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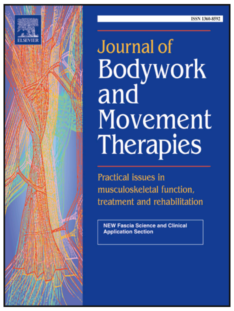

Immediate effects and one-week follow-up after neuromuscular electric stimulation alone or combined with stretching on hamstrings extensibility in healthy football players with hamstring shortening

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Title: Immediate effects and one-week follow-up after neuromuscular electric stimulation alone or combined with stretching on hamstrings extensibility in healthy football players with hamstring shortening

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ABSTRACT

Objective: To assess the immediate and mid-term (after 7 days) effects of electric current combined with simultaneous muscle stretching (EME technique) per comparison to the isolated use of the same current (without applying simultaneous muscle stretching), over the hamstring extensibility in football players with hamstring shortening, and to estimate the clinical benefit of the interventions according to the muscular extensibility.

Methods: Forty-eight participants were randomized to receive one session of EME technique (n=26) or one session of the electrical current (EC) alone (n=22). The measurement of the hamstrings extensibility through the active knee test was carried out before and immediately after each intervention and one week later.

Results: A significant interaction group x time was observed ($F_{2,84} = 7.112$, $p = 0.001$; partial eta squared = 0.145). The hamstrings extensibility changed significantly immediately after the EME technique (147.3° ± 16.4° to 153.5° ± 14.2°, $p < 0.05$), but not after the EC only (144.2 ± 10.2º to 141.7 ± 7.8º, $p>0.05$). One week after the intervention no significant differences were found to the baseline values in both groups. The number needed to treat to prevent one new case of hamstring shortening was 3.

Conclusion: The combination of electric current with simultaneous stretching is an effective technique to acutely increase the hamstring extensibility of football players with hamstring shortening.

Keywords: muscle stretching; electric current; technique; range of movement; sport.

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INTRODUCTION

Impaired hamstring extensibility is associated with increased risk of injuries in the lower limbs (Croisier et al 2002; Davis et al 2005; Henderson et al 2009) and incidence of low back pain (Feldman et al 2001). Decreased hamstring extensibility has been reported in athletes of different sport disciplines (Reid and McNair 2004). In stop-and-go sports like football, the incidence of hamstring injuries is estimated at approximately 6 players per season with each injured player missing three matches per season (Woods et al 2004). Among the modifiable risk factors in hamstring injury is the loss of range of motion (Heiderscheit et al 2013; Croisier et al 2008). However, its influence as potential factor involved in the development of a tear within the muscle/connective tissue is controversial. Studies that analyze the possible clinical benefits of each previous intervention are needed, in order to analyze its preventive effect on injuries.

In this sense, several stretching techniques have been used aiming to improve flexibility, although the protocols used are diverse, both regarding intervention duration and follow-up (Rogan et al 2013). In recent years, alternative techniques have been proposed, such as techniques acting remotely like ischemic compression (Espejo-Antúnez et al 2016), neurodynamic sliding (Castellote-Caballero et al 2013) or Electric Muscle Elongation (EME) (Espejo-Antúnez et al 2012).

The EME technique constitutes an electrotherapy procedure based on increasing muscle tension of the shortened muscle through the application of electrical current (interferential current or biphasic symmetrical pulsed current) combined with simultaneous stretching and contraction of the antagonist muscle group. This technique is hypothesized to increase muscle extensibility due to a decrease of the ortho-sympathetic activity by the reduction of nociceptive transmission and an increase of the temperature, which increases the sliding capacity of the collagen matrix (Maya and

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Albornoz 2010). Stretching combined with interferential current and transcutaneous electrical nerve stimulation (TENS) current have shown to increase the extensibility of the hamstrings (passive and active knee extension) (Espejo-Antúnez et al 2015; Espejo-Antúnez et al 2016; Piqueras-Rodríguez et al 2016). The *Gate Control Theory* (Melzack and Wall 1965) and related neurophysiological mechanisms could explain the effect of electrical modalities *versus* non-electrical modalities (eg: static stretching) on stretch tolerance.

