

IMPACT OF DYNAMIC BALANCE AND HIP ABDUCTOR STRENGTH ON CHRONIC ANKLE INSTABILITY

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ABSTRACT

Introduction: Ankle sprains are injuries that commonly occur during physical activity. They constitute between 15-75% of all sport injuries, and they can develop into chronic ankle instability (CAI) and functional disability. Subjects with CAI have exhibited diminished dynamic balance and weakness in the hip abductor muscles. Therefore, the purpose of this study was to investigate whether dynamic balance and hip abduction strength measures were related to the level of severity in CAI. **Material y Methods:** 40 students with Cumberland ankle instability tool (CAIT), defined by the CAIT, were divided into two groups: severe instability and mild instability group. Participants were assessed in dynamic balance and hip abduction strength. **Results:** No significant correlations were found between CAIT, Y-Balance and abduction strength variables in any group. Y-Balance test explained 24.7% of the CAI variance in the regression analysis, being statistically significant in the predictive model ($p < 0.01$). Hip abductor strength was rejected from the model. **Discussion:** This study reinforces the necessity of the inclusion of balance exercises for the lower extremity as a key content when designing rehabilitation programs for athletes with CAI. However, hip abductor strength exercises are still remains controversial. This knowledge would allow sports therapists to design more effective rehabilitation programs.

Key Words: ankle rehabilitation, chronic ankle instability, dynamic balance, hip strength

IMPACTO DEL EQUILIBRIO DINÁMICO Y FUERZA DE LOS ABDUCTORES DE CADERA EN LA INESTABILIDAD CRÓNICA DEL TOBILLO

RESUMEN

Introducción: Los esguinces de tobillo son lesiones comunes durante la actividad física. Constituyen entre el 15-75% de todas las lesiones deportivas, pudiendo degenerar en una inestabilidad crónica de tobillo (ICT) e incapacidad funcional. Los sujetos con ICT han mostrado un equilibrio dinámico disminuido y debilidad en los músculos abductores de la cadera. Por lo tanto, el objetivo de este estudio fue investigar si el equilibrio dinámico y la fuerza de abducción de la cadera estaban relacionadas con el nivel de gravedad de la ICT. **Material y Método:** 40 estudiantes con ICT, definida por el cuestionario Cumberland ankle instability (CAIT), se dividieron en dos grupos: inestabilidad grave e inestabilidad leve. **Resultados:** No se encontraron correlaciones significativas entre las variables del CAIT, Y-Balance y fuerza en ningún grupo. El Y-Balance explicó el 24,7% de la varianza de ICT en el análisis de regresión, siendo estadísticamente significativo en el modelo predictivo ($p < 0,01$). **Discusión:** Este estudio refuerza la necesidad de incluir ejercicios de equilibrio para las extremidades inferiores como un factor clave en el diseño de programas de rehabilitación para los deportistas con ICT, no así los ejercicios de fuerza de abductores de cadera. Este conocimiento permitiría a los terapeutas deportivos diseñar programas de rehabilitación más eficaces.

Palabras clave: rehabilitación del tobillo, inestabilidad crónica del tobillo, equilibrio dinámico, fuerza de cadera

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INTRODUCTION

Lateral ankle sprains are among the most common injuries that occur during physical activity, especially activities involving jumping and landing, sprinting and quick and unexpected changes of direction (Fong, Hong, Chan, Yung, & Chan, 2007). Specifically, ankle sprains constitute between 15-75% of all sport-related injuries, and mainly occurs in “high-risk” team sports like handball, basketball, soccer and volleyball (Fernandez, Yard, & Comstock, 2007; Hootman, Dick, & Agel, 2007).

