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ORIGINAL ARTICLE

Ultrasonography effectiveness of the vibration vs cryotherapy added to an eccentric exercise protocol in patients with chronic mid-portion Achilles tendinopathy: A randomised clinical trial

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Tendinopathy is a very common disease in the general population as well as in athletes. The aim of the present study was to examine the tendon thickness and cross-sectional area (CSA) in subjects with chronic mid-portion Achilles tendinopathy (AT) who engaged in either an eccentric exercise (EE) programme with vibration training or an EE programme combined with cryotherapy. A sample of 61 patients with chronic mid-portion AT were recruited and divided into two groups: EE programme vibration training (n = 30) and EE programme combined with cryotherapy (n = 31). Three ultrasound assessments were performed: pre-intervention and at 4, and at 12 weeks. The comparison of thickness and CSA measures at baseline, 4, and 12 weeks showed a significant ($P < 0.05$) increase at 0, 2, 4, and 6 cm in maximal isometric contraction and at rest in subjects with chronic mid-portion AT. The EE vibration training resulted in a statistically significant CSA increase compared with the cryotherapy group in patients with chronic mid-portion AT.

KEYWORDS
exercise therapy, tendinopathy, ultrasonography

1 | INTRODUCTION

Tendinopathy is a very common disease in the general population as well as among athletes.[1] Because of the Achilles tendon's structure, as one of the strongest and largest tendons in the human body, it is highly susceptible to suffer from tendinopathy.[2] Of individuals who suffer from Achilles tendinopathy (AT), 75% are between 30 and 49 years old, and they are usually injured while performing sports.[2] Kujala et al[3] estimated that the incidence of tendon injuries is between 30% and 50% of all sports injuries and 6% in sedentary people. In addition, AT is diagnosed in 55% to 65% of all Achilles tendon examinations.[4]

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The aetiology of tendinopathy remains unclear. Histopathological examination of the tendon tissue clearly shows no evidence of prostaglandin-mediated inflammation.[5,6] Pingel et al[7] reported that degenerative changes in tendon structure, poor neovascularisation, and core tendon growth are caused by a failed healing process. Moreover, a lack of flexibility in the lower limb; biomechanical factors such as hyper-pronation, disturbances in blow flow, and a high body mass index (BMI); and a sedentary lifestyle are considered risk factors.[8–10] Ohberg and Alfredson[11] reported that the appearance of new vessels in the tendon pain areas is related to pain. A nerve ingrowth in the mid-Achilles portion could be another source of pain.[1,12]

Several studies have shown the efficacy of loading interventions, such as eccentric exercise (EE) training, as one of the main treatment options for AT.[13,14] Likewise, Beyer et al[4] compared effectiveness of eccentric training (EEC) to heavy slow resistance training in patients with AT and found benefits to both interventions. Mafi et al[15] reported better short-term clinical results for EEC compared with concentric exercise in subjects with AT.

Hilgers et al[16] presented whole-body vibration training as an alternative to conventional interventions for motor control disorders in the lower limbs, showing benefits in endurance and muscle strength in individuals with multiple sclerosis. Therefore, Horstmann et al[17] suggested that improving triceps surae muscle strength, modulating the neuromuscular system, increasing lower limb muscle flexibility, and relieving pain symptoms are likely good approaches for patients with AT. Following those suggestions, they carried out a study in 58 patients with AT, performing a 12-week whole-body training intervention that demonstrated benefits in pain, sonographic, and muscle strength parameters. Because of this, whole-body vibration has proven to be a good therapeutic choice in AT subjects.

Cryotherapy treatment has also shown benefits in subjects with AT. Knobloch and Hufner[18] found that cryotherapy improves pain and normalises blow flow in subjects with AT. In addition, it has been observed that cryotherapy and compression were effective at increasing tendon oxygen saturation in patients with AT.[19] Therefore, it has been observed that cryotherapy could have positive effects combined with other therapies and alone in patients with AT.

