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Research Article

Balance impairments in patients with a sub-acute ankle sprain receiving no exercise therapy: A comparative study

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Abstract

Aim: To compare single-leg balance performance between subacute ankle sprain patients receiving no exercise therapy and healthy persons.

Methods: Forty-eight subacute ankle sprain patients (age = 34.3 ±9.7 years) and 10 healthy persons (age = 30.1 ±4.7 years) participated in the study. Participants underwent an assessment of body functions and a 30-second single-leg balance test on a force plate under stable and unstable conditions. Center of pressure (COP) range, length and speed in mediolateral (ML) and anteroposterior (AP) directions were calculated.

Results: All healthy persons finished the 30-second balance test under both conditions. Forty-three patients (90%; P=.374) were able to complete the test on the stable surface and 38 patients (79%; P=.125) on the unstable surface. Ankle sprain patients showed increased COP AP speed compared to healthy persons for stable conditions (P=.009) and a larger COP AP range for unstable conditions (P=.001). Furthermore, muscle strength in inversion and eversion were correlated to COP performance (P<.050).

Conclusion: Specific ankle strength exercises, including muscle strength exercises in the frontal plane, might improve balance performance in ankle sprain patients.

Introduction

Ankle sprains represent approximately 15% of all sports-related injuries [1], and the incidence of re-injury of a sprained ankle is 3–34% during the first year after the initial trauma [2]. Furthermore, up to 74% of patients who reinjure their ankle have chronic ankle instability, [2] which has a negative influence on daily life activities and sport performance. It is also known that ankle sprains lead to high direct and indirect health care costs [2,3]. The high costs and high incidence rates make it necessary to gather comprehensive information on ankle sprain mechanisms and consequences in order to better tailor treatments.

Potential risk factors and mechanisms that contribute to increased ankle sprain recurrence include altered intrinsic body functions, such as decreased proprioception in the ankle ligaments, muscle weakness and limited range of motion, and extrinsic factors such as inappropriate footwear [2,4].

Genthon *et al.* [5] showed that ankle sprain patients present asymmetric balance in their bipedal stance during the first 10 days after injury. From day 10 to day 30 bipedal balance improved and returned to normal after 30 days [5]. However, the effects of functional deficits may become more evident while balancing on one leg [4,6,7]. A review of McKeon *et al.* [4] showed that balance performance of the injured ankle was impaired after an acute lateral ankle sprain compared to healthy controls. Although patients significantly improve their postural control (e.g., Center Of Pressure Range, Length And Speed) during the first four weeks after an ankle sprain, [8,9] they frequently experience residual functional deficits (Muscle Strength, Mobility) and impaired postural control after this four-week period [8,10].

It is important to identify residual functional deficits and balance impairments in order to tailor treatments. If clinicians can address these deficits, better prevention of recurrent ankle sprain injuries should be possible. Previous studies assessed such parameters in patients with a history of ankle sprain [4,11,12]. However, no study correlated these residual functional deficits with postural balance during the subacute phase (four weeks after the sprain), during which patients could still benefit from a specific treatment.

Therefore, the aim of this study was 1) to assess the relationship between balance performance and individuals' body functions (muscle strength, range of motion, pain); and 2) to compare single-leg balance performance between subacute ankle sprain patients receiving no exercise therapy and healthy persons.

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Materials and methods

Design

This is a case-control study comparing ankle sprain patients to healthy controls.

Participants

Forty-eight subacute lateral ankle sprain patients visiting the emergency department with a grade I or II ankle sprain were consecutively included in the study four weeks after their initial trauma. Ten healthy persons were selected as a convenience sample of students and matched by age, BMI and sex to the ankle sprain patients (Table 1). All participants were aged from 18 to 55 years and had a BMI < 30. Patients were excluded if they had a grade III rupture of the ankle ligament, any neurological, musculoskeletal or other disorders that could influence postural control or if they had a recurrent ankle sprain on the same site within the last 12 months.

Medical ethical approval was obtained (09_116); all participants were informed about the procedures and signed informed consent forms.

Procedures

The ankle sprain patients were discharged from the emergency department after the physician provided standard instructions regarding rest, ice, compression and elevation (RICE protocol) and pain-free movement for four weeks. In addition, patients received a semirigid Aircast ankle brace during this four-week period.

After four weeks, the ankle sprain patients underwent a clinical examination by an experienced physical therapist during which joint mobility, muscle strength and pain level were measured. After the clinical examination, the patients underwent a 30-second single-leg balance test on a force plate (AMTI Accugait, Watertown, MA, USA) at a sample frequency of 1,000 Hz. The healthy persons underwent the same single-leg balance test as the ankle sprain patients.

Test description

Muscle strength: Maximum isometric muscle strength of the ankle plantar and dorsal flexors, invertors and evertors was measured with a handheld dynamometer (HOGGAN FET 2, in N) [13,14] with the patient in a supine position (with a trunk-hip angle of 45 degrees) and the knee in extension. Handheld dynamometry has been shown to be a reliable method to measure ankle strength (ICC>0.77) [14]. The examiner holds the dynamometer stationary while the patient exerts maximal force against it. The foot was placed in a neutral position. Each test was repeated three times and the best performance was retained for analyses.

Joint mobility: The range of motion (ROM) of the ankle joint in the sagittal plane was measured with a manual goniometer (in degrees) [15] with the patient in a supine position (with a trunk-hip angle of 45 degrees). The patient was asked to bring the ankle actively into correct position, and thereafter the ankle was passively positioned in the maximum plantar flexion and dorsiflexion angles. The center of the goniometer was positioned just below the lateral malleolus, on the axis of rotation of the joint, in line with the lower leg midline and the fifth metatarsal. Dorsiflexion was measured in an extended knee position as well as with a 90° bended-knee position.

Pain: Pain was evaluated using the Visual Analogue Scale (VAS) during rest and walking, ranging from 0 points (no pain) to 10 points (severe pain) [16].

Single-leg balance evaluation: Participants were instructed to remain as motionless as possible for 30 seconds while they were standing on the test leg on the force plate. They were instructed to look directly at a point on the wall 150 cm away. They were allowed to practice this position before the measurements started. Single-leg balance tests in stable and unstable (6 cm Airex mat) conditions were assessed and the legs were examined alternately, each side three times. A measurement was stopped if the participant hopped on the weight-bearing leg or touched down the non-weight-bearing leg.

Data processing

Each single-leg balance test lasted 30 seconds, of which only the middle 26 seconds were analyzed to avoid the "edge effect" of the test [17]. Single-leg balance was measured as the center of pressure (COP) excursion range in mediolateral (ML) and anteroposterior (AP) directions (in mm), indicating the maximum deviation of the COP in the ML and AP axes. COP length was defined as the total length of the path movements during 26 seconds (in mm), and the mean COP speed

Table 1. Baseline characteristics of ankle sprain patients and healthy controls.

	Ankle sprain patients (n=48)	Healthy persons (n=10)	*P* value
Side ankle sprain: Left/Right	20/28	-	
Grade ankle sprain: 1/2	33/15	-	
Male/Female	26/22	4/6	.415
	Mean ± SD (range)	Mean ± SD (range)	
Age (years)	34.3 ± 9.7 (18 - 55)	30.1 ± 4.7 (21 - 36)	.189
BMI (kg/m^2)	24.2 ± 2.9 (18.4 - 29.8)	23.0 ± 2.3 (20.0 - 27.4)	.218
Muscle strength (N)	-	-	
Dorsiflexion	184.2 ± 96.1 (51.6 - 667.2)	-	
Plantar flexion	326.5 ± 118.4 (119.7 - 671.7)	-	
Inversion	85.0 ± 39.2 (14.0 - 177.9)	-	
Eversion	89.9 ± 40.3 (21.4 - 180.2)	-	
Joint mobility (°)	-	-	
Dorsiflexion (extended knee position)	7.7 ± 5.0 (-5 - 20)	-	
Dorsiflexion (90° bended knee position)	15.8 ± 5.9 (4 - 26)	-	
Plantar flexion	47.0 ± 11.6 (18 - 70)	-	
VAS for pain (10 point scale)	-	-	
Rest	1.1 ± 1.6 (0.0 - 6.0)	-	
Walking	2.6 ± 2.4 (0.0 - 8.0)	-	

(mm/s) in ML and AP directions is the sum of the displacement scalars during 26 seconds.

For each participant, the best performance of three single-leg balance tests was included in data analysis. To do this, the standard score for normalization was calculated by taking the raw COP score minus the mean COP range of the population, divided by the COP standard deviation of the population. After normalization of the COP range in ML and AP directions, the best performance was chosen. The COP data were low-pass filtered at 10 Hz with a fourth-order and zero-lag Butterworth filter [18]. Parameters were extracted with MATLAB and the open-source Biomechanical Tool Kit package for MATLAB [19].

Sample size

Given an expected correlation coefficient of 0.5, a desired (one-sided) probability level of 0.05 and a desired statistical power level of 80%, the minimum sample size was 23 ankle sprain patients.

Statistical analyses

Analyses were performed using SPSS 18 (SPSS Inc., Chicago, IL, USA). The statistical review of the study was performed by a biomedical statistician. Descriptive statistics were used to present the study population (Age, BMI, Grade of Ankle Sprain and Pain).

Fisher's exact test was used to compare the proportion of participants in each group who managed to complete the 30-second balance test and the ones who did not.

Only single-leg balance tests lasting 30 seconds were used for further statistical analyses. All balance parameters were checked for normality.

Spearman's correlation coefficient was used to check for associations between functional deficits of the injured ankle and an individual's balance performance. For that, muscle strength was normalized for body weight [20]. Correlations between 0.3 and 0.5 were considered moderate and a correlation of ≥0.5 was considered strong [21]. In addition, we assessed differences in balance performance between ankle sprain patients and healthy persons using the Mann-Whitney test. To do so, we only used one ankle side per healthy subject (5 left ankles, 5 right ankles). *P*-values less than .050 were considered statistically significant.

Results

Forty-eight subacute ankle sprain patients (26 men, 22 women) with a mean age of 34.3 (±9.7) years and a mean BMI of 24.2 (±2.9) kg/m^2 and 10 healthy persons (4 men, 6 women) with a mean age of 30.1 (±4.7) years and a mean BMI of 23.0 (±2.3) kg/m^2 participated in the study (Table 1). Muscle strength, joint mobility and pain level of the injured ankle were assessed during clinical evaluation, and results are shown in Table 1.

Correlations between body function and balance in the ankle sprain patients

Passive ROM, muscle strength in plantar and dorsiflexion and pain were not related to balance performance on the stable or the unstable surface. However, muscle strength in inversion and eversion correlated with COP range.

For the unstable surface, COP range in ML direction was moderately correlated to muscle strength in inversion (R=0.486, *P*=.002). Muscle strength and eversion were strongly correlated with CAP range in ML direction (R=0.568, *P*<.001) and moderately to COP range in AP direction (R=0.362, *P*=.026).

Single-leg balance test

All healthy persons managed to complete the single-leg balance test on the stable as well as on the unstable surface with both legs. Forty-three of the 48 patients (90%) managed to complete the test on the stable surface (*P*=.374) and no more than 38 patients (79.1%) were able to finish this test on the unstable surface (*P*=.125).

Compared to the healthy persons, ankle sprain patients presented a higher COP speed in AP direction (*P*=.009) and larger COP length (*P*=.034) for the stable surface (Table 2). In addition, the COP range in AP direction was increased for the unstable surface in the ankle sprain patients (*P*=.001, Table 2).

Discussion

This is the first study to investigate single-leg balance performance and assess its relation to an ankle sprain patient's body function (Grade I and II) during the subacute phase. This study showed that four weeks after a lateral ankle sprain, fewer patients were able to perform a 30-second single-leg balance test compared to healthy age-, sex- and BMI-matched persons. The ankle sprain patients who were able to complete the balance test presented a larger COP range and speed in AP direction compared to healthy persons. Furthermore, ankle sprain patients showed lower muscle strength in inversion and eversion. Passive ROM and pain levels during walking were not related to balance performance.

Hertel *et al.'s* [8] results for COP speed (ML 2.9 ± 0.7 cm/s, AP 3.4 ± 0.7 cm/s) and COP range (ML 2.5 ± 0.6 cm, AP 2.1 ± 0 .4 cm) in

Table 2. Balance parameters of the injured side of the ankle sprain patient and both sides of the healthy persons.

	Ankle sprain patients		Healthy persons		*P* value
	Mean ± sd	range	Mean ± sd	range	
Stable surface	(n=43)	-	(n=10)	-	-
COP range ML (mm)	27.1 ± 5.7	19.7-49.2	23.7 ± 4.6	18.0-30.8	.084
COP range AP (mm)	39.0 ± 13.2	15.1-84.4	31.9 ± 11.7	18.1-52.6	.152
COP length (mm)	1090.9 ± 303.4	490.6-1710.0	890.4 ± 253.1	525.1-1486.1	.034
COP speed ML (mm/s)	27.3 ± 7.3	14.3-43.2	24.6 ± 7.8	14.4-44.1	.220
COP speed AP (mm/s)	26.6 ± 8.5	9.7-50.5	19.3 ± 5.4	11.3-28.4	.009
Unstable surface (AIREX)	(n=38)	-	(n=10)	-	-
COP range ML (mm)	32.0 ± 7.7	22.5-57.6	28.9 ± 4.5	22.3-35.8	.286
COP range AP (mm)	51.0 ± 10.6	31.8-78.4	39.4 ± 6.6	28.4-47.0	.001
COP length (mm)	1549.8 ± 468.8	522.6-2552.2	1306.0 ± 408.8	861.7-2101.2	.110
COP speed ML (mm/s)	40.9 ± 13.2	13.0-65.8	33.6 ± 12.1	21.2-58.3	.060
COP speed AP (mm/s)	35.6 ± 11.6	12.7-69.2	31.0 ± 8.1	21.0-44.9	.232

patients four weeks post injury were comparable to our results for the stable surface. They found that the COP speed in both directions at four weeks improved significantly compared to one day and two weeks after injury. For the COP range, they only found an improvement in ML direction compared to one day after the sprain [8]. Furthermore, they found a difference for COP speed in ML direction when they compared the injured and non-injured side. However, using the non-injured leg as a reference level is not recommended due to changes in this side as well; therefore, comparisons with healthy age-matched persons might reveal even larger differences [10]. In addition, more challenging tasks, like single-leg balancing on an unstable surface, resulted in larger and faster COP excursions because all sensory sensors and sensory integration are stimulated [22]. Our data showed a larger COP range only in AP direction for the unstable surface, and an increased COP speed in AP direction for the stable surface was found. If the velocity of COP increases, it becomes more difficult for the body to adequately compensate for the excursions and keep the COP within the base of support [8].

Nilsson *et al.* [23] found that clinical strength measures (repetitions of rising on toes and heels) in the sagittal plane were correlated to the ability to perform a single-leg balance test. They did not study muscle strength in the frontal plane, [23] but we found that increased muscle strength in inversion and eversion directions (frontal plane) was strongly correlated to a larger COP range in ML direction on the unstable surface. Because the patients had an inversion trauma, it is likely there is a deficit in the frontal plane. Besides strength, full ROM of the ankle is thought to be necessary to perform daily life activities optimally [23]. Nevertheless, our results did not show a relation between decreased ROM and balance performance. Deficits in ROM might have a larger influence on tasks requiring greater ROM such as walking, running and jumping.

