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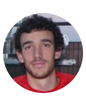

Francesco Budini
Karl-Franzens-Universität Graz

Michael Hutchinson
St Vincent's University Hospital

David Bradley
St. James's Hospital

Giuseppe De Vito
University College Dublin

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ORIGINAL ARTICLE

Dexterity Training Improves Manual Precision in Patients Affected by Essential Tremor

Francesco Budini, PhD,[a] Madeleine M. Lowery, PhD,[b] Michael Hutchinson, PhD, MD,[c] David Bradley, PhD, MD,[c] Luke Conroy, MSc,[d] Giuseppe De Vito, PhD, MD[a]

From the [a]School of Public Health, Physiotherapy and Population Science, University College Dublin, Dublin; [b]School of Electrical, Electronic and Mechanical Engineering, University College Dublin, Dublin; [c]Department of Neurology, St. Vincent's University Hospital, Dublin; and [d]Clarity Centre for Sensor Web Technologies, University College Dublin, Dublin, Ireland.

Abstract

Objective: To evaluate the effect of a short-term dexterity-training program on muscle tremor and the performance of hand precision tasks in patients with essential tremor (ET).

Design: Three testing sessions: baseline, after 4 weeks without any interventions (control), and after 4 weeks of dexterity-training carried out 3 times per week.

Setting: Biomechanics research laboratory.

Participants: Patients (N=8) with a diagnosis of ET.

Intervention: Training program consisted of 12 dexterity training sessions where each session comprised 4 tasks involving both goal-directed manual movements and hand postural exercises.

Main Outcome Measures: Testing included an ET-specific quality of life questionnaire and postural and kinetic tremor assessments. Each training session was scored to evaluate the performance.

Results: After training, improvements were observed in the performance of the 2 goal-directed tasks ($P<.01$); however, postural and kinetic tremor did not change.

Conclusions: This study suggests that dexterity training could be effective in increasing fine manual control during goal-directed movements, which are known to be the most compromised in this pathology. The absence of a decrease in tremor severity highlights the necessity for developing this novel training technique further, perhaps over a longer period of time. This study could provide guidelines for the prescription of self-directed and personalized home-based exercises and will offer clinicians a treatment that might be used as an adjuvant or an alternative to the classical pharmacotherapy.

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Essential tremor (ET) is the most common tremor-related disease[1] and is primarily characterized by kinetic and postural instability.[2] ET is expressed mainly by the hands but may also involve the head, voice, chin, and lower limbs.[3]

For many years, the treatment of this neurologic disorder has exclusively been based on pharmacologic treatments and surgery.[4,5] The use of medications often provokes significant side effects and seldom reduces tremor to asymptomatic levels,[6,7] causing a proportion of patients to withdraw from pharmacotherapy.[8] Surgical procedures can be efficacious[9,10] but are performed only in very severe and selected cases.[5] Interestingly, studies conducted on healthy individuals have reported an improvement in steadiness (a general term used to indicate a reduction of physiological tremor or an increased precision in executing tasks requiring a high degree of motor control) as a result of structured interventions involving a physical task, such as yoga, functional and manual tasks, and light-load training,[11-15] possibly suggesting that a similar result could be also obtained in the ET population. Indeed, a study investigating the differences between monozygotic twins affected by ET demonstrated that environmental factors and the activities performed during life may influence the severity of tremor.[16] Therefore, it is suggested that

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even though part of the difficulty in performing specific tasks is related to the disease, part may also be ascribed to the fact that affected patients avoid executing it because of the objective difficulty and the embarrassment related to it. As a consequence, the performance of these tasks becomes further compromised. The present study was carried out to examine the effects of a novel training approach based on hand dexterity exercises on both muscle tremor and the ability to perform precise manual tasks in patients with ET. We hypothesized that training would decrease tremor amplitude and improve performance of the trained fine manual tasks.

Methods

All participants provided informed consent to the protocol; ethical approval for this work was granted by the Ethics and Medical Research Committee, St. Vincent's University Hospital, Dublin, Ireland.

Participants

The inclusion period from the beginning of recruitment to the end of the study was 12 months. During this period, over 25 volunteers with a diagnosis of ET for at least 1 year, confirmed in accordance with the Movement Disorder Society consensus statement[17] by 2 experienced neurologists (M.H., D.B.), were recruited. Twelve volunteers took part in the study, but only 8 volunteers (5 men, 3 women; mean age, 50.9y; age range, 31−69y) completed the study. The hand reported to have the most severe tremor was examined. If tremor was subjectively symmetrical, the dominant hand was tested.