Although the majority of patients recover completely after their first acute injury, residual or chronic ankle instability (CAI) may exist after sprains, and recurrent ankle sprains might continue to occur during physical activity (Boyle, & Negus, 1998; Mulloy Forkin, Koczur, Battle, & Newton, 1996). In fact, it has been reported that CAI is developed by approximately 40% of people with a previous history of ankle sprain (Bosien, Staples, & Russell, 1955), and it may lead to a wide spectrum of disability in daily life activities and athletic tasks (Hertel, 2002; Hubbard & Hertel, 2006). In addition, people with CAI are at higher risk of osteoarthritis and articular degeneration in the ankle compared to healthy individuals (Pisani, Pisani, & Parino, 2005; Tol, Struijs, Bossuyt, Verhagen, & Van Dijk, 2000; Valderrabano, Hintermann, Horisberger, & Fung, 2006). This entity is characterised by a subjective feeling of the ankle “giving way”, weakness, pain and impaired function that presents itself for a minimum of 1-year post-initial sprain (Delahunt, Coughlan, Caulfield, Nightingale, Lin, & Hiller, 2010). Clinicians typically assess CAI by self-reported questionnaires, being the Cumberland Ankle Instability Tool (CAIT) one of the most popular.

Although traditionally CAI has been linked to ligamentous laxity (Karlsson, Bergsten, Peterson, & Zachrisson, 1991; Lentell, Baas, Lopez, McGuire, Sarrels, & Synder, 1995), subtalar instability (Clanton, 1989), syndesmosis instability (Staples, 1975) and bony deformity (Larsen & Angermann, 1990); in the last years it has been suggested that because the lateral ankle sprains are associated with high-velocity and high-impact movements, the investigation of CAI should focus on dynamic and functional measures of neuromuscular performance (De Noronha, Refshauge, Crosbie, & Kilbreath, 2008). Thus, in the last decade, a growing number of studies have tried to establish whether subjects with CAI showed deficits or impairments on some measures of the neuromuscular performance (de Noronha, Franca, Hauptenthal, & Nunes, 2013; Fousekis, Tsepis, & Vagenas, 2012; Read, Oliver, De Ste Croix, Myer, & Lloyd, 2016). Although still inconclusive, some studies have indicated that subjects with CAI exhibit diminished dynamic balance in comparison with their paired healthy controls (Gribble, Hertel, & Denegar, 2007; Hertel, Braham, Hale, & Olmsted-Kramer, 2006; McKeon & Hertel, 2008; Olmsted, Carcia, Hertel, & Shultz, 2002; Ross & Guskiewicz, 2004). In addition, although with less vigour

than dynamic balance, two studies have found significant weakness in the hip abductor muscles on the injured side in comparison with the healthy (control) side in subjects with unilateral CAI (Friel, McLean, Myers, & Caceres, 2006; Nicholas, Strizak, & Veras, 1976).

These afore-mentioned findings regarding the consequences of the CAI on the neuromuscular performance have led clinicians and sport therapists to consider the inclusion of dynamic balance and hip abduction strength exercises when designing rehabilitation programs for this population. However, to the authors' knowledge, no studies have purposely compared the individual contribution of both dynamic balance and hip abduction strength measures on CAI. This knowledge would allow clinicians and sports therapists to design more effective rehabilitation programs that focus their attention on the element that correlated most with this entity.

Therefore, the primary purpose of this study was to investigate whether dynamic balance and hip abduction strength measures were related to the level of severity in CAI. A secondary aim was to compare the individual contribution of both neuromuscular measures on the explained variance of the CAI.

METHOD

Participants

A total of 40 physically active students (32 men and 8 women; age: 22.6 \pm 4.0 years; body mass: 72.3 \pm 10.2 kg; height: 174.7 \pm 8.5 cm) with CAI as defined by the CAIT, completed this study. "Physically active" was defined as exercising at least three times per week for a minimum of 30 min each time. All participants were engaged in recreational sports, such as basketball, volleyball, soccer and/or tennis.

Participants were allocated into two different groups: (1) the severe instability group (SI) (n= 23); and (2) the mild instability group (MI) (n =17). The SI group was defined as participants with a CAIT score less than 22, and the MI group was defined as participants with a CAIT score greater than or equal to 22 and less than or equal to 27 (De Noronha, et al., 2008).

