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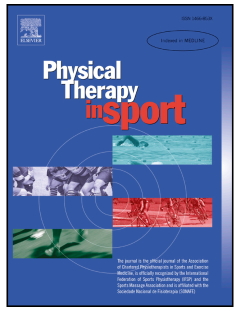

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Feature Article

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Feature Article

Vibration increases multifidus cross-sectional area versus cryotherapy added to chronic non-insertional Achilles tendinopathy eccentric exercise

Abstract

Objective: To assess multifidus muscle thickness, cross-sectional area (CSA) and disability in patients with chronic non-insertional Achilles tendinopathy (AT) who developed an eccentric exercise (EE) vibration program compared to an EE program with cryotherapy.

Design: Single-blinded randomized clinical trial.

Setting: Outpatient clinic.

Participants: A total sample of 61 patients diagnosed with chronic non-insertional AT was recruited and randomly divided into two groups. A group (n=30) developed the EE program plus vibration and B group (n=31) received the EE program plus cryotherapy for 12 weeks. Multifidus thickness and CSA were measured at rest and during maximal isometric contraction by ultrasound imaging. The Victorian Institute for Sport Assessment (VISA-A) was used to asses functionality.

Results: Multifidus CSA was statistically significant increased ($P < 0.05$) for the EE vibration program group with respect to EE plus cryotherapy during maximal isometric contraction and at rest at 12-weeks after intervention in individuals with chronic non-insertional AT. Despite both interventions showed differences for the multifidus thickness and AT disability variables over time, there were not between-groups differences.

Conclusions: Authors encourage the use of vibration with respect to cryotherapy added to EE programs in order to enhance multifidus CSA in addition to lower limb functionality in individuals who suffer from chronic non-insertional AT.

Introduction

Achilles Tendinopathy (AT) was described as a common overuse injury of the lower limb and one of the most prevalent conditions in athletes as well as in the general population (Hakan Alfredson, 2003). Cook et al. (Cook, Khan, & Purdam, 2002) described the AT as a clinical condition characterized by pain, swelling, morning stiffness and impaired function during sports activities, such as hopping and running. In addition, AT can be divided into three categories: insertional tendinopathy, whose prevalence may reach up to 25% of AT; non-insertional tendinopathy whose prevalence may reach up to 66% of AT; and other disturbances (e.g. bursitis) (Li & Hua, 2016; Paavola et al., 2002).

Regarding the description reported by Li and Hua (Li & Hua, 2016), non-insertional and insertional AT were located from 2 to 6 cm proximal to the Achilles insertion at the calcaneus bone. Albers et al. (Albers, Zwerver, Diercks, Dekker, & Van den Akker-Scheek, 2016) reported an AT incidence rate from 1.16 to 2.35 per 1000 persons-year. In addition, individuals who suffer from tendinopathy symptoms showed a negative impact of quality of life, sports, basic daily life and working activities (Silbernagel, Gustavsson, Thomee, & Karlsson, 2006).

Current literature reported that the etiology of the AT is multifactorial, comprising both intrinsic and extrinsic factors. Common intrinsic factors included an increased body mass index (BMI) (Gaida, Cook, & Bass, 2008), sex (Longo et al., 2009), obesity, hypertension, systemic diseases (Holmes & Lin, 2006), and altered gait kinematics (Munteanu & Barton, 2011). Extrinsic factors could include training loads failed programs (Di Caprio, Buda, Mosca, Calabro', & Giannini, 2010; Karsten Knobloch, Yoon, & Vogt, 2008), training surfaces (Di Caprio et al., 2010), temperature (Milgrom, Finestone, Zin, Mandel, & Novack, 2003), previous tendinopathy episodes (Saragiotto et al., 2014), an ankle dorsiflexion range of motion (ROM) decrease (Mahieu, Witvrouw, Stevens, Van Tiggelen, & Roget, 2006), overpronation (Van Ginckel et al., 2009), and muscle strength (Mahieu et al., 2006). Moreover, degenerative changes, a lack of the inflammation biomarkers and poor neovascularization in tendon structures have been observed in histopathologic studies of the tendon tissue (H Alfredson, Thorsen, & Lorentzon, 1999; Pingel et al., 2013).

