RESEARCH ARTICLE

Bilateral Idiopathic Carpal Tunnel Syndrome: Clinical-Functional Characterization and Efficacy of Two Combined Postoperative Physiotherapeutic Treatments

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Objective: To evaluate the efficacy of combined association instrument myofascial mobilization (IASTM) and stretching in patients with idiopathic bilateral carpal tunnel syndrome (CTS) operated on one hand and to analyze the response of the operated (OH) and non-operated (NH) hand according to the sequence of therapies. Research on these parameters has not yet been found in the literature.

Methods: Randomized controlled crossover study with 43 participants using the objective and subjective outcome variables. Patients were randomly assigned to two groups: starting with stretching followed by IASTM and starting with IASTM followed by stretching. Then patients underwent surgery on the hand with more severe involvement and physical therapy rehabilitation was started 30 days after for a period of 4 weeks. After the 1-week interval the participants who started with stretching were referred to IASTM and *vice versa*, following the same previous patterns. The outpatient reassessments took place at 3 to 6 months. Crossover ANOVA and effect sizes were used as analysis methods.

Results: Time was the most significant outcome for all variables both during therapies and at 6-month follow-up. Regarding response to the combined therapies between OH and NH, there were differences for both OH and NH, with the greatest impact on NH for the palmar grip and VAS variables. The treatment sequences were significant for pain on the NH and mental SF-12, suggesting that starting with IASTM followed by stretching had a superior outcome for these outcomes.

Conclusion: The combination of IASTM with stretching, used in the postoperative period of bilateral idiopathic CTS, proved to be supplementary, with significant results and large effect sizes for most of the outcomes assessed, both during the time of application of the therapies and in the 6-month follow-up for both hands, and may constitute a viable therapeutic alternative for this population.

Key words: Carpal tunnel syndrome; Crossover study; Muscle stretching exercises; Myofascial mobilization; Physical therapy; Surgical decompression

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Introduction

Carpal tunnel syndrome (CTS) is the most common median nerve compression neuropathy in the adult population worldwide, arising from any pathological condition that causes decreased cross-sectional area or expansion of the carpal tunnel components.[1]

The incidence of CTS is three to four new cases in 1000 people per year and has been showing an increase in cases over the last decade.[2] This syndrome affects three times more women than men, with prevalence between 30 and 40 years for women and between 60 and 80 years for men, with bilateral involvement in 60% of cases.[3] A Brazilian study showed similar prevalence to those cited above.[4]

CTS is related to constitutional factors and comorbidities. The main constitutional factors are advanced age, gender, high body mass index, menopause, and pregnancy.[5] Relevant clinical comorbidities are diabetes *mellitus*, hypothyroidism, obesity and rheumatoid arthritis.[6] If a causative agent cannot be found, this syndrome is referred to as idiopathic.[7]

The clinical condition is made up of pain, numbness,[8] and tingling in the median nerve (MN) territory in the hand or arm, which can be associated with weakness and atrophy of the tenar muscles, causing loss in the hand strength.[2] The presence of sensory changes restricted to the distribution of the MN in the hand and Tinel and Phalen's signs are key findings in determining the clinical diagnosis.[9]

Clinical treatment is encouraged in mild and moderate CTS.[10] Surgical treatment is indicated in severe cases[11]—the surgical approach can be done either by open surgery (OS) or endoscopic surgery (ES).[12,13] There are no statistical differences in postoperative outcomes between OS and ES procedures in literature.[14–16]

Postoperative physiotherapy has been advocated in the literature for the rehabilitation process of the operated hand.[17] However, despite the high prevalence of bilateral CTS, there are literature controversies on the use of postoperative therapies and their benefits, as well as a lack of common ground on the protocols to be established in postoperative rehabilitation.[18]

Instrument myofascial mobilization (IASTM) and stretching are one of the methods used for rehabilitative physiotherapy,[19,20] however, their combined use has never been employed in the postoperative period of idiopathic bilateral CTS, as well as the practice of performing these therapies bilaterally on the entire upper limb, shoulder, cervical and thoracic region, on the anterior, lateral and posterior sides is unprecedent.

The present study aims to evaluate the efficacy of two combined therapies in patients with idiopathic bilateral CTS submitted to surgery on one hand. It also aimed to evaluate the response to combined therapies in operated (OH) and non-operated (NH) hands after unilateral surgical release in this type of sample.

Methods

This is a prospective, randomized, double-blind, 2 × 4 crossover sample study (Crossover 2 × 4). All participants were recruited by the Neurosurgery team of Irmandade da Santa Casa de Londrina, in the carpal tunnel outpatient's unit, from January 2018 to February 2019. The study was approved by the ethics committee of Irmandade da Santa Casa de Londrina under number 3,276,439, registered at ClinicalTrials.gov (NCT04347746), and the informed consent form was signed by all participants.

