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Research

Exercises using a touchscreen tablet application improved functional ability more than an exercise program prescribed on paper in people after surgical carpal tunnel release: a randomised trial

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K E Y W O R D S

Carpal tunnel syndrome
Exercise therapy
Feedback sensory
Mobile applications

A B S T R A C T

Question: In people who have undergone surgical carpal tunnel release, do sensorimotor-based exercises performed on the touchscreen of a tablet device improve outcomes more than a conventional home exercise program prescribed on paper? **Design**: Randomised, parallel-group trial with concealed allocation, assessor blinding, and intention-to-treat analysis. **Participants**: Fifty participants within 10 days of surgical carpal tunnel release. **Intervention**: Each participant was prescribed a 4-week home exercise program. Participants in the experimental group received the ReHand tablet application, which administered and monitored exercises via the touchscreen. The control group was prescribed a home exercise program on paper, as is usual practice in the public hospital system. **Outcome measures**: The primary outcome was functional ability of the hand, reported using the shortened form of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) questionnaire. Secondary outcomes were grip strength, pain intensity measured on a 10-cm visual analogue scale, and dexterity measured with the Nine-Hole Peg Test. Outcomes were measured by a blinded assessor at baseline and at the end of the 4-week intervention period. **Results**: At Week 4, functional ability improved significantly more in the experimental group than the control group (MD –21, 95% CI –33 to –9) on the QuickDASH score (0 to 100). Although the mean estimates of effect on the secondary outcome also all favoured the experimental group, none reached statistical significance: grip strength (MD 5.6 kg, 95% CI –0.5 to 11.7), pain (MD –1.4 cm, 95% CI –2.9 to 0.1), and dexterity (MD –1.3 seconds, 95% CI –3.7 to 1.1). **Conclusion**: Use of the ReHand tablet application for early rehabilitation after carpal tunnel release is more effective in the recovery of functional ability than a conventional home exercise program. It remains unclear whether there are any benefits in grip strength, pain or dexterity. **Trial registration**: ACTRN12618001887268. **[Blanquero J, Cortés-Vega MD, García-Frasquet MÁ, Sánchez-Laulhé PR, Nieto Díaz de los Bernardos MI, Suero-Pineda A (2019) Exercises using a touchscreen tablet application improved functional ability more than an exercise program prescribed on paper in people after surgical carpal tunnel release: a randomised trial. *Journal of Physiotherapy* 65:81–87]**

Introduction

Carpal tunnel syndrome is a focal and compressive neuropathy in which raised pressure in the carpal canal results in median nerve compression and impaired nerve perfusion, leading to discomfort and paraesthesia in the hand.[1,2] Conservative treatments are recommended as initial management, whereas surgery is generally recommended in refractory cases.[2]

Carpal tunnel decompression is the accepted surgical treatment when conservative measures fail,[1] with the rate of surgical intervention after initial conservative management being between 57 and 66%.[2] Open carpal tunnel release is the standard surgical technique.[1] However, the method of post-surgical rehabilitation that should be used is controversial.[3] Post-surgical immobilisation, despite a lack of scientific evidence reporting its value[3–5] and the existence of Level 1 evidence of its lack of benefit,[6] is still employed by approximately half of surgeons, although the number of professionals advocating for it is decreasing annually.[6] Several groups of authors have found that there is no beneficial effect obtained from postoperative immobilisation compared to soft dressing allowing movement after carpal tunnel release.[7–9] Other studies have reported that early mobilisation results in an improvement in pain, grip and pinch strength,[10] as well as a reduction in the time to return to activities of daily living and work,[10,11] compared to immobilisation. In light of this evidence, the European guidelines[12] state that exercises should be considered for the postoperative period.