Regarding the treatments for the management of the AT, exercises are recommended in clinical practice guidelines and in systematic reviews (Malliaras, Barton, Reeves, & Langberg, 2013; Martin et al., 2018; Murphy et al., 2018). Several authors reported the effectiveness of an eccentric exercise (EE) training, becoming one of the main load intervention options for AT. For example, the Alfredson eccentric program based on progressive calf raises in standing carried out twice a day (H Alfredson, Pietila, Jonsson, & Lorentzon, 1998). Beyer et al. (Beyer et al., 2015) compared EE with a heavy slow resistance training who included calf loading exercises with multiple intensities (15 to 6 repetitions) and found benefits in both programs. Mafi et al. (Mafi, Lorentzon, & Alfredson, 2001) observed short-term clinical benefits for EE compared with concentric exercise in individuals with AT.

Hilgers et al. (Hilgers, Mundermann, Riehle, & Dettmers, 2013) reported whole-vibration training (WBVT) added to a load interventions and founded benefits in motor control and muscle strength in subjects with multiple sclerosis. In addition, WBT was employed to improve the lower limb function, increase the triceps surae strength, lower limb flexibility, and for the management to the AT symptoms (Horstmann, Jud, Frohlich, Mundermann, & Grau, 2013). As a result of this findings, WBVT has proved being a good intervention choice based on load management for individuals with AT.

Knobloch and Hufner (K Knobloch & Hufner, 2010) observed the effectiveness of a cryotherapy and compression intervention approach to improve the Achilles tendon oxygen saturation during recovery. In addition, a cryotherapy intervention has shown benefits in pain and normalizing the blood flow in subjects with AT. Therefore, it has been reported the effectiveness of the cryotherapy intervention with and without other therapies in individuals with AT. In the same line, Romero et al. (Romero-Morales, Javier Martin-Llantino, Calvo-Lobo, Palomo-Lopez, Lopez-Lopez, et al., 2019) carried out an EE program combined with WBT or cryotherapy in subjects with AT. The EE with WBVT program showed a cross-sectional area increase at 0, 2, 4, 6 cm to the Achilles tendon insertion compared to the cryotherapy group. In addition, a rectus anterior (RA) thickness increase has been reported in both groups in favor of the EE vibration intervention compared to cryotherapy in subjects with AT in maximal isometric contraction and at rest (Romero-Morales et al., 2018). This evidence suggests that WBVT and cryotherapy added to a load intervention could be effective to manage the AT symptoms and may also be able to modifying the muscle architecture.

Current research showed that ultrasound imaging (USI) has been employed to assess the thickness and CSA of the muscles related to fascial and muscular features and could be useful in addition to a physical therapy examination. In addition, USI also has been employed to assess the motor control (Teyhen et al., 2007). Regarding the foot an ankle structures, Lobo et al. (Lobo, Morales, et al., 2016) observed by USI a reduced peroneus longus CSA in individuals with ankle sprains. Lobo et al. (Lobo, Marin, et al., 2016) reported a reduced CSA and thickness of the abductor hallucis and flexor hallucis in subjects with hallux valgus. Romero et al. (Romero-Morales, Martin-Llantino, Calvo-Lobo, Almazan-Polo, Lopez-Lopez, et al., 2019) showed an abductor hallucis brevis (AHB) and flexor digitorum brevis (FDB) thicknesses increase, as well as FDB and flexor hallucis brevis (FHB) CSA increased in patients with AT. Regarding the plantar fascia complex, a reduced plantar fascia was showed in individuals with pes planus (Angin, Crofts, Mickle, & Nester, 2014) and AT (Romero-Morales, Martín-Llantino, Calvo-Lobo, López-López, et al., 2019). There is considerable evidence that abdominal wall muscles and multifidus play an important role in patients with lumbopelvic pain (LPP) (Kiesel, Underwood, Mattacola, Nitz, & Malone, 2007; Whittaker, Warner, & Stokes, 2013). In addition, several authors highlighted the importance of deep posterior muscles of the spine in the management of patients with LPP giving a biomechanical and a neurophysiological approach (McGill, Grenier, Kavcic, & Cholewicki, 2003; Wilke, Wolf, Claes, Arand, & Wiesend, 1995). The multifidus muscle has an important role to control the spinal segments (Van, Hides, & Richardson, 2006), providing stiffness and stabilizing the spine (Wilke et al., 1995) and working in a coordinated manner with the anterior muscles of the abdominal wall – external oblique (EO), internal oblique (IO), transversus abdominis (TrAb) and rectus anterior (RA) (Teyhen et al., 2007). The lumbar multifidus features are widely studied in both healthy populations (Shi, Zheng, Chen, & Huang, 2007) and individuals with spinal pain (J. Hides, Gilmore, Stanton, & Bohlscheid, 2008). Stokes et al. (Stokes, Hides, Elliott, Kiesel, & Hodges, 2007) argued that in this context, quantitative and standardized assessment of the paraspinal muscles employing static and dynamic imaging may be useful to evaluate the morphology and behavior during contraction in patients with and without pathologies. Different assessment tools were employed to evaluate the multifidus muscles morphology and features, such as magnetic resonance (Julie A Hides et al., 2007), electromyography (Kim, Kang, Jang, & Oh, 2015) and USI. In this line, several authors indicated that USI provides a complete evaluation of the muscle architecture and soft tissues being relatively inexpensive, reliable and non-invasive technique (Romero-Morales, Martín-Llantino, Calvo-Lobo, Palomo-López, et al., 2019; Teyhen et al., 2007, 2009).

The overarching research question is whether a load program with vibration or cryotherapy intervention could have influence in the morphology of the paraspinal muscles and lower limb functionality among individuals with AT. Thus, the aim of the present study was to assess the multifidus muscle thickness, CSA and the disability related to Achilles tendon dysfunction in patients with chronic non-insertional AT who developed an EE vibration program compared to an EE program with cryotherapy.

Materials and Methods

Design and sample

This research consisted of a secondary analysis of a prospective, single-blinded, randomized, clinical-trial carried out in chronic non-insertional AT individuals over a period of 12-weeks between January 2017 and January 2018. The study was also registered in clinical trials database (NCT03515148) and following the Consolidated Standards of Reporting Trials (CONSORT) recommendations (Welch et al., 2015).

A total sample of 61 subjects diagnosed with chronic non-insertional AT (age 41.2 ± 10 years) was recruited and randomly divided into two groups - A group (n = 30) developed the EE program plus vibration; B group (n = 31) received the EE program plus cryotherapy (Figure 1). The previous draft to select and include the individuals for this study was developed by a specialized medical doctor with more than 10 years of experience in sport medicine. The inclusion criteria for the present study were as follows: aged 18 to 65 years, presence of symptomatology in the mid portion of Achilles tendon for at least 3 months (Håkan Alfredson & Cook, 2007), had a pain score by the visual analog scale (VAS) of at least 3 out of 10 points and had not received any physical or surgery treatment. Individuals who presented one of the following items were excluded of the present study: infections or systemic disease (H Alfredson et al., 1998), fractures (Romero-Morales et al., 2018), lower limb injuries or diseases within the last 12 months and negative experiences with the present assessments or the interventions in the past (Håkan Alfredson & Cook, 2007).

Ethical considerations

The study was approved by the human research committee of the Hospital Universitario La Princesa and all subjects signed the informed consent form before the participation in the study.

Interventions and procedure

All the participants carried out a 12-week EE load program according to modified guidelines by Alfredson et al. (Stevens & Tan, 2014). For the present study, all individuals developed 90 EE repetitions in a closed kinetic chain, by completing three sets of 15 repetitions in two training situations (45 repetitions with the knee completely extended and 45 repetitions with the knee slightly flexed), twice a day and 7 days per week (Romero-Morales, Javier Martin-Llantino, Calvo-Lobo, Palomo-Lopez, Lopez-Lopez, et al., 2019; Romero-Morales et al., 2018). In addition, to ensure both interventions were reproducible, the Template for Intervention Description and Replication (TIDieR) guidelines and checklist were followed (Negrini, 2015). A protocol deviation was developed for the 4-week follow up was added even though not in the registered procedure. Subject´s compliance to the protocol was self-reported in a written report (Romero-Morales, Javier Martin-Llantino, Calvo-Lobo, Palomo-Lopez, Lopez-Lopez, et al., 2019).

The EE vibration program was developed following the Hazell et al. (Hazell, Jakobi, & Kenno, 2007) recommendations on a Power Plate My3 (Performance Health Systems, US). Individuals were placed in a standing position on the vibration platform with a vibration frequency of 35 Hz and at amplitude of 4 mm for 5 minutes. Therefore, the subjects carried out the EE load training on the platform during the vibration.

For the cryotherapy group, patients were seated on a chair dressed in shorts and without shoes and socks. This intervention was performed prior to the EE program with the affected lower limb immersed in a 70-liter bucket and 55-deep centimeters at 8 ± 2ºC water for 17 minutes (khanmohammadi, Someh, & Ghafarinejad, 2011). After the cryotherapy intervention, EE program was performed.

Outcome assessments

All USI images were developed by the same therapist (P.M.L) with 3 years of experience and specialization. A high-quality ultrasound system (LogiQ P7, GE, UK) with 2 to 5.5 MHz convex transducer (4C RS type; 38-mm footprint) was employed to record the ultrasound images in B-Mode. All USI evaluations were developed with the patients in a prone lying position at rest and during a maximal isometric contraction with the ipsilateral extended lower limb for 5 seconds. Prior the ultrasound examinations, a demonstration of an isometric contraction was carried out. In addition, the participants were instructed to take a breath in and out, pause and then try to contract the biceps femoris muscle. To familiarize patients with the exercise prior to measuring, all the participants performed 3 contractions with a verbal and visual evaluator feedback. According to Wallwork et al. (Wallwork, Hides, & Stanton, 2007), transducer locations were established by palpation, skin marks and USI verification employing the sacrum, L4-L5 spinous as a reference points. The thickness of the multifidus muscle was recorded at the levels of L4-5 zygapophyseal joints with on-screen calipers. In addition, the measurements were conducted from the "tip of the target zygapophyseal joint to the inside edge of the superior border of the multifidus muscle" (Wallwork et al., 2007) (Figure 2A). For the CSA, "the transducer was placed on the skin 25 mm distal from the spinous process of L5 and vertical to the vertebral column" (Huang et al., 2014)(Figure 2B). Three evaluations were developed – pre-intervention, at four and 12 weeks- with the mean of three repeated values for each measure. All the images were measured offline with the ImageJ software (v .2.0, Bethesda, US) (Schneider, Rasband, & Eliceiri, 2012).

The disability related to Achilles tendon dysfunction was evaluated using the Victorian Institute for Sport Assessment (VISA-A). This scale is comprised of eight items, scored 0 to 100. In addition, the VISA-A showed a good test-retest (r = 0.93), intra-rater (r = 0.90), and inter-rater reliability (r = 0.90) (Robinson et al., 2001).

Data analysis

SPSS 23.0 software (IBM SPSS Statistics; NY: IBM) was used for data analysis. First, Shapiro-Wilks test was employed for the normality assumption. Second, the Student t test was used considering the homogeneity of variance using the Levene´s test for the baseline comparison. Third, a two-way analysis of variance (ANOVA) for repeated measures was developed to assess the effects of intra-subjects (pre and post) and inter-subject (treatment groups) values on the dependent variables. In addition, the Bonferroni´s correction post-hoc analyses were carried out. The level of significance was set at $P < 0.05$ with an α error of 0.05 (95% confidence interval) and a desired power of 80% (β error of 0.2).

Results

Sociodemographic data did not show significant differences between groups (Table 1). In addition, all the participants self-reported compliance to the protocol during the 12-weeks follow up. Multifidus thickness measures showed a significant ($P < 0.05$) decrease at 12-weeks in both groups in maximal contraction and at rest, but no significant differences were observed between intervention groups (Table 2). Multifidus CSA was significant increased ($P < 0.05$) in measures at 12-weeks in maximal isometric contraction and at rest in favor of the EE vibration program group (Table 2). VISA-A values were improved reporting a significant ($P < 0.05$) increase at 4 and at 12-weeks in both groups, but no significant differences ($P > 0.05$) were observed between intervention groups.

Discussion

Based on our findings, this is the first study that has evaluated the tendon dysfunction and multifidus muscle thickness and CSA in subjects with chronic non-insertional AT who developed an EE vibration program compared with an EE cryotherapy intervention.