Inclusion criteria included the following: aged between 30 and 70 years and diagnosis of ET. Exclusion criteria included the following: (1) presence of other concomitant neurologic disorders; (2) significant musculoskeletal abnormalities or pain, cardiovascular disease, or respiratory disease that would interfere with study procedures or affect safety; (3) visual or cognitive impairments severe enough to render a participant unable to read the questionnaires or follow the instructions for the other measures; and (4) use of medications known to affect tremor.

Experimental design

The participants were tested 3 times at the biomechanics research laboratory at the University College of Dublin. Participants were required to abstain from alcohol, nicotine, and caffeine intake on the testing days. Each testing session included the completion of an ET-specific quality of life and tremor self-assessment questionnaire and measurements of postural and kinetic tremor. After the first testing session, all individuals were asked to maintain their normative lifestyle/physical activity and medications intake and come back after 4 weeks for a second identical testing session: this was used as the control period. After the second testing session, the participants took part in a 4-week dexterity-training program, which was immediately followed by the third testing session. All training sessions were performed at the biomechanics research laboratory at the University College of Dublin. The period from the testing session performed at week 4 to the period performed at week 8 was the intervention period. The training consisted of 12 sessions (3 times per week for 4wk); each session lasted about 30 minutes and involved 4 dexterity tasks. All the training sessions were supervised by the main investigator. The main investigator also performed all the testing and analyzed the data.

List of abbreviations:
ET essential tremor

ET-specific questionnaire

The questionnaire developed and validated by Troster et al[18] includes 30 items and is divided into 5 scales: communication (3 items), work and financial (6 items), hobbies and leisure (3 items), physical (9 items), and psychosocial (9 items).

Tremor recording

Postural tremor

The volunteer sat on a chair with the forearm in full pronation supported on a table with the hand horizontal (palm down) and the fingers loosely extended. Tremor was recorded for 20 seconds using a 3-axis accelerometer[a] fixed to the dorsal aspect of the hand with the y axis aligned with the third metacarpal bone. Postural recording of tremor was also performed with the arm outstretched at shoulder level.

Kinetic tremor

Kinetic tremor was recorded both at a predefined speed with the forearm supported on a table and at a free speed with the arm unsupported.

Forearm supported

The experimental setup was the same as that used for the hand postural tremor assessment. The subject held a handlebar to which a fixed load (2kg for men and 1.5kg for women) was attached. Following the rhythm of a metronome (0.17Hz), the volunteer performed 4 repetitions for each of the following wrist movements: flexion, extension, and adduction (in random order).

Forearm unsupported

The participant stood in front of a 1-m-long wire comprising 9 bends of the same size and shape while holding a 20-g wand with a 7-cm diameter metal loop at its extremity. The volunteer was instructed to start from the left and follow the bent wire shape with the wand loop engaged in the circuit trying not to touch it while performing movements of prono-supination only.

During all postural and kinetic tests, surface electromyography was recorded over the forearm extensor and flexor muscles (common fingers extensor and flexor). Silver/silver chloride bipolar electrodes[b] were placed at an interelectrode distance of 20mm. A ground electrode was placed distally on the forearm at the level of the head of the ulna.

Dexterity training

The training intervention was a novel approach tested here for the first time, to our knowledge. Each training session lasted approximately 30 minutes and consisted of 2 goal-directed dexterity tasks (exercises 1 and 4) and 2 postural tasks (exercises 2 and 3).

Exercise 1

As in the common buzz wire game, the volunteer moved a wand along a bent metal wire aiming not to touch it. When the wand touched the wire, an electronic device recorded the contact time. This exercise was performed 5 times, and the average contact time was used as the overall score.

Exercise 2

The volunteer pointed the cursor of a wireless three-dimensional computer mouse at the center of a target projected on the computer screen for 20 seconds. The score was the average position of the cursor on the target over the last 8 seconds. The participant was asked to perform 10 repetitions with the average of these representing the overall score for the session.

Exercise 3

The volunteer followed the center of a target moving around the computer screen with the cursor of a wireless three-dimensional mouse. After every 4 seconds of successful continuous tracking, the target decreased in size. The exercise consisted of 5 rounds; each round lasted 1 minute. This task was scored as the average number of successful 4-second continuous positive tracking sequences achieved in each of the 5 rounds. Because the required movement at wrist level was minimal, this task was classed as postural.