Inclusion criteria for participants were: age of 18 years or older with idiopathic bilateral CTS, presenting one or more of the clinical criteria defined by Burton *et al*.,[2] physical status I or II by the American Society of Anesthesia (ASA), normal laboratory test results to exclude associated pathology (blood count, renal function, glycemic curve, rheumatic profile, and thyroid profile), having no upper limb limitations as well as skin lesions that could prevent them from performing the suggested therapies, and presenting, through the electroneuromyography (ENMG) exam, indicating severe impairment in one of the hands, according to Stevens' criteria.[21]

Participants with a history of allergy to the drugs used in this treatment, drug users, people with psychiatric disorders or intellectual disability (MR), pregnant women, patients who had received previous treatment with infiltration of corticosteroids or who had symptoms for less than 6 months were excluded.

Patients underwent surgery on the hand that presented the most severe degree of involvement on ENMG, but this degree was bilaterally severe, the more symptomatic hand was selected. The surgical approach used was CA, with a palmar incision and local anesthesia with a 1% lidocaine solution, adrenaline 1:100,000 and 8% sodium bicarbonate in a 1:10 ratio, following the precepts described in WALANT.[22] Anesthetic infiltration followed the technique described as Hole-in-one.[23] All participants were operated on using the same technique by a single neurosurgeon, without the use of a splint or restriction for the use of the hand post-surgery.

After 30-day postoperative period participants were referred to rehabilitation process according to the randomized groups. Starting with stretching followed by IASTM (group S/M) or starting with the IASTM technique followed by stretching (group M/S).

Study Protocol

The selected participants, both from group S/M and group M/S, received the same bilateral treatment in the upper limbs. Static active stretching was performed on six muscle groups located in the cervical region, shoulder, wrist, and fingers, totaling 22 exercise sequences, in the standing position. One stretching series was performed for each exercise sequence, lasting 40 seconds and with a 1-minute rest interval between each muscle group. Stretching was performed aiming for the greatest possible amplitude to the point of

discomfort, but not to the point of pain, remaining in the position for 40 seconds. Supervised stretching was performed twice a week for 4 weeks, with a total time per session of approximately 45 minutes.

The IASTM was performed exposing the target region, without the presence of any cosmetics on the skin. The protocol consisted in mobilizing the thorax muscles in the anterior and posterior region, shoulder, arm and forearm muscles, both in the anterior and posterior face, in dorsal, ventral and lateral decubitus. In myofascial mobilization, up to five types of instruments (crochets) were used, with appropriate conformation of opening and inclination for each muscle group, allowing the best coupling between the crochet and the portion of myofascial tissue to be mobilized. The IASTM technique had centripetal direction and was divided into three successive phases: digital palpation, instrumental palpation with crochets and mobilization.

At the end of mobilization with the crochets, a superficial scraping was added, using the convex part of the crochets, on the insertions of the major pectoral and trapezius muscles at the level of the sternum and occipital bone respectively, with a total time per session of approximately 45 minutes.

Assessment Instruments

The outcome analyses were evaluated from objective and subjective variables, according to guidelines as proposed by Erickson *et al.*[24]: (i) the best of three successive measurements, with 30 seconds rest between measurements for maximum force in isometric contraction of the palmar grip and digital pinch, using Hydraulic Hand Dynamometer and Hydraulic Pinch Gauge, respectively (both from Jamar®Patterson Medical, Warrenville, IL, USA) following its manual for measurement acquisition; (ii) visual analogue scale (VAS) adapted with the Wong–Baker face scale,[25] the evaluations of pain intensity were related to the current moment; and (iii) the impact of STC was evaluated by scores of the Sensitive and Function domains of the Boston Carpal Tunnel Questionnaire (Boston Carpal Tunnel Questionnaire-BCTQ) and scores of the Mental and Physical domains of the quality of life questionnaire SF-12 (12-Item Short Form Health Survey).[26]

Statistical Analysis

The sample size for a crossover design, with statistical power of 80%, weighting the hypothesis of loading, typical of these study designs, was estimated at 15 participants per group.[27]

Statistical Package for Social Sciences version 25.0 (IBM, Armonk, NY, USA) and Stata version 15.0 (Stata, College Station, TX, USA) software were used, and a 5% significance level was set for the applied tests. The ANOVA crossover models were estimated by Ordinary Least Squared (OLS), using the pkcross Stata v.15 routine.

The observations from period T0 served as baseline, that is, the ANOVA crossover models were developed from the difference results of period T0 (T1 = T1'-T0, …, T4 = T4'-T0), as indicated by Tudor *et al.*[28]

In addition to the crossover ANOVA, the differences between treatments were also evaluated only in the first period to completely exclude the effects of carryover. From the differences in outcomes at T0 and T1 between the groups (S/M and M/S), the Mann–Whitney (z) test was used.

This same test was used to compare the scalar variables of the profile between the sequences in the sample description, and in this section the Fisher's exact test was used for the categorical variables. To compare the results between the operated and non-operated hand and between the T0 and T4 periods, that is, paired samples, the Wilcoxon (z) test was used.

After determining the statistical significance of the outcome variables, the effect size was calculated by Cohen's *d*, with classification based on established criteria.[29] For instruments (i) and (ii), the procedures were developed in the context of the operated hand (OH), and non-operated hand (NH).

Results

Recruitment and Sample Profile

The study followed the CONSORT guidelines for its completion. After recruiting 252 patients with bilateral CTS, 45 participants met the eligibility criteria, of which two were excluded from the study for various reasons and two participants lost follow-up before joining physiotherapy treatment. Forty-three participants were randomized, however oner participant from the M/S group and two from the S/M group did not complete all the evaluation phases. Therefore, 19 in the S/M group and 21 in the M/S group remained for final analysis (T4). The allocation flowchart is shown in Fig. 1.

Table 1 presents the main information about the participants' profile according to the treatment sequences. In general, the groups were homogeneous in terms of characteristics. In the case of the severity of the operated hand, all cases were considered as severe, according to the research inclusion criteria.

ANOVA Crossover

Tables 2 and 3, in addition to bringing the results of the crossover ANOVA, also indicate the required descriptions for replications of crossover studies in meta-analysis, as recommended by Li *et al.*[30] Table 2 highlights the results for the objective outcomes (hand pressure strength and digital pinch) and Table 3 highlights the results for the subjective outcomes (VAS, BCTQ, and SF-12).

In the case of objective measures, we observed an effect of time for both hand pressure and pinch strength in both hands (Table 2). Evidence in favor of a treatment effect was also found for the digital pinch measure (in both hands), however, as the carryover effect was also shown to be significant, the results on the treatment effect are inconclusive. It is worth noting that the separability measure of treatment and

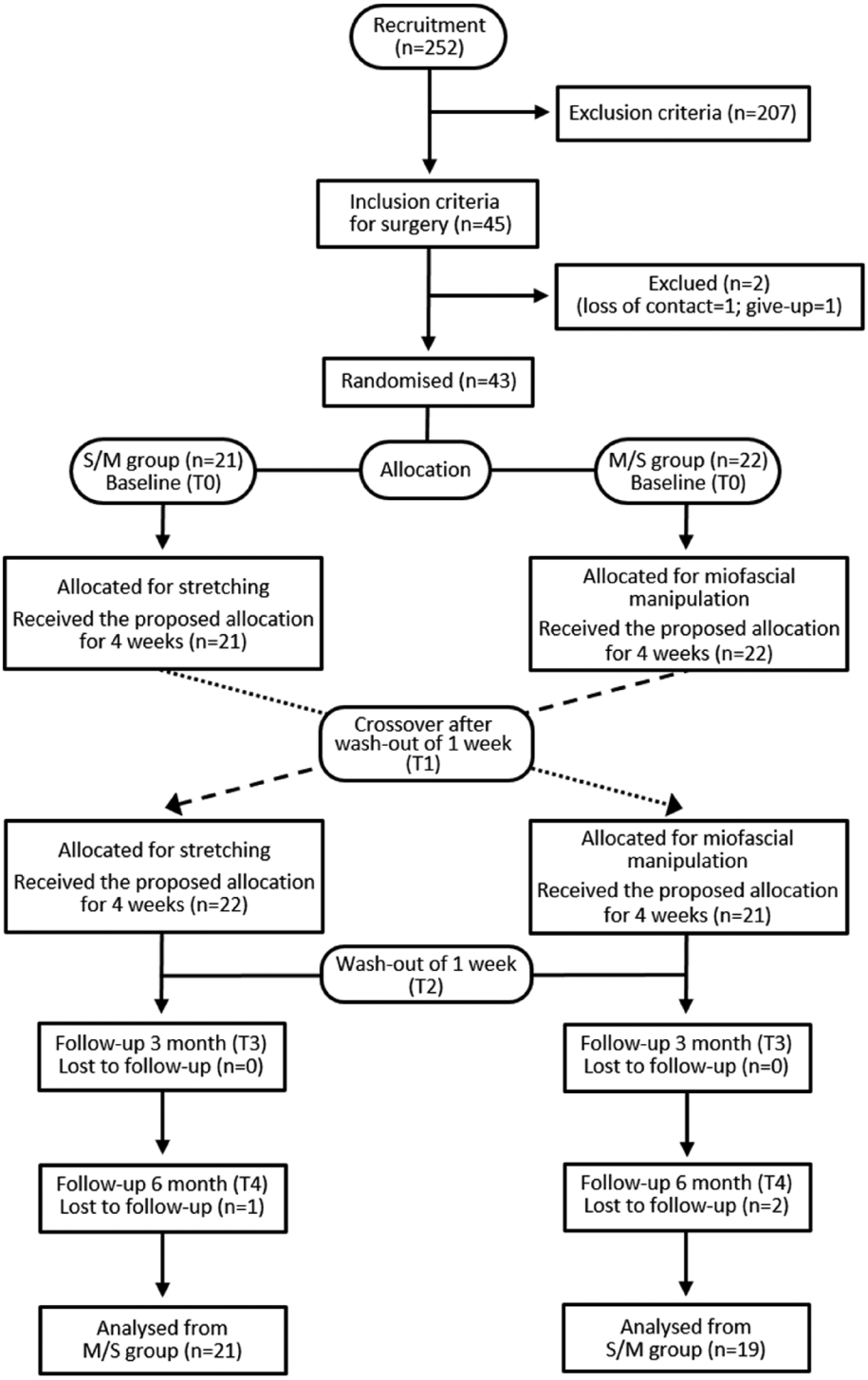

Fig. 1 Sample allocation flowchart.

carryover (1-Cramer' V) indicates that 50% of the variability can be individualized, that is, half of the variance is shared between treatment and carryover. These values refer to all outcomes.

Regarding subjective measures, the effect of period was highly significant for all outcomes (Table 3). The effect of sequence was found to be significant for the VAS of the non-operated hand and the physical and mental domains of the SF-12. Unlike the objective measures, in the case of the VAS of the operated hand and the mental domain of the SF-12, there was a significant effect of treatment and no effect of carryover, however, this conclusion should be cautiously

TABLE 1 Sample Profile by Treatment Sequence

Variables	Category	Treatment sequence [n (%)]			Test	
		S/M [n = 21]	M/S [n = 22]	Total [n = 43]	χ^2/z	*P*-value
Sex	Female	19 (90.5)	21 (95.5)	40 (93.0)	0.410¥	0.607
Ethnicity	White	13 (81.3)	14 (73.7)	27 (77.1)	0.282¥	0.700
Marital status	Married	16 (80.0)	15 (71.4)	31 (75.6)	0.408¥	0.719
Occupation	Housewife	6 (28.6)	11 (52.4)	17 (40.5)	2.471	0.208
Education	High school	14 (73.7)	13 (61.9)	27 (67.5)	0.631	0.511
Family income	Up to 1.000 BRL	9 (52.9)	14 (66.7)	23 (60.5)	0.741	0.509
BMI	Non-normal weight	19 (90.5)	17 (77.3)	36 (83.7)	1.374¥	0.412
Dominant hand	Right	19 (90.5)	20 (90.9)	39 (90.7)	0.002¥	1.000
Stevens NH	Light	6 (28.6)	3 (13.6)	9 (20.9)	5.322¥	0.070
	Moderated	9 (42.9)	5 (22.7)	14 (32.6)		
	Severe	6 (28.6)	14 (63.6)	20 (46.5)		
Age (years)	mean ± SD	50.52 ± 7.86	52.45 ± 12.57	51.51 ± 10.46	−0.207	0.836
Symptom time (years) OH	mean ± SD	5.15 ± 4.62	5.62 ± 2.92	5.38 ± 3.83	−1.27	0.205
Symptom time (years) NH	mean ± SD	4.68 ± 4.19	4.14 ± 3.18	4.41 ± 3.68	−0.345	0.730

Abbreviations: NH = Non-operated hand; SD = Standard Deviation; S = Stretching; M = Miofascial mobilization; BRL = Brazilian Real; BMI = Body Mass Index. χ^2/z = Fisher's exact test (χ^2) and the Mann–Whitney test (z) [for age and symptom time].; *Note*: The categories indicated in the table are the most frequent. ¥Indicates that even with the reclassifications, an expected count of less than five was obtained in two cells

interpreted and needs further investigation, as the carryover effect was marginally significant ($P = 0.06$ and $P = 0.09$ respectively). In the case of the BCTQ sensitive domain both treatment and carryover were significant.

Effect Size

In addition to the Crossover ANOVA models the Mann–Whitney and Wilcoxon tests were run as a counter test. At the same time, we calculated the effect size using Cohen's *d* (95% CI), whose values, when the Mann–Whitney and Wilcoxon tests were significant, are shown in Table 4. As displayed in Table 4, all period effects can be considered large, except for the SF-12 physical domain. In general, there is evidence that physical therapy acted positively in the improvement of patients who underwent surgery. This positive effect seems to be shared by both surgery and physical therapy procedures.

The point estimate of the treatment effect size for the digital pinch measurement and VAS of the non-operated hand can be considered large. Generically, IASTM performed better than stretching for digital pinch and pain reduction in the unoperated hand. Despite small and intermediate effect sizes the effect of the sequence was also significant for some outcomes: (i) VAS of the non-operated hand; (ii) function domain of the BCTQ; and (iii) SF-12 in both domains. Thus, there are indications that starting with IASTM leads to a greater improvement in these items than starting with stretching for patients who underwent CTS surgery, although the effect size is not large.

This finding can be viewed in Fig.2(a) and (c), respectively. It can be seen that for almost the same level of the operated and non-operated hand in the outcomes of grip strength (≈ 28) and VAS (≈ 2) in the fourth period, the operated hand has a lower level of grip strength (15.1 *vs* 18.1) and higher VAS score (7.8 *vs* 6.3) in the baseline period (i.e., the difference between the fourth period and baseline period was greater for the operated hand than the non-operated hand).