The results of the present study showed a significant thickness decrease in both groups at 12-weeks and a CSA increase in favor to the EE vibration group at 12-weeks. Hides et al. (J A Hides, Stokes, Saide, Jull, & Cooper, 1994) reported that in healthy subjects, the lumbar multifidus has been symmetrical between sides and also increased the muscle size caudally. In individuals with low back pain (LBP) the multifidus muscle has shown a decrease in the CSA for the ipsilateral side to painful symptoms (J A Hides et al., 1994). In addition, the atrophy for this muscle was predominantly quantified to the L5 spinal level (J A Hides et al., 1994). Based on our data, an EE load program for the lower limb (with either vibration or cryotherapy intervention added) showed benefits for patients with AT and may also potentially benefit individuals with LBP and LPP pain disturbances. This approach could be useful added a conventional motor control and core interventions. In addition, USI evaluation have the capability to check the voluntarily contraction of the multifidus muscle in real time being useful for the clinical practice to diagnosis and follow of the effectiveness of load programs and manual therapy interventions (Wallwork et al., 2007). In this line, Hides et al. (J. Hides et al., 2008) reported that dynamic studies of the multifidus muscle by USI could provide a visual feedback about neuromotor control approaches in individuals with and without pathology (e.g. LBP or LPP).

Current evidence about the benefits for strength and coordination/stabilization programs showed that those interventions reduced the symptoms and improved the function in individuals with disturbances in multifidus muscles evaluated by USI. Kliziene et al.(Kliziene, Sipaviciene, Klizas, & Imbrasiene, 2015) showed that a core stabilization program increased the multifidus CSA in women with chronic LBP. Those findings coinciding with our results, which show a multifidus CSA increase in favor to the vibration approach with the modified Alfredson EE program. An increase of the multifidus CSA is beneficial in order to improve the trunk stability, protecting the spine and working in a coordinated manner with the anterior abdominal wall muscles to transferring loads from the lower limb.

Considering our findings related to Achilles tendon dysfunction in patients with chronic non-insertional AT, an improvement at 12-weeks was observed in both groups. Several authors reported similar results in order to improve the function and the symptoms in patients with chronic non-insertional AT with a load management approach, such as EE (Fahlstrom, Jonsson, Lorentzon, & Alfredson, 2003; Rompe, Nafe, Furia, & Maffulli, 2007; Sayana & Maffulli, 2007).

Clinical implications

Our findings supported that a lower limb EE with WBVT program may have benefits in patients with disturbances related to paraspinal muscles (e.g. LBP, LPP). This program could be useful in an isolated manner, or in addition to traditional approaches, such as manual therapy interventions.

Limitations and future directions

The main study limitations were a lack of control group and the present findings can only be extrapolated to subjects with chronic non-insertional AT. Tensiomyography, sonoelastography or electromyography were not employed and may be useful to provide more information about the soft tissues at rest and at contraction (Bunce, Hough, & Moore, 2004). Additionally, while the thickness and CSA were evaluated, consistency changes in the muscle (e.g. connective tissues infiltration or fatty deposits) were no recorded. Futures studies could include individuals with other tendon disturbances (e.g. patellar or plantar fascia tendinopathy), sports populations and subjects with LBP or LPP. Moreover, the tendon pain education based on recommendations about tendon pathology could be effective to improve the patient adherence added to a load program in individuals with AT (Sancho, Morrissey, Willy, Barton, & Malliaras, 2019).

Conclusions

The present study showed a multifidus CSA increase in the EE vibration program with respect to an EE cryotherapy program at 12-weeks at rest and at maximal isometric contraction in individuals with chronic non-insertional AT. Multifidus thickness was decreased in both groups without inter-group differences. At last, VISA-A values also reported benefits in both groups, but no differences between groups were found. Authors encourage the use of vibration with respect to cryotherapy added to EE programs in order to enhance multifidus CSA in addition to lower limb functionality in individuals who suffer from chronic non-insertional AT.

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Figure legends

Figure 1. Flow chart diagram

Figure 2. Multifidus thickness and CSA ultrasound procedure. Legend a-b, significant difference between follow up and baseline values ($P < 0.05$). A-B, significant difference between groups ($P < 0.05$).