Despite this, the EME technique has been proposed as an alternative or adjunct tool to improve muscle extensibility. This is particularly interesting in athletes diagnosed with hamstrings shortening considering this syndrome as an intrinsic risk factor for hamstrings injury in football players (Gabbe et al 2006). However, there are no studies that statistically analyse the clinical benefit obtained from stretching on this risk factor described.

Considering the greater effects of extensibility evidenced when stretching and electrical stimulation are combined, compared to stretching alone (Espejo-Antúnez et al 2016; Piqueras-Rodríguez et al 2016), and the lack of studies evaluating the effect of the EME technique at short and mid-term in this population, the present study aims to assess the immediate and mid-term (after 7 days) effects of biphasic symmetrical pulsed current with simultaneous muscle stretching (i.e., EME technique) per comparison to the isolated use of the same current (without applying simultaneous muscle stretching), in the hamstring extensibility of football players with hamstring shortening. In addition, we propose to evaluate the clinical benefit of the intervention in the incidence of hamstring shortening after the procedure is performed.

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METHODS

Experimental Approach to the Problem

A single-blinded, randomized, controlled trial was carried out. Participants were randomized to either a group receiving an EME technique or a group receiving only the electrical current (EC). Both study groups continued regular soccer training. Randomization was performed by allowing the participants to choose one of two sealed numbered, opaque, envelopes containing the allocation to the groups. The required sample size was computed in advance based on the effect size calculated from a previous study evaluating the effect of EME technique in hamstrings extensibility (Espejo-Antúnez et al 2016). The statistical power for the repeated measure analysis of variance (General Linear Model) was calculated with the G*Power software (version 3.1.2, Kiel University, Kiel, Germany) and revealed that 20 participants per group were required with a power of 90%, a correlation between repeated measures of 0.2 and a two-sided 5% significance level. A target of 26 participants per group was identified to accommodate a maximum dropout rate of 30%.

A physiotherapist aware of the study design performed the enrolment, assignment and provided the interventions. The measurements of the outcome, hamstrings extensibility, were carried out before and immediately after each intervention (not more than 2 minutes from completion) and one week later by a physiotherapist who was blinded to group assignment.

Subjects

Based on a non-probabilistic convenience sampling, a total of 63 amateur football players voluntarily participated in this study (Figure 1). All the study participants were registered in the Football Federation of the Extremadura Community. Recruitment occurred through verbal advertisement and research posts in the local sport clubs.

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The inclusion criteria were: practicing football with a frequency of at least three times per week plus the weekend game; with previous history of hamstring injury (a year before) but not at the time of the intervention; less than 80º in the right-straight leg raise test (Kendall et al 2005). Participants were excluded according to the following criteria: participation in a hamstrings muscle stretching programme; acute low back pain or acute musculoskeletal pain/injury in the lower limbs; and/or recent spinal/abdominal surgery or consumption of analgesics/anti-inflammatory drugs during the last six months before the evaluation and intervention of the study. The study was carried out after the approval of the Bioethics Committee of the University of Extremadura (Register nº:118/2015), fulfilling the recommendations of the Helsinki Declaration, and after obtaining an informed consent signed by the participants of the study.

PLACE FIGURE 1 HERE

Procedures

Before the data collection, all participants were informed about the study procedures. All data were collected in a quiet room at a temperature of 23ºC, with the participants wearing comfortable clothes (t-shirt and shorts). Height and weight measurements were attained using a standard scale and stadiometer (Seca 285, Seca, Birmingham, United Kingdom). Hamstring extensibility was assessed on the right leg using the active knee extension test by their specificity to the possible changes induced by the intervention (Gajdosik and Lusin 1983).

Prior to the assessment, two pairs of markers were fixed to the skin of the lateral thigh and leg using tape (i.e., over the apex of the greater trochanter, ii. iliotibial tract level with the posterior crease of the knee when flexed to 80°, iii. neck of the fibula and iv. prominence of the lateral malleolus), representing the axis of the thigh and the axis of the leg. The participant was positioned in supine with the right hip and the knee at 90º

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of flexion and the ankle joint in neutral position. A solid box was used to keep the neutral lumbar area and avoid compensations on the pelvis. In addition, the left lower limb was fixed to the table with a strap (Figure 2). Then, the participant was asked to "while maintaining contact with the thigh on the box, try to straighten the knee as much as you can". When the participant reached the maximum knee extension, the angle of the knee joint was recorded in a sequence of seven consecutive photographs taken with a camera mounted on a tripod positioned 3 meters away from the participant, at the same level of the knee joint, an in the sagittal plane. The measurement was performed twice, with a minute rest. The knee angle of each photograph was obtained with the Posture Assessment Software (SAPO); this method showed excellent reliability in the determination of knee angles [intraclass correlation coefficient (ICC) = 0.96] (Ferreira et al 2010). The knee angle was determined as the average of five consecutive (from picture number 2 to number 6) photographs of each position. The mean values were used for the statistical analysis.