Discussion

The present study presented robust results of objective and subjective measures evaluated the postoperative rehabilitation of patients with bilateral idiopathic CTS, demonstrating that IASTM and stretching was effective, and the effect size was considered large for most outcomes.

Crossover ANOVA findings were expressed in terms of the sequence applied, the treatment, carryover and the follow-up period (T4-T0).[30] The adoption of a crossover study model, which used the individual himself, coupled with analysis of the bilateral data using Crossover ANOVA, which manages the influence of repeated measures as a result of bilaterality, produced reliable results for the outcomes assessed.[31]

The groups were evaluated for a number of different outcomes, and findings were found to be pointwise for both OH and NH with respect to some variables for sequence and treatment. However, when checking the results considering the period, they were significant and with effect sizes considered large for most outcomes, demonstrating that the combination between these two techniques was effective both during their implementation and at 6-month follow-up, suggesting that these therapies have a supplementary effect.[32]

The isolated use of stretching in the postoperative rehabilitation of CTS in AC with palmar incision was described by Nathan *et al.*[33] The authors performed dynamic stretching at the wrist for 2 weeks and obtained satisfactory results.[33] Schmid *et al.*[34] conducted physical therapy

TABLE 2 Objective Outcomes (Difference to Baseline) from a Two-Treatment, Four-Period Crossover Trial

Outcome	Treatment sequence S/M (n = 81) M/S (n = 87)	Treatment period △ [mean (±SD)]				Effect *F* (p)			
		T1 (n = 43)	T2 (n = 43)	T3 (n = 42)	T4 (n = 40)	Sequence	Treatment	Carryover	Period
Hand grip strength (OH)	S/M	4.02 (4.08)	9.14 (5.98)	11.23 (6.12)	13.25 (5.72)	0.58 (p = 0.45)	2.08 (p = 0.15)	0.70 (p = 0.41)	**73.23 (p < 0.00)**
	M/S	5.92 (3.27)	9.91 (4.30)	12.32 (4.57)	13.17 (6.07)				
Hand grip strength (NH)	S/M	3.49 (1.98)	7.06 (4.21)	9.70 (4.32)	10.32 (4.51)	0.73 (p = 0.40)	0.79 (p = 0.38)	1.61 (p = 0.21)	**65.73 (p < 0.00)**
	M/S	4.91 (3.28)	8.17 (3.90)	10.20 (4.19)	10.67 (5.15)				
Tip pinch gauge (OH)	S/M	0.51 (0.45)	1.24 (0.57)	1.40 (0.66)	1.59 (0.78)	0.00 (p = 0.98)	**12.18 (p < 0.00)**	**8.58 (p < 0.00)**	**54.38 (p < 0.00)**
	M/S	0.73 (0.37)	1.17 (0.56)	1.29 (0.61)	1.27 (0.74)				
Tip pinch gauge (NH)	S/M	0.45 (0.31)	1.17 (0.63)	1.32 (0.68)	1.51 (0.82)	0.24 (p = 0.63)	**9.54 (p < 0.00)**	**6.71 (p = 0.01)**	**52.42 (p < 0.00)**
	M/S	0.75 (0.38)	1.20 (0.56)	1.35 (0.62)	1.33 (0.75)				

Abbreviations: △ = Difference; OH = Operated hand; NH = Non-operated hand; T = Period; SD = Standard Deviation; S = Stretching; M = Miofascial mobilization. Effect *F* (p) refers to *F* test (p-value) of the effects estimated from Crossover ANOVA.; ***Note*:** The values highlighted in bold are significant at 5%

TABLE 3 Subjective Outcomes (Difference to Baseline) From a Two-Treatment, Four-Period Crossover Trial