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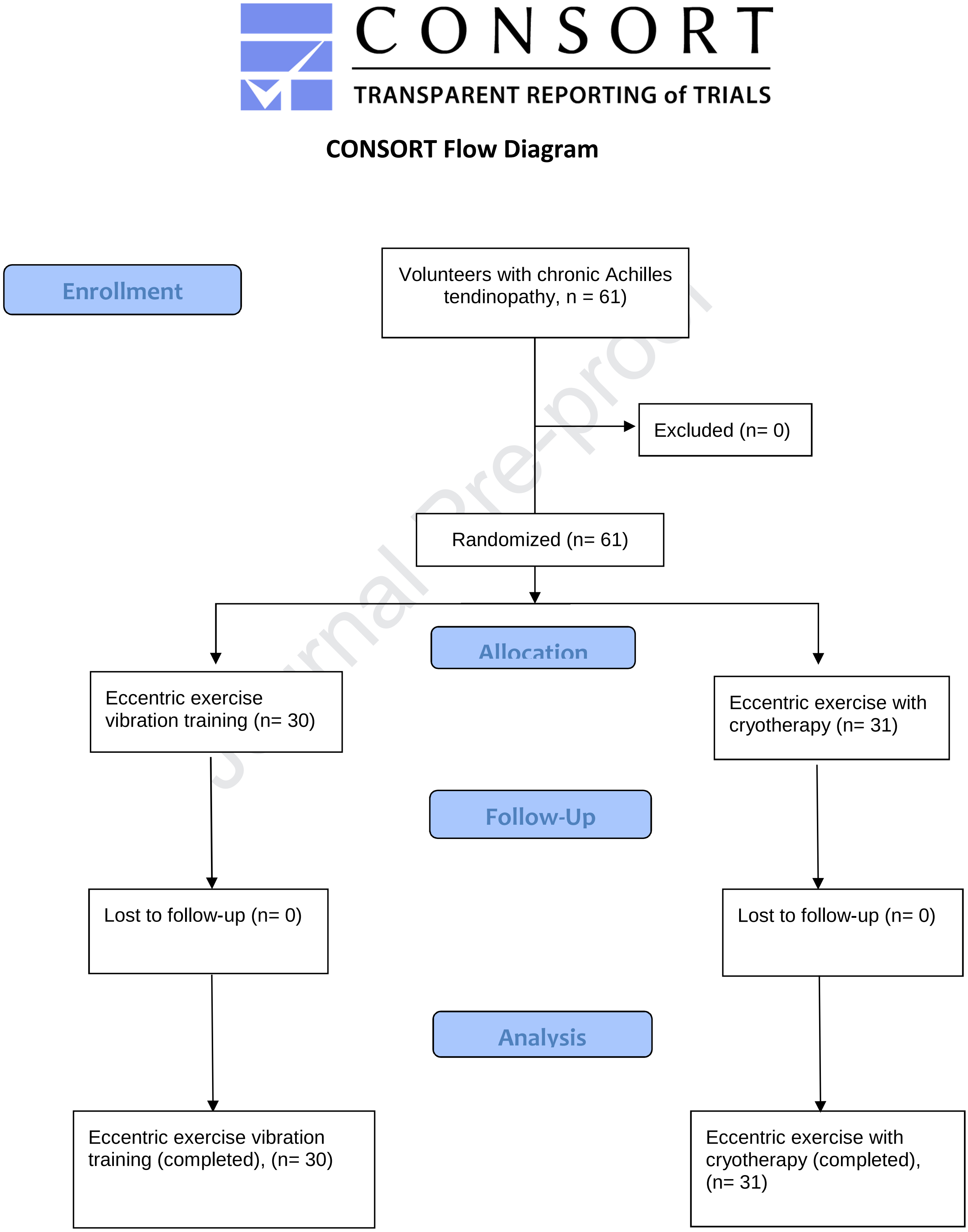