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A systematic review identified that home exercise programs have similar effects as face-to-face rehabilitation on function, dexterity and strength after carpal tunnel release.[4] In one of the reviewed studies, Provinciali et al compared a multimodal rehabilitation program against a 2-week home exercise program in a sample of 100 participants; no significant between-group differences were found in the Boston Carpal Tunnel Questionnaire, Jebsen-Taylor test, and 9-Hole Peg Test after 3 months of follow-up.[13] Pomerance et al compared, in a sample of 150 participants, the treatment by a hand therapist against a home exercise program; they found no significant differences in pain, grip and pinch strength or the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire after 3 and 6 months of follow-up.[14] They also made an observation about the relative cost-effectiveness of home exercise programs and face-to-face rehabilitation, concluding that the latter seems to be unjustified for uncomplicated patients with conventional short incisions.[14]

Carpal tunnel syndrome is not just a peripheral problem; it has a central involvement, which rehabilitation (including home exercise programs) ought to address. This central involvement is characterised by cortical reorganisation caused by chronic median nerve dysfunction and altered somatosensory afference.[15] In people with carpal tunnel syndrome, this impacts sensorimotor integration and motor performance,[16,17] resulting in deficits in dextrous manipulation and finger force distribution control.[18,19] Those abilities are basic for activities of daily living, relating directly to the impairment of functionality and quality of life in people with carpal tunnel syndrome.

Some recent preliminary studies have shown that an exercise application (app) on a tablet device can improve dexterity and corticospinal drive to spinal motoneurons.[20,21] This study is part of a larger body of research that has studied the effectiveness of a sensorimotor approach for the recovery of hand trauma pathologies, through the enhancement of neuromuscular control and the effect at cortical level.[22] Therefore, one way to expand this field of knowledge is through a new sensorimotor modality via a tablet touchscreen using the ReHand app. ReHand is an app specifically developed for the trauma approach of the wrist, hand and fingers through exercises that are performed on the touchscreen. The app has been developed by and under the supervision of healthcare professionals, including surgeons, physiotherapists and occupational therapists, so the functionalities seek to meet the needs that these professionals identified through their patients in practice.

Therefore, the research question for this randomised trial was:

In people who have undergone surgical carpal tunnel release, do sensorimotor-based exercises performed on the touchscreen of a tablet device improve outcomes more than a conventional home exercise program prescribed on paper?

Method

Design

An assessor-blinded, parallel-group, randomised controlled trial was undertaken in people who had undergone surgical carpal tunnel release. The study was conducted from November 2018 to January 2019. Participants were randomly allocated to an experimental group or a control group using a computer-generated, concealed allocation schedule. All participants received a 4-week home exercise program. Participants in the experimental group were allocated a program that included sensorimotor-based exercises performed using a tablet touchscreen. Participants in the control group received a home exercise program conventionally provided on paper for rehabilitation after carpal tunnel release in the public healthcare system. Data were collected by a blinded assessor prior to randomisation and 4 weeks later.

Participants, therapists, centres

People aged between 18 and 65 years old who had undergone surgical carpal tunnel release were consecutively screened at Virgen Macarena and Virgen del Rocio University Hospitals, Seville, Spain. Two experienced hand surgeons performed screening against these inclusion criteria: diagnosis of carpal tunnel syndrome was based on history, examination, and nerve conduction studies; open carpal tunnel release with a standard surgical approach was no more than 10 days prior to the baseline measurement; and a tablet device was accessible to the person for the study period. Potential participants were excluded if they had: a history of neurological, psychiatric or cognitive disorder; or a plan to receive physiotherapy during the 4-week study period.

After confirmation of eligibility and completion of the baseline measurements, an independent researcher randomly allocated participants via a computer-generated, random allocation schedule without knowledge of the baseline measurement results. This researcher also: explained how to carry out the randomly allocated intervention; asked the participant not to reveal this intervention to any of the study's investigators; answered any questions from the participant; and provided telephone support. In addition, this independent researcher oversaw the weekly monitoring of the participants. Since it was not possible to blind participants, efforts were made to keep participants unaware of the details of the intervention being allocated to the opposite group. For this reason, the two interventions were described in the information sheet as home-based exercise programs with differing formats.

Interventions

Participants in both groups were advised to carry out their allocated exercise intervention autonomously at home, completing one session a day on at least 5 days a week, for 4 weeks. The exercise program lasted approximately 25 minutes per session. The differences between the two groups were the exercise program employed and how adherence to treatment was measured.