Outcome	Treatment sequence S/M (n = 81) M/S (n = 87)	Treatment period △ [mean (±SD)]				Effect *F* (p)			
		T1 (n = 43)	T2 (n = 43)	T3 (n = 42)	T4 (n = 40)	Sequence	Treatment	Carryover	Period
VAS (OH)	S/M	−3.67 (0.80)	−5.52 (0.81)	−6.00 (0.86)	−6.00 (0.88)	0.81 (p = 0.37)	**11.38 (p < 0.00)**	3.56 (p = 0.06)	**125.59 (p < 0.00)**
	M/S	−3.86 (0.56)	−5.14 (0.83)	−5.59 (0.73)	−5.76 (0.70)				
VAS (NH)	S/M	−2.33 (0.80)	−3.57 (0.75)	−4.00 (0.79)	−4.11 (0.74)	**4.56 (p = 0.04)**	1.10 (p = 0.30)	1.08 (p = 0.30)	**68.93 (p < 0.00)**
	M/S	−3.09 (1.06)	−4.18 (1.30)	−4.59 (1.22)	−4.67 (1.24)				
BCTQ (sensitive)	S/M	−14.81 (5.81)	−21.33 (5.70)	−23.10 (5.88)	−25.16 (6.99)	1.09 (p = 0.30)	**9.31 (p < 0.00)**	**6.43 (p = 0.01)**	**90.99 (p < 0.00)**
	M/S	−14.73 (4.71)	−19.14 (5.45)	−21.14 (4.94)	−22.14 (4.74)				
BCTQ (function)	S/M	−7.76 (3.11)	−12.10 (3.71)	−14.75 (2.75)	−16.11 (3.70)	0.34 (p = 0.09)	2.41 (p = 0.12)	**5.38 (p = 0.02)**	**92.65 (p < 0.00)**
	M/S	−6.68 (3.50)	−10.50 (3.85)	−12.82 (4.08)	−13.14 (4.26)				
SF-12 (physical)	S/M	−1.31 (5.05)	1.72 (4.87)	1.22 (5.52)	0.52 (5.58)	**5.36 (p = 0.03)**	0.34 (p = 0.56)	2.48 (p = 0.12)	**5.21 (p < 0.00)**
	M/S	0.97 (4.07)	3.83 (4.71)	5.20 (4.32)	4.88 (4.26)				
SF-12 (mental)	S/M	10.63 (7.63)	16.82 (7.74)	20.43 (8.20)	22.26 (8.93)	**5.15 (p = 0.03)**	**3.80 (p = 0.05)**	2.94 (p = 0.09)	**24.46 (p < 0.00)**
	M/S	8.22 (4.68)	11.76 (6.56)	14.90 (7.23)	15.48 (7.92)				

Abbreviations: △ = Difference; OH = Operated hand; NH = Non-operated hand; T = Period; S = Stretching; M = Miofascial mobilization; VAS = Visual Analogue Scale; BCTQ = Boston Carpal Tunnel Questionnaire; SF-12 = 12-Item Short Form Health Survey. Effect F (p) refers to F test (p-value) of the effects estimated from Crossover.; *Note*: The values highlighted in bold are significant at 5%

TABLE 4 Effect Size by Sequence, Treatment and Period

Outcome	Measure	Cohen's *d* (IC 95%)		
		Sequence	Treatment	Period
Hand grip strength	OH	–	–	1.93 (1.40; 2.46)
	NH	–	–	2.55 (1.96; 3.14)
Tip pinch gauge	OH	–	–	2.68 (2.08; 3.29)
	NH	–	−0.86 (−1.49; −0.24)	3.08 (2.43; 3.73)
VAS	OH	–	–	−6.78 (−7.92; −5.64)
	NH	0.53 (0.23; 0.84)	0.80 (0.18; 1.43)	−3.67 (−4.39; −2.96)
BCTQ	Sensitive	–	–	−5.01 (−5.91; −4.12)
	Function	−0.39 (−0.70; −0.09)	–	−5.13 (−6.03; −4.22)
SF-12	Physical	−0.64 (−0.95; −0.33)	–	0.50 (0.06; 0.95)
	Mental	0.59 (0.28; −0.90)	–	2.07 (1.52; 2.61)

Abbreviations: OH = Operated hand; NH = Non-operated hand; VAS = Visual Analogue Scale; BCTQ = Boston Carpal Tunnel Questionnaire; SF-12 = 12-Item Short Form Health Survey.; ***Note:*** The cell values indicate that the respective bivariate tests (Mann–Whitney for sequence and treatment, and Wilcoxon for period) were significant at the 5% level. For the sequence we considered all periods (i.e., M/S [n = 87] and S/M [n = 81]). For treatment we considered the baseline difference of the outcome in the first period between the groups (i.e., M [n = 22] and S [n = 21]). And to assess the effect of period we took the endpoint value at baseline and the endpoint value at the fourth period as paired samples (i.e., n = 40)

treatment with tendon mobilization exercises and MN in the postoperative period of AC with palmar opening. The authors observed a beneficial effect after a one-week physical therapy, with a reduction of edema in the MN in the operated hand indicated by MRI examination.[34]

The benefits observed from stretching in CTS may stem from improving the viscoelastic properties of the musculoskeletal tissue,[35] restoring proprioceptor and nociceptor dysfunctional patterns at both central and peripheral nervous system levels,[36] and remodeling the subsynovial connective tissue (TCSS).[37]

The use of myofascial mobilization in postoperative rehabilitation of CTS has not yet been reported in literature, although it is indicated in TCSS dysfunctions such as fascia pain syndromes, low back pain, plantar fasciitis and myofascial trigger points (Robert[38]). The beneficial effects of myofascial mobilization on the TCSS would be related to the following causes: the release of adhesions existing between the connective tissue and the MN allowing the free gliding of the MN along the fascia; the biomechanical restructuring both locally and at a distance recomposing the body's tension network; and the stimulation of fibroblast growth that triggers an increase in collagen synthesis, maturation, and alignment rebuilding the TCSS.[39–42]

