

# The Effect of Temperature on Hand Function in Patients with Tremor

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**ABSTRACT:** Hand therapists may notice a patient's tremor when treating another diagnostic problem, such as arthritis or a fracture. In these instances, the tremor may become apparent as the patient attempts to don or doff a splint or to practice a home exercise program, or it may be reported in terms of difficulty with dressing or eating. The authors hypothesized that limb cooling would temporarily improve hand function among patients with essential tremor (ET) and that limb warming would temporarily improve hand function among patients with resting tremor secondary to Parkinson disease (PD). Twenty patients with ET and 20 patients with PD completed this single-blind randomized crossover study. Scores following exposure to cold water were compared with scores following exposure to warm water. For patients with ET, subtest scores for the Archimedes spiral, simulated feeding, and checkers were, statistically, significantly lower (i.e., improved) following exposure to cold water than following exposure to warm water; scores for Archimedes spiral, card turning, simulated feeding, and checkers were significantly lower following exposure to cold water than at baseline. Scores for Archimedes spiral and card turning were also significantly lower following exposure to warm water than at baseline. For patients with PD, no statistically significant differences were noted between treatments or from baseline except the score for small common objects, which was lower (improved) following exposure to warm water than at baseline. The significant findings from this study support the therapeutic use of cooling to temporarily decrease tremor, thereby improving hand function among patients with ET.

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Patients undergoing hand therapy have concomitant medical diagnoses, some of which affect the use of their hands synergistically. This is especially true among older patients.<sup>1-4</sup> A therapist may observe a patient's tremor during hand therapy treatment. Tremor may make it difficult or even impossible for a patient to write his or her name or to don or doff a splint. Traditional medical and therapy treatment options to manage hand tremor are well-documented.<sup>5</sup> Unfortunately, these solutions do not always solve the problem or improve hand function.

The purpose of this study was to determine whether limb cooling would temporarily improve

hand function among patients with essential tremor (ET) and whether limb warming would temporarily improve hand function among patients with Parkinson disease (PD).

Tremor is defined as "an involuntary, rhythmic, oscillatory movement produced by reciprocally innervated antagonist muscles."<sup>6</sup> Tremor is commonly seen in general medical practice, and it can pose a significant diagnostic and therapeutic challenge to clinicians. Tremor may be classified many different ways, e.g., by cause, or by whether it occurs at rest or with action.<sup>6,7</sup>

Tremor may be physiologic (i.e., considered "normal") or pathologic. In physiologic tremor, synchronous or asynchronous oscillations involve individual motor units, or groups of muscles that are mutually innervated by a given nerve or its branches. In comparison, in pathologic tremor, rhythmical contractions involve muscle groups,<sup>7</sup> that is, muscles innervated by different nerves and their branches.

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Physiologic tremor occurs when a person tries to maintain a posture.<sup>6</sup> The amplitude of physiologic tremor varies from time to time and from person to person.<sup>8</sup> Any voluntary muscle activation leads to a low-amplitude, fine tremor. This may be observed with fine motor activity, as when using microscopic instruments, threading a needle, or performing a tracing task.<sup>7</sup> The frequency of physiologic tremor is usually 8 to 12 Hz in the hands and may be slower in other parts of the body. Physiologic tremor may be exacerbated by exercise, emotional stress, and medications, including amphetamines, certain antidepressants, and anticonvulsants.<sup>6</sup>

Pathologic tremor may be caused by ET, PD, or other parkinsonian syndromes, or by Wilson disease, peripheral neuropathy, cerebellar disease, midbrain disease, or drugs, or it may be psychogenic.<sup>6</sup> While action or intention tremor may be associated with other diagnoses, such as multiple sclerosis, ET is defined in this study as existing in the absence of other diagnoses that could cause tremor. Tremor is generally thought to be involuntary; however, cases of psychogenic and hysterical tremors have been reported.<sup>7</sup> These tremors may be difficult to distinguish from pathologic tremors.

Essential tremor, characterized by postural and action (intention) tremors without other associated features, is the most common movement disorder seen clinically.<sup>6,7,9</sup> Its cause is unknown.<sup>7</sup> It affects between one and three million people in the United States.<sup>6</sup> The incidence of ET increases with age,<sup>9</sup> and the tremors may be sporadic or familial.<sup>7</sup> The familial form occurs as an autosomal dominant trait and usually manifests in the patient's second decade of life.<sup>9,10</sup> The onset of ET is insidious, with progression that varies over time. Onset may be in childhood or adulthood, and the tremor tends to progress slowly with age. No racial or sex differences have been reported for this diagnosis.<sup>6</sup>

Essential tremor should not be confused with temporary tremor due to weakness, such as might be observed following upper extremity cast removal. The frequency of ET is usually between 4 and 8 Hz. It is most obvious when the hands are held in a posture, and voluntary movement may accentuate it. In some patients the tremor may also persist at rest, often making it difficult to distinguish ET from PD.<sup>6,10</sup>

Although other body parts may be involved in ET, the hands are most often affected. This fact, along with the high incidence of tremor, is relevant to hand therapists. There may also be head tremor or voice tremor. Essential tremor may be associated with other movement disorders, including writer's cramp, spasmodic dysphonia, and cervical dystonia.<sup>6,9,10</sup>

A person's quality of life may be greatly affected by ET,<sup>9</sup> as discussed in detail later in this paper. Stress and emotions, including anger and fear, may exacerbate the tremor severity.<sup>10,11</sup> For about 50% of people

with ET, tremor lessens temporarily after the ingestion of alcohol.<sup>6,7,9</sup> Medical management includes medications categorized as beta-adrenergic-receptor antagonists, anticonvulsants, such as primidone and gabapentin, and benzodiazepines, such as diazepam or clonazepam.<sup>6,7,10</sup> Traditional therapy includes weighted implements, long-handled and angled implements, and proximal stabilization.<sup>5</sup>

A majority of patients with PD manifest a resting tremor. The symptom complex of this diagnosis includes tremor, bradykinesia, rigidity, and postural instability. The diagnosis of PD is defined neurochemically by deficiency of dopamine in the striatum.<sup>6,7</sup>

Classic parkinsonian resting tremor of the upper extremity is characterized as "pill-rolling," a phrase that describes the look of the hand tremor. The lower extremities, jaw, and lips may also be affected. Tremor frequency is 4 to 6 Hz, and the tremor occurs mainly distally. Unlike ET, parkinsonian tremor lessens when the hands are moving. Initially, the tremor tends to be asymmetric. Emotional stress tends to increase the tremor amplitude.<sup>6</sup> As mentioned above, patients with PD may also have a postural and a kinetic tremor. Medications used in medical management include dopaminergic agents, such as levodopa and dopamine agonists.<sup>6,7</sup> To promote function, occupational therapy traditionally focuses on enlarged and weighted implements, adaptive devices, and maximizing "on-time" (i.e., the patient's most functional time in relation to the medication regimen).<sup>5</sup>

The therapeutic effects of temperature have been well documented with orthopedic patients.<sup>12</sup> For these patients, heat and cold are applied to control pain and to prime musculoskeletal tissue for exercises. Both heat and cold are thought to promote relaxation of underlying muscle indirectly through nerve stimulation.<sup>12</sup> Cooling results in reduced nerve conduction velocity, vasoconstriction, reduction of core muscle temperature, and lowering of skeletal muscle tension.<sup>12</sup> It also decreases both the extensibility of soft tissue and muscle strength.<sup>13,14</sup> Cooling, therefore, leads to reduction of muscle contractility and has been used therapeutically to reduce muscle spasm.<sup>12,14</sup>

In contrast to cold, heat results in faster nerve conduction, vasodilatation, increased extensibility or reduced resistance of soft tissue, and improved mobility of joints.<sup>13,14</sup> Therapeutically, heat is used to reduce muscle spasms in chronic cases, whereas cold is used in the acute stage.

Some studies have explored the effect of temperature on tremor. Lakie et al.<sup>15</sup> studied the effect of cooling and heating on target shooting performance in normal subjects. They found that warming the limb led to an increase in the amplitude of physiologic tremor, whereas cooling the limb resulted in a reduction in the amplitude of physiologic tremor and better target shooting performance among persons

using guns. The peak frequency of tremor remained stable.<sup>15</sup>

Arblaster et al.<sup>11</sup> demonstrated that cooling could reduce physiologic tremor by half. Subjects in this study had one forearm immersed in water at 10°-15° C for four minutes, resulting in a 50% reduction in physiologic tremor for at least one hour.

Based on this finding, Arblaster et al. then studied the effect of cooling on patients with ET. The more symptomatic upper extremity of 15 patients with ET was immersed for 5 minutes in water at 15°-18°C, resulting in a significant decrease in the cooled limb's tremor amplitude. It was reported that most of the subjects noticed immediate improvement of their tremor. The article by Arblaster et al. did not, however, describe the study methods. Nor did it objectively investigate the amount of improvement in hand function with activities of daily living (ADLs). Furthermore, we have not found any study that objectively measures the therapeutic effect of temperature on tremor in terms of hand function and ADL.

Lakie et al.<sup>8</sup> studied the effect of limb cooling in patients with ET. These investigators studied 16 normal subjects and 16 patients with ET. All subjects initially had the more symptomatic upper extremity immersed in water at skin temperature for ten minutes, to stabilize skin resistance. The extremity was then immersed, for five minutes, in either cold water (15°C) or warm water (44°C), then dried. Measurement of tremor was made every five minutes for 30 minutes or more. The alternative temperature modality was then applied, and the tremor was again measured.

Following cooling, the subjects with ET demonstrated a "striking" decrease in tremor, with improvement in writing performance as determined by drawing the Archimedes spiral. The handwriting of one subject reportedly became legible after being illegible for 15 years. In five subjects, a tremor that had been conspicuous became inconspicuous. Participants subjectively acknowledged upper extremity functional gains, which lasted from 36 to 150 minutes. The tremor amplitude of the non-cooled arm was also reduced.

In comparison, following heating of the same extremity, tremor increased in amplitude up to three-fold. In three subjects, the tremor became visible after heating. The increase in tremor amplitude following heating was of shorter duration than was the decrease following cooling. Lakie et al.<sup>8</sup> hypothesized that an oscillation in a peripheral feedback circuit leads to tremor in ET patients, and the oscillation rate is determined by the delