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Altered postural control variability in older-aged individuals with a history of lateral ankle sprain

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A R T I C L E I N F O

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A B S T R A C T

The current study aimed to examine postural control performance during a single-leg balance task in elderly individuals with and without a previous history of lateral ankle sprain (LAS). Eighteen adults with a previous history of LAS (mean age = 66 years old) and 12 healthy controls (mean age = 65 years old) were included in the study. Participants performed three trials of a single-leg balance task during an eyes-opened condition for 20-s. Center of pressure (COP) trajectories in the anteroposterior (AP) and mediolateral (ML) directions were collected with a force plate. The following postural control measures were calculated in the AP and ML directions: 1) Sample Entropy (SampEn); 2) Approximate Entropy (ApEn); 3) mean of Time-to-Boundary minima (mean TTB); and 4) COP velocity (COPV). Older-age participants with a history LAS exhibited lower ApEn-AP, SampEn-AP, and SampEn-ML values compared to healthy controls ($p < 0.05$). The information gained from this investigation indicates more rigid postural control patterns, less adaptability, and more difficulty maintaining COP during a single-leg balance task in adults with a previous history of LAS. Our data suggest that there is a need to consider history of musculoskeletal injury when evaluating factors for postural control and fall risk in the elderly. Future investigations are needed to assess the effect of LAS on age-related declines in postural control and discern associations between potential risk factors of fall-related injuries and LAS in an elderly population.

1. Introduction

Postural control is an important factor for completing activities of daily living and maintaining an active lifestyle. Age-related declines in postural control are significant public issues for older adults because of the limitations on participation in physical activity, social events, work, and driving [1]. Furthermore, age-related declines in postural control are directly associated with fall risk [2], which are linked to decreased quality of life (QOL), increased risk of hypokinetic disease and mortality, loss of independence, as well as significant healthcare expenditures as a leading causative factor for nonfatal and fatal injuries [3]. Thus, developing successful clinical interventions aimed to attenuate age-related postural instability is critical for prevention of associated negative effects of fall-related injury.

The ability to maintain balance and upright posture not only declines with age, but also is commonly compromised in younger adults with a history of lateral ankle sprain (LAS) [4,5]. It has been estimated that up to 73.6% of individuals who incur an initial LAS continue to experience residual symptoms, recurrent ankle sprains, persistent ankle instability, and/or persistent disability [6], leading to reductions in physical activity levels and health-related QOL [6]. Furthermore, a history of LAS contributes significantly to the development of post-traumatic ankle osteoarthritis (PTOA) [6], which increases the risk for co-morbidities [7].

Altered integration of sensory input and motor output is common and persistent following an initial LAS [8] and is hypothesized to contribute to postural insufficiencies [9]. Both a history of LAS and aging have the potential to disrupt sensorimotor communication to the lower extremity postural muscles via the peripheral and central nervous systems, evidenced by decreased corticospinal excitability of postural muscles and reweighted dominance on hip musculature strategies in older adults [10,11] and individuals with a history of LAS [8,12,13]. Furthermore, increased reliance on visual feedback for postural control has been observed in late adulthood [14] and in young adults following LAS [15], which may disrupt proper recruitment of postural muscles and postural corrections during a balance task, leading to postural instability.

Trajectories of the center of pressure (COP) during quiet standing, including linear (i.e., COP velocity) and nonlinear dynamic measures (i.e., entropy analysis and Time-to-Boundary [TTB]), have been used to

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detect sensorimotor alterations in young adults with a history of LAS [4,5,16,17]. Entropy measures provide theoretical estimates to define randomness and regularity in postural control systems by identifying probability of point-to-point fluctuations in COP time series [18]. A COP time-series exhibiting more fluctuation (greater variation or less predictability) generates larger entropy values [18]. Decreased entropy values likely represent repeatable or predictable COP excursion patterns during single-leg stance, while increased entropy values represent more random or erratic COP excursion patterns, suggestive of unstable systems [19]. Both increased and decreased entropy following injury are considered to represent decreases in the optimal level of postural control variability [19]. Glass et al. [16] demonstrated decreased sample entropy (SampEn) during balance tasks in young adults with LAS history compared to healthy controls, suggesting a loss of an optimal state of postural control variability. Finally, TTB is a spatio-temporal COP analysis quantifying the amount of time needed for the COP to reach the boundaries of support [4]. Lower TTB values represent postural deficiencies, as an individual has less time and fewer movement solutions to make postural corrections [4]. Wikstrom et al. [5] identified decreased TTB during an eyes-open single-leg stance in those with ankle instability compared to healthy controls.

Young adults with LAS history [4,5,16,17] and older adults without musclosketal injury [20,21] present with altered postural control variability during quiet single-leg stance. However, little attention has been placed on the compound effect of LAS profile on postural control variability in older-aged adults. This restricts our understanding of how the development of postural deficiencies associated with LAS earlier in life may exacerbate expected negative consequences of aging on balance observed later in life. Therefore, the purpose of this study was to examine postural control variability during a single-leg balance task with linear and nonlinear measures in elderly individuals with and without a history of LAS.