PLACE FIGURE 2 HERE

The reliability of this method of hamstring extensibility assessment was tested in six subjects (age: 20–26 years old) outside the sample, but subject to the criteria for inclusion/exclusion previously defined, in two sessions four days apart. The ICC for active extension knee test was ICC = 0.992. The ICC was used to calculate the standard error of measurement (SEM) and, then, the SEM was used to compute the smallest real difference (SRD). The SEM was 0.640º and the SRD was 1.774º.

Interventions

The participants of the group 1 received the EME technique as previously described (Espejo-Antúnez et al 2016; Maya and Albornoz 2010). In brief, a low frequency current (biphasic symmetrical pulsed) through double-bipolar application (Sonopuls

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692, Enraf Nonius, Rotterdam, The Netherlands) was applied to the hamstrings of the right lower limb. The current parameters were 50 Hz of frequency and 300 µs of phase length. To apply the current we used self-adhesive electrodes, 45 cm^2 size (9 x 5 cm) (StimCare Premium Electrodes, Empi Inc., St.Paul, MN, USA), placed longitudinally covering the length of the hamstrings (the upper electrodes were located approximately 3 cm below the common origin in ischial tuberosity and the lower electrodes above the myotendinous junction of the muscular bellies). The hair of the area was previously shaved. The participant was placed in the same position as to measure hamstrings extensibility with the right knee extended and the lower limb on the shoulder of the physiotherapist who was applying the technique. After that, the physiotherapist made a hip flexion to stretch the muscle, until a feeling of resistance or stiffness appeared; once the participant reported that he/she was feeling the stretch, the intensity of the electrical current was increased until a clear contraction was produced; at the same time, the physiotherapist asked the participant to contract isometrically the antagonist muscles (knee extensors). The stretching continued until the participant reported that he/she was feeling a new stretching sensation. At this point, the intensity of the current was increased again until the stretching sensation disappeared and a new cycle of the procedures above-mentioned was then performed. The duration of the procedure was 80 seconds, divided in two sets of 30 seconds with a 10-second rest period, as used in previous studies (Espejo-Antúnez et al 2015; Espejo-Antúnez et al 2016; Piqueras Rodríguez et al 2016).

The group 2 received the same type of electric current, with the same frequency and length parameters, in the same body position. In this group, the intensity of the electric current was increased up to reach the minimum threshold of noticeable muscle contraction, but without applying any stretching over the hamstring muscle and any

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contraction of the antagonist muscles. The instructions given to the participants were: "when you perceive an electrical sensation in the thigh which causes you a tingling and noticeable muscle contraction, say now". At this point, the intensity of the electric current was no longer increased.

During the follow-up week, the participants did not perform any hamstring muscle stretching and no sports injuries in the lower limbs were recorded.

Statistical analysis

Data analysis was made with the statistic software SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). The normality of data distribution was tested with the Shapiro–Wilk Test. Data are reported as mean ± SD. The Student's independent t-test and the chi-square test were used for baseline comparisons between groups in scale and nominal data, respectively. A repeated-measures ANOVA was used to compare the changes in hamstrings extensibility between groups over time (group × time). Post-hoc comparisons were performed using Bonferroni Tests. Effect size was reported using partial eta-squared (η2p). Qualitatively, the clinical benefit of the intervention on the improvement in the optimal extensibility and therefore the impact on this associated risk factor was assessed by calculating clinical relevance indicators, such as relative risk (RR), absolute risk reduction (ARR), relative risk reduction (RRR), and number needed to treat (NNT). We take as normal reference values 180 (degrees)–extension value<20 (Ayala et al 2013). The significance level was established at $p < 0.05$.