Experimental group

Participants in the experimental group performed the home exercise program using the ReHand tablet app. This app was developed under the guidance of several healthcare professionals (surgeons, physiotherapists and occupational therapists) for use on Android and iOS tablets to enhance, through controlled active work, the dexterity and functionality of the wrist, hand and fingers after traumatic injury. ReHand has a range of specific exercises for these purposes, which can be configured into an exercise program according to the pathology and progress of the patient. All of the exercises are performed on the tablet touchscreen (Figure 1). For the experimental group, a specific program was designed for rehabilitation after carpal tunnel release consisting of exercises for mobility, co-ordination and dexterity of the hand, wrist and fingers, as described in detail in Table 1. The exercises are performed by making taps and movements while touching the touchscreen and guided by feedback, thereby enabling sensorimotor-based, controlled, active exercise. To assist users to understand each exercise on the app, it gives both step-by-step real-time instructions and a video demonstration of the exercise being performed. The explanation of this intervention to the participants randomised to the experimental group included: a 5-minute demonstration of how to use the ReHand app on a tablet; information about how to download the app from Android and iOS sources; provision of a username and password; and telephone support.

Data were transferred from the app to a web management panel, which allowed monitoring of adherence to the prescribed exercise program. In this group, this system was used by the researcher in charge of monitoring. Those participants who did not use the app in the first 5 days were telephoned to ensure that they were not experiencing technical difficulties.

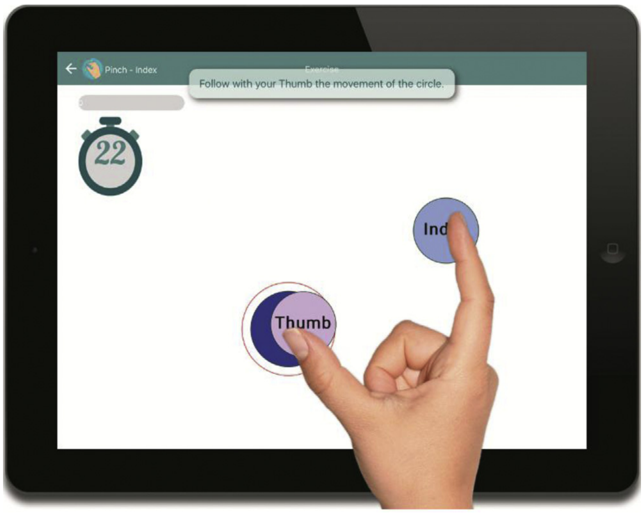

Figure 1. Example of performance of an exercise in the experimental intervention.

Control group

The participants of this group received a home exercise program on paper. This program is conventionally used in the public hospital system for early rehabilitation after carpal tunnel release. The exercises are focused on mobility of the entire upper limb, with greater emphasis on those exercises relating to the hand. These exercises are detailed in Table 2. A researcher monitored the exercises performed by the participant through a weekly telephone call.

Outcome measures

Baseline measures were collected between 7 and 10 days after surgery and prior to random allocation to a study group. Final measures were collected 4 weeks later, at the end of the intervention period. All measures were assessed in each participant individually and face-to-face. The measurements were made by a single physiotherapist with extensive clinical experience, who was blinded to each participant's allocated group. Participants were also blind to allocation during the baseline measurements and subsequently they were instructed not to reveal to the assessor the group to which they belonged.