Rehabilitative ultrasound imaging (RUSI) has been used to evaluate musculoskeletal features that could influence a physical therapy evaluation, such as thickness and cross-sectional area (CSA).[20] RUSI has been used to examine motor control.[21] Considering the lower limbs, Lobo et al[22] reported that peroneus longus CSA was reduced in subjects with lateral ankle sprains. CSA and thickness of the abductor hallucis and flexor halluces were reduced in subjects with hallux valgus.[23] Angin et al[24] found thinner plantar fascia in subjects with pes planus. In addition, other novel evaluation systems, such as infrared thermography, are being studied to assess the Achilles tendons,[25,26] but further research is needed in this emerging line. Therefore, RUSI is considered a relatively inexpensive, non-invasive, and portable technique that provides an examination of the thickness and CSA of multiples tissues.[25] Moreover, it has been used to measure thickness[27,28] and CSA[29,30] in subjects with AT.

The aim of the present study was to examine the tendon thickness and CSA in subjects with chronic mid-portion AT who performed an EE programme vibration training compared with an EE programme combined with cryotherapy. It was hypothesised that an EE programme vibration training is more effective than an EE programme combined with cryotherapy in patients with mid-portion AT.

Key Messages

- we examined the tendon thickness and cross-sectional area in subjects with chronic mid-portion Achilles tendinopathy in two treatment programmes combined with cryotherapy
- the eccentric exercise vibration increase training resulted in a statistically significant cross-sectional area in these patients
- preventive treatment in patients with Achilles tendinopathy are extremely important to improve foot care and overall health

2 | METHODS

2.1 | Design

A prospective, single-blinded, randomised, controlled clinical trial (NCT03029910) was performed from January to December 2017 following the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

2.2 | Ethical considerations

The study was approved by the ethics committee of Hospital Universitario de la Princesa (2828A), Madrid, Spain. All the participants in the study signed the informed consent form. The study also adhered to the ethical standards of the Declaration of Helsinki for human experimentation.[29]

2.3 | Participants

For this study, 61 patients with chronic mid-portion AT (age: 41.2 ± 10 years) were recruited and divided into two groups: EE programme vibration training (n = 30) and EE programme combined with cryotherapy (n = 31) (Figure 1). Participants' inclusion criteria were as follows: aged between 18 and 65 years, having symptoms for at least 3 months,[31] and having mid-portion Achilles pain (2–7 cm proximal to insertion) on palpation.[13] Exclusion criteria were a lower limb disease within the last 12 months, previous fracture or surgical intervention,[31] any systemic disease,[13] and past negative experiences with EE[32] vibration and cryotherapy interventions.

2.4 | Eccentric exercise programme

Both groups performed a 12-week EE programme based on the guidelines given by Alfredson et al[13]. The patients performed 90 repetitions by completing three sets of 15 repetitions in two training positions (knee fully extended and knee slightly flexed) once a day. Throughout the intervention, the EE programme was performed in self-loading. The subjects were advised that they might feel slight pain.[13]

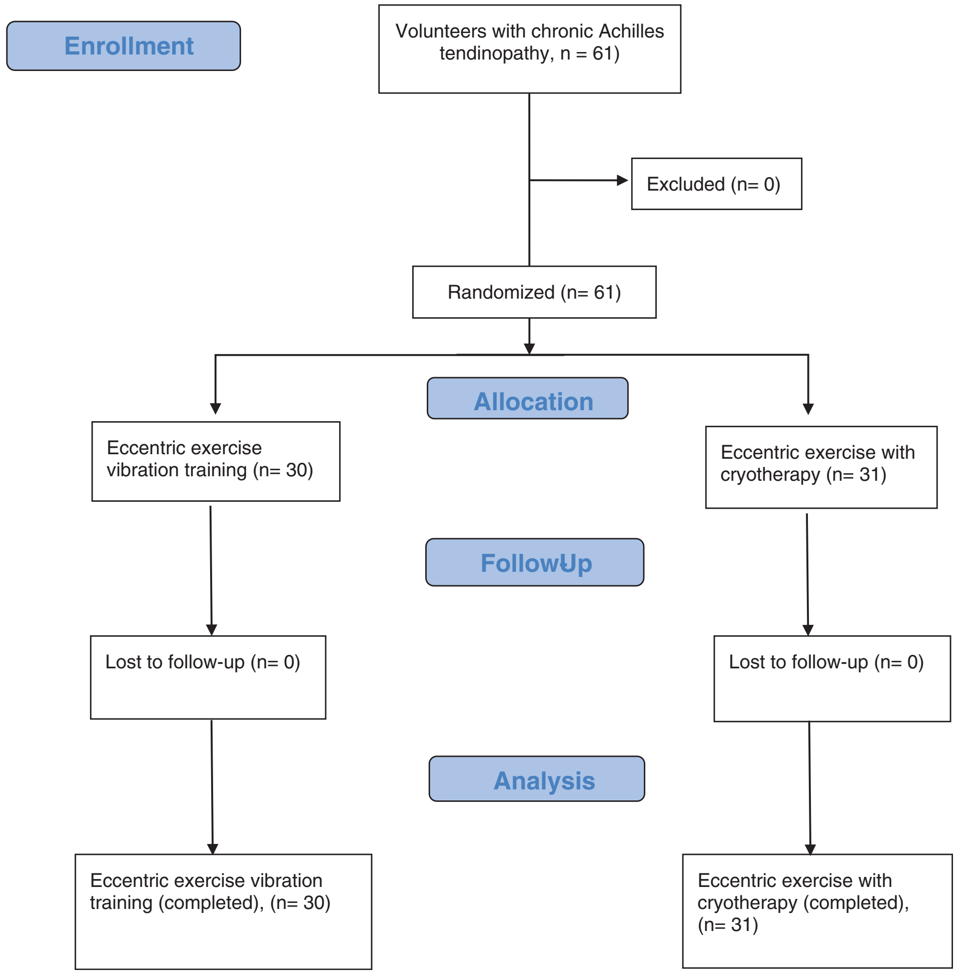

FIGURE 1 CONSORT flow algorithm outlining participant enrolment, allocation, follow up, and attrition numbers for this study

2.5 | Eccentric exercise vibration training

The vibration training was performed on a Power Plate My3 (Performance Health Systems, Northbrook, Illinois). Following the guidelines in Hazell et al[33], patients were placed in a standing position on the vibration platform that was set to a vibration frequency of 35 Hz at an amplitude of 4 mm for 5 minutes. The patients performed the EE programme on the platform during the vibration.

2.6 | Cryotherapy intervention

Prior to the EE programme, a cryotherapy intervention was carried out. Patients were dressed in shorts without shoes and socks and were seated on a chair. Patients immersed the affected lower limb in a 70-L bucket and 55-cm deep at 8°C ± 2°C water for 17 minutes.[34] Immediately after the intervention with cryotherapy, the EE programme was carried out.

2.7 | Sonographic assessment

A sonographic assessment was performed with a LogiQ P7 (GE Healthcare; UK) with a 4 to 13 MHz-range linear transducer (L6–12- RS type; 38-mm footprint). According to Rompe et al,[35] ultrasound images were obtained in a prone position with both feet free from the examination table. Achilles tendon thickness and CSA measures were recorded at 0, 2, 4, and 6 cm from the calcaneal insertion at rest and in maximal isometric contraction. During the study investigation, three assessments were carried out: pre-intervention and at 4 and at 12 weeks. The mean of three repeated values was calculated for each measure. ImageJ software (version 2.0; US National Institutes of Health, Bethesda, Maryland) was used to measure all of the images offline.[36]

2.8 | Statistical analysis

SPSS 23.0 software (IBM SPSS Statistics for Windows; IBM Corp., NY, New York) was used for data analysis. The Shapiro-Wilks test was used for the normality assumption. For the baseline comparison, the Student *t* test was used considering the homogeneity of variance using Levene´s test. A two-way analysis of variance (ANOVA) for repeated measures was used to examine the effects of intra-subjects (pre- and post-) and inter-subject (treatment group) aspects on the dependent variables. The post hoc analyses were carried out by means of Bonferroni´s correction. An α error of 0.05 (95% confidence interval) and a desired power of 80% (β error of 0.2) were used. The level of significance was set at $P < 0.05$.

