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The effect of dual tasking on foot kinematics in people with functional ankle instability

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ABSTRACT

Background: Some cases of repeated inversion ankle sprains are thought to have a neurological basis and are termed functional ankle instability (FAI). In addition to factors local to the ankle, such as loss of proprioception, cognitive demands have the ability to influence motor control and may increase the risk of repetitive lateral sprains.
Objective: The purpose of this study was to investigate the effect of cognitive demand on foot kinematics in physically active people with functional ankle instability.
Methods: 21 physically active participants with FAI and 19 matched healthy controls completed trials of normal walking (single task) and normal walking while performing a cognitive task (dual task). Foot motion relative to the shank was recorded. Cognitive performance, ankle kinematics and movement variability in single and dual task conditions was characterized.
Results: During normal walking, the ankle joint was significantly more inverted in FAI compared to the control group pre and post initial contact. Under dual task conditions, there was a statistically significant increase in frontal plane foot movement variability during the period 200 ms pre and post initial contact in people with FAI compared to the control group ($p < 0.05$). Dual task also significantly increased plantar flexion and inversion during the period 200 ms pre and post initial contact in the FAI group ($p < 0.05$).
Conclusion: participants with FAI demonstrated different ankle movement patterns and increased movement variability during a dual task condition. Cognitive load may increase risk of ankle instability in these people.

1. Introduction

Lateral ankle sprains (LAS) are among the most common sport related injuries. Inversion of the rearfoot leads to disruption of the lateral ligament complex and up to 70% of cases experience recurrent sprains and chronic ankle instability (CAI) [1]. This may play a role in the development of ankle osteoarthritis [2].

Repeated inversion sprains are thought to have neuromotor origins if they occur when the normal mechanical constraints at the ankle are intact. This has been termed functional rather than mechanical ankle instability (FAI) [3,4]. Indeed, proprioceptive ability, postural control, strength of ankle muscles, and feedback (reflex-mediated) and feedforward (anticipatory) neural control have all been shown to be impaired in FAI [5–7]. This suggests that altered sensorimotor control is a contributory factor to the recurrent LAS [4–6]. Furthermore, it has been demonstrated that sagittal and frontal plane rearfoot movement variability is increased during single leg landing and stop jump maneuver in cases of FAI [8,9]. This is important because consistent movement patterns are related to greater automaticity of motor control [10] and greater movement variability have already been associated with risk of musculoskeletal injury and falling (e.g., in Parkinson's, Alzheimer's and older people) [11].

Movement patterns are also altered in cases of CAI. Increased rearfoot inversion has been reported before, at and immediately after initial contact (IC) during walking, throughout the gait cycle during walking and jogging, and in the pre landing phase of running [12–14]. People with CAI exhibit less dorsiflexion at the point of peak dorsiflexion during jogging [15]. Furthermore, people with FAI exhibit greater maximum ankle plantar flexion before IC compared to those with mechanical ankle instability [16]. Together the changes in movement pattern and movement variability may indicate sensorimotor deficits because the system connecting the

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central nervous system to muscles and nerves around ankle may be altered in FAI [4,17].

To compound the altered movement patterns, the cognitive load associated with integration of inputs from visual, vestibular, and somatosensory systems could further increase risk of LAS in FAI [18]. The capacity of the CNS is finite and simultaneous execution of two attention-demanding tasks may affect performance of one or both tasks [18]. The level of interference between the two tasks is influenced by individual differences in sensorimotor expertise, difficulty of the postural task, and level of cognitive load [19]. Reduced postural stability during dual tasking has previously been reported in people with FAI, suggesting that postural control may demand more attention in FAI [20]. The effects of the impaired feedback, feedforward and local sensorimotor deficits in FAI may therefore be compounded by the demands for cognitive attention during a movement task.

Inappropriate movement patterns in the ankle prior to and after initial foot contact (e.g. increased inversion), combined with local neurological impairments and greater central cognitive load, may therefore combine to increase the risk of re-spraining the ankle in cases of FAI. It was hypothesized that dual task conditions would result in inappropriate foot and ankle kinematics and increase movement variability in people with FAI compared to those without FAI. Therefore, the purpose of this study was to investigate the effect of cognitive demand on foot kinematics in physically active people with functional ankle instability.

2. Methods

2.1. Participants

Ethical approval was obtained from the institutional ethics committee. Initially, 65 participants with self-reported CAI were recruited. All reported a history of at least one significant unilateral inversion ankle sprain occurring more than 12 months ago. Each episode must have resulted in pain, swelling, limited weight bearing or full immobilization for a minimum of three days, a failure to return to pre injury function and repeated episodes of ankle spraining. All reported at least 2 episodes of the ankle 'giving way' in the past 1 year [3].

