Gait & Posture 41 (2015) 106–111

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Proactive and reactive neuromuscular control in subjects with chronic ankle instability: Evidence from a pilot study on landing

Oron Levin [a,*], Benedicte Vanwanseele [b], Jo R.J. Thijsen [a], Werner F. Helsen [a], Filip F. Staes [c], Jacques Duysens [a,d]

[a] KU Leuven Movement Control and Neuroplasticity Research Group, Leuven, Belgium
[b] KU Leuven Human Movement Biomechanics Research Group, Leuven, Belgium
[c] KU Leuven Research Group for Musculoskeletal Rehabilitation, Faculty of Kinesiology and Rehabilitation Sciences, Group Biomedical Sciences, 3001 Leuven, Belgium
[d] Department of Research, Development & Education, Sint Maartenskliniek, Nijmegen, The Netherlands

ARTICLE INFO

Article history:
Received 23 June 2014
Received in revised form 27 August 2014
Accepted 14 September 2014

Keywords:
Ankle sprain
Anticipation
Inversion
Landing
Reflex

ABSTRACT

To understand why subjects with chronic ankle instability (CAI) have frequent sprains, one must study the preparation/reactions of these subjects to situations related to ankle inversion in real life. In the present pilot study, we examined whether subjects with CAI altered their neuromuscular control and reflex responses during and after ankle perturbations in landing. EMG signals were collected from the tibialis anterior (TA), peroneus longus (PL), medial gastrocnemius (MG), and gluteus medius (GLM) of both legs in 9 subjects with CAI and 9 subjects with intact ankles (control). A trapdoor was used to produce an ankle inversion of 25° with the left leg (control) or the affected leg (CAI) in 0%, 50% or 100% of the landing trials. As compared to controls, subjects with CAI had increased proactive activity in the contralateral side prior to touchdown during landing trials with 50% (PL) and 100% (PL and MG) chance of inversion (all, $p < 0.05$). The increase proactive control on the contralateral side could be part of a strategy to smooth the impact of landing on the affected side in subjects with CAI. Following touchdown, the CAI group showed decreased ipsilateral short latency reflex (SLR) responses in all test conditions both in distal (PL and MG) and in proximal muscles (GLM) on the affected side (all, $p < 0.05$). Finally, subjects with CAI adjusted their reflex gain differently as compared to controls when exposed to a possible inversion. Overall, individuals with CAI displayed different neuromuscular strategies from controls while landing.

1. Introduction

Damage to mechanoreceptors within the lateral ankle ligaments and muscles is expected to impair somatosensory processing and alter neuromuscular control in individuals with chronic ankle instability (CAI) [1,2]. For example, ruptures to muscle spindles due to an earlier sprain are expected to impair muscle reactions and decrease inflow of sensory feedback [2]. When landing from a jump, these changes can be manifested either in altered muscular activity prior to landing (anticipation) or in a reduction of reflexes after landing.

Several studies on jumps have already shown that individuals with CAI produce lower proactive activity in the peroneus muscle on their injured side prior to touchdown on an unstable landing surface [3,4]. This observed reduction in peroneus activity was accompanied by increased inverted position of the ankle joint suggesting that ‘‘*decrease in peroneal longus activity prior to the expected initial contact with the ground leaves the ankle joint in a vulnerable position*’’ (cf. Delahunt et al. [4]). Whether such proactive changes also occur contralaterally to the most affected side is less clear. Based on previous work [5], one may expect contralateral effects as well.

Second, subjects with CAI are expected to demonstrate impaired neuromuscular reactions due to interruption of afferent inputs from the injured ankle [1,2,6–10]. Yet, evidence from

* Corresponding author at: KU Leuven Movement Control and Neuroplasticity Research Group, Department of Kinesiology, Group Biomedical Sciences, Tervuursevest 101, 3001 Leuven (Heverlee), Belgium. Tel.: +32 16 329098; fax: +32 16 329197.
E-mail address: oron.levin@faber.kuleuven.be (O. Levin).

http://dx.doi.org/10.1016/j.gaitpost.2014.09.005
0966-6362/

descriptive laboratory studies comparing CAIs and controls are not conclusive [11]. For example, Delahunt et al. [4] found lowered reactive activation in peroneus longus (PL) during landing on non-inverting landing surface. Gutierrez et al. [12] reported, on the other hand, that individuals with CAI displayed significantly increased reactive peroneal activation following landing on an inverting surface. Furthermore, most studies so far have focused on lower leg muscles while it has been emphasized that reactions to ankle inversion should be "whole body" responses, involving both proximal and distal leg muscles [13,14]. Evidence from recent studies show indeed that subjects with CAI demonstrate altered neuromuscular control beyond the surrounding ankle muscles and beyond ankle kinematics [4,11,15,16]. Hence, in the present study, reflex responses from both distal and proximal muscles of the lower limbs were analyzed. It was predicted that, as compared to control subjects, reflex responses in CAIs would be decreased both in distal and in proximal muscles of the affected limb.