3 | RESULTS

Regarding Table 1, socio-demographic data did not show statistically significant differences ($P > 0.05$). As shown in Table 2, the comparison of thickness measures at baseline, 4, and 12 weeks showed a significant ($P < 0.05$) increase at 0, 2, 4, and 6 cm in maximal isometric contraction and at rest. No statistically significant differences were found between intervention groups. Regarding Table 3, the comparison of CSA measures at baseline, 4, and 12 weeks showed a significant ($P < 0.05$) increase at 0, 2, 4, and 6 cm in maximal contraction and at rest in favour of the EE vibration training group. (Figure 2A-D, respectively). At last, the comparison of CSA measures at baseline, 4 and 12 weeks showed a significant ($P < 0.05$) increase at 2, 4, and 6 cm, being positive between contraction and at rest.

TABLE 2 Thickness measures

Measurement (cm)	Cryotherapy intervention (n = 31)	Eccentric exercise vibration training (n = 30)	Intra-subject effects: Time *P*-value	Intra-subject effects: Treatment X Time *P*-value
Thickness at rest 0 cm			0.001*	0.359
Baseline	4.65 ± 0.8	4.77 ± 0.9		
4 weeks	4.79 ± 0.7	4.82 ± 0.7		
12 weeks	5.09 ± 0.7	5.3 ± 0.7		
Thickness contraction 0 cm			0.001*	0.121
Baseline	4.85 ± 0.8	5.08 ± 0.8		
4 weeks	5.10 ± 0.7	5.17 ± 0.7		
12 weeks	5.29 ± 0.8	5.67 ± 0.8		
Thickness at rest 2 cm			0.001*	0.333
Baseline	5.70 ± 1.1	5.97 ± 1,2		
4 weeks	5.98 ± 1.1	6.07 ± 1,0		
12 weeks	6.20 ± 1.1	6.43 ± 1,0		
Thickness contraction 2 cm			0.001*	0.830
Baseline	5.94 ± 1.3	6.11 ± 1.3		
4 weeks	6.15 ± 1.2	6.32 ± 1.1		
12 weeks	6.50 ± 1.3	6.60 ± 1.0		
Thickness at rest 4 cm			0.001*	0.874
Baseline	6.41 ± 2.0	6.92 ± 1.8		
4 weeks	6.64 ± 1.9	7.20 ± 1.8		
12 weeks	7.02 ± 2.1	7.55 ± 1.8		
Thickness contraction 4 cm			0.001*	0.660
Baseline	6.70 ± 2.3	7.25 ± 2,2		
4 weeks	6.97 ± 2.1	7.40 ± 2,1		
12 weeks	7.26 ± 2.3	7.84 ± 2.2		
Thickness at rest 6 cm			0.001*	0.354
Baseline	7.64 ± 2.1	8.94 ± 2.7		
4 weeks	7.91 ± 2.2	9.22 ± 2.8		
12 weeks	8.01 ± 2.2	9.49 ± 2.8		
Thickness contraction 6 cm			0.001*	0.428
Baseline	8.01 ± 2.6	9.36 ± 3.2		
4 weeks	8.24 ± (2.5)	9.69 ± 3.3		
12 weeks	8.39 ± (2.6)	9.96 ± 3.4		

Values are mean ± SD unless otherwise indicated.
**P*-value statistically significant differences.

4 | DISCUSSION

The goal of the study was to examine whether the EE vibration training programme and cryotherapy with EE led to benefits for thickness and CSA in patients with mid-portion AT.

4.1 | Tendon thickness

Both groups in our study showed an increase in tendon thickness at 0, 2, 4, and 6 cm in maximal isometric contraction and at rest. According to Docking and Cook,[37] a pathological tendon may compensate for areas of disorganisation by increasing in tendon thickness. In addition, the increase of a tendon thickness could be related to the mechanical stimuli induced by high-intensity exercise, such an EE, which can be the primary mechanism for muscle and tissue hypertrophy.[36] Cook et al.[38] reported that only 30% of subjects with AT could return to values prior to the injury. Although AT tendons can improve their function, the ultrasound values did not improve.[39]

4.2 | Cross-sectional area

The results of the present study showed a CSA increase at 0, 2, 4, and 6 cm in both intervention groups in maximal isometric contraction and at rest. Between groups, statistically significant differences were found ($P < 0.05$) in favour of the EE vibration training group in all measures. Similar results were found in a study by Rosenberg et al.,[40] reporting a CSA increase in subjects who performed resistance vibration training. In addition, the intensity of the contraction force produced by the vibratory training depends on the previous stretching of the tissue, being maximal during EE.[17] Therefore, a more intense muscular contraction is produced with EE vibration training, causing adaptations such as CSA tendon increase. In line with Arya and Kulig,[41] the results of our study show an increase of CSA in subjects with mid-portion AT. Cook and Purdam[42] reported that the CSA increase is produced to compensate the compression forces that occur in the lower limb.

TABLE 1 Socio-demographic data

Data	Cryotherapy	EE vibration training	*P*-value
Gender			0.645
Men (n, %)	5 ± 16.13	4 ± 13.33	
Women (n, %)	26 ± 83.87	26 ± 86.66	
Age (years)	42.1 ± 9.2	41.1 ± 8.2	0.645
BMI (kg/m^2)	24.8 ± 2.4	25.2 ± 2.5	0.442
Injury time, mean (SD)	4.4 ± 2.6	4.1 ± 4.4	0.145

Abbreviations: BMI, body mass index; EE, eccentric exercise.

TABLE 3 Cross-sectional area measurements

			Intra-subject effects	
Measurement (cm^2)	**Cryotherapy intervention (n = 31)**	**Eccentric exercise vibration training (n = 30)**	**Time *P*-value**	**Treatment × time *P*-value**
CSA at rest 0 cm			0.001*	0.013*
Baseline	77.82 ± 29.4	80.77 ± 23.3		
4 weeks	83.38 ± 28.9	85.53 ± 24.0		
12 weeks	90.35 ± 34.7	100.88 ± 32.9		
CSA contraction 0 cm			0.001*	0.002*
Baseline	86.07 ± 34.4	85.47 ± 25.9		
4 weeks	91.59 ± 33.7	93.27 ± 27.9		
12 weeks	97.87 ± 38.4	109.30 ± 36.5		
CSA at rest 2 cm			0.001*	0.003*
Baseline	171.32 ± 69.6	173.78 ± 58.4		
4 weeks	178.88 ± 70.6	183.91 ± 60.4		
12 weeks	187.84 ± 80.2	213.25 ± 80.8		
CSA contraction 2 cm			0.001*	0.006*
Baseline	172.88 ± 65.9	174.74 ± 52.9		
4 weeks	184.71 ± 71.8	189.23 ± 54.8		
12 weeks	195.90 ± 80.8	223.58 ± 81.6		
CSA at rest 4 cm			0.001*	0.001*
Baseline	193.51 ± 79.5	192.62 ± 59.8		
4 weeks	202.52 ± 77.7	206.04 ± 65.6		
12 weeks	210.83 ± 83.6	233.35 ± 81.2		
CSA contraction 4 cm			0.001*	0.005*
Baseline	192.21 ± 70.0	190.54 ± 48.8		
4 weeks	207.13 ± 75.0	210.22 ± 60.4		
12 weeks	218.65 ± 84.9	241.62 ± 78.0		
CSA at rest 6 cm			0.001*	0.015*
Baseline	216.37 ± 86.0	224.75 ± 72.7		
4 weeks	225.00 ± 87.0	237.06 ± 79.3		
12 weeks	236.19 ± 93.0	263.92 ± 88.5		
CSA contraction 6 cm			0.001*	0.019*
Baseline	212.94 ± 79.6	212.79 ± 61.4		
4 weeks	225.71 ± 84.0	231.64 ± 66.6		
12 weeks	238.75 ± 91.3	263.19 ± 80.1		
CSA difference contraction: at rest 0 cm			0.144	0.143
Baseline	8.25 ± 8.1	4.70 ± 8.4		
4 weeks	8.21 ± 6.6	7.73 ± 7.1		
12 weeks	7.52 ± 5.1	8.42 ± 7.0		
CSA difference contraction: at rest 2 cm			0.001*	0.585
Baseline	1.56 ± 17.5	0.96 ± 24.2		
4 weeks	5.83 ± 15.6	5.32 ± 9.7		
12 weeks	8.06 ± 12.3	10.33 ± 18.5		
CSA difference contraction: at rest 4 cm			0.002*	0.930
Baseline	−1.30 ± 26.7	−2.08 ± 22.9		
4 weeks	4.61 ± 17.2	4.19 ± 16.8		
12 weeks	7.83 ± 11.0	8.27 ± 20.1		
CSA difference contraction: at rest 6 cm			0.021*	0.543
Baseline	−3.43 ± 27.4	−11.96 ± 29.5		
4 weeks	0.72 ± 17.7	−5.41 ± 20.5		
12 weeks	2.56 ± 13.1	−0.73 ± 20.4		

