Clinical Biomechanics 41 (2017) 54–59

Contents lists available at ScienceDirect

Clinical Biomechanics

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

Assessment of evertor weakness in patients with chronic ankle instability: Functional versus isokinetic testing

Romain Terrier [a,b,*], Francis Degache [c], François Fourchet [d], Boris Gojanovic [d], Nicolas Forestier [a]

[a] University Savoie – Mont BlancEA 7424 - Inter-university Laboratory of Human Movement Science, France
[b] CEVRES Santé, Savoie Technolac, BP 322, 73377 Le Bourget du lac cedex, France
[c] University of Health Sciences, University of Applied Sciences and Arts Western Switzerland, Lausanne, Switzerland
[d] Motion Analysis Laboratory, Physiotherapy Department, Hôpital La Tour, Avenue J-D Maillard 3, 1217 Meyrin, Geneve, Switzerland

ARTICLE INFO

Article history:
Received 10 June 2016
Accepted 1 December 2016

Keywords:
Ankle sprain
Evertors' strength deficits
Functional test
Weight bearing
Isokinetics
Closed kinetic chain

ABSTRACT

Background: Ankle sprain is the most common sport-related injury and eccentric weakness of ankle evertors is regarded as a significant muscular deficit related to chronic ankle instability. However, the eccentric performance of the evertors is rarely assessed by clinicians because procedures used for research purposes (i.e. isokinetic tests) are not easily applicable in daily practice.

Methods: The present study assessed the ability of two different testing procedures to distinguish between groups of 12 healthy subjects or 12 patients suffering from chronic ankle instability. On the one hand, the strength of evertors was assessed with a *gold standard* isokinetic procedure. On the other hand, we assessed the ability of the subjects to control ankle inversion during weight bearing (functional standing test).

Findings: Data showed no significant difference between groups for isokinetic peak torque values normalized to body weight. Conversely, the functional test revealed a significantly impaired ability to control ankle inversion during weight bearing in subjects with chronic ankle instability.

Interpretation: This suggests that this easy-to-apply functional test is better suited compared to isokinetic testing procedures to assess weakness of evertors in patients suffering from chronic ankle instability. Moreover, this test may also be used to objectively monitor improvements during rehabilitation or progression in prevention protocols.

1. Introduction

Lateral ankle sprain is the most common musculoskeletal injury reported in physically active populations; *in addition, the majority of patients with a history of lateral ankle sprain will sustain at least one additional sprain resulting in functional limitations and leading often to the defined condition of chronic ankle instability* (Gribble et al., 2016). Indeed, it has been shown (Freeman et al., 1965; Gerber et al., 1998; Gribble et al., 2016; Waterman et al., 2010; Willems et al., 2002) that 40 to 70% of patients who suffered an initial ankle sprain were at risk for developing Chronic Ankle Instability (CAI). CAI has been described as a consequence of either or both mechanical and functional insufficiencies (Gribble et al., 2013). Mechanical instability is conditioned by ligament laxity, impaired arthrokinematics or impingements. These deficits are usually managed by specific articular mobilizations (Hoch et al., 2012) and/or surgical approaches (Tourné et al., 2010). Functional instability is understood as sensorimotor joint control alterations (Hertel, 2002) mainly caused by proprioceptive (Munn et al., 2010) and/or ankle evertor muscles strength deficits (Pietrosimone and Gribble, 2012). Rehabilitation aims to restore these key parameters using supervised protocols, including specific proprioceptive and strengthening exercises.

Rehabilitation specialists also need to perform simple and reliable functional tests in order to (i) identify individuals suffering from functional deficits potentially leading to CAI and (ii) objectively assess improvements during the rehabilitation process. On the one hand, dynamic postural control deficits associated with CAI can be assessed using the well-known star excursion balance test (see Gribble et al., 2012 for a review). On the other hand, the eccentric performance of the ankle evertors is of primary interest as it takes part in the active control of the sudden anke inversion (Collado et al., 2010; Graziani et al., 2001; Munn et al., 2003). While isokinetic eccentric muscular weakness has been considered as a factor responsible for CAI by some authors (Abdel-Aziem and Draz, 2014; David et al., 2013; Hartsell and Spaulding, 1999; Willems et al., 2002; Yildiz et al., 2003; Tropp, 1986), it is worth noting that there is no clear consensus about the relationships between evertor isokinetic weakness and CAI (Bernier et al., 1997; Kaminski et al., 1999; Kwon et al., 2013; Lentell et al., 1990). In

* Corresponding author at: Laboratoire Interuniversitaire de Biologie de la Motricité (E.A. 7424), Département des Sciences et Techniques des Activités Physiques et Sportives (STAPS), Université Savoie Mont-Blanc, 73376 Le Bourget du lac, France.
E-mail address: romain.terrier@cevres.com (R. Terrier).