Exercise 4

The volunteer had to pour water from 1 bowl into 3 graded pipes of progressively smaller diameter (20, 15, and 10mm) using a table spoon while trying to minimize the amount of water spilled. The exercise continued for 5 minutes. At the end of the 5 minutes, the amount of water poured in the pipes and the amount of water spilled was measured.

Data analysis

The acceleration and electromyography were synchronized and sampled at 250 and 2000Hz, respectively, and stored on a computer using a 16-bit analog to digital converter data acquisition system.[c] The electromyographic signal was amplified with a gain of 1000, offline high-pass filtered (fourth order, zero-lag, Butterworth filter, cutoff frequency 20Hz). Tremor severity during postural measurements was quantified by examining the SD of the acceleration signal calculated over 20 seconds for each of the 3 axes. The position and amplitude of the dominant peaks in the power spectra of the accelerometer signals, and the area and power within ±0.5Hz of the peak, were calculated (2048-point, hamming window fast Fourier transform). The kinetic data were similarly analyzed after high pass filtering at 1Hz. To quantify myoelectrical activity, the root mean square values of the flexor and extensor electromyographic signals were measured for each postural and kinetic contraction within the same 20-second interval used for the acceleration analysis.

Because the measures of the tremor had a highly skewed distribution, a nonparametric approach was selected. To assess the effect of training on muscle tremor, Wilcoxon signed-rank tests were used to compare the change during the control period (baseline vs week 4) and the intervention period (week 4 vs week 8). The effect of the exercises along the entire period of training was assessed using linear regression analysis. For this analysis, the results of the first training session were excluded because it was considered a familiarization trial. The improvement in the performance in each of the 4 exercises across the 4-week intervention period was investigated by averaging the group result for each session.

In addition, Cohen *d* was used to evaluate the magnitude of the treatment effect with 0.2, 0.5, and 0.8 considered small, moderate, and large effect sizes, respectively. An alpha level of $P<.05$ was adopted for each comparison.

Results

All the participants completed the prescribed 12 training sessions. Clear progress was evident in both exercises in which a goal-directed movement was required (fig 1), whereas no changes were seen in the performance of postural training. Figures 1A and B show the linear regression of the group average score for the 2 exercises where positive results were found (exercise 1: $R^2=.95$, $P<.01$, $d=.49$; exercise 4: $R^2=.79$, $P<.01$, $d=.08$).

Acceleration data measured during postural and kinetic tremor did not improve as a consequence of training (fig 2). This result was consistent for all the 4 kinetic and 2 postural tests for each of the 3 axes analyzed and for every parameter used for the quantification of tremor (SD of the raw signal, position and amplitude of the dominant peaks in the power spectra, and area and power within ±0.5Hz of the peak area and power).

There was a trend of the average group score for self-reported impairment of function in 4 (communication, work and finances, physical, and psychosocial) of the 5 scales on the ET-specific questionnaire (table 1).

Discussion

This study was carried out in order to evaluate the effectiveness of a novel dexterity-training approach on fine motor control in patients with ET. The main finding was an improvement in the performance of the 2 dexterity-training exercises focused on a kinetic/goal-directed task. Contrary to our expectations, no reductions in the magnitude of postural or kinetic tremor occurred. The results of an ET-specific questionnaire did not show significant changes in any of the 5 items investigated.

Dexterity training

Interestingly, both goal-directed tasks showed a progressive positive improvement (see figs 1A and B). This result is important because it indicates that it is possible to increase fine manual control during goal-directed movements that are known to be the most difficult for patients affected by ET.[2,4] Our hypothesis was that even if compromised by the disease, fine manual dexterity could be improved if appropriately stimulated. The result of the training scores highlighted that this principle is valid. It remains to be clarified why similar positive outcomes were not obtained in relation with the postural tasks.