The involvement of the TCSS in the pathophysiology of CTS was recognized by Matsuura *et al.*[43] The structural changes in the TCSS that would jeopardize the normal sliding between the NM and the flexor tendons, causing repeated injury to the NM by displacement of the tendons.[43] This type of injury has been documented in both animal studies[44] and in a cadaveric model.[45]

As such, stretching and IASTM would act as supplementary rather than competitive therapies, justifying, in part, the good results obtained in their combination in the postoperative period of CTS.[19,45,46]

In the presence of idiopathic bilateral CTS there is an option in literature to perform surgery on both hands simultaneously[47,48] or to operate on one hand and evaluate the effect of surgery on OH and NH.[49,50]

The results of surgery on NH are conflicting in literature. Unno *et al.*[51] evaluated patients with bilateral CTS operating on only one hand and reported improved hand NH both immediately postoperatively and at follow-up for 6 months after surgery, regardless of the severity of NH impairment.[51]

According to Agrawal and Southern,[52] the improvement of NH hand in bilateral CTS cases showed spontaneous recovery in 37% of cases after 6 months of follow-up period. However, there is disagreement in the literature regarding the NH hand as shown in the study by Afshar *et al.*[53] The authors reported that NH remained unchanged after 6 months of follow-up in a bilateral CTS sample containing 24% NH hands classified as severe according to Stevens' ENMG criteria.[53]

The reasons for the improvement in the NH hand after performing contralateral surgery may be related to the decrease in the persistent paresthetic stimulus that deactivates interneurons located in the spinal cord and brainstem,[54] disinhibiting the sensory pathways (De[55]). These precepts assume that CTS is a complex neuropathy with both central and peripheral nervous system involvement. However, there is a need for additional research in order to clarify in more detail the mechanisms involved in bilateral CTS.[56]

The causes for the obtained results in the OH are still controversial. According to Bland[57] the reasons for the improvement observed in the OH cannot be explained only by the surgical release of the flexor retinaculum. The author analyzed 32,936 surgical interventions using AC and concluded that 17% of patients had a moderate improvement

