Clinical Biomechanics 29 (2014) 1151–1157

Contents lists available at ScienceDirect

Clinical Biomechanics

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

Persistence of long term isokinetic strength deficits in subjects with lateral ankle sprain as measured with a protocol including maximal preloading

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ARTICLE INFO

Article history:
Received 13 February 2014
Accepted 23 September 2014

Keywords:
Ankle injury
Isokinetic testing
Muscle strength

ABSTRACT

Background: The assessment of muscle function is a cornerstone in the management of subjects who have sustained a lateral ankle sprain. The ankle range of motion being relatively small, the use of preloading allows to measure maximal strength throughout the whole amplitude and therefore to better characterize ankle muscles weaknesses. This study aimed to assess muscle strength of the injured and uninjured ankles in subjects with a lateral ankle sprain, to document the timeline of strength recovery, and to determine the influence of sprain grade on strength loss.
Methods: Maximal torque of the periarticular muscles of the ankle in a concentric mode using a protocol with maximal preloading was tested in 32 male soldiers at 8 weeks and 6 months post-injury.
Findings: The evertor muscles of the injured ankles were weaker than the uninjured ones at 8 weeks and 6 months post-injury ($P < 0.0001$, effect size $= 0.31–0.42$). Muscle weaknesses also persisted in the plantarflexors of the injured ankles at 8 weeks ($P = 0.0014$, effect size $= 0.52–0.58$) while at 6 months, only the subjects with a grade II sprain displayed such weaknesses ($P < 0.0001$, effect size 0.27–0.31). The strength of the invertor and dorsiflexor muscles did not differ between sides.
Interpretation: The use of an isokinetic protocol with preloading demonstrates significant but small strength deficits in the evertor and plantarflexor muscles. These impairments may contribute to the high incidence of recurrence of lateral ankle sprain in very active individuals.

1. Introduction

Lateral ankle sprain (LAS) is one of the most common injuries in athletes (Doherty et al., 2014; Verhagen et al., 2004; Waterman et al., 2010a) and in the military (Waterman et al., 2010b). Residual intermittent pain, feeling of weakness or instability and episodes of giving way (Braun, 1999; Delahunt et al., 2010) are manifestations of chronic ankle instability (CAI) that is a common sequel of LAS that may persist many years after the injury (Braun, 1999; van Rijn et al., 2008). In addition, individuals with a history of ankle sprains have a risk of re-injury which is twice the risk of injury of those who have never sustained an ankle sprain (Verhagen et al., 2004; McHugh et al., 2006).

A decrease in function of the periarticular muscles has been suggested as a potential contributing factor to the participation restrictions seen in subjects with established CAI (Kaminski and Hartsell, 2002). The persistence of periarticular muscle weaknesses in subjects with a LAS or CAI has been demonstrated with various isokinetic protocols. While some authors reported strength deficits in the invertors (Hiller et al., 2011; Wilkerson et al., 1997), evertors (Arnold et al., 2009; Wilkerson et al., 1997; Willems et al., 2002), plantarflexors (Aiken et al., 2008; Fox et al., 2008) and dorsiflexors (Willems et al., 2005), others have failed to find any muscle weakness (Bernier et al., 1997; Kaminski et al., 1999; Lentell et al., 1995; Porter et al., 2002). In the studies in which muscle weaknesses were reported, loss of strength was observed both in the acute (Aiken et al., 2008; Wilkerson et al., 1997) and chronic (Fox et al., 2008; Willems et al., 2002) phases, suggesting that strength deficits

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http://dx.doi.org/10.1016/j.clinbiomech.2014.09.010
0268-0033/

may persist in the long term. Surprisingly, none of the studies have reported results that indicate if the severity of the injury (grade I or II LAS) had any influence on the magnitude of the strength loss.

Dynamic muscle strength testing offers the advantage to measure strength at several angular positions. Moreover, controlling for angular velocities in isokinetic testing allows the measurement of strength in conditions replicating the characteristics of movements observed in daily activities. Typically, standard protocols used to test the maximal voluntary contraction in dynamic conditions require subjects to build their strength as fast as possible from a resting position. This method of testing dynamic strength does not allow for maximal strength to be recorded at the beginning of the movement because maximal force cannot be generated in the early phase of a muscle contraction (Gravel et al., 1988; Jensen et al., 1991; Kramer et al., 1991). By comparing a standard protocol to a static preloading protocol, Gravel et al. (1988) showed that subjects needed 365 ms (11°) to reach 90% of the maximal force level of the ankle plantarflexors at an angular velocity of 30°/s. The use of preloading allows time to achieve maximal recruitment before the start of the dynamic effort and thus, ensures measuring maximal force at each angle of the ankle range of motion (ROM). In dynamic activities, muscle activation occurs in advance of a self- (ex. cutting maneuvers) or externally initiated predictable perturbation (standing on a moving bus) (Kennedy et al., 2012). This mechanism, which in fact is preloading, contributes to maintain postural stability. Muscle weaknesses and proprioceptive deficits, such as alleged in CAI, may both alter this mechanism (Holmes and Delahunt, 2009; Kennedy et al., 2012); likely by increasing the duration of the period of force development and by decreasing the maximal level of strength available for joint protection.

