Clinical Biomechanics 29 (2014) 439–443

Contents lists available at ScienceDirect

Clinical Biomechanics

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

Impaired control of weight bearing ankle inversion in subjects with chronic ankle instability

R. Terrier [a,b,*], K. Rose-Dulcina [b], B. Toschi [b], N. Forestier [b]

[a] CEVRES Santé, Savoie Technolac, BP 322 Le Bourget du lac cedex, France
[b] Laboratoire de Physiologie de l'Exercice (E.A. 4338), Département des Sciences et Techniques des Activités Physiques et Sportives (STAPS), Université de Savoie, France

ARTICLE INFO

Article history:
Received 4 September 2013
Accepted 9 January 2014

Keywords:
Ankle
Inversion
Sprain
Chronic instability
Evertor muscle weakness
Weight bearing
Angular velocity

ABSTRACT

Background: Previous studies have proposed that evertor muscle weakness represents an important factor affecting chronic ankle instability. For research purposes, ankle evertor strength is assessed by means of isokinetic evaluations. However, this methodology is constraining for daily clinical use. The present study proposes to assess ankle evertor muscle weakness using a new procedure, one that is easily accessible for rehabilitation specialists. To do so, we compared weight bearing ankle inversion control between patients suffering from chronic ankle instability and healthy subjects.

Methods: 12 healthy subjects and 11 patients suffering from chronic ankle instability conducted repetitions of one leg weight bearing ankle inversion on a specific ankle destabilization device equipped with a gyroscope. Ankle inversion control was performed by means of an eccentric recruitment of evertor muscles. Instructions were to perform, as slow as possible, the ankle inversion while resisting against full body weight applied on the tested ankle.

Results: Data clearly showed higher angular inversion velocity peaks in patients suffering from chronic ankle instability. This illustrates an impaired control of weight bearing ankle inversion and, by extension, an eccentric weakness of evertor muscles.

Interpretation: The present study supports the hypothesis of a link between the decrease of ankle joint stability and evertor muscle weakness. Moreover, it appears that the new parameter is of use in a clinical setting.

1. Introduction

Data from 16 years of injury surveillance for 15 sports revealed that ankle sprain was the most common injury and that it accounts for 15% of all reported injuries (Hootman et al., 2007). Other researchers have reported that lateral ankle sprain incidence can reach 25% of all sport related traumatisms (O'loughlin et al., 2009). Beyond a simple acute injury, several studies (Freeman et al., 1965; Gerber et al., 1998; Yeung et al., 1994) revealed that 40–70% of patients who suffered from an initial ankle sprain are at risk for developing chronic ankle instability (CAI). CAI is mainly characterized by recurrent injuries, ankle joint instability, and frequent ankle inversion destabilization without capsulo-ligamentar injury also called "giving way" (Delahaunt et al., 2010; Zhang, 2012). As highlighted by Hertel (2002), CAI may be the consequence of mechanical instability, functional instability or a combination of both.

It has been theorized that fibularis (ankle evertors) weakness could decrease the joint dynamic stability and therefore largely contribute to functional joint instability (Fox et al., 2008; Lentell et al., 1995). As highlighted by Kaminski et al. (1999) or Fox et al. (2008), conflicting results have been reported. Some studies have shown deficits of ankle evertor strength in subjects suffering from chronic ankle instability (CAI) when compared to healthy subjects (e.g. Hartsell and Spaulding, 1999; Kannus and Renstrom, 1991; Staples, 1975; Tropp, 1986; Willems et al., 2002) while other studies found no significant differences (e.g. Bernier et al., 1997; Kaminski et al., 1999; Lentell et al., 1990; McKnight and Armstrong, 1997; Munn et al., 2003). Studies dealing with ankle evertor strength evaluation are classically based on isokinetic tests. Following a standardized procedure proposed 20 years ago (Leslie et al., 1990; Simoneau, 1990), it has been demonstrated that ankle eversion peak torque produced in isokinetic movement gives a reliable measurement of evertor strength for healthy (Aydog et al., 2004) and CAI subjects (De Nohonha and Borges, 2004; Sekir et al., 2008). However, such assessment procedures are not widely used by rehabilitation specialists because the equipment is expensive and the evaluation procedure preparation is time consuming. Actually, it is difficult for rehabilitation specialists to find reliable muscle measurement procedures (De Nohonha and Borges, 2004; Eggart et al., 1993; Plante and Wikstrom, 2013) and evertor weakness is generally not objectively assessed in clinical daily practice. Several research

* Corresponding author at: CEVRES Santé, Laboratoire de Physiologie de l'Exercice, Savoie Technolac, Le Bourget du lac cedex, France.
E-mail address: romain.terrier@cevres.com (R. Terrier).

0268-0033/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.clinbiomech.2014.01.005

groups have proposed alternative methods. They notably showed that hand-held dynamometers are reliable and more easily attainable for clinicians (Kelln et al., 2008; Spink et al., 2010). Thus, this procedure can be used to compare ankle musculature strength between controls and CAI subjects (Plante and Wikstrom, 2013). However, isokinetic as well as hand-held dynamometer procedures are associated with an additional major limit since weight bearing (functional) tests are not possible.

