Surg Radiol Anat
DOI 10.1007/s00276-011-0784-z

ORIGINAL ARTICLE

RMI study and clinical correlations of ankle retinacula damage and outcomes of ankle sprain

Antonio Stecco · Carla Stecco · Veronica Macchi · Andrea Porzionato · Claudio Ferraro · Stefano Masiero · Raffaele De Caro

Received: 22 September 2010 / Accepted: 14 January 2011

Abstract Recent studies reveal the role of the ankle retinacula in proprioception and functional stability of the ankle, but there is no clear evidence of their role in the outcomes of ankle sprain. 25 patients with outcomes of ankle sprain were evaluated by MRI to analyze possible damage to the ankle retinacula. Patients with damage were subdivided into two groups: group A comprised cases with ankle retinacula damage only, and group B those also with anterior talofibular ligament rupture or bone marrow edema. Both groups were examined by VAS, CRTA and static posturography and underwent three treatments of deep connective tissue massage (Fascial Manipulation technique). All evaluations were repeated after the end of treatment and at 1, 3 and 6 months. At MRI, alteration of at least one of the ankle retinacula was evident in 21 subjects, and a further lesion was also identified in 7 subjects. After treatment, VAS and CRTA evaluations showed a statistically significant decrease in values with respect to those before treatment ($p < 0.0001$). There were also significant improvements ($p < 0.05$) in stabilometric platform results. No significant difference was found between groups A and B. The initial benefit was generally maintained at follow-up. The alteration of retinacula at MRI clearly corresponds to the proprioceptive damage revealed by static posturography and clinical examination. Treatment focused on the retinacula may improve clinical outcomes and stabilometric data.

Keywords Ankle sprain · Retinacula · Proprioception · Fascia · Fascial manipulation · Deep connective tissue massage

A. Stecco and C. Stecco contributed equally to this work.

A. Stecco · C. Ferraro · S. Masiero
Physical Medicine and Rehabilitation Clinic,
University of Padova, Padua, Italy

C. Stecco (✉) · V. Macchi · A. Porzionato · R. De Caro
Section of Anatomy, Department of Human Anatomy and Physiology, University of Padova, Via A. Gabelli 65,
35121 Padua, Italy
e-mail: carla.stecco@unipd.it

Introduction

Ankle sprain is one of the most common musculoskeletal injuries, representing 10–15% of all sports injuries. It is often considered a minor trauma but, according to many Authors [5, 6, 22, 41], 6–18 months after trauma, 72% of examined subjects still show recurring symptoms and repeated lateral ankle sprains [54]. Hubbard et al. [21] examining the causes of this clinical situation, called it chronic ankle instability (CAI), to highlight the fact that it derives from a combination of mechanical and functional variables. Their work also suggests that approximately 54% of the variance observed in patients with CAI remains unexplained, indicating that deeper knowledge of peripheral sensorimotor factors would contribute to better understanding of complex ankle pathology. In particular, one element which has been neglected until now is the role played by ankle retinacula in proprioception and ankle biomechanics. In fact, according to Viladot et al. [51], Pisani [38] and Stecco et al. [49], the ankle retinacula cannot be considered merely as passive elements of stabilization, but as a sort of specialization of the fasciae to better perceive the movements of the foot and ankle as proprioceptive organs. There are no studies analyzing possible damage to these retinacula and their role in the outcomes of ankle sprain.

For Platzer [39], Abu-Hijleh and Harris [1], Numkarunarunrote et al. [35] and Benjamin [4], the retinacula are thickenings of the deep fasciae of the leg (crural fascia) and foot and therefore not separable from them. From a histological point of view, few descriptions can be found in the literature. Klein et al. [24] stated that the ankle retinacula were formed of three histological layers (an inner gliding layer, a thick middle layer containing collagen bundles and an outer layer of loose connective tissue containing vascular channels) and that elastic fibers were few and scattered among the fibroblasts. These findings were also confirmed by Stecco et al. [49], who demonstrated that the ankle retinacula are formed of 2–3 layers of parallel collagen fiber bundles, densely packed with a little loose connective tissue, without elastic fibers but with many nerve fibers and corpuscles. Further studies [38, 49, 51] report that there are many proprioceptors inside the ankle retinacula, with specific features which allow them to perceive muscular stretch and which play an important role in proprioception. The ankle retinacula can be clearly evaluated at MRI, as highlighted by Numkarunarunrote et al. [35] and Stecco et al. [49]. They appear as low signal intensity bands with a mean thickness of 1 mm, but a description of their possible alterations is still lacking.

We hypothesize that, during an ankle sprain, the excessive load and traction on the connective tissues around the joint may damage the ankle retinacula and consequently proprioception, helping to explain the sensorimotor deficits in patients who have suffered ankle sprain or who have chronic ankle instability. A substantial body of research [10, 12, 14, 15, 17, 19, 20, 25, 29, 30, 34, 36, 40, 43, 44] has revealed alterations in reflex responses and efferent motor controls, but there is certainly also damage to peripheral somatosensory information [23, 26, 53]. The specific origin of the proprioceptive alteration is usually due to damage to the ankle ligaments, but this explanation is limited, since proprioceptive damage may also occur without specific lesions of the ankle ligaments. Therefore, the purpose of the present study was to analyze whether specific alterations of the ankle retinacula can be identified at MRI in patients with chronic ankle instability caused by previous ankle sprain but without serious damage of the ankle ligaments. We also wishes to verify the effectiveness of deep connective tissue massage focusing on the ankle retinacula in alleviating symptoms correlated with CAI.