Abbreviation: CSA, cross-sectional area.
Values are mean (SD) unless otherwise indicated.
**P*-value statistically significant differences.

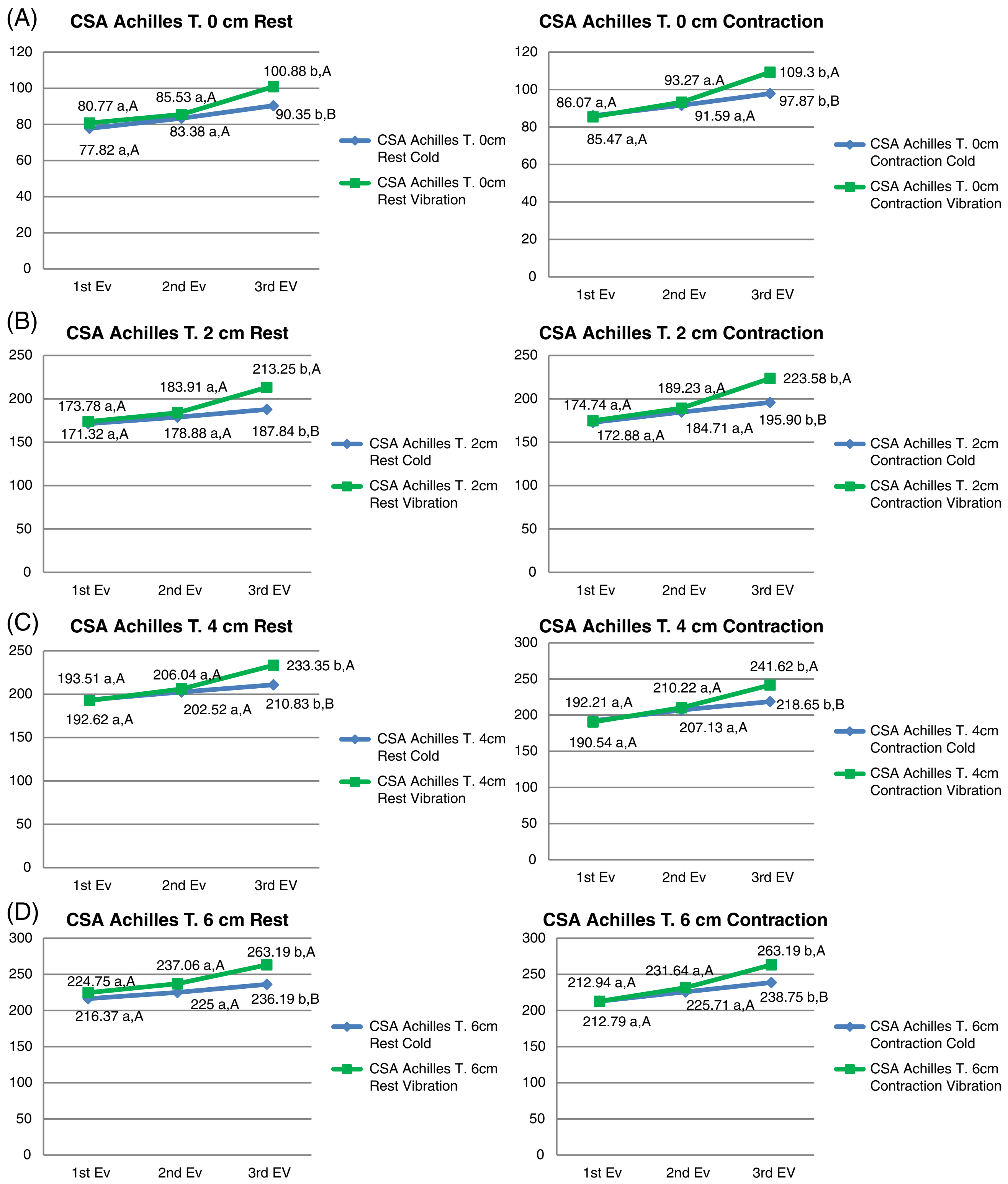

FIGURE 2 Cross-sectional area values at 0, 2, 4, and 6 cm. A, B, Significant difference between follow up and baseline values ($P < 0.05$). A-B, significant difference between groups ($P < 0.05$). EV, evaluation

For the difference between CSA in muscle contraction and at rest, statistically significant differences ($P < 0.05$) were found at 2, 4, and 6 cm from the insertion of the calcaneus at 12 weeks in both groups. The difference in CSA was increased at the end of the intervention with respect to the baseline. According to Reeves and Cooper,[43] a transverse tendon deformation only occurred in selected regions of the distal Achilles tendon at 20% and 30% of maximal voluntary contraction, unlike the proximal portion of the Achilles. Therefore, the contraction tendon surface is slightly lower in the proximal tendon areas at low intensity. Nuri et al[31] reported a decrease in CSA with a 50% maximal voluntary contraction in subjects with AT. Our study showed a CSA increase being positive the difference between contraction and at rest, supporting EE and hypertrophy theories.[38] Likewise, no statistically significant differences were observed between EE vibration training and cryotherapy, which indicates that this improvement is due exclusively to the performance of the EE.

4.3 | Limitations

Several limitations should be considered in the present study. First, the vibration and cryotherapy interventions contained an eccentric exercise; therefore, it is difficult to conclude whether the increases in measures were caused by the eccentric exercise or the vibration and cryotherapy in a reliable manner. Second, other ultrasonography modes, such as M-mode, and software analysis, such as sonoelastography, were not used but may be useful for the study of muscle tissue characteristics.[44] Short-term follow up was performed, but long-term follow up must be performed in future studies for to know if the effects in CSA are maintained.

5 | CONCLUSIONS

EE vibration training programme and cryotherapy with EE produced a thickness and CSA increase at 0, 2, 4, and 6 cm in maximal isometric contraction and at rest in subjects with chronic mid-portion AT. No statistically significant differences were found between intervention groups for thickness measures. EE vibration training has shown a statistical CSA increase than the cryotherapy group in patients with chronic mid-portion AT.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to report.

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