The results showed that patients only had very moderate pain during rest (mean ± sd 1.1 ±1.6) and walking (2.6 ±2.4) four weeks after the sprain. No correlation between pain and balance performance could be identified. In contrast, previous studies showed that pain stimulation has a negative influence on postural balance in healthy subjects in a bipedal stance [24,25]. Interestingly, Corbeil *et al.* [25] showed that pain effects only appeared when a threshold was attained; a weak pain intensity (3 out of 10) did not influence COP performance except for COP range in AP direction. Because our patients had a low degree of pain, the tests were performed in a single-leg stance and the pain stimulation was not continuous. As compared to the tests in healthy subjects, this might explain the different findings.

The strengths of our study design are as follows: First, no exercise therapy was given in the acute phase to study the natural recovery of the injury. Second, we did not include patients aged above 50 because increased age is a known risk factor for decreased balance performance due to musculoskeletal weakness and a weight shift [23,26]. Third, for comparisons, a healthy age-, sex- and BMI-matched control group was included. Also, patients with a BMI over 30 were excluded, because obesity is a well-known factor influencing balance performance [27]. Finally, other studies revealed deficits in postural control in not only the injured but also the uninjured leg of ankle sprain patients compared with healthy persons [9,12]. The authors of these studies think that these deficits may be the result of proprioceptive deficits of the ankle ligaments, impaired strength of the muscles and/or mechanical instability of the ankle joint, which results in larger COP excursions [8,28]. The time-point postural control deficits are resolved between the uninjured limb (on average 7 days) and the injured limb (at least 4 weeks after injury) [9]. To avoid any bias, for comparisons, a healthy control group should be included because using the uninjured limb may lead to inappropriate conclusions, and a hasty return to work and sport activities and might increase the risk of a recurrent sprain.

A limitation of this study is that muscle strength was measured with a handheld dynamometer. If the patient is strong, he or she might be able to overpower the assessor. In this situation, the tested person would not be generating an isometric contraction, [13] which might lead to an underestimation of generated power. Therefore, the use of a handheld dynamometer with an external belt-fixation could have been more appropriate. A second limitation might be that the stable surface condition is not challenging enough to the postural control systems of these young patients. Having subjects close their eyes would make it more challenging in addition to the unstable surface but could decrease the number of participants able to perform the task. Third, the small size of the control group might affect the statistical power of the study; however, we matched both groups for age, sex and BMI to reduce this.

Balance and coordination training are common components of rehabilitation programs to treat patients with a (sub)acute ankle sprain and chronic ankle instability [7]. These programs often comprise so-called proprioceptive exercises on unstable surfaces, such as a wobble board, foam or ankle disc [29,30]. It is assumed that single-leg standing on these unstable surfaces stimulates the use of proprioceptive signals from around the ankle and in this way is beneficial for ankle instability [29]. These rehabilitation programs have been shown to be effective in reducing the number of recurrent injuries in patients with an ankle sprain [11,30]. Based on our results, adding frontal plane ankle strength exercises to standard treatment and balance exercises should be studied in future research.

Conclusion

In conclusion, ankle sprain patients still have disturbed balance performance and a decreased ability to fulfill a 30-second single-leg balance test four weeks after the ankle sprain. The larger COP excursions and higher speed in AP direction represent an inability to limit excessive center of mass movement during single-leg balance tests. Muscle strength in inversion and eversion was negatively related to these COP excursions in ML directions for unstable conditions. Therefore, it might be useful to add more specific strength exercises in the frontal plane in current treatment protocols.

Author contributions

Jean-Luc Ziltener and Lara Allet contributed to study design; Ilona M. Punt, Stephane Armand and Lara Allet contributed to data acquisition and data analysis; Ilona M. Punt, Stephane Armand, Jean-Luc Ziltener and Lara Allet contributed to the data interpretation and writing the article which was approved by all authors.

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