Materials and methods

MRI study

Twenty-five subjects (11 males, 14 females; mean age 22.4 ± 6.4 years) with chronic ankle instability after ankle sprain were included in the MRI study (Table 1). All patients had presented symptoms for at least 4 months (average 2.7 years, range 4 months–7 years) and had suffered an ankle sprain classified as 0-I grade on the Hamilton scale (Fig. 1) [18]. Patients with a history of ligament hyperlaxity, previous contralateral ankle sprain, positive talar-tilt test and any rheumatological, metabolic or neurological pathologies were excluded.

MRI included T1-weighted SE sequences, T2-weighted fat saturation and Gradient Echo FFE sequences in the sagittal, coronal and axial planes on a 1.5 T MR system (Philips Medical Systems, Gyroscan Intera, Best, The Netherlands). Data were transferred to an Aquarius workstation (TeraRecon TM, San Mateo, CA, USA), and 3D reconstructions (volume rendering technique, maximum intensity projection, multiplanar reconstructions) were obtained. The images were visualized by multiplanar reformatting (MPR) analysis on the axial, sagittal and coronal planes of the windows, and the thickness of the deep fasciae of the leg and retinacula of the ankle were recorded. For integrated anatomo-clinical evaluation, MR images were examined jointly by two of the authors, specialists in Radiology (V.M.) and Orthopedics (C.S.).

Clinical study

All patients with MRI evidence of ankle retinacula damage were enlisted for the clinical study. In particular, two groups were identified: the group A included the subjects with only ankle retinacula damage, the group B those with further lesions, such as anterior talo-fibular ligament damage or bone edema. The same physiatrist (S.M.) carried out all clinical examinations before treatment and at follow-up. A self-assessed disability questionnaire (CRTA scale) [45, 46] and the visual-analogic scale (VAS, score 0–10), were given to all subjects. The CRTA questionnaire was created in France by *Rééquilibration Fonctionnelle Méthode*® and also validated for Italian by the *Centro di Ricerca in Terapie Alternative* (CRTA). It is formed of 12 items, each with a score ranging from 0 to 10 (normal). The first six items regard activities of daily living (ADLs), and the second six items overload activities. The last item regards pain during walking: a score of 6 corresponds to pain appearing within 100 m, and a score of 1 corresponds to pain appearing only during sports activities. The range of motion of the ankle joint and postural evaluation with stabilometric platform (ARGO®) was also carried out for each subject [21]. This platform, measuring 600 × 600 mm and operating at a recording frequency of 100 MHz [31], allows assessment of oscillations of the center of gravity via projections onto an underlying platform. It calculates the instantaneous position of the center of pressure and records the temporal sequence of the two coordinates. This system can calculate many supporting

Table 1 Principal features of the patients

Patients	Date of trauma	Side of the lesion		First treatment			Circumstance			Activity		Localization of edema			Presence of ecchymosis
		Right	Left	Rest	RICE	Emergency	Fall	During a walk	During running	Free time	Sport	Medial	Lateral	All the foot	
1	2004	X				X	X				X		X		
2	2006	X				X			X		X			X	X
3	2005	X				X			X		X		X		X
4	2006		X			X			X		X		X		X
5	2006	X				X			X		X		X		
6	2001	X			X				X		X		X		
7	2008	X			X				X		X		X		
8	2007		X		X				X		X		X		
9	2007	X				X	X				X		X		
10	2008	X			X				X		X		X		
11	2007	X		X			X				X				
12	2006	X				X	X			X		X	X		
13	2008		X		X		X				X		X		X
14	2008	X		X			X			X					
15	2005	X			X		X				X	X	X		X
16	2005		X		X		X				X				X
17	2002	X				X	X			X		X	X		
18	2002		X			X	X				X				
19	2009	X		X			X				X	X			
20	2008		X		X		X				X		X		
21	2007	X		X				X			X		X		
22	2006	X		X			X			X			X		
23	2008		X			X	X				X		X		
24	2008	X			X		X				X		X		
25	2009		X		X				X		X		X		

	ATFL	CFL	Drawer test	Talar Tilt test
Grade I	partial tear	intact	normal	normal
Grade II	complete tear	intact	2+ drawer	normal
Grade III	complete tear	complete tear	3+ drawer	3+ tilt

Fig. 1 Classification of low ankle sprains according to Hamilton

parameters, which are very useful for formulating a diagnosis and assessing clinical evolution during therapy. In our study, the following global parameters were used: sway path (mm/s), i.e., speed of swing; sway area (mm^2/s), i.e., the integral of the sway path, automatically calculated by the software, corresponding to the average width of swing; maximum swing A-L and L-L (mm), indicating the maximum width of swing on two planes (A-P and L-L), and the elliptic area, which contains 95% of the trajectory points. These parameters were selected because several [e.g., 2, 8, 33] have emphasized their importance in correct analysis of a subject. According to some internationally recognized evaluation methods [2, 8, 21, 32, 41], the examination should consists of 10 s of pre-recording and then 52 s of recording, evaluated first with open eyes and then with closed eyes, at a frequency of 100 Hz. All analyses were performed with both feet on the force plate because at first evaluation all patients' ankles were too painful to allow them to stand on a non-stance limb. Patients were barefoot, with heels together and with toes just touching the white line, following the manufacturers' instructions. The toes were set 30° apart.