Primary outcome

Changes in self-reported functional ability were measured on the DASH questionnaire, which is considered to be one of the main measurements in carpal tunnel research.[3] The DASH questionnaire has been shown to be reliable and valid, and has been successfully translated into Spanish.[3,23] Functional ability was measured through the shortened form of the DASH questionnaire (QuickDASH), which has a discriminant ability, cross-sectional reliability and test-retest reliability similar to the DASH questionnaire,[24] which further demonstrates its validity and practical utility in people who have undergone carpal tunnel release.[25]

Secondary outcomes

Grip strength measurement was performed using a hydraulic grip dynamometer[a]. Participants were seated comfortably upright, with both feet on the ground, shoulders adducted and neutrally rotated, elbow flexed at 90 deg, forearm in neutral rotation, and wrist between 0 deg and 30 deg dorsiflexion and between 0 deg and 15 deg ulnar deviation. Three successive trials were recorded for each test, with 30 seconds of rest between each measurement. The average of the three measurements was used in the analysis. This procedure has been well documented as reliable.[26]

Pain severity was assessed on a visual analogue scale of 0 to 10 cm, where a score of 0 equated to 'no pain' and 10 equated to the 'most severe pain'.

The Nine-Hole Peg Test is one of the most commonly used tools for assessing dexterity.[27] The test uses a square board with nine holes, with a container holding nine pegs attached to it. The participant must pick up one peg at a time and put it into a hole until all the holes are filled in any order. Then, the participant must remove all the pegs one at a time and return them to the container. Standard instructions for the test were given along with a brief demonstration.[28] Participants performed a brief practice test prior to the actual test.

Assessor blinding was evaluated at the end of the trial by asking the assessor if any of the participants had indicated to which group they had been allocated.

Data analysis

The intention-to-treat principle was used for data analysis. Mean scores, SDs and between-group differences (95% CIs) were calculated for all outcomes at baseline and at the end of the 4-week intervention period. The between-group differences and their respective 95% CIs were calculated using linear mixed models with group, time and group-versus-time interaction terms. The confidence level adopted was 5% and statistical analyses were performed using commercial software[b].

Results

Flow of participants

Of 72 screened subjects, 50 met the selection criteria and completed the study. The flow of participants is detailed in Figure 2. The mean age of the participants was 50 years (SD 8), of whom nine (18%) were men and 41 (82%) were women. The mean age of the participants in the experimental group was 51 years (SD 8), of whom three were male and 22 were female. The mean age of participants in the control group was 49 years (SD 7), of whom six were male and 19 were female. The groups had similar baseline scores on all the outcome measures. Baseline demographic and clinical characteristics of participants are presented in Table 3.

Compliance with the study protocol

All participants were allocated the treatment in line with their random allocation. All participants underwent baseline and final

Table 1
Description of experimental intervention (app-based exercises) for rehabilitation after carpal tunnel release.

Exercise (each repetition of the exercise lasts 25 seconds)	Repetitions
1. Pinch exercise with the index finger, performing a controlled movement in a painless range guided by feedback	4
2. Pinch exercise with the middle finger, performing a controlled movement in a painless range guided by feedback	4
3. Pinch exercise with the ring finger, performing a controlled movement in a painless range guided by feedback	4
4. Flexion-extension exercise of the index finger, performing a controlled movement in a painless range guided by feedback	4
5. Flexion-extension exercise of the middle finger, performing a controlled movement in a painless range guided by feedback	4
6. Hand-eye co-ordination exercise, making taps on the screen with each finger as the circles change colour	4
7. Hand opened and fingers extended, wrist stabilisation and little finger in contact with the tablet screen. Controlled wrist flexion-extension movement in painless range guided by feedback	4
8. Closed fist holding a stylus, wrist stabilisation and stylus in contact with the tablet screen. Controlled wrist flexion-extension movement in painless range guided by feedback	4

Table 2
Description of control intervention (home exercise program) conventionally used in public health services.

Exercise	Sets	Repetitions
1. Make a fist and then extend the fingers	3	15
2. With the hand opened and fingers extended, maximally extend the wrist	3	15
3. With the hand opened and fingers extended, maximally abduct the fingers	3	15
4. Contact each finger's pad with the thumb pad	3	15
5. With a (semi-) closed fist, flex and extend the wrist	3	15
6. With the hand opened and fingers extended, deviate the hand towards radius and ulna	3	15
7. With a semi-closed fist, perform rotating movements of the fist	3	15
8. Standing or sitting in a chair, extend the elbow so that the upper limb hangs beside the body	3	10
9. From the previous position, slowly raise the upper limb to the horizontal plane with the elbow in extension	3	10
10. From the previous position, flex the elbow and touch the same shoulder with your fingers	3	10

measures. No participants revealed their group allocation to the assessor.

Effect of intervention

At Week 4, functional ability improved significantly more in the experimental group than the control group (MD –21, 95% CI –33 to –9) on the QuickDASH score (0 to 100). Summary data are presented in Table 4 and individual-participant data are presented in Table 5 on the eAddenda.

Although the mean estimates of effect on the secondary outcome also all favoured the experimental group, none reached statistical significance: grip strength (MD 5.6kg, 95% CI –0.5 to 11.7), pain (MD –1.4 cm, 95% CI –2.9 to 0.1), and dexterity (MD –1.3 seconds, 95% CI –3.7 to 1.1). Summary data are presented in Table 4 and individual-participant data are presented in Table 5 on the eAddenda.

Discussion

The main finding of this study was that an exercise program administered via an app on a tablet produced a significantly greater improvement in self-reported functional ability than an exercise program prescribed on paper. This result suggests that the innovative format of rehabilitation through movements and taps on dynamic touchscreen targets might provide more effective rehabilitation after carpal tunnel release than the results obtained with a home exercise program prescribed on paper.

It is important to consider whether the effect observed on the primary outcome is likely to be clinically worthwhile. The protocol for this study did not prospectively nominate the smallest effect on the primary outcome that would make using the app (as opposed to using the paper handout) to carry out the home program worthwhile. It seems reasonable to assume that this smallest worthwhile effect would be marginal, given that the costs, risks and inconveniences of the experimental and control interventions in the study were not very different. Specifically, apps are generally relatively inexpensive, the risk of adverse effects was low in both groups (neither group reported any adverse events), and the time and effort involved in performing the exercises was very similar in both groups. One factor that would increase the cost of the experimental intervention would be providing a tablet to patients who do not have one. However, many patients already have at least temporary access to a tablet and an institution may be able to loan a tablet with the experimental app loaded on it to successive patients after carpal tunnel release. Therefore, the authors consider that the mean estimate of the effect (21 points extra benefit on the 100-point QuickDASH from using the app instead of the paper handout) would make using the app worthwhile. Arguably, even the lower end of the confidence interval