Participants were eligible if they had a history of ankle sprain followed by CAI, as defined by a CAIT score less than or equal to 27 for at least one ankle. Lateral ankle sprain was defined as an inversion injury that resulted in pain, swelling, and abnormal gait (Gross, 1987). Inclusion criteria were identified using the CAIT to determine eligibility for inclusion in the study. This criteria included: history of ankle sprain at least in one ankle joint, the perception that the ankle gives way, is weaker, is more painful, or is less functional than preinjury and having the diagnosis of functional ankle instability according to the CAIT (Hiller, Refshauge, Herbert, & Kilbreath, 2007). Participants were excluded from the study if they had had an ankle sprain six week before the

start of the study (Delahunt et al., 2010), a history of lower limb fracture or surgery, neurological, visual or vestibular deficit or other orthopaedic or arthritic problem in the tested leg which may have affected performance, or any other significant injury or condition likely to cause a disturbance of balance or affect the participant's performance.

Prior to any participation, the experimental procedures and potential risks were fully explained to the participants and all provided written informed consent. The study was approved by the Ethic Committee of the University, and conformed to the Declaration of Helsinki.

Design

A cross-sectional design was used to establish the relationship between CAI, as determined by CAIT scores, and performance in an examination of dynamic balance (Y-balance test) and peak isometric hip abduction torque.

Procedure and equipment

A cross-sectional design was used to investigate the relationship between CAI, as determined by CAIT scores, and performance in an examination of dynamic balance (Y-balance test) and peak isometric hip abduction torque.

Prior to testing, participants performed a 5-minute warm-up on a stationary bike at a low to moderate intensity (self-perceived). After the warm-up was completed, participants were assessed on the dynamic balance and isometric strength in a counterbalanced order. The same examiner, who was blinded to CAIT scores, conducted both assessment tests in all participants. In those participants who reported bilateral CAI, only the ankle with the highest CAIT score was analysed to ensure an appropriate number of participants having severe instability to make correlational analysis.

Chronic ankle instability was measured using CAIT, a questionnaire with 9 Likert-scale questions, providing a numeric value that classifies the severity of the instability. The CAIT has been shown to be a simple, reliable, and valid questionnaire for discriminating and measuring the severity of functional ankle instability (Hiller, Refshauge, Bundy, Herbert, & Kilbreath, 2006).

Isometric hip abduction strength for the leg with CAI (or the lowest CAIT score) was tested with a portable handheld dynamometer (Nicholas Manual Muscle Tester, Lafayette Indiana Instruments). The handheld dynamometer was calibrated before testing and all test procedures were standardized according to established protocols by Thorborg, Petersen, Magnusson, & Hölmich (2010). Hip abduction strength was tested in a supine lying position in a plinth with the participant's legs extended. Participants stabilized themselves by holding onto the side of the table (figure 1). The examiner applied resistance via a dynamometer placed 2 cm above of lateral malleolus while the participant

had to push in an abduction direction. Maximum voluntary contractions were repeated 3 times, and held for 5 seconds each time (Thorborg et al., 2010). Thirty seconds rest periods were given between repetitions. The highest of these measurements was used in the analysis.



FIGURE 1: Hip abduction strength test with handheld dynamometer.

The dynamic balance was measured using the Y-balance® test and following the guidelines proposed by Shaffer et al., (2013). Participants were allowed a maximum of 5 trials to obtain 3 successful trials for each reach direction (anterior, posteromedial and posterolateral). Specifically, testing order was completed as dominant anterior, non-dominant anterior, dominant posteromedial, non-dominant posteromedial, dominant posterolateral, and non-dominant posterolateral. The average of the 3 reaches was normalized by dividing by the previously measured leg length to standardize the maximum reach distance ((excursion distance/leg length) x100 = % maximum reach distance) (Gribble, Hertel, & Plisky, 2012). Leg length was defined as the length measured in centimetres from the anterior superior iliac spine to the most distal portion of the medial tibial malleolus. To obtain a global measure of the balance test, data from each direction were averaged for calculating a composite score (Filipa, Byrnes, Paterno, Myer, & Hewett, 2010).