Within the 65 physically active individuals (sport activities = > 3 times per week) with CAI, cases of FAI were identified using Functional Ankle Ability Measure (FAAM), and a questionnaire assessing the presence of experiences associated with FAI. An experienced physical therapist performed the anterior drawer and talar tilt test to assess mechanical instability (1–5 scale), and scores 1 (very hypomobile) or 4 and 5 (loose, very loose) excluded [21]. Participants were excluded if they scored >90% in the FAAM ADL score, or >80% in the FAAM sport score [3,22]. Participants were excluded if they had known vestibular, visual, auditory, cognitive, neurological, metabolic, musculoskeletal or other disorder, a history of lower limb fracture or surgery, or took any medication affecting cognition/motor performance. Participants were excluded if they were receiving ankle rehabilitation, or showed acute clinical signs and symptoms in the lower limb or a sprained ankle within the prior 3 months [3]. This screening identified 21 people with FAI.

As a control group 19 physically active individuals with no history of ankle sprain and a score 100 on both FAAM questionnaires were recruited from local sport centers. They were recruited to be age-matched with our FAI sample. They were excluded if they had the history of foot and ankle disorder, surgery or met any of the other exclusion criteria applied to the FAI group. All participants provided written consent to participate. Table 1 shows pathology and function-related information.

Table 1
Subjects demographic information (Mean ± SD).

	CON (n = 19)	FAI (n = 21)
Gender (*M:F*)	11:8	11:10
Age (*y*)	24.95 ± 3.12	25.57 ± 4.77
Mass (*kg*)	67.00 ± 13.61	67.33 ± 15.33
Height (*m*)	1.74 ± 0.09	1.72 ± 0.12
FAAM- sport score (%)	100 ± 0.0	63.42 ± 16.86
FAAM- ADL score (%)	100 ± 0.0	80.90 ± 7.74
Hours of exercises (*h/w*)	7.05 ± 3.85	9.24 ± 5.52
Giving way and sprains (*n/yr*)	N/A	6.43 ± 3.68

CON: control; FAI: functional ankle instability.

2.2. Instrumentations

A seven camera motion capture system (Qualysis, Sweden) was used to obtain three-dimensional kinematic data for the foot and leg (100 Hz). Reflective markers were attached to the head of first, second and fifth metatarsals and the posterior calcaneus. Markers were attached to medial and lateral femur epicondyles and medial and lateral malleoli. A rigid cluster of four 14 mm markers was positioned over the lateral aspect of the shank.

2.3. Data collection

All participants were acclimatized to the lab and protocol before testing. One relaxed standing trial was performed to define the 0° position. Participants completed three randomized conditions (five trials per condition): (1) normal walking on a 10 m walkway, (2) normal walking while performing a cognitive task, (3) same cognitive task while sitting. Prior to testing, one practice trial of numerical task was performed while sitting and walking.

Participants walked barefoot at a self-selected speed while looking forward. During the dual task condition participants did the same whilst repeatedly subtracting seven from a randomly selected number between 200 and 250 (other than numbers ending with 7and 0) [23]. Participants were asked to perform the motor and cognitive tasks to the best of their ability, not to stop walking if they made mistake, and instructed to avoid prioritization of either task. The time required to walk the 10 m and the number of subtractions during this time were recorded using a stopwatch (precision of 0.01 s) and tape recorder. At least 60 s rest was allowed between each walking trial.

In the third condition participants sat and completed as many subtractions as possible within the same time that was needed to complete the walking distance over the practice trial.

2.4. Data processing

Evaluation of performance on the cognitive task included the total number of subtractions and the number of correct answers.

Kinematic data was exported to Visual 3d (C-motion, USA) and a 4th order Butterworth low-pass filter (cut off 6 Hz) applied. Movement data was motion of the foot relative to the shank. The Calibrated Anatomical System Technique (CAST) was adopted to establish an anatomical model of the foot and shank [24].

The joint coordinate system was used to calculate joint rotations. 0° was relaxed standing. The foot velocity algorithm (FVA) was used to determine IC and toe off (TO) [25] and kinematic data normalized in the time domain. Transition between swing and stance phase is critical in cases of LAS because this is when most sprains occur. 200 ms pre, 100 ms pre, IC, 100 ms post, 200 ms post, and TO were therefore identified for all trials and ankle