In addition, when maximal strength is assessed at a given angular velocity, it is important to remove the period of force development because its duration might differ between sides and as a consequence of injury or training. A different duration to reach maximum force will influence the angular position at which the peak value is obtained and therefore, the comparison of strength value reported at different angular positions will not be valid due to muscle length–tension relationship. Assessing muscle strength with preloading allows comparisons of maximal voluntary strength at comparable angular positions. The procedure with preloading is even more relevant when assessing strength over a short ROM and at moderate angular velocity (Gravel et al., 1988).

The main objective of our study was to characterize and compare the dynamic maximal voluntary strength of the periarticular muscles of the injured and uninjured ankle in subjects with a unilateral LAS at mid and long term post-injury using an isokinetic concentric protocol preceded by maximal preloading. This was assessed by comparing the mean torques between sides at specific intervals throughout the ROM at 8 weeks and 6 months after the trauma. The second objective was to assess the timeline of strength recovery by comparing the mean torques at 8 weeks and 6 months post-injury. The third objective was to verify the possible influence of sprain severity on the presence of strength weaknesses by comparing the mean torques in subsets of subjects with grade I and II LAS.

2. Methods

2.1. Participants

We recruited thirty-six soldiers with a diagnosis of grade I or II LAS. Men or women eligible for the study had to meet the following criteria: 18 years of age or older, inversion injury 5 days or less before the first testing session, and a pain intensity between 2 and 8 on a 10-cm visual analog scale (VAS) during testing of their anterior talofibular (inversion stress test) or calcaneo-fibular ligaments (talar tilt test) (Magee, 2014). Subjects with residual signs or symptoms of a previous injury at any of the other joints of the lower limbs or trunk, who had had a previous surgery of the lower limbs, or who had a neurological or systemic health problem that could interfere with the measurements were excluded from the study. We assessed the severity of the injury (grade I or II) by performing the anterior drawer test (Magee, 2014) by two independent experienced physiotherapists. An excessive posterior displacement of the tibia and fibula on the talus, in comparison to the uninjured side, indicated a positive test (grade II LAS). In the event of a disagreement, a third physiotherapist, blinded to the results of the first two physiotherapists, was asked to make a decision. This project was approved by the review board of the Centre de santé Valcartier. The participants signed an informed consent form before being included in the study.

2.2. Study design

The subjects recruited participated in three testing sessions including clinical measures of impairment (ROM, swelling, pain intensity, muscle strength), limitation of activity, and restriction of participation (Lower Extremity Functional Scale). At the second and third visit, they also filled out a questionnaire documenting the presence (Y/N), frequency (four level Likert scale) and circumstances (three level Likert scale) of signs and symptoms of CAI (residual pain, giving way, feeling of weakness, swelling and sprain recurrence). Testing sessions were carried out within 5 days following the sprain (S1: 4.1 days (SD: 1.5)), at 8 weeks (S2: 60.4 days (SD: 5.2)), and 6 months (S3: 190.4 days (SD: 17.2)) post-trauma. Eight weeks is the average time period after which patients with a LAS are usually discharged from our military physiotherapy clinic. The isokinetic strength was not assessed at S1 (acute phase) and thus, the data presented are for the assessments carried out at S2 and S3. Between S1 and S2, patients received non-standardized physiotherapy interventions, on average 2 to 3 times/week, consisting in PRICE (ice, crutches, taping, lower limb elevation), electrotherapy modalities, accessory joint mobilizations, bracing, and a home program including ROM, static and dynamic strengthening as well as postural control exercises.

2.3. Testing procedures

We measured the isokinetic concentric strength of the plantarflexors, dorsiflexors, invertors, and evertors of the ankle bilaterally on a Biodex system 3 dynamometer (Biodex Medical Systems, Shirley, NY, USA) at 60°/s, using a maximal preloading protocol. The order of muscle groups and sides tested were identical for a given subject at S2 and S3, but were randomized between subjects. For each muscle group, subjects had to perform three maximal concentric contractions and one sub-maximal practice trial was carried out prior to testing. Each trial was preceded by a two-second maximal voluntary static contraction (preloading). A 10-second rest period was allowed between trials. Active testing was performed with the passive isokinetic mode of the Biodex dynamometer, which behaves like the concentric mode but allows weak muscles to be tested throughout the selected ROM. Standardized verbal cues and visual feedback on a computer screen were used to ensure that subjects were producing a maximal voluntary effort.

For muscle testing, the subjects sat on the dynamometer chair with their backs support inclined 20° backwards from the vertical and the foot of the non-tested limb supported. The limb being tested was positioned with the hip at 60° and the knee at 45° of flexion (0° refers to full extension). This position minimizes tension on the hamstrings and on neuromeningeal structures that may limit ROM at the end of dorsiflexion with the knee fully extended. The foot was placed in the Biodex boot and stabilized with a custom made device that minimized heel lifting during the powerful contraction of the plantarflexors. The tip of the lateral malleolus was aligned with the axis of the dynamometer for the assessment of the dorsiflexors and plantarflexors. For the invertors and evertors, the ankle was positioned in 10° of plantar flexion. The axis of the dynamometer was aligned through the calcaneus by tilting the dynamometer head 50° backwards, which allowed a superimposition with the estimate sagittal component of the subtalar