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, v. 20.0 for Windows; SPSS Inc, Chicago).

Means \pm standard deviations (SD) were used to describe the variables (Table 1). Data normality and homoscedasticity were confirmed before inferential analysis through Kolmogorov–Smirnov and Levene’s tests, respectively. The CAIT scores were correlated against the dynamic balance and isometric peak hip abduction strength measures using Pearson product moment correlation coefficient (r).

RESULTS

Table 1 shows descriptive statistics of the two groups. Only significant differences were found in CAIT score between groups.

TABLE 1

Descriptive statistics of the severe and mild groups and the t-test comparing them.

	Age (yr)	Height (m)	Mass (kg)	CAIT
Severe (n=23)	22.4 \pm 4.4	1.74 \pm 0.09	70.9 \pm 11.7	17.6 \pm 2.7*
Mild (n=17)	22.6 \pm 3.0	1.8 \pm 0.1	75.4 \pm 8.1	24.3 \pm 2.0*

* $p < 0.05$

Table 2 shows the statistical comparisons of both groups according to the t-test and effect size. MI group showed greater postural control and ABD strength than SI group, although we only found significant differences between groups in composite variables ($p < 0.05$).

TABLE 2

Statistical comparisons between severe and mild groups.

	SI	MI	p	ES [95% CI]
Composite (cm)	83.99 \pm 9.90	90.55 \pm 8.75	.048	0.69 [1.152, 1.222]
ABD (N)	164.02 \pm 40.83	188.44 \pm 36.54	.070	0.62 [0.070, 1.160]

Abbreviations: SI: severe instability; MI: mild instability; ABD: Abduction; ES: Effect size.
* $p < 0.05$

The Pearson product moment correlations between the measured variables in the SI and MI groups are presented in table 3. No significant correlations were found between CAIT, Y-Balance and ABD strength variables in any group.

TABLE 3
Correlations between CAIT, composite and abductor isometric force
in the severe and mild instability group

SEVERE GROUP	CAIT	Composite	ABD
CAIT			
Composite	0.497		
ABD	0.388	0.348	
MILD GROUP			
CAIT			
Composite	0.168		
ABD	-0.122	-0.234	

Abbreviations: CAIT: Cumberland Ankle Instability Tool; ABD: Abduction; size. * $p < 0.05$

The regression analysis (Table 4) resulted in one predictive model per group. For the SI group, the two variables that were entered into the regression analysis explained 24.7% of the CAI variance. Only the composite variable was identified as being statistically significant in the predictive model ($p < 0.01$), while the ABD strength variable was rejected from the model. For the MI group both variables were rejected from the predictive model.

TABLE 4
Regression analysis identifying measures most associated with chronic ankle instability

SI group	t	p	R ²	[95.0% CI]	
Composite	3.185	0.003*	0.247	0.049	0.225
ABD Strength	1.499	0.144	-	-0.006	0.039
MI group					
Composite	0.656	0.519	-	-0.073	0.139
ABD Strength	-0.387	0.702	-	-0.031	0.022

* $p < 0.05$. Hyphen in R² column indicates a rejected variable from the regression model.
Abbreviations: SI: severe instability; MI: mild instability; ABD: Abduction.

DISCUSSION

CAI is a term commonly use to describe a functional disability of the ankle (Nakasa, Fukuhara, Adachi, & Ochi, 2008) and it has the potential to decrease individuals' participation in sport/physical activities (Verhagen, de Keizer, & van Dijk, 1995). Therefore, it is necessary to identify the main neuromuscular measures impaired to develop effective rehabilitation programs with the aim of decreasing the prevalence of CAI. However, most of the studies have focused on linking single neuromuscular factors with CAI (univariate approach), rather than investigating a combination of several neuromuscular factors that might

contribute to CAI (multivariate approach) (Hubbard, Kramer, Denegar, & Hertel, 2007a, 2007b; Santos, & Liu, 2008). Therefore, the aims of this study were to determine whether dynamic balance and hip abduction strength measures were related to the level of severity in CAI and to establish the percentage of explained variance accounted for both neuromuscular measures in CAI.