The difference between kinetic and postural task results cannot be attributed to an intrasession adaptation because the 2 goal-directed exercises were always performed as the first and last task. An explanation for the discrepancy in the observed results could be found in the compensatory strategies adopted in different exercises. It is known from mathematical modeling that functional electrical stimulation of wrist extensor and flexor muscles is an

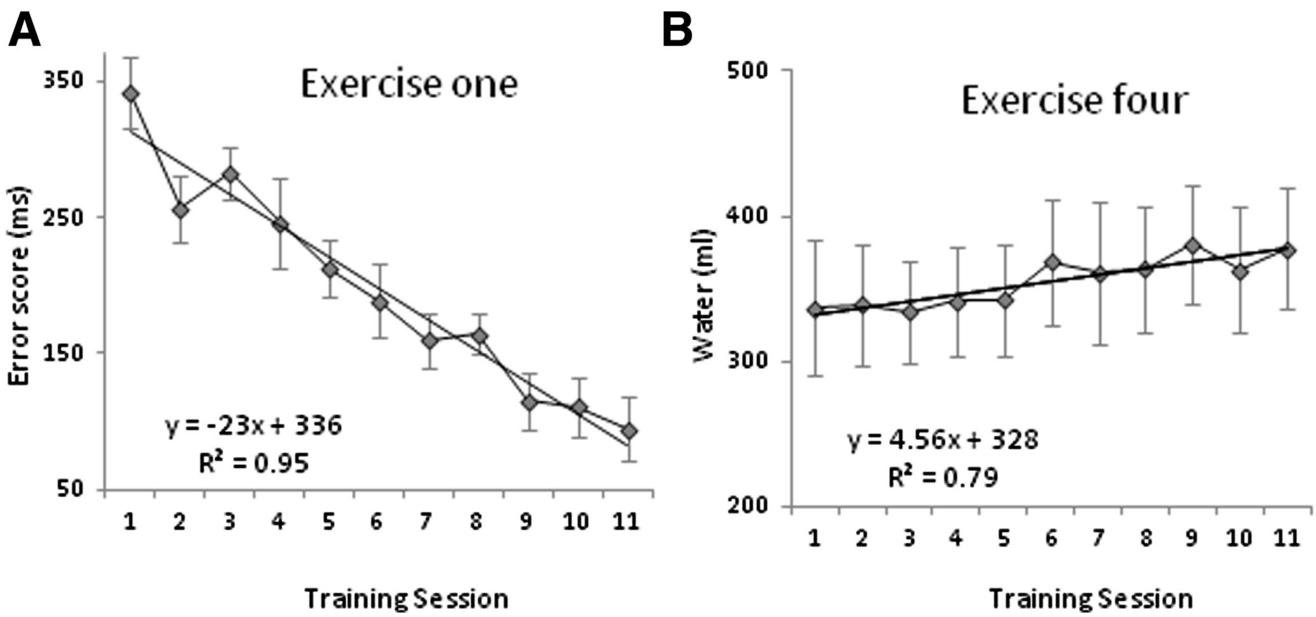

Fig 1 Each dot represents the group average score (±SE) for each of the 11 training sessions: errors are scored as contact time (ms) between the wand the volunteers were moving and the buzz wire circuit (A); water refers to the amount of water (mL) successfully poured in the graded pipes minus the water spilled out in 5 minutes (B).

effective compensation strategy for reducing tremor.[19] Similarly in our study, the goal-directed exercises involved patterns of agonist and antagonist contractions not needed for the postural tasks as visible from the electromyography recorded throughout the performance of similar tasks during the testing sessions. Moreover, it is known that agonist-antagonist control schemes are used to compensate limb drift,[20] and such compensation affects hand precision but not isometric tremor.[21] These studies could suggest that compensative strategies to reduce limb fluctuations can be adopted during complex movements only. Finally, because goal-directed movements are subject to greater tremor than postural contractions in ET,[2] the lack of improvement in the performance of postural tasks observed in the present study could be also attributed to the smaller impairment observed at baseline during this type of contractions (postural) in comparison with that observed during goal-directed movements. In support of this suggestion, it was previously shown that patients with ET improved manual dexterity immediately after a period of bilateral upper limb strength training in the most affected limb only.[22] Although the training intervention adopted in this previous study and in our study is very different, the relation between tremor severity at baseline and percentage of improvement seems to be a common feature.