RESULTS

From 63 participants assessed for eligibility, 48 met the inclusion criteria and agreed to participate in the study being randomized to the Group 1 (n = 26) or Group 2 (n = 22). After the baseline assessments and the intervention, 2 participants in each group

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dropped out; therefore, they were not included in the data analysis. Subsequently, 44 participants, 24 in Group 1 and 20 in Group 2 were included in the analysis (Figure 1).

The groups were statistically similar regarding age, weight, height, body mass index, training hours and hamstring extensibility at baseline (Table 1). The number of females was significantly lower than males in both groups (Table 1). No correlation was found between gender and hamstrings extensibility at baseline and after the interventions.

PLACE TABLE 1 HERE

At baseline, no differences were observed between groups in the active knee test (Group 1: 147.3° ± 16.4° vs. Group 2: 144.2 ± 10.2º, p = 0.467). A significant interaction group x time was observed ($F_{2,84}$ = 7.112, p = 0.001; partial eta squared = 0.145). The hamstrings extensibility changed significantly in the Group 1 ($F_{2,46}$ = 8.873, p = 0.001; partial eta squared = 0.278), but not in the Group 2 ($F_{2,38}$ = 1.342, p = 0.273; partial eta squared = 0.066) (Figure 3).

Compared to rest, a significant increase in active knee extension was observed immediately after the EME technique (147.3° ± 16.4° vs. 153.5° ± 14.2°; mean difference: 6.2º, 95% CI [2.4, 10.1], p = 0.003); one week after the intervention no significant differences were found to the baseline values (147.3° ± 16.4° vs. 143.7° ± 11.0°; mean difference: -3.6º, 95% CI [-9.1, 1.8], p = 0.183) (Figure 3).

PLACE FIGURE 3 HERE

Immediately after the intervention the hamstring extensibility was significantly higher in the Group 1 in comparison to the Group 2 (153.5° ± 14.2° vs. 141.7 ± 7.8º; mean difference: 11.9º, 95% CI [4.7, 19.0], p = 0.002) (Figure 3). Table 2 shows the clinical relevance analysis. Comparison between groups showed significant variables for the RR (0.49 (0.29-0.82), RRR (0.51 (0.18-0.71), ARR (0.47 (0.20-0.73), and NNT 3(2-6).

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DISCUSSION

The purpose of this study was to evaluate the immediate and mid-term (after 7 days) effects of an EME technique in football players with limited hamstring extensibility. The main result indicates that a single application of a biphasic symmetrical pulsed current combined with stretching acutely increases hamstring extensibility but the results are not maintained at 1-week follow-up.

Our results are in agreement with previous studies (De la Cruz et al 2002; Espejo-Antúnez et al 2015) reporting immediate improvements in the knee extension test after applying EME. However, the magnitude of the improvement in the present study was lower than in those studies. This fact could be related with the differences in hamstring extensibility at baseline, as well as with the technique. Although in general the technique used was the same, there are some differences between studies in the type of current and electrodes. For instance, De la Cruz et al (2002) and Espejo-Antúnez et al (2015, 2016) used an interferential current (medium frequency) and pad electrodes with wet sponge covers, the present study used a biphasic symmetrical pulsed current (low frequency) and self-adhesive electrodes.

The significant improvement in hamstring extensibility observed immediately after the intervention, could be related with two mechanisms. First, the increase of tolerance to stretching (Aquino et al 2010; Halbertsma and Goeken 1994). The tolerance to stretching has been described as the primary mechanism in the increase of muscle extensibility (LaRoche and Connolly 2006; Magnusson et al 1996). Second, the structural/mechanical changes in the viscoelastic properties of the hamstring muscle (Reid and McNair 2004). Furthermore, the EME technique could be considered a dynamic stretch to require an active contraction of the antagonist muscle. According to Amiri-Khorasani and Kellis (2013), the muscle activation possibly increases the activity

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of muscle spindles and subsequently the afferent proprioceptive feedback. This fact might have influenced the results in the active knee extension test.

Additionally, the effect of the current on pain relief (Maya and Albornoz 2010) could have also played a role in our results. The influence of the current on the endogenous inhibitory analgesic systems could modify the perception of the stretching intensity, achieving a more effective stretching. These arguments regarding the action of TENS on immediate changes are partially consistent with those recently reported (Karasuno et al 2016).