All subjects were then treated by the same therapist (A.S.) according to a specific protocol, as defined by the Fascial Manipulation technique [9, 37, 47, 48]. The therapist has more than 10 years of experience in this method and is an official teacher of the Fascial Manipulation technique. All subjects underwent three therapy sessions,

Fig. 2 Various points treated according to Fascial Manipulation technique. **a** Pressure is applied selectively over muscle bellies of first dorsal interosseus. **b** Pressure is applied over fascia of distal portion of abductor hallucis muscle. **c** Pressure is applied over fascia of proximal third of peroneal muscles. **d** Example of direct treatment of retinacula

once a week. During each session, four or five points located over the retinacula, called center of fusion, or on the deep muscular fascia, called centers of coordination (Fig. 2), were treated by the therapist. In each session, the treated points were selected from a pattern according to three parameters: the patient's perception of pain, the palpated sensation of fibrosis by the therapist and the limitation of movement along a specific direction of the involved joint. Each session lasted 40 min. All patients were always asked to suspend sports activities for at least 4 days after treatment to avoid further stress to the treated areas.

All subjects were evaluated at the beginning and end of this therapeutic cycle, and also at each follow-up, after 30, 90 and 180 days.

The Statistical Package for the Social Sciences (version 17 for Windows, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. As data did not have normal distribution, the Wilcoxon signed rank test was used to analyze the values of each group and the Mann–Whitney test to evaluate differences between the two groups. The alpha level was set at 0.05.

Fascial manipulation technique

The manual therapy known as Fascial Manipulation technique© views the myofascial system as a three-dimensional continuum and is based on a comprehensive and functional interpretation of the human fascial system. Musculoskeletal dysfunction is considered to occur when the muscular fascia no longer slides, stretches and adapts correctly. Subsequent adaptive fibrosis may develop as a consequence of unremitting non-physiological tension in a fascial segment. Particular attention is directed to the retinacula, considered as fascial reinforcements round the joints. A systematic rationale based on the anatomy of the fascia and the resulting analytical process guarantees personalized treatment for each patient. Therapists use their elbows, knuckles or fingertips over specific points defined by the method and selected according to a precise clinical examination, as indicated by Fascial Manipulation protocols. Localized hyperemia caused by deep friction may affect the ground substance of the retinacula or the deep fascia, restoring gliding between fibers and allowing a new tensional adaptation throughout the fascial system to re-establish a physiological balance.

Results

MRI study

In MR images, the retinacula of the ankle appeared as low signal intensity bands, sharply defined within the context of the subcutaneous tissue in T1-weighted sequences, with a mean thickness of 1.25 mm (SD ± 0.198). Bone insertions were easily located, but separation from the crural fascia was not evident.

The MR study in 21 patients with outcomes of ankle sprain revealed specific alterations of the ankle retinacula, such as edema, interruption of continuity, thickening or adhesion to the subcutaneous layers. In detail, four subjects had a partial or full-thickness gap of one retinaculum, nine had edema around at least one retinaculum, six had an abnormally increased signal in T2-weighted images, two abnormal retinaculum thickening, with uneven appearance of the retinacula, and two adhesion to the subcutaneous planes (Table 2; Fig. 3). These alterations were observed separately or in association. Seven subjects also presented outcomes of anterior talo-fibular ligament rupture and/or bone marrow edema. Two subgroups were identified: group A, formed of the 14 subjects (8 females, 6 males) who only had retinacular alterations, and group B, formed of the 7 subjects (3 females, 4 males) who also had ligament or bone lesions.

Clinical study

The VAS scale, performed before treatment, gave the following mean values: group A 4.0, group B 3.9. The CRTA evaluation, concerning six ADL items, showed average values of 2.76 in group A and 2.73 in group B for each item. Six items of the questionnaire concerning overload activities gave the following average values: 3.76 in group A and 4.40 in group B. The last item, corresponding to the average value concerning distance without fatigue, was 1.78 in group A and 2.0 in group B. Table 3 lists mean values before treatment. The clinical examination revealed the following limitations in ROM: 45% of patients presented less than 15° in dorsi-flexion, 35% less than 5° in eversion and 35% less than 10° in abduction. Table 4 lists the main values recorded on the stabilometric platform before treatment.

At the end of the therapeutic cycle, VAS values were, respectively, 1.1 in group A [the 95% confidence interval (CI) for the mean clarity is (0.178, 1.542)] and 0.57 in

Table 2 Types of damage of the ankle retinacula as appears at MRI study

Subject	Sex	Age (years)	Side	MRI findings						
				Bone edema or result of intracancellous fracture	Damage of anterior talofibular ligament	Alterations of retinacula (F: flexor retinaculum; E: extensor retinaculum; P: peroneal retinaculum)				
						Rupture	Increased thickness	Edema	Abnormal increased signal	Adhesion with the other planes
1	F	27	Right		X			X (E)		
2	M	18	Right	X (talus)				X (P)		
3	F	22	Right		X			X (E)		
4	M	18	Left		X				X (E)	
5	F	21	Right	X (fibula)						X (F)
6	M	21	Right		X				X (P)	
7	M	22	Right		X		X (E)			
8	F	34	Left			X (F)		X (F)		
9	F	18	Right			X (E)				
10	F	18	Right					X (F)		
11	F	27	Right						X (E)	
12	F	26	Right					X (P)		
13	M	24	Left					X (E)		
14	M	23	Right					X (F)		
15	F	20	Right				X (F)			
16	M	24	Left			X (E)		X (F)		
17	M	23	Right			X (P)				
18	M	16	Left						X (P)	
19	M	23	Right							X (P)
20	F	21	Left						X (F)	
21	F	25	Right						X (E)	
	10 M 11 F	22.4 (±4)	15 R 6 L	2	5	4	2	9	6	2

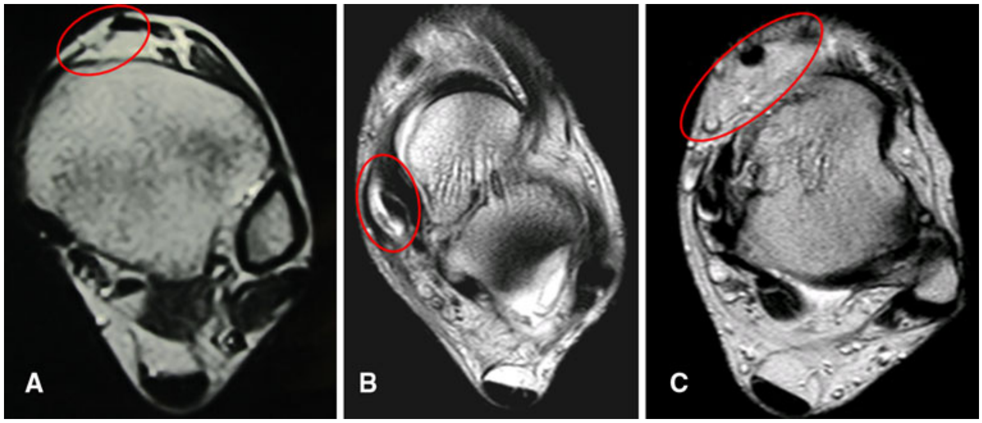

Fig. 3 MRI visualization of various types of ankle retinacula alterations. **a** Evident full-thickness gap of one retinaculum. **b** Edema around retinaculum. **c** Adhesion of retinaculum and subcutaneous tissue (leading to poor identification of retinaculum)

Table 3 Mean values of VAS scale and CRTA questionnaire (A–F: daily living activities, G–L: overload activities)

	Before treatment		After treatment		Follow-up					
					1 month		3 months		6 months	
	Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B	Group A	Group B
Mean values of the VAS	4.00	3.93	0.86	0.27	1.17	0.77	0.17	0.60	0.33	0.62
Mean values of the CRTA items for the daily living activity										
A	3.29	2.07	1.29	1.45	0.67	0.09	0.09	0.17	0.00	0.31
B	3.71	3.07	1.57	1.55	1.00	0.18	0.17	0.10	0.17	0.46
C	3.00	3.29	1.29	1.36	0.67	0.27	0.25	0.10	0.33	0.00
D	2.43	3.07	0.71	1.09	0.50	0.27	0.25	0.10	0.09	0.08
E	2.29	2.57	1.29	1.00	0.67	0.18	0.10	0.30	0.33	0.15
F	1.86	2.29	0.71	1.09	0.33	0.27	0.09	0.10	0.00	0.08
Mean values of the CRTA items for the overload activities										
G	3.86	3.64	1.29	1.73	1.00	0.73	0.50	0.50	0.00	0.31
H	3.57	4.36	1.29	2.00	1.33	0.82	0.25	0.70	0.50	1.00
I	3.00	3.86	1.29	1.45	0.67	0.55	0.00	0.40	0.00	0.23
J	4.00	5.57	1.71	1.82	0.83	1.00	0.25	0.80	0.17	0.62
K	3.86	4.43	2.14	1.64	1.00	0.55	0.25	0.40	0.33	0.77
L	4.29	4.57	2.00	2.09	1.17	0.82	0.50	0.40	0.67	0.85
Pain during walking	2.00	1.79	0.86	0.50	0.50	1.00	0.09	0.90	0.67	0.54
Total value of the CRTA questionnaire	41.16	44.58	17.44	18.77	10.34	6.73	2.79	4.97	3.26	5.40
p value of the comparison between groups A and B	0.54		0.52		0.04		0.02		0.22	

group B (CI 0.695, 1.235), showing statistically significant decrease in values with respect to those before treatment ($p < 0.0001$). The CRTA (self-reported questionnaire) showed significant improvements ($p < 0.0001$) in both ADLs and overload activities. In detail, the ADL results showed improvements of 1.14 in group A and 1.26 in group B, for each of the analyzed items; items concerning overload activities showed improvements of 2.14 in group A and 2.25 in group B (Table 3). The average values for distance without fatigue after treatment were 0.86 in group A and 0.5 in group B. The clinical examination indicated clear improvements in ROM, with only 14% of patients with dorsi-flexion of less than 15° and only 9.5% with eversion of less than 5°.

There were also significant improvements ($p < 0.05$) in the stabilometric platform results (sway path, sway area, maximum swing A-L, maximum swing L-L, ellipse area), with both open and closed eyes (Fig. 4; Table 4).

Table 4 Mean values of stabilometric platform analysis

	Mean values before treatment		Difference between the values before treatment and the values							
	Group A	Group B	After treatment		At the follow-up					
			Group A	Group B	At 1 month		At 3 months		At 6 months	
					Group A	Group B	Group A	Group B	Group A	Group B
Close eyes										
Sway path	12.405	10.860	1.144	2.204	3.139	0.979	0.835	1.157	9.118	10.407
Sway area	24.558	17.232	6.316	5.923	5.398	3.683	2.888	2.821	12.058	13.748
Ant-post oscillations	34.559	23.853	6.294	0.878	7.008	5.639	2.112	7.449	19.299	18.299
Medio-lat oscillations	18.608	17.065	0.038	4.134	4.043	2.881	2.229	1.825	13.532	12.468
Ellipse area	275.975	170.780	89.889	51.568	57.034	96.981	84.329	75.594	85.534	85.378
p value between the two groups	**0.420**		**0.841**		**0.5476**		**0.691**		**1.000**	
Open eyes										
Sway path	9.031	7.437	2.169	1.189	1.353	0.676	0.219	0.994	6.174	7.380
Sway area	15.305	7.596	6.669	1.762	1.363	2.891	0.800	4.151	8.085	8.219
Ant-post oscillations	25.131	17.875	8.027	1.517	2.277	2.191	0.903	0.913	20.185	13.000
Medio-lat oscillations	16.706	10.532	4.034	0.206	5.108	0.223	3.783	3.815	10.995	12.034
Ellipse area	167.731	72.990	58.844	10.311	34.780	4.634	45.057	33.134	85.649	57.027
p value between the two groups	**0.420**		**0.095**		**0.421**		**0.309**		**0.7164**	

Note mean values before treatment and mean differences in values before and after treatment at 1, 3 and 6 months

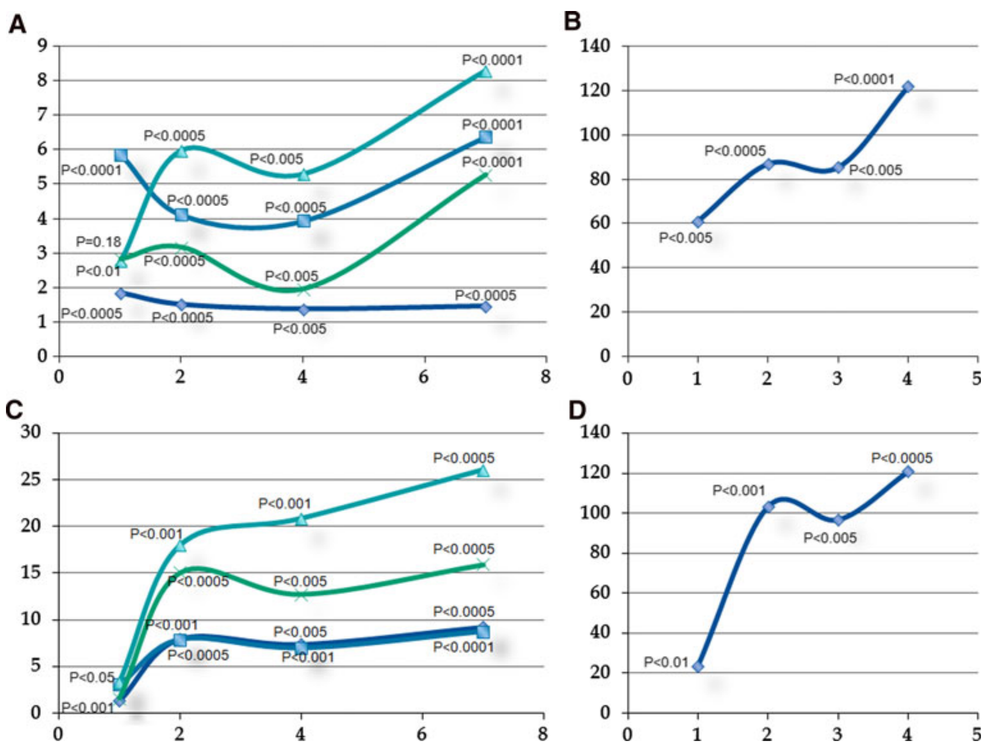

Fig. 4 Trend of stabilometric platform values analyzed with eyes closed (graphs **a** and **b**) and open (graphs **c** and **d**). In detail, graphs **a** and **c** show trends of sway path (*diamonds*), sway area (*squares*), antero-posterior oscillation (*triangles*) and medio-lateral oscillation (*multiplication symbol*); graphs **b** and **d** show trend of ellipse area

No significant differences were found between groups A and B as regards subjective recovery ($p = 0.273$), reported instability, ROM or stabilometric analysis (Table 2), both at the end of treatment and during the follow-ups.

At 1, 3 and 6 months, the initial benefits were generally maintained, as shown in Tables 3 and 4. In particular, the mean VAS value increased slightly at 1 month (CI group A 0.687, 1.653; group B 0.698, 2.238), but fell at the

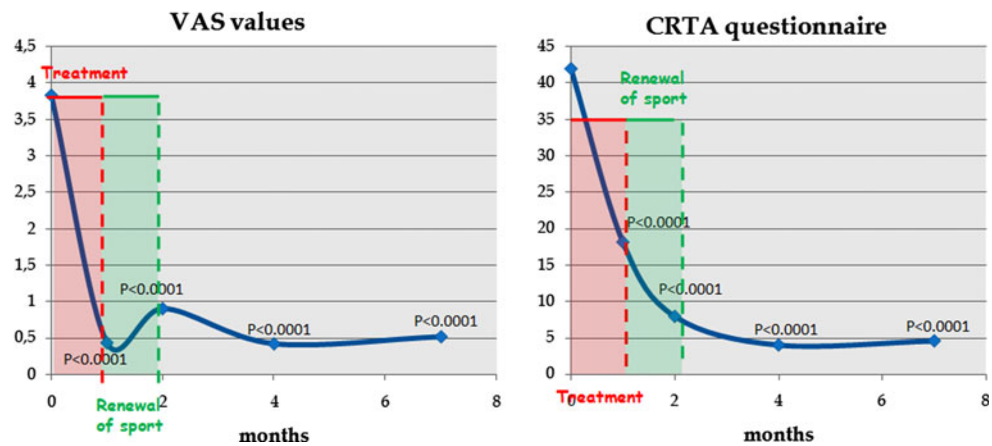

Fig. 5 Trends of mean values of VAS and CRTA evaluations

subsequent follow-up [mean value at 6 months: 0.52 (CI group A 0.083, 0.743; group B 0.743, 1.166) $p < 0.0001$, compared with the mean VAS value at the end of therapy], as shown in Fig. 5.

Discussion

This study shows for the first time that the ankle retinacula may present specific alterations, such as abnormal retinacula thickness or full-thickness gaps, and that these alterations can be clearly evaluated by MRI. The high-signal intensity of the retinacula matches the appearance of the deep fascial planes described in patients with eosinophilic fascitiis of the arm [3] and soft-tissue pathologies [27], as well as in acute and chronic plantar fasciitis [55] and ilio-tibial band syndrome [13]. These findings are not simply of speculative interest, as in clinical practice they allow better analysis of the outcomes of ankle sprain. In particular, this study highlights for the first time the need to consider also the ankle retinacula within the picture of ankle sprain outcomes, so that appropriate and timely therapy can be guaranteed, as augured by Wikstrom et al. [52], and chronic ankle instability can be avoided [11, 28, 50]. The ankle retinacula are rich in proprioceptors [38, 49, 51], so that damage to them may easily cause incorrect activation of embedded receptors, resulting in inaccurate proprioceptive afferents, which is one of the most frequent outcomes of ankle sprains. Poorly coordinated joint movement would then cause peri-articular inflammation, in turn activating nociceptors around the joint.

The anatomical continuity between the ankle retinacula and the deep fascia of the lower may explain why Bullock-Saxton et al. [7], Sedory et al. [44] and McKeon et al. [29, 30] have all reported alterations of motor neuron pool excitability in muscles acting on joints proximal to the ankle with CAI. Damage to the ankle retinacula may alter the lines of forces inside the deep fascia of the whole lower limb and thus the capacity for contraction of the underlying muscles. For the same reason, after unilateral balance training, improvements in motor control in both trained and untrained limbs may be observed [16, 42].

Our data analysis shows a decrease in VAS values of 71.5% in group A and 85.5% in group B at the end of therapy. The CRTA self-reported questionnaire shows a decrease in average values of 58.7% in group A and 53.8% in group B. The item about distance without fatigue shows a reduction of the average value in each group: 57% in group A and 71.9% in group B, corresponding to an increase in distance covered without symptoms.

It is of interest to note that there were no statistically significant differences in the various parameters of either group A or group B, either before or after treatment. Therefore, we hypothesize that the symptoms in the two groups are due more to changes in myofascial structure than to alterations in bones or ligaments, and that when a correct state of myofascial tension is restored, the symptoms of ankle sprain outcomes may decrease.

The particular trend of the VAS value at the first follow-up, as shown in Fig. 5, may be explained by the fact that, during this period, patients have started sports activities again, and are thus making movements and applying loads which they have not done for some time. This improvement in overload activities between the end of treatment and the first follow-up is also confirmed by the trend of the CRTA questionnaire (Fig. 5), which shows a progressive reduction in values, corresponding to increased sports activities. Although this may lead to a slight increase in pain, if the tension and glide capacity of the retinacula have been properly restored during treatment, gradual renewal of sports will allow proper deposition of new collagen fiber bundles inside the retinacula, further enhancing their physiological function. McKeon and Hertel [29] also note the cumulative effect of balance training in patients with outcomes of ankle sprain.

This study has two major limitations: there was no control group, but all patients presented with stable symptoms for an average period of 2.7 years. This fact permits to consider with interest every type of changes in the symptoms of the patients after a short therapy. The second limitation concerns the lack of control MRI at the end of treatment. However, in the absence of serious clinical problems, the cost of MRI did not allow us to re-prescribe it.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Abu-Hijleh MF, Harris PF (2007) Deep fascia on the dorsum of the ankle and foot: extensor retinacula revisited. Clin Anat 20:186–195
2. Baratto L, Morasso PG, Re C, Spada G (2002) A new look at posturographic analysis in the clinical context: sway-density versus other parameterization techniques. Mot Control 6:246–270
3. Baumann F, Brühlmann P, Andreisek G, Michel BA, Marincek B, Weishaupt D (2005) MRI for diagnosis and monitoring of patients with eosinophilic fasciitis. Am J Roentgenol 184:169–174
4. Benjamin M (2009) The fascia of the limbs and back—a review. J Anat 214:1–18
5. Braun BL (1999) Effects of ankle sprain in a general clinic population 6 to 18 months after medical evaluation. Arch Fam Med 8:143–148
6. Brown CN, Mynark R (2007) Balance deficits in recreational athletes with chronic ankle instability. J Athl Train 42:367–373
7. Bullock-Saxton JE, Janda V, Bullock MI (1994) The influence of ankle sprain injury on muscle activation during hip extension. Int J Sports Med 15:330–334
8. Chiari L, Rocchi L, Cappello A (2002) Stabilometric parameters are affected by anthropometry and foot placement. Clin Biomech 17:666–677
9. Day JA, Stecco C, Stecco A (2009) Application of Fascial Manipulation technique in chronic shoulder pain—anatomical basis and clinical implications. J Bodyw Mov Ther 13:128–135
10. Delahunt E, Monaghan K, Caulfield B (2006) Altered neuromuscular control and ankle joint kinematics during walking in subjects with functional instability of the ankle joint. Am J Sports Med 34:1970–1976
11. Denegar CR, Miller SJ (2002) Can chronic ankle instability be prevented? Rethinking management of lateral ankle sprains. J Athl Train 37:430–435
12. Docherty CL, Arnold BL (2008) Force sense deficits in functionally unstable ankles. J Orthop Res 26:1489–1493
13. Fairclough J, Hayashi K, Toumi H, Lyons K, Bydder G, Phillips N, Best TM, Benjamin M (2006) The functional anatomy of the iliotibial band during flexion and extension of the knee: implications for understanding iliotibial band syndrome. J Anat 208:309–316
14. Fox J, Docherty CL, Schrader J, Applegate T (2008) Eccentric plantar-flexor torque deficits in participants with functional ankle instability. J Athl Train 43:51–54
15. Freeman MA, Dean MR, Hanham IW (1965) The etiology and prevention of functional instability of the foot. J Bone Joint Surg Br 47:678–685
16. Gauffin H, Tropp H, Odenrick P (1988) Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. Int J Sports Med 9:141–144
17. Gribbe PA, Hertel J, Denegar CR (2007) Chronic ankle instability and fatigue create proximal joint alterations during performance of the Star Excursion Balance Test. Int J Sports Med 28:236–242
18. Hamilton WG (1994) Current concepts in the treatment of acute and chronic lateral ankle instability. Sports Med 4:264–266
19. Hertel J (2002) Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. J Athl Train 37:364–375
20. Hertel J (2008) Sensorimotor deficits with ankle sprains and chronic ankle instability. Clin Sports Med 27:353–370
21. Hubbard TJ, Kramer LC, Denegar CR, Hertel J (2007) Correlations among multiple measures of functional and mechanical instability in subjects with chronic ankle instability. J Athl Train 42:361–366
22. Ivins D (2006) Acute ankle sprain: an update. Am Fam Physician 74:1714–1726
23. Jerosch J, Bischof M (1996) Proprioceptive capabilities of the ankle in stable and unstable joints. Sports Exerc Inj 2:167–171
24. Klein DM, Katzman BM, Mesa JA, Lipton JF, Caligiuri DA (1999) Histology of the extensor retinaculum of the wrist and the ankle. J Hand Surg 24A:799–802
25. Konradsen L, Magnusson P (2000) Increased inversion angle replication error in functional ankle instability. Knee Surg Sports Traumatol Arthrosc 8:246–251
26. Lentell G, Baas B, Lopez D, Mc Guire L, Sarrels M, Snyder P (1995) The contribution of propriocective deficits, muscle function, and anatomic laxity to functional instability of the ankle. J Orthop Sports Phys Ther 21:206–215
27. Loh NN, Ch'en IY, Cheung LP, Li KC (1997) Deep fascial hyperintensity in soft-tissue abnormalities as revealed by T2-weighted MR imaging. Am J Roentgenol 168:1301–1304
28. McGuine TA, Keene JS (2006) The effect of a balance training program on the risk of ankle sprains in high school athletes. Am J Sports Med 34:1103–1111
29. McKeon PO, Hertel J (2008) Systematic review of postural control and lateral ankle instability. Part II: Is balance training clinically effective? J Athl Train 43:305–315
30. McKeon PO, Ingersoll CD, Kerrigan CD, Saliba E, Bradford BC, Hertel J (2008) Balance training improves function and postural control in those with chronic ankle instability. Med Sci Sports Exerc 40:1810–1819
31. Michalak K, Jaśkowski P (2003) Dimensional complexity of posturographic signals: influence of window width on dimensional complexity estimation. Curr Topics Biophys 27:27–36
32. Mitchell A, Dyson R, Hale T, Abraham C (2008) Biomechanics of ankle instability. Part 2: Postural sway-reaction time relationship. Med Sci Sports Exerc 40:1522–1528
33. Morasso P, Re C, Giacomozzi C, Macellari V (2002) A testing device for the verification of the accuracy of the COP measurements in stabilometric platforms. Gait Posture 16:S215–S216
34. Myers JB, Riemann BL, Hwang JH, Fu FH, Lephart SM (2003) Effect of peripheral afferent alteration of the lateral ankle ligaments on dynamic stability. Am J Sports Med 31:498–506
35. Numkarunarunrote N, Malik A, Aguiar RO, Trudell DJ, Resnick D (2007) Retinacula of the foot and ankle: MRI with anatomic correlation in cadavers. Am J Roentgenol 188:348–354
36. Palmieri-Smith RM, Hopkins JT, Brown TN (2009) Peroneal activation deficits in persons with functional ankle instability. Am J Sports Med 37:982–988
37. Pedrelli A, Stecco C, Day JA (2009) Treating patellar tendinopathy with Fascial Manipulation. J Bodyw Mov Ther 13:73–80
38. Pisani G (2006) Chirurgia del piede, 3rd edn. Edizioni Minerva Medica, Turin

39. Platzer W (1978) Locomotor system. In: Kahle WH, Leonhardt W, Platzer W (eds) Color atlas and textbook of human anatomy, 1st edn. Thieme, Stuttgart
40. Riemann BL (2002) Is there a link between chronic ankle instability and postural instability? J Athl Train 37:386–393
41. Ross SE, Guskiewicz KM, Bing Y (2005) Single-leg jump-landing stabilization times in subjects with functionally unstable ankles. J Athl Train 40:298–304
42. Rozzi SL, Lephart SM, Sterner R, Kuligowski L (1999) Balance training for persons with functionally unstable ankles. J Orthop Sports Phys Ther 29:478–486
43. Safran MR, Benedetti RS, Bartolozzi AR, Mandelbaum BR (1999) Lateral ankle sprains: a comprehensive review. Part 1: Etiology, pathoanatomy, histopathogenesis, and diagnosis. Med Sci Sports Exerc 31:S429–S437
44. Sedory EJ, McVey ED, Cross KM, Ingersoll CD, Hertel J (2007) Arthrogenic muscle response of the quadriceps and hamstrings with chronic ankle instability. J Athl Train 42:355–360
45. Solere R, Solere H (2006) Traitement d'une entorse de la cheville en ostéopathie. 8 Avril, Bologne
46. Solere R, Soyer-Gobillard MO (2004) Vers de nouveaux modèles théoriques et thérapeutiques non médicamenteux par l'élargissement du champ des connaissances des sciences motrices, de la réhabilitation et de la santé. Revue Internationale de Recherche en Kinésithérapie 2:31–37
47. Stecco L (2004) Fascial manipulation, 1st edn. Piccin, Padua
48. Stecco L, Stecco C (2009) Fascial manipulation: practical part, 1st edn. Piccin, Padua
49. Stecco C, Macchi V, Porzionato A, Morra A, Parenti A, Stecco A, Delmas V, De Caro R (2010) The ankle retinacula: morphological evidence of the proprioceptive role of the fascial system. Cells Tissues Organs 192:200–210
50. Verhagen E, van der Beek A, Twisk J, Bouter L, Bahr R, van Mechelen W (2004) The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. Am J Sports Med 32:1385–1393
51. Viladot A, Lorenzo JC, Salazar J, Rodríguez A (1984) The subtalar joint: embryology and morphology. Foot Ankle 5:54–66
52. Wikstrom EA, Naik S, Lodha N, Cauraugh JH (2010) Bilateral balance impairments after lateral ankle trauma: a systematic review and meta-analysis. Gait Posture 31:407–414
53. Willems T, Witvrouw E, Verstuyft J, Vaes P, De Clercq D (2002) Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. J Athl Train 37:487–493
54. Yeung MS, Chan KM, So CH, Yuan WY (1994) An epidemiological survey on ankle sprain. Br J Sports Med 28:112–116
55. Yu JS (2000) Pathologic and post-operative conditions of the plantar fascia: review of MR imaging appearances. Skeletal Radiol 29:491–501