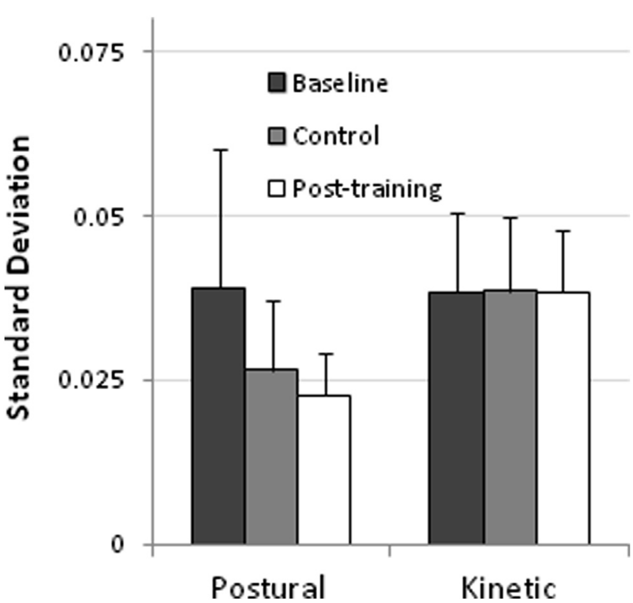

Fig 2 Group average tremor amplitudes (+SE), expressed as SD of the acceleration signal, are plotted for postural and kinetic tremor. The values of the 3 axes are averaged for graphic simplicity. No differences were found between baseline (black bars), control (grey bars), and posttraining (white bars) measurements.

Magnitude of postural and kinetic tremor

Several studies conducted on healthy volunteers suggest that the capacity of an individual to perform accurate targeted movements can be specifically trained and improved.[11-15,23] This would imply that people who are often required to produce fine manual tasks show less tremor than people who are not. Musicians, for example, exhibit lower motor unit synchronization and tremor amplitude than weight lifters and untrained subjects.[24] Similarly, elite pistol shooters show less tremor than those at a pre-elite level.[25] The present study was conducted in the belief that this concept might also be true for patients with ET. However, in the present study, no decrease in postural and kinetic tremor was observed after the training period.

Possible explanations for the lack of improvement in objective tremor measurements include duration of the intervention and because training exercises and test recordings did not involve the same tasks. Furthermore, there is considerable variability of tremor severity in patients with ET, even within the same

Table 1 Questionnaire results: individual and group average percentages of perceived impairment

	Communication			Work and Finances			Hobbies and Leisure			Physical			Psychosocial			Average Subject Score		
Subject No.	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
1	0	0	0	0	0	0	0	0	0	36	33	28	28	22	19	13	11	9
2	0	0	0	0	0	0	83	67	50	100	100	100	53	31	11	47	39	32
3	67	67	0	25	20	17	100	92	92	97	100	100	83	83	89	74	72	59
4	0	0	8	8	4	4	0	0	0	0	0	0	3	11	8	2	3	4
5	25	0	0	8	0	0	0	0	0	42	22	22	8	0	0	17	4	4
6	0	0	8	0	0	0	0	0	33	17	14	3	3	3	3	4	3	9
7	17	17	17	4	4	4	0	50	42	28	28	28	25	11	14	15	22	21
8	8	17	17	4	4	4	0	0	0	17	19	25	19	22	17	10	13	13
Group average	15	13	6	6	4	4	23	26	27	42	40	38	28	23	20			

NOTE. Scores are obtained in the questionnaire at the 1st, 2nd, and 3rd testing sessions reported for each volunteer and each scale used. Values represent the percentage of perceived impairment. The average subject score column shows the subject average score of the 5 scales per each testing session. The group average data show the 1st, 2nd, and 3rd testing sessions for each scale used.
Abbreviations: 1st, baseline testing session; 2nd, control testing session; 3rd, posttraining testing session.

recording session, as highlighted by several authors.[9,26-28] Figure 3, for example, compares 2 postural hand measures recorded during the same testing session in a representative subject from our study, only 60 seconds apart. The differences between the trials are far greater than any possible effect of training. This variability of measures repeated at any time distance in this patient population may require a different testing approach perhaps based on several averaged recordings across all the intervention periods or even a 24-hour continuous quantification of tremor as shown by some authors.[28,29]

Questionnaire

ET is a pathology known to be associated with psychological implications.[30,31] We hypothesized that taking part in a rehabilitation program would have positive effects on the self-perception level of impairment related to the disease. This was not demonstrated in this study, possibly because of considerable intersubject variability (score range, 2%–74%; 100% represents maximal perception of impairment) (see table 1). The 3 volunteers with the highest baseline scores (17%, 47%, and 74% of perceived impairment, respectively) were those who experienced the most marked decrement in the perception of impairment (−73%, −32%, and −20% decrement respectively). The remaining 5 participants' scores were relatively low and did not change considerably at the end of the training period (average level of perceived impairment: 9% before training and 11% after training). This observation suggests that our training program may be effective in reducing the perception of impairment because of tremor in patients with more severe clinical features.