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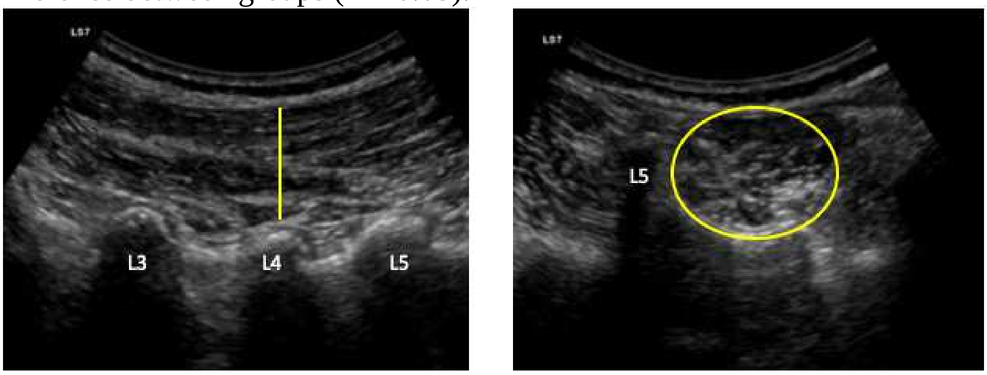

Table 1. Sociodemographic and clinical characteristics of the sample population

Data	**Cryotherapy**	**EE Vibration Training**	***P* value**
Sex			0.645
Men, (n, %)	5 ± 16.13	4 ± 13.33	
Women, (n, %)	26 ± 83.87	26 ± 86.66	
Age, y	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: body mass index, BMI

Table 2. Multifidus ultrasound measurements and VISA-A values

Measure (unit)		Cryotherapy n=31	Eccentric Exercise Vibration Training n=30	Intrasubject Efects: Time *P* value	Intrasubject Efects: Treatment X Time *P* value
Multifidus Thickness Rest (mm)				.001*	.163
	Baseline	23.4 ± 3.6	24.5 ± 3.2		
	4 weeks	23.1 ± 3.2	23.8 ± 2.7		
	12weeks	22.7 ± 2.9	22.7 ± 2.9		
Multifidus Thickness Contraction (mm)				.001*	.181
	Baseline	22.8 ± 3.4	23.8 ± 3		
	4 weeks	22.4 ± 3.1	23 ± 2.8		
	12weeks	22.1 ± 2.9	22.2 ± 2.7		
Multifidus CSA Rest (mm^2)				.001*	.001*
	Baseline	1036.7 ± 165.8	1085 ± 177.7		
	4 weeks	1069.4 ± 165	1.113 ± 181		
	12weeks	1094.3 ± 171	1173.8 ± 192.2		
Multifidus CSA Contraction (mm^2)				.001*	.010*
	Baseline	1081.1 ± 189.1	1091 ± 189.9		
	4 weeks	1121.8 ± 201.5	1179. ± 201.2		
	12weeks	1143.6 ± 202.4	1235 ± 208.1		
VISA-A				.001*	.094
	Baseline	56.7 ± 9.3	57 ± 16.1		
	4 weeks	66.1 ± 8.5	66.9 ± 11.8		
	12weeks	72.8 ± 10.5	77.7 ± 12		

Values are mean ± SD unless otherwise indicated. a-b, significant difference between follow up and baseline values ($P < 0.05$). A-B, significant difference between groups ($P < 0.05$).

Abbreviature: CSA, cross-sectional area

HIGHLIGHTS

- We developed an eccentric exercise vibration program compared to program with cryotherapy for patients with Achilles tendinopathy.
- Individuals who suffer from chronic non-insertional AT improve with both of them programs.
- Preventive treatment in sportsman is essential to improve foot and ankle health.

Dear Editor in Chief Professor Doctor Zoe Hudson, PhD MCSP:

The authors of this paper certify none conflicts of interest.

Without any other intention and thanking in advance your commitment, attention, dedication and good practice.

Yours faithfully,

the authors,

Dear Editor in Chief Professor Doctor Zoe Hudson, PhD MCSP:

This paper entitled Vibration increases multifidus cross-sectional area versus cryotherapy added to chronic non-insertional Achilles tendinopathy eccentric exercise

certify:

- The name of the ethics committee: Hospital de la Princesa Ethics Committee, Madrid, Spain.

This study also adhered to the Declaration of Helsinki for Human experimentation. All the participants signed the informed consent form.

Without any other intention and thanking in advance your commitment, attention, dedication and good practice.

Yours faithfully,

the authors