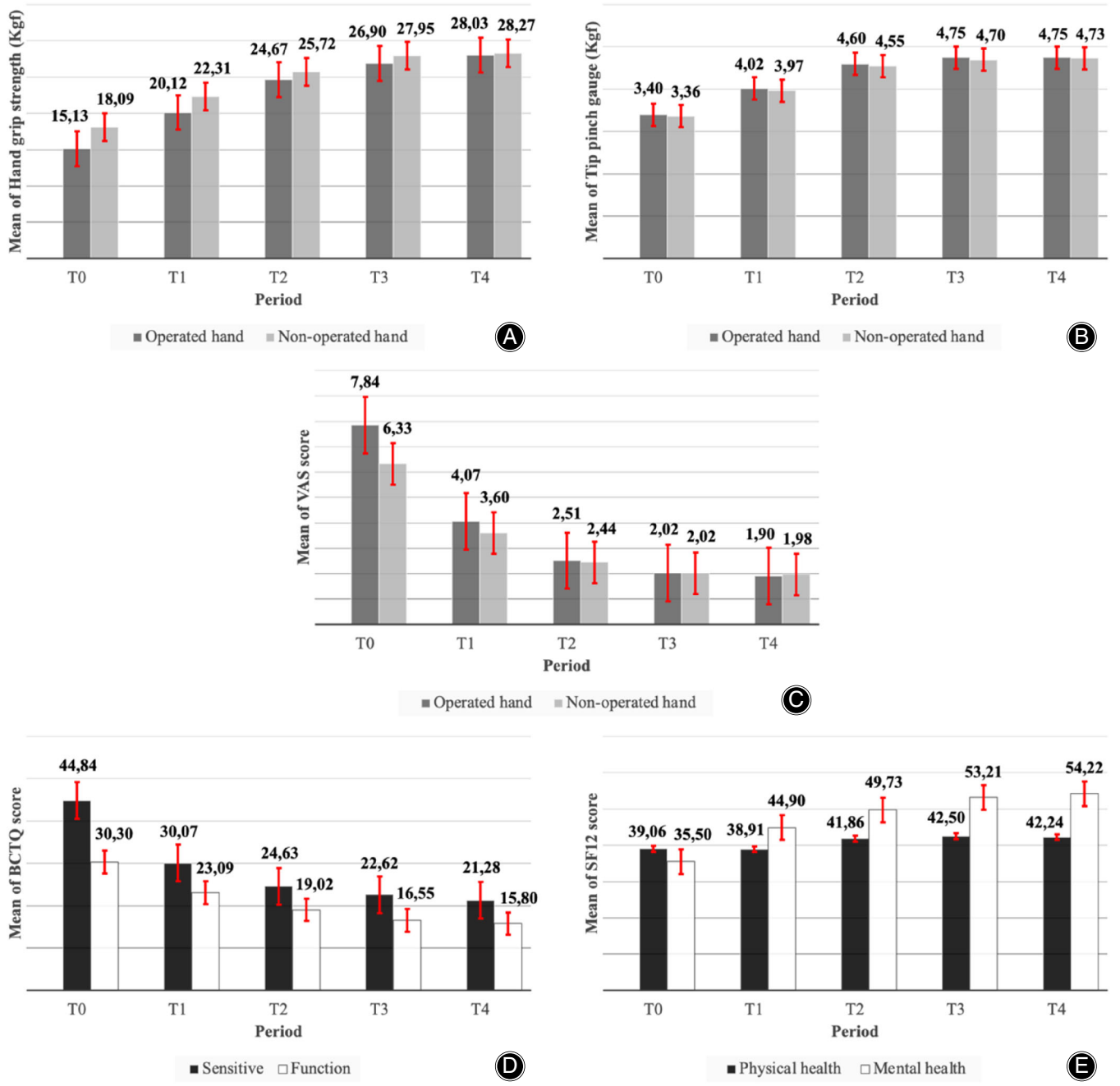

Fig. 2 Outcomes means by period. VAS = Visual Analogue Scale; BCTQ = Boston Carpal Tunnel Questionnaire; SF-12 = 12-Item Short Form Health Survey. The graphs illustrate the positive development of the outcomes throughout physiotherapy, supported by the statistical analyses carried out in the research and the effect sizes shown in Table 4. The values refer to the original measures and not to the baseline differences, since the baseline differences were evidenced in Tables 2 and 3.

while in 8% of cases there was a worsening of symptoms. Therefore, to think of the improvement obtained in the OH as resulting from the pressure decrease inside the carpal tunnel due to the surgical release of the transverse carpal ligament may not be a reality, as this did not occur in 25% of the operated cases.[57]

In a recent systematic review and meta-analysis, Georgeto *et al.*,[58] present favorable evidence of clinical and surgical treatments, as they potentially improve symptom severity, functional status and pain intensity in patients with bilateral CTS during periods of 1- and 3-month follow-up.

Thus, in order to improve the results of both OH and NH, the use of post-surgical physiotherapy has been recommended in recent literature. However, despite the existence of several protocols for postoperative rehabilitation for CTS, their implementation remains a controversial point in literature and is not supported by national medical insurance in some countries, such as France.

The reasons for divergences regarding the acceptance of physiotherapy in the postoperative period of CTS are due, in part, to the limitations found in literature when addressing the use of therapies in the post-surgical rehabilitation of CTS, such as: the scarcity of studies containing exclusive samples of patients with idiopathic bilateral CTS, since these cases present clinical peculiarities that distinguish them from unilateral CTS;[59] the low quality of evidence on the benefits of different types of rehabilitation arising from problems in the allocation and concealment of bilateral CTS patients in randomized studies;[60] the presence of overestimated results due to the use of statistical tests that disregard the repetition of data arising from bilaterality;[61] the absence of a standardization of rehabilitation programs worldwide[62] and the lack of a gold standard instrument for assessing the results of the therapies employed that entails the use of many different outcome measures, making it difficult to compare the findings between studies.[63]

Strength and Limitations

We believe that our study can contribute to these questions, because we proceeded with an unpublished RCT in the literature, with a sample containing exclusively patients with idiopathic bilateral CTS, we evaluated the combined results of surgery and physical therapy in this sample, both during the treatment period, as well 6- months follow-up, with several outcome measures, and the statistical method employed controlled by patients with bilateral CTS, avoiding that the results of the outcome measures were overestimated.

The limitations of this study were that it was carried out in a single center, which jeopardized its external validity, and the absence of a control group without physical therapy treatment in order to compare the results obtained in the evaluation periods, and the design of the experiment did not allow for the separation of the effects of surgery and physical therapy.

However, further studies are required in order to overcome the deficiencies in randomized clinical trials using samples containing only bilateral idiopathic CTS patients, with allocation being made per participant and not per wrist, appropriate statistical analyses in view of the data repetition due to bilaterality, and the attempt to establish a pattern of therapies, as well as the measures to evaluate the results so as to produce reliable evidence and allow the comparison between the studies.

Conclusion

The current study presented robust results of objective and subjective measures in the post-surgical rehabilitation of patients with idiopathic bilateral CTS, demonstrating that the proposed therapeutic model was effective for all the variables evaluated, and the effect size was considered large for most of the outcomes. This research showed robust results for the period, demonstrating that the therapeutic combination used in the postoperative period of bilateral idiopathic CTS brought good results during its application, as well as these were maintained in the 6-month follow-up. An improvement of both OH and NH was also noted from a functional and sensitivity point of view.

Although the beneficial effects of physical therapy and surgery are difficult to dissociate, the outcome performance over time shows that surgery followed by the proposed physical therapy treatments or some interaction between them has positive effects on operated and unoperated hands in patients with idiopathic CTS bilateral, may be a valid strategy used for this population.

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