In this sense, the effect of the TENS as a preparatory stimulus may explain the clinical relevance of the immediate effect of the intervention that combined transcutaneous electrical nerve stimulation to stretching (Table 2). Recently, some studies have analysed the clinical benefit of diverse procedures for the prevention of hamstring injuries in amateur football players (Nouni-Garcia et al 2017; Van der Horst et al. 2013), nevertheless, none studied the preventive effect of stretching combined with electric current in this population. Nouni-Garcia et al 2017, have found after two sessions performed ‘the FIFA 11 programme’ protocol twice a week in 43 football players that the number needed to treat to prevent one new case was 3.31 in biceps femoris injuries and 10.7 in recurrent hamstring injuries. The FIFA 11 programme includes strength exercises, plyometrics and hamstring strengthening, but not stretching. Previously Piqueras-Rodríguez et al 2016 applied an intervention similar to ours reporting similar results (NNT: 2 [2 to 3] p≤0.001). The RR (0.26 (0.11 to 0.63)), RRR (0.74 (0.37 to 0.89)) and ARR (0.65 (0.41 to 0.90)) were also similar (Table 2). In this study, the same type of current was applied but with different application times (3 exercises of stretching of the hamstring without pain for 15 seconds, twice, with a total

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of 6 repetitions) and frequency (1 session/week for 8 weeks). In addition, the comparison between groups was performed by isolating the stretching component instead of the electric component, which hinders the discussion between studies.

The results obtained about the number of patients that must be treated over a given period of time to prevent 1 adverse event (NNT) (Table 2), followed by a reduction of 70% in the incidence of hamstring injury (previously hypothesized by Van der Horst et al 2013 after applying eccentric hamstring exercises), could be grounds for future studies. The conflicting evidence regarding the effectiveness of hamstring injury prevention programmes (Van Beijsterveldt et al 2013a) and the strongly associated risk factors in male football players (Van Beijsterveldt et al 2013b) makes it necessary to identify the influence of each component as well as establishing a clear definition of hamstring injury. In addition, the lack of evidence for stretching as a sole intervention for prevention of hamstring injury (Goldman and Jones 2010) means that the results shown should be taken cautiously. The location of the injury and the importance of other risk factors constitute aspects that should also be investigated in future studies.

An unexpected finding was the return to baseline values one week after the intervention. This may be because the combination of electrical stimulation and stretching had similar effects to those produced by static stretching, with results limited to 1 hour after the procedure (Magnusson et al 1996). Malliaropoulos et al (2004) observed the same evolution in 80 Greek athletes with hamstrings injury; after applying an intervention based on stretching, values returned to pre-test conditions in the active knee extension test, between the fifth and seventh day after the procedure. In this sense, some authors (Taylor et al 1990; Reid & McNair 2004) suggest that short time effects are under the influence of the viscoelastic properties of the muscle. Therefore, the effects are temporary. Other authors support that any decrease may be explained by changes in the

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myoelectric activity, according to the mechanical tension supported by the muscle (LaRoche and Connolly 2006; Rade et al 2012).

Regarding the group that received biphasic symmetrical pulsed current alone, no positive effects were found among male adult amateur soccer players in any of the assessments. The lack of significant differences in this group could be attributable to the lack of muscle stretching component, although, despite being a technique commonly used by health professionals, the clinical benefit of its use as a measure to improve hamstrings extensibility is not clear (Van Doormal et al 2017).

The present study has some limitations. First, the programme was tested as a single intervention. Also, the absence of repetitions during the following week may have caused the intervention to become ineffective at mid-term (after 7 days). In addition, the sample included both women and men. Although there are differences in the hamstring extensibility in function of gender (Youdas et al 2005), the improvements produced by an intervention are similar between women and men (Cipriani et al 2011). Another limitation was the fact that only the right leg was assessed. Studies comparing hamstring extensibility between legs in athletes have found a low frequency of unilateral shortness (López-Miñarro et al 2011). Future studies should perform the intervention in both lower limbs, analysing the added value of this intervention applied in a repeated or isolated way. Future studies should also determine the influence of each component of the intervention, determining whether the acute increases in extensibility are only related with the stretching component of the technique or if the combination of stretching and electric current induces greater gains.