2. Methods

2.1. Study design

In this case-control study, participants reported to the research laboratory for a single testing session. All methodological protocols were approved by a university Institutional Review Board.

2.2. Participants

Thirty older-age participants (60–69 years) were recruited from local and university communities. All participants read and signed a university-approved informed consent prior to study enrollment. All participants were in good health and had no history of 1) diagnosed balance or vestibular disorders; 2) self-reported low back pain in the past 12 months; 3) concussion in the past 12 months; 4) diagnosed cardiopulmonary disorder, scoliosis, or spondylitis; 5) self-reported musculoskeletal injuries in the extremity in the past 2 years other than LAS; 6) diagnosed neurovascular disorders; 7) previous lower extremity surgery; and 8) diagnosed lower extremity joint OA. After interviewing participants with self-reported questionnaires, they were allocated to the LAS or control group (Table 1). All participants in the LAS group (n = 18) had a history of at least one significant LAS before the age of 35 resulting in swelling, pain, and temporary loss of function. No participant with a previous history of LAS had acutely sprained his/her ankle in the previous three months. Participants in the control group (n = 12) had no history of LAS. Additionally, to understand the impact of previous LAS, all participants were asked if they: 1) modified their activity and occupational involvement due to ankle injury, 2) felt an injury risk when playing sports or participating in physical activity, and 3) were concerned about environmental conditions or ground surfaces they might encounter during activities of daily living.

Table 1
Demographic and Ankle Injury Characteristics for Lateral Ankle Sprain (LAS) and Control Groups: Mean (Standard Deviation).

Variable	LAS	Control	p-value
n	18 (6 male, 12 female)	12 (7 male, 5 female)	–
Age (year)	66.0 (4.3)	65.0 (4.0)	0.54
Height (cm)	167.2 (7.9)	171.5 (9.0)	0.18
Body Mass (kg)	77.7 (17.3)	76.6(16.1)	0.86
Body Mass Index (kg/m^2)	27.6 (4.5)	25.9 (4.3)	0.55
The number of lateral ankle sprains	1.8 (2.1) (range: 1–10)	–	
Time since last ankle sprain (month)	363.4 (255.8)	–	
Time since first ankle sprain (month)	540.0 (60.0)	–	
# of giving-way episodes in past 6 months	1.1 (1.9) (range: 0–20)	–	
# of giving-way episodes in past 6 months	More than twice = 4 once = 1 no episode = 13	–	
Modified physical activity because of LAS	Yes: 2 No: 16	Yes: 0 No: 12	
Feel a risk for ankle injury when playing sports	Yes: 4 No: 14	Yes: 0 No: 12	
Concerned with surrounding environment	Yes: 4 No: 14	Yes: 0 No: 12	

2.3. Procedures

Static postural control was measured during a single-leg stance balance task on the designated leg under an eyes-open condition. Center of pressure (COP) trajectories in the anteroposterior (AP) and mediolateral (ML) directions were measured using a force platform (AccuSway Plus, AMTI, Watertown, MA) integrated with Balance Clinic software (AMTI, Watertown, MA) at a sampling rate of 100 Hz during three, eyes-opened 20-s trials. The COP time series data were filtered with a low pass, fourth order Butterworth filter set at a cutoff frequency of 5 Hz. Participants were asked to stand barefoot on the testing limb in single-leg stance in the middle of the force platform keeping their hands on the waist and their foot flat on the force plate. Three practice trials preceded the test trials. A trial was discarded and repeated if (1) the non-testing limb made contact on the force platform or the stance limb; (2) participants hopped or took a step with the stance limb; (3) they lifted their forefoot or heel; and/or (4) they removed their hands from their waist.

SampEn was calculated for the COP displacement time series data in the AP (SampEn-AP) and ML (SampEn-ML) directions with a custom MATLAB file using mathematical algorithms previously described [18]. The mathematical algorithms of SampEn measures are based on the likelihood that short sequences of consecutive data points approximately repeat throughout time series [18]. SampEn provides an index of regularity and randomness in each trial of collected COP time series data, with the value close to 0 reflecting more repeatable or predictable behavior [18]. Each COP time series from the testing trials contains 2000 data points. SampEn takes the negative natural logarithm for conditional probability that a small window of data points (vector length, m) would repeat itself at m + 1 [18]. Data points in 2 windows (m) that fall within a given error tolerance (r) of each other are counted, and the likelihood of these data points remaining matched for the incremented length of the window of data points to m + 1 is assessed across the time series [18]. Therefore, a series length and an error tolerance window should be specified to calculate SampEn. Input parameters for our SampEn calculation were 1) a series length (m) of 3 data points and 2) a tolerance widow (r) normalized to 0.3 times the standard deviation of individual time series, using a technique previously described [22].