Regression analysis showed that solely composite score of Y-Balance accounted for almost 25% of the variance of CAI in the SI group, while abductor hip strength was rejected in this predictive model for both groups. The results obtained in this study are similar to those reported by Gribble, Hertel, & Denegar (2007) and Olmsted et al., (2002), in which a CAI status was significantly influenced for the normalized distances reached in the star excursion balance test (SEBT), a similar protocol which measures dynamic balance in single-limb stance. There are other models that have tried to identify which factors have higher influence in CAI (Gribble et al., 2007; Hubbard et al., 2007a; Kumar-Jain, 2014). However, we cannot compare between our and their results as they have analysed different functional instability variables. In this sense, Hubbard et al., (2007a) calculated side-to-side differences in CAI and healthy subjects, and found that inversion laxity and deficits in functional plantarflexion and dorsiflexion strength and dynamic balance in the CAI ankle contributed approximately to 38% of variance in individuals with CAI. In the same way, Kumar-Jain (2014) showed that proprioception in ankle inversion, evertor muscle strength, and inversion/eversion stiffness accounted for 55.4% of variance in individuals with CAI. On the other hand, some researches (De Noronha, Franca, Hauptenthal, & Nunes, 2013; McKeon & Hertel, 2008; Plisky, Rauh, Kaminski, & Underwood, 2006) have shown that athletes with poor SEBT performance were more likely to have an ankle injury during a competitive season. For example, Plisky et al., (2006) reported that high school athletes with poor SEBT performance are 2.5 times more likely to sustain a lower extremity injury.

In relation to hip strength, in contrast to our results, some studies have found deficits in individuals with CAI (Ambegaonkar, Mettinger, Caswell, Burt, & Cortes, 2014; Bullocksaxton, Janda, & Bullock, 1994; Friel et al., 2006; Negahban et al., 2013), so weakness in hip strength could lead to functional alterations at the ankle (Friel et al., 2006; Hubbard, Kramer, Denegar, & Hertel, 2007b). For example, Friel et al., (2006) found a decrease in hip abductor strength in subjects with CAI. Based on these results, it has been speculated that the hip abductors help to keep the hip abducted reducing foot pronation and avoiding ankle inversion (Gauffin, 1991). On the contrary, McHugh, Tyler, Tetro, Mullaney, & Nicholas (2006) and Gribble & Robinson (2009) in the same line as our study reported that hip weakness didn't predict CAI. We must bear in mind that the hip abductors are located in the proximal part of the lower

limb and, although they play an important role in both leg stability and force transfer from trunk to the lower limbs, they are only one of the many hip muscle groups involved in these functions as the hip is part of a big kinetic chain.

The results of the current study may help clinicians and sports therapists to develop more focused and effective rehabilitation strategies for athletes with CAI. Thus, the findings of this study reinforces the necessity of considering the inclusion of balance exercises for the lower extremity as a key content when designing rehabilitation programs for athletes with CAI. However, the implementation of hip abductor strength exercises in the rehabilitation programs for athletes with CAI still remains controversial.

Limitations and future directions

The current study has some limitations. First, we used a retrospective design, so we do not know whether the ankle injury caused diminished postural control, weakness to the hip abductor musculature or vice versa. In this way, a long prospective study of injury-free participants would be necessary to find stronger conclusions. The relatively small sample size could determine the low percentage of variance and we only measured two neuromuscular parameters (dynamic balance and hip abductor strength) that may lead to CAI, so future researches should increase sample size and use other neuromuscular measures (i.e. eccentric ankle inversion strength, ankle range of motion) that may influence CAI variance.

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