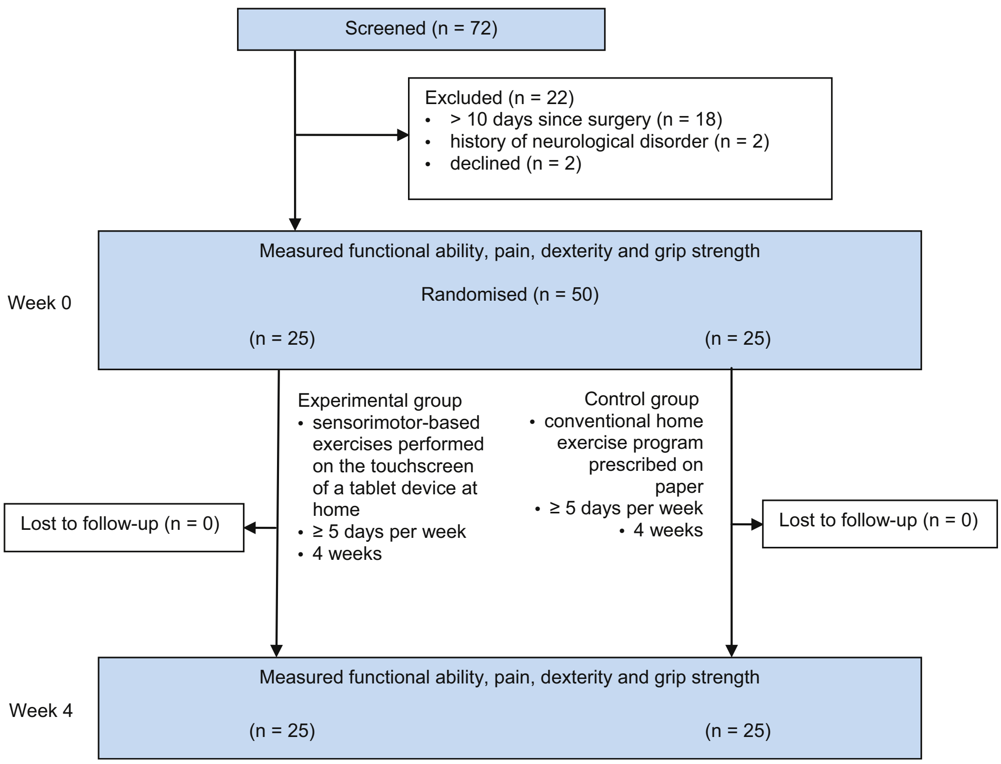

Figure 2. Design and flow of participants through the trial.

Table 3
Baseline characteristics of participants (n = 50).

Characteristics	Exp (n = 25)	Con (n = 25)
Age (*yr*), mean (SD)	51 (8)	49 (7)
Gender, n female (%)	22 (88)	19 (76)
Functional ability (QuickDASH) *(0 to 100)*, mean (SD)	73 (14)	66 (24)
Pain (VAS) *(0 to 10)*, mean (SD)	5.1 (2.6)	4.8 (2.9)
Dexterity (NHPT) *(s)*, mean (SD)	22.7 (3.9)	23.4 (5.3)
Grip strength *(kg)*, mean (SD)	17.6 (12.0)	17.4 (14.7)

Con = control group, Exp = experimental group, NHPT = Nine-Hole Peg Test, QuickDASH = shortened form of the Disabilities of the Arm, Shoulder, and Hand questionnaire, VAS = Visual Analogue Scale.

(ie, 9 points extra improvement from using the app) might be considered worthwhile by some patients, especially those who already have a tablet.

It is also important to consider whether the results on the primary and secondary outcomes are believable and consistent with other research. The believability of the primary outcome is well supported by the robustness of the study's methods, which included concealed allocation, assessor blinding, complete follow-up and intention-to-treat analysis. The statistically significant result on the primary outcome is unlikely to be a Type-I error (ie, a chance finding) because it was prospectively registered and only four statistical tests were conducted in total. It is notable that the primary outcome was a subjective measure and the benefit was not also demonstrated on another objective measure, which raises the possibility of a 'polite patient' effect. However, participants were kept unaware of the opposite group's intervention, which should have minimised the potential for such an effect. Furthermore, further insight about the secondary outcomes can be obtained by considering each one individually.

The grip strength data are quite consistent with existing evidence. In the present study, grip strength increased from 17.4 to 25.9 kg in the control group. This value in the control group after 4 weeks of intervention corresponds to data observed by Pomerance et al,[14] where, after 4 weeks of home therapy exercises, a grip strength of 24 kg was observed. The mean between-group difference in change in grip strength in the present study was 5.6 kg in favour of the experimental group. While this result was non-significant, the confidence interval includes the possibility that the true mean effect could be over 11 kg. This could be partly explained by conclusions drawn by Kamath et al,[29] whereby the improvement in grip strength was greatest from the tenth day to the third month after the operation. Our hypothesis was that the sensorimotor-based, controlled and early work that ReHand allows might accelerate the recovery of strength. Early recovery of strength may also be related to the enhancement of other measures, such as functional ability and pain, aligning with findings from previous studies. For example, Pomerance et al found an average DASH and self-reported pain scores of 18 and 1 points, respectively, after 6 months of home exercises after carpal tunnel release.[14] This progression of the DASH score aligns with the results obtained in the current control group, where this functional score improved from 66 to 53 points during 1 month of conventional exercises, suggesting that a similar evolution to Pomerance et al would be followed at 6 months. However, the less favourable end of the confidence interval must also be considered. This negligible adverse effect (ie, 0.5 kg less improvement in grip strength) is reassuring because, even in the worst-case scenario, it shows that the improvement in the primary outcome was obtained without substantial detriment to the recovery of grip strength.