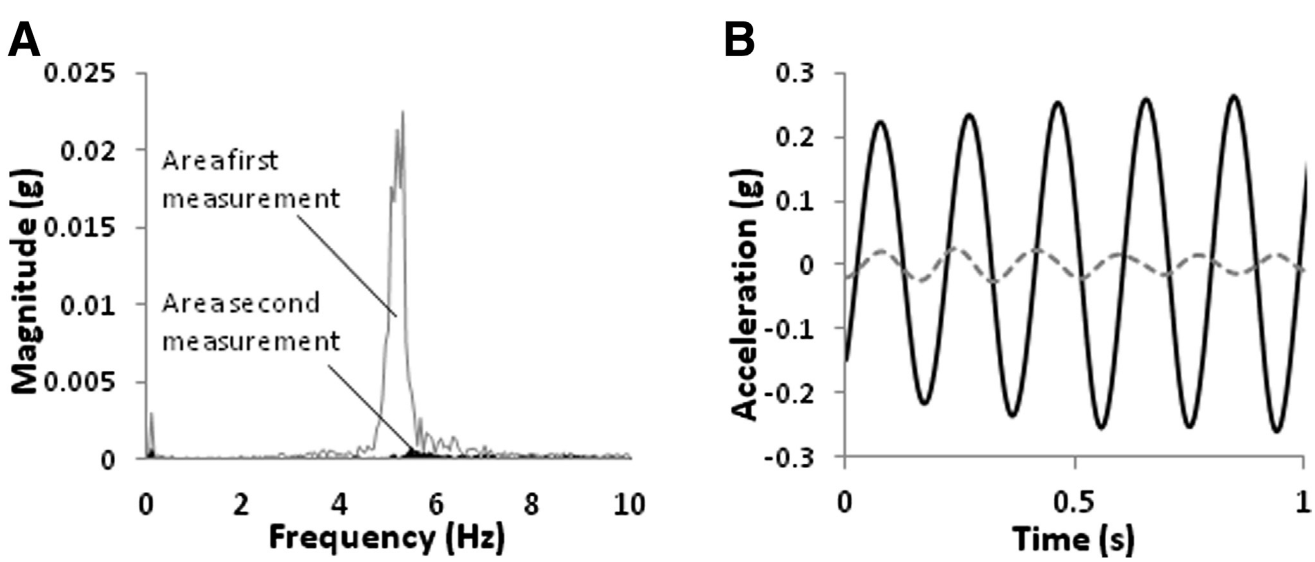

Fig 3 Magnitude of the fast Fourier transform processed on the z axis during a sustained 20-second postural contraction (A) and a segment of 1 second extracted from the raw acceleration data used for the fast Fourier transform calculation (B). The first measurement corresponds to the white area in panel A and to the continue line in panel B; it was recorded at 10:57 AM. The second measurement was recorded at 10:58 AM of the same day on the same subject and corresponds to the nearly invisible black area in panel A and to the dotted line in panel B.

Study limitations

The main limitations were the specificity of the tests, duration of the intervention, and effectiveness of some exercises. In fact, the training and test did not involve the same tasks. The period of intervention lasted only 4 weeks, and only 2 of the 4 exercises proposed improved along the period of training, possibly suggesting that the other exercises were not representing an appropriate stimulus.

Another important limitation of this study is the small number of participants, which limits the external validity of the findings.

Finally, a control group of healthy volunteers would have highlighted whether healthy individuals and individuals affected by a movement disorder show different degrees of manual dexterity improvement in response to the same intervention protocol.

Conclusions

Short-term dexterity training in patients with ET improved the execution of goal-directed manual tasks and also may have promising positive psychological implications in patients with a high self-perception of their level of impairment. However, objective postural and kinetic measures of tremor did not decrease. This study shows the potential of this alternative functional rehabilitation approach along with the necessity of further research and development.

Suppliers

a. Crossbow Technology, 1421 Mccarthy Blvd, Milpitas, CA 95035-7433.
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Keywords

Essential tremor; Rehabilitation

Corresponding author

Francesco Budini, PhD, UCD Health Science Center, Belfield, Dublin 4, Ireland. *E-mail address:* francesco.budini@gmail.com.

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