 ankle sprain with the initial sprain occurring more than 1 year before the study onset and current self-reported functional deficits due to ankle symptoms. The subjects were allocated to groups based on their ankle health status (CAI or healthy), and healthy test limbs were side matched (right or left) to the involved CAI test limbs [9]. Subjects were excluded if they had an ankle sprain within the 6 weeks before the study onset, a history of lower extremity injury or surgery, balance disorders, neuropathies, diabetes, or other conditions known to affect balance. The subjects provided informed consent, and the study was approved by the university's institutional review board.

Table 1. *Subject demographics*

	CAI Group	Control Group
Mean ± SD age, y	23 ± 4.2	22.9 ± 3.4
Mean ± SD height, cm	173 ± 10.8	173 ± 9.4
Mean ± SD mass, kg	72.4 ± 14	70.8 ± 18
Men:women	5:10	5:10
No. previous sprains, mean ± SD	4.5 ± 3.2	N/A
Mean ± SD time since last sprain, mo	15.2 ± 9.3	N/A
Godin score, mean ± SD	94 ± 47	84 ± 40
FAAM ADL, mean ± SD	87.2 ± 7.1	100 ± 0
FAAM Sport, mean ± SD	68.5 ± 5.7	100 ± 0

CAI = chronic ankle instability; SD = standard deviation; N/A = not applicable; Godin score = Godin Leisure-Time Exercise Questionnaire score; FAAM ADL = Foot and Ankle Ability Measure Activities of Daily Living scale score; FAAM Sport = Foot and Ankle Ability Measure Sport subscale score.

Instruments

The sEMG signals were collected from disposable, pre-gelled, 10-mm, round Silver-Silver Chloride (Ag-AgCl) electrodes and amplified with a high-gain, differential-input biopotential amplifier with a gain of 1000 and digitized with a 16-bit data acquisition system (MP 150, Biopac Systems Inc, Goleta, CA) at 2000 Hz with a common-mode rejection ratio of 110 dB, an input impedance of 1.0 MΩ, and a noise voltage of 0.2 mV. Acqknowledge software (v.4.0, Cambridge, England) was used for data collection and processing of EMG signals. The EMG data were collected by using real-time processing with a 10- to 500-Hz band pass filter and a 10-sample moving average RMS algorithm. A foot switch (BIOPAC Systems, Santa Barbara, CA) was used to identify ground contact during the SEBT, forward lunge, and lateral hopping exercises. All the subjects wore standard athletic shoes for all exercises (X755WB; New Balance, Brighton, MA).