The next secondary outcome was dexterity assessed using the Nine-Hole Peg Test, which (like grip strength) was non-significant, had a mean estimate that favoured the experimental treatment, and had a confidence interval that only extended a relatively small way into the detrimental range (ie, at worst, 1 second less improvement on a test that takes 20 seconds on average). It is therefore possible, but uncertain, that the improvement in self-reported functional ability might be due to improved dexterity (which would be plausible, given that many of the items on the QuickDASH contain a dexterity component). We suggest that any amelioration of critical hand variables, such as pain, weakness or reduced functional ability, could arise from enhancement of the sensorimotor system at both peripheral and central levels, achieving greater and more controlled ability to fire motor units, optimising recruitment of the muscles involved. Manual dexterity is related to the optimal development and function of the corticospinal system.[30] The major contributor to the corticospinal system in primates is the primary motor cortex, which is related directly to primary somatosensory cortex. Thus, alteration in the primary somatosensory cortex conditions the performance of the primary motor cortex.[31] To assess this relationship, coherence between cortical activity recorded by electroencephalography and muscular activity recorded by electromyography has been used elsewhere, providing data on the status of the information sent from the motor cortex and its transmission to the spinal motoneurons during muscle activation.[32] Previous studies have shown that the performance of tasks that require great attention and precision[33] and are influenced by practice[34] (such as the activities included in the tablet app) influences this coherence, generating changes at the corticospinal level that reflect an optimisation in the sensorimotor integration between the cortex and the muscle,[34] achieving improvements in motor performance.[35] This was one of the results obtained by Larsen et al[21] through tablet-based motor practice (3 × 10 minutes) with the non-dominant hand in 16 healthy females. Thus, it is proposed that through performing this type of task, communication between the motor cortex and motoneurons can be facilitated, inducing and strengthening synaptic plasticity between both networks and a higher coherence.[35] A significant effect on dexterity will be necessary to demonstrate the relevance of this mechanism, which could be the focus of future research. In the meantime, it can be assumed that the improvement in self-reported functional ability may or may not come from improved dexterity, but it certainly does not come at the expense of substantial detriment to dexterity.

The remaining secondary outcome is pain, which has a fundamental role in this cortical synchrony. As one of the main generators of the alterations in the primary somatosensory cortical representations,[36] pain creates a redistribution of activity within a muscle[37] and changes the mechanical behaviour of the movement.[38] This suggests that controlled painless activities (such as those implemented in ReHand through previous pain-free movement calibration) are appropriate because they seek to avoid the

Table 4
Mean (SD) of groups, mean (SD) difference within groups, and mean (95% CI) difference between groups.

Outcome	Groups				Difference within groups		Difference between groups
	Week 0		Week 4		Week 4 minus Week 0		Week 4 minus Week 0
	Exp (n = 25)	Con (n = 25)	Exp (n = 25)	Con (n = 25)	Exp	Con	Exp minus Con
Functional ability (QuickDASH) *(0 to 100)*	73 (14)	66 (24)	39 (24)	53 (24)	–34 (18)	–13 (24)	–21 (–33 to –9)
Pain (VAS) *(0 to 10)*	5.1 (2.6)	4.8 (2.9)	4.0 (2.7)	5.0 (3.2)	–1.2 (2.8)	0.2 (2.3)	–1.4 (–2.9 to 0.1)
Dexterity (NHPT) *(s)*	22.7 (3.9)	23.4 (5.3)	18.1 (2.3)	20.1 (4.7)	–4.6 (3.6)	–3.3 (4.6)	–1.3 (–3.7 to 1.1)
Grip strength *(kg)*	17.6 (12.0)	17.4 (14.7)	31.6 (12.7)	25.9 (13.1)	14.1 (12.2)	8.5 (8.9)	5.6 (–0.5 to 11.7)

Con = control group, Exp = experimental group, VAS = visual analogue scale, NHPT = Nine-Hole Peg Test, QuickDASH = shortened format of the Disabilities of the Arm, Shoulder, and Hand questionnaire.