Another important aspect concerns the role of expectation. Previous work revealed that healthy subjects had a higher level of EMG activity in soleus just prior to touchdown when they expected to land on an inverting surface [17]. Similarly, it is known that expectation can affect reflex responses [18,19]. Thus, landing on a platform that possibly could invert would lead to larger SLR and LLR responses even in the absence of an actual inversion. In this pilot study we aimed to underscore changes in neuromuscular control during landing in CAI. Specifically, we explored injury-related changes in proactive and reactive activity of the lower limb musculature on the affected and unaffected sides. In addition, we explored how proactive and reactive activity is influenced by anticipation.

2. Materials and methods

Participants were nine (4 males) young active adults with self-reported history of unilateral CAI and nine (5 males) young active adults with no history of ankle or lower limb injuries. All individuals with CAI were amateur handball players. CAI was defined as a history of traumatic ankle sprains requiring 2 or more medical consultations, complaints of repetitive lateral ankle sprains for at least 6 months, presence of fear of ankle "giving way", and reporting an ankle-related decreased performance level of recreational, competitive, or professional activities [16,20,21]. Demographic details of the participants are summarized in Table 1. All participants read and signed an informed consent form which was approved by the local Ethics Committee of the KU Leuven.

2.1. Apparatus

The experimental setup consisted of a standing platform and a landing surface, consisting of a trapdoor and a solid box as illustrated in Fig. 1A (for details, see Grüneberg et al. [17] and Nieuwenhuijzen et al. [22]). The standing platform was positioned 5 cm in front and 20 cm above the landing surface. Accelerometers (ADXL335, Analog Devices, MA, USA) were mounted on the trapdoor and the solid box to detect the onset of touchdown.

Electromyography (EMG) signals were recorded from the tibialis anterior (TA), the peroneus longus (PL), medial head of the gastrocnemius (MG), and the gluteus medius (GLM) of both legs, using an eight-channel electrode system (MESPEC 8000, Mega Electronics Ltd., Finland). The reference electrode was placed on the lateral femur condyle of both legs. EMG signals were (pre-) amplified ($\times$1000), filtered (4–500 Hz), sampled at 1000 Hz (CED 1401 Cambridge Electronic Design, Cambridge, UK) in parallel with output from trapdoor potentiometer and the two accelerometers. All data were stored on PC for off-line analysis.

2.2. Procedure

All participants were allowed to practice the jumps with and without inversion prior to data collection. A typical experimental run consisted of a total of 40 trials. In the first 20 trials performed in two separate blocks, participants had a prior knowledge on the state of the trapdoor: 10 landings with inversion, i.e., trapdoor open after landing (100% INV) and 10 landings without inversion, i.e., trapdoor locked (100% LOCK). The remaining 20 trials were conducted with 50% chance of inversion, resulting in 10 trails with inversion (50% INV) and 10 trails without inversion (50% LOCK) that were presented at random. Participants were not informed about the upcoming condition in this second set of 20 trials. Landing on the trapdoor was always with the left foot (control) or the affected foot (CAI). Participants were instructed to land with both feet simultaneously while touching down the solid box next to the trap door with their right foot (control) or the non-affected foot (CAI). The participants initiated the drop by positioning the right leg (controls) or non-affected leg (CAIs) slightly forward as a response to a "get ready" verbal command and jump by pushing off with an almost straight leg as a response to a "go" verbal command and were instructed to remain in an upright standing position after landing. The subjects had to look straight ahead before jumping and had to keep their arms closed in front of the chest (to eliminate effect of arm-movements). During the conditions with 50% chance of inversion, the trapdoor was manually prepared by the experimenter before each jump after which the "get ready" signal

Table 1
Demographic details of the participants, showing: gender (M = male, F = female), age, weight height and body mass index (BMI) of the control subjects and subjects with chronic ankle instability (CAI). For CAIs, the affected leg was indicated (R = right, L = left). Selection criteria for CAIs were in line with the recommendations of the International Ankle Consortium [21].

Control						CAI						
Subject	Gender	Age (y)	Weight (kg)	Height (m)	BMI (kg/m^2)	Subject	Gender	Age (y)	Affected leg	Weight (kg)	Height (m)	BMI (kg/m^2)
AE	F	21	60	1.70	20.7	BR	M	30	R	80	1.85	23.4
ED	F	21	50	1.65	18.4	EJ	M	27	L	94	1.84	27.8
HT	F	21	63	1.75	20.6	GO	F	29	R	52	1.61	20.1
JD	M	22	84	1.96	21.9	JM	M	19	L	80	1.85	23.4
JG	M	25	70	1.70	22.9	JS	F	18	L	70	1.67	25.1
KD	F	22	64	1.69	22.4	KC	F	24	R	75	1.72	25.4
MB	M	21	62	1.79	19.4	LH	F	23	L	69	1.68	24.4
SB	M	23	80	1.88	22.6	OJ	M	22	L	62	1.70	21.5
SS	M	23	75	1.86	21.7	RH	F	21	L	55	1.60	21.5
Mean		21.1	67.6	1.78	21.2	Mean		23.7		70.8	1.72	23.7*
SD		1.36	10.7	10.1	1.54	SD		4.24		13.2	9.27	3.40

*Significant difference between controls and CAIs for BMI ($p = 0.042$, Mann-Whitney U Test); otherwise ($p > 0.1$).