In summary, the literature presently shows discrepancies about ankle evertor muscle weakness in CAI subjects and measurement tools used by researchers are not easily transferable to rehabilitation specialists' daily practice for functional ankle musculature strength testing. Therefore, the present study aims to provide additional data about potential evertor muscular weakness associated with chronic ankle instability, using a new procedure easily accessible for rehabilitation specialists and performed in weight bearing conditions. We focused on eccentric evertor evaluation because it can be considered as the critical component of ankle control during physiological ankle movements (Asthton-Miller et al., 1996; Fox et al., 2008). Moreover, it has been shown that strengthening protocols included in rehabilitation programs for unstable ankles should be focused on the control of eccentric evertors' contractions (Collado et al., 2010; David et al., in press; Graziani et al., 2001).

To this aim, we compared weight bearing ankle inversion control between CAI and healthy subjects by means of the prototype of an instrumented device currently in development (Myolux Techno™, CEVRES Santé, France). We hypothesized that inversion angular velocity and acceleration peaks were higher for CAI than for healthy subjects during controlled (i.e. instruction was to perform, as slow as possible, the inversion movement) weight bearing ankle inversion. Such results would reflect an impaired capacity of ankle inversion control. If this hypothesis is confirmed, the angular velocity and acceleration peaks recorded during weight bearing inversion control with the device used in this study, would be considered as interesting evaluation parameters for rehabilitation specialists in order to assess ankle evertor muscle weakness and its potential association with CAI. We also analyzed complementary parameters related to weight bearing ankle control such as inversion movement amplitude and duration.

2. Methods

2.1. Subjects

A group of healthy subjects (Healthy group) and a group of CAI subjects (CAI group) participated at the study. The healthy group was composed of 12 healthy active subjects (6 men and 6 women; 19.1(1.7) yrs; 180(10) cm; 66.8(8.4) kg) with no known history of ankle sprain, neurological or motor dysfunctions. The CAI group was composed of 11 CAI subjects (5 men and 6 women; 18.6(1.2) yrs; 170(7) cm; 65.2(9.4) kg). Exclusion and inclusion criteria for CAI subjects have been determined from the recommendations of the International Ankle Consortium (Gribble et al., 2013). Exclusion criteria were any history of previous surgeries to the musculoskeletal structures (i.e., bones, joint structures, nerves) in either lower extremity; any history of a fracture in either lower extremity requiring realignment; and any acute injury to musculoskeletal structures of other joints of the lower extremity in the previous 3 months that impacted joint integrity and function (i.e., sprains, fractures). For the CAI group, inclusion criteria were a minimum of two lateral sprains on the same ankle, with the most recent one during the last year but more than 3 months prior to study enrolment; a feeling of ankle joint instability; and frequent ankle "giving way". Even if not validated, a French translation of the Ankle Instability Instrument (Docherty et al., 2006) was administrated to the subjects. As recommended by the International Ankle Consortium (Gribble et al., 2013), all subjects included in the CAI group answered "yes" to at least 5 yes/no questions including question 1. More precisely, the number of "yes" responses was 7.6(1.1). The average number of sprains of the tested ankle before the study was 3.5(1.5). Doctors categorized the most serious sprain as grade 1 for 18% of subjects, grade 2 for 64% of subjects and grade 3 for 18% of subjects. Finally, each subject declared to experience at least one episode of ankle "giving way" each month. For all included subjects, the chronic instability concerned the left ankle. Hence, we have tested left ankles of CAI and healthy subjects. The study was approved by the local research ethic committee and the subjects' informed consent was obtained in conformity with the declaration of Helsinki for the experimentation on humans.

2.2. Task and apparatus

This experiment consisted of measuring ankle inversion parameters (movement displacement and duration, angular velocity and acceleration peaks) during a weight bearing ankle inversion control task in healthy and CAI subjects. We used a custom version of a Myolux™ device (Myolux Techno ™ prototype developed from Myolux Medik II ™, CEVRES Santé, France) previously described (Forestier and Terrier, 2011; Forestier and Toschi, 2005). As illustrated in Fig. 1 (device for a left ankle), this device is equipped with an articulator placed under the rearfoot. This articulator generates angular displacements along the physiological subtalar axis (also called Henke axis) to generate ankle inversion and eversion movements. In weight bearing conditions, the articulator automatically moves in inversion requiring eccentric evertor muscle activation to control this movement. The articulator of the custom device was equipped with an inclinometer sensor (SCA61T VTI Technologies, Vantaa, Finland – scale range + −90°/s – sensitivity 35 mV/°) and a gyroscope sensor (IXZ-500 InvenSense, Sunnyvale, USA – scale range + −500°/s – sensitivity 2mv/°/s) to acquire angular displacement and velocity signals associated with inversion movements. These sensors were instrumented, and signals were recorded at 100 Hz by means of an acquisition card (NI USB 6009, 14 bits) and custom software developed in Labview™. Signals were then analyzed with custom software developed in Matlab™ (Analyse™, GRAME, Quebec). Angular acceleration signals were calculated from angular velocity signals (finite-difference algorithm).

Fig. 1. Illustration of the Myolux Techno™ device. This ankle rehabilitation device has been designed to produce specific ankle inversion in weight bearing conditions. Such an inversion movement can be controlled only by means of ankle evertor muscles eccentric recruitment.