mechanisms that cause alteration of the sensorimotor system and provide a stimulus to return to the initial pattern. Therefore, a significant reduction of pain in the experimental group would be expected to have contributed to improvement in functional ability. Again, however, the result was non-significant, the mean estimate favoured the experimental group, and the confidence interval excluded all but the most trivial of detrimental effects (ie, 0.1 points less improvement on the 10-point visual analogue scale). Therefore, to summarise all the secondary outcome results: it is unknown whether the improvement in self-reported functional ability might have been due to improvements in pain, dexterity and/or strength, but it is clear that the significant benefit on the primary outcome was achieved without substantial detriment to recovery on the three secondary outcomes.

Another possible explanation for the presence of an effect on the primary outcome but not elsewhere could be greater variability in the secondary outcomes. For example, the fundamental action the Nine-Hole Peg Test entails grapping small objects. This action involves two movements: a controlled and precise movement of the index finger and thumb to perform the pinch, and another action transporting the executing hand.[39] In people with carpal tunnel syndrome, the disorganisation at the central level[16] may cause an alteration in the function of the entire upper limb, which would correspond to an increase in the transport variability of the executing hand.[40] In the present study, the intervention of the control group involved a series of exercises not only at the wrist, hand and finger (as in the experimental group) but also at the elbow and shoulder level. This can have an effect on the kinematics of the entire upper limb in the control group, since co-ordinated movements of the entire upper limb (including the elbow and shoulder) are involved in hand transport in the Nine-Hole Peg Test. Furthermore, there was considerable improvement in the experimental group (from 22.7 to 18.1 seconds) and in the control group (from 23.4 to 20.1 seconds), which brought the participants – especially those in the experimental group – close to the normative values of 19 seconds in men and 17.7 seconds in women.[27] This may have caused a ceiling effect in the experimental group but not in the control group.

Some limitations of this study must be acknowledged. No measurements were made during the treatment period or at a post-intervention follow-up. Such measures would have helped to reveal the evolution of any benefits, and whether they were sustained. They may have also helped to discern whether and when the outcome measures of the control group reached those of the experimental group. Another limitation was the absence of cost-utility variables. These could have indicated the effects of the experimental intervention on the consumption of health resources based on the quality of life reported by the participants.

In summary, our data suggest that a home program performed using the tablet-based ReHand app in early rehabilitation after surgical carpal tunnel release appears to be more effective in the recovery of the functional ability than a conventional home program prescribed on paper. Future research should seek to clarify the effects on the secondary outcomes, which appear promising but remain uncertain due to imprecision around the between-group estimates. Future research could also investigate possible effect on other variables, such as the proprioceptive system, quality of life or consumption of resources, as well as the effect on other high-incidence trauma pathologies such as distal radius fractures.

What was already known on this topic: Carpal tunnel syndrome causes discomfort and paraesthesia in the hand. Conservative treatments are recommended as initial management. Surgery is generally recommended in severe and refractory cases. The best method of post-surgical rehabilitation is unknown.
What this study adds: Use of a tablet app for early rehabilitation after carpal tunnel release is more effective in the recovery of functional ability than a conventional paper-based home exercise program. It remains unclear whether the effect is accompanied by any benefits in grip strength, pain or dexterity.

Footnotes: [a] Baseline, Irvington, NY, USA. [b] SPSS, IBM Corporation, Armonk, NY, USA.

eAddenda: Table 5 can be found online at https://doi.org/10.1016/j.jphys.2019.02.008.

Ethics approval: The Virgen Macarena and Virgen del Rocio University Hospitals Ethics Committee approved this study. All applicable institutional and governmental regulations concerning the use of human volunteers were followed. All participants gave written informed consent before data collection began.

Competing interests: Andalusian Health Service (SAS) has a collaboration agreement concerning the ReHand solution, and may benefit financially if this research generates a successful marketing value related to ReHand. The terms of this agreement have been reviewed and approved by Andalusian Health Service in accordance with its policy on Financial Conflict of Interest. Alejandro Suero and Jesús Blanquero were the initiators of the project and founded a spin-off.

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