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PRACTICAL APPLICATIONS

EME could provide a valuable treatment tool to those subjects in whom at a certain phase, extensibility gain in a quick and effective way is needed to improve athletic performance or the performance of classical stretching are not possible due to high levels of pain. These results together with the technological tools in app format for the diagnosis of hamstring shortening (Piqueras-Rodríguez et al, 2016b), could facilitate the sports decisions made by the clinician and the coach.

CONCLUSIONS

The combination of biphasic symmetrical pulsed current and stretching is an effective technique to acutely increase hamstring extensibility of football players with hamstring shortness. In accordance with the clinical benefit, the EME technique had an immediate lower risk of hamstring shortening compared with those in the EC group.

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Conflict of interest statement

The authors declare no conflict of interest.

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Table 1. Baseline characteristics of the participants of the study

	Group 1 (n=24)	Group 2 (n=20)	p value
Age (years)	22.2 ± 3.8	21.0 ± 1.8	0.191
Gender (male/female)	19 / 5	11 / 9	0.087
Weight (kg)	74.5 ± 6.7	68.2 ± 13.8	0.054
Height (m)	1.76 ± 0.05	1.71 ± 0.09	0.067
Body mass index (kg/m^2)	23.8 ± 2.0	23.2 ± 3.0	0.425
Sports Training (hours/week)	7.1 ± 1.7	6.2 ± 3.0	0.218

Group 1: Electric Muscle Elongation technique; Group 2: Electric current without stretching

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Table 2: Clinical Benefit of the improvement outcome for the football players

	Relative Risk (RR) (95% CI)	**Relative Risk Reduction (RRR) (95% CI)**	**Absolute Risk Reduction (ARR) (95% CI)**	**Number needed to treat (NNT) (95% CI)**	**p-value**
AKE post-intervention (º)	0.49 (0.29-0.82)	0.51 (0.18-0.71)	0.47 (0.20-0.73)	3 (2-6)	**0.0106***

RR: Relative Risk. Risk in the outcome in the treatment group/risk of the outcome in the control group. ARR: Absolute Risk Reduction: Difference in the risk of the outcome between groups; or the risk in the control group-risk of the outcome in the treatment group.
RRR: Relative Risk Reduction: the percent reduction in risk of the group 1 compared with the group 2; or the absolute risk reduction/risk of the outcome in the group 2.
NNT: Number needed to treat: the number of patients that must be treated over a given period of time to prevent 1 adverse event.

AKE: Active Knee Extension; CI: Confidence Interval; p-value: level of significance