http://dx.doi.org/10.1016/j.clinbiomech.2016.12.002
0268-0033/

addition, such a deficit has rarely been evaluated in clinical practice (Eggart et al., 1993; De Nohonha and Borges, 2004; Plante and Wikstrom, 2013). Hence, isokinetic evaluation is still considered the *gold standard* procedure for research purposes, whereas this methodology is not easily transferable to daily practice due to cost, space requirements, portability and time consuming constraints considered as barriers by clinicians. Moreover, because subjects are sitting (i.e. not in weight bearing conditions) during the test, it is necessary to normalize torque data to body mass for comparison purposes. Alternative testing methods like hand-held dynamometers have been shown to be reliable and more practical for clinicians (Spink et al., 2010). However, it is worth considering that open kinetic chain conditions of ankle isokinetic testing and hand-held dynamometers never match the closed kinetic chain function of ankle evertors (Dvir, 2004; Edouard et al., 2011; Fourchet, 2013; Van Cingel et al., 2009). In other words, while ankle inversion sprain is a weight bearing closed kinetic chain mechanism, evertors performance is systematically assessed using open kinetic chain tests (e.g. manual testing, hand-held or isokinetic dynamometers). In this context, an alternative practical functional test was recently proposed to assess ankle evertor weakness in closed kinetic chain in CAI patients (Terrier et al., 2014). This new functional testing option assesses the ability of the ankle to resist an inversion challenge in weight bearing conditions, through the use of a specific ankle inversion destabilization device called Myolux(™) (Forestier and Terrier, 2011; Terrier and Forestier, 2015; Terrier et al., 2014). The Myolux™ device has been shown to primarily recruit ankle evertors under static (Forestier et al., 2015) and dynamic (Donovan et al., 2014; Forestier and Toschi, 2005) conditions.

To perform this test, which mainly requires eccentric evertor control, the Myolux(™) device is equipped with a gyroscope sensor. This previous study demonstrated that an impaired control of weight bearing ankle inversion, revealed by significantly higher angular velocity peaks, can be regarded as a relevant discriminating factor between healthy and CAI subjects. Under such conditions, and in contrast to isokinetic tests, this functional weight bearing ankle inversion challenge is executed against body mass. This means that the test is more demanding for heavier subjects as body mass is taken into account in the net velocity values (this being the performance parameter). The performance of active joint protection does not require any normalization procedure.

The aim of the present study was to assess the ability of two different ankle eccentric evertor testing conditions to discriminate between healthy and CAI groups. The first condition referred to eccentric isokinetic tests, while the second referred to the new functional weight bearing test. We hypothesize that the functional weight bearing test is more sensitive to identify the weakness of ankle evertors compared to isokinetic testing procedures.

2. Material & Methods

2.1. Subjects

A group of healthy subjects (healthy group) and a group of CAI subjects (CAI group) participated in the study. As presented in the Table 1, the healthy group included 12 healthy active subjects (four males and eight females; mean age 19(1.5) yr; mean mass 62.1(10.9) kg; mean height 169.3(8.3) cm) with no history of ankle sprain, neurological or motor dysfunctions. The CAI group included 12 CAI subjects (nine males and three females; mean age 19.5(1.9) yr; mean mass 71.9(16.4) kg; mean height 175.5(11.6) cm). Exclusion and inclusion criteria for CAI subjects have been applied according to the recommendations of the International Ankle Consortium (Gribble et al., 2013). Exclusion criteria consisted of any history of previous surgery to 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 that impacted joint integrity and function (i.e., sprains, fractures) in the previous 3 months. For the CAI group, inclusion criteria were a minimum of two lateral sprains on the same ankle, the most recent one during the last year but >3 months prior to study enrolment; a feeling of ankle joint instability, and frequent ankle "giving way". No member of the CAI group performed rehabilitation exercises during the study. A non-validated French translation of the Ankle Instability Instrument (Docherty et al., 2006) was provided 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 (see table 1 for data about inclusion criteria). Finally, each subject declared to experience at least one episode of ankle "giving way" per month. All CAI subjects were affected by unilateral instability and their unstable ankle (dominant or not) was tested. The distribution between dominant and non-dominant ankles tested in the healthy group matched the distribution in the CAI group. The study was approved by the local research ethics committee and subjects' informed consent was obtained in conformity with international standards (Harriss and Atkinson, 2013).

Table 1
Subjects demographics and inclusion criteria for the both experimental groups.

Subjects demographics	Healthy (n = 12)	CAI group (n = 12)	*t*-Test results
Gender	Male: 4 Female: 8	Male: 9 Female: 3	
Age (mean ± SD; yr)	19(1.5)	19.5(1.9)	NS
Mass (mean ± SD; kg)	62.1(10.9)	71.9(16.4)	NS
Height (mean ± SD; cm)	169.3(8.3)	175.5(11.6)	NS
Inclusion criteria			
Yes answers to all questionary (mean ± SD)	0 ± 0	7.2(2.2)	$p < 0.001$
Previous sprains of the tested ankle (mean ± SD)	0 ± 0	3.6(2.6)	$p < 0.001$

2.2. Task and apparatus

2.2.1. Eccentric isokinetic test

Peak torques (PT) of ankle invertors and evertors were tested by the same examiner using an isokinetic HUMAC NORM® dynamometer (Humac Norm, Humac, CA, USA). Data were acquired by a personal computer using the HUMAC software, which calculated and displayed torque and joint displacement values. Calibration of the isokinetic dynamometer with the computing software was performed using certified weight before data collection.

2.2.2. Functional test: eccentric weight bearing ankle inversion control

This previously described functional test (Terrier et al., 2014) consisted of measuring angular ankle inversion velocity during a weight bearing ankle inversion challenge in healthy and CAI subjects. This test was performed using a custom version of a Myolux™ device (Myolux Medik e-volution™ developed from Myolux Medik II™, CEVRES Santé, France) equipped with an articulator located under the rear foot and described in previous papers (e.g. Donovan et al., 2014; Donovan et al., 2015; Forestier and Terrier, 2011; Forestier and Toschi, 2005; Terrier et al., 2014). This articulator generated angular displacements along the physiological subtalar axis (also called Henke axis) to induce ankle inversion and eversion movements. In weight bearing conditions, the ankle automatically moves in inversion, requiring eccentric evertor activation to control this movement. The articulator of the custom device was equipped with an Inertial Measurement Unit (Shimmer3, Dublin, Ireland) to capture from the integrated gyroscope angular velocity signals associated with inversion movements at 51.2 Hz. Signals were then analysed with a custom software developed in Matlab™ (Analyse™, GRAME, Quebec).