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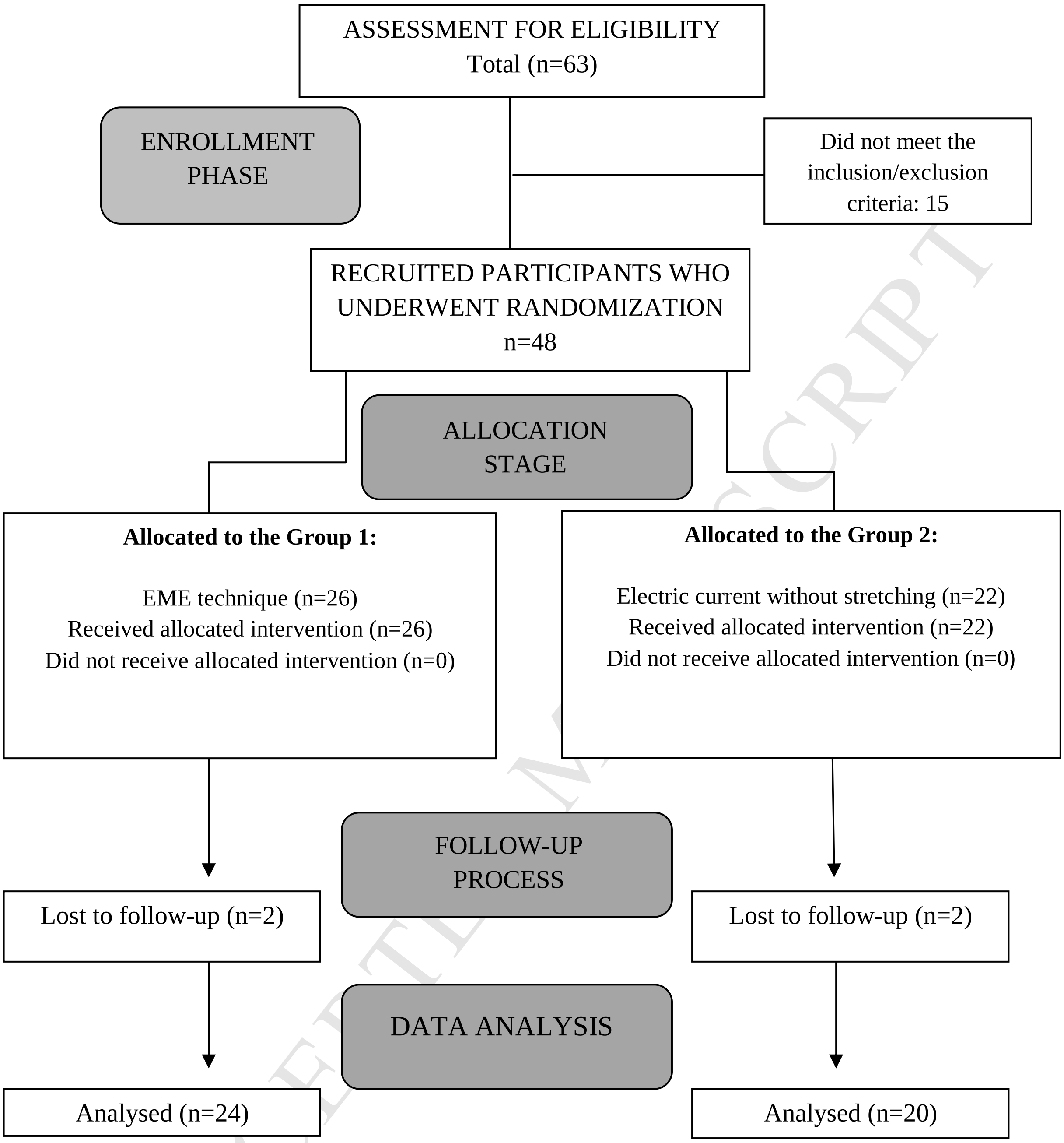

Figure 1. Flow-chart diagram of the study selection process

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Figure 2. Active Knee Extension Test

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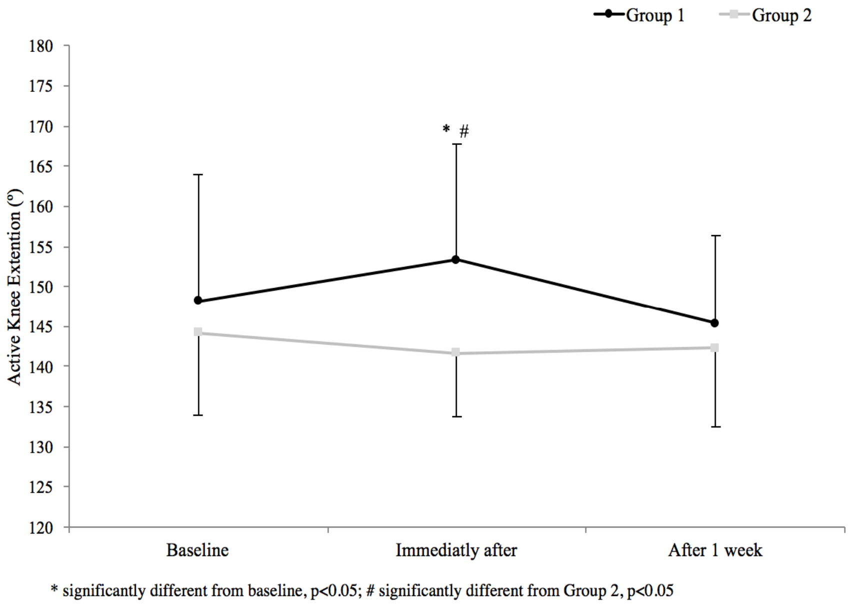

Figure 3. Changes in active knee extension immediately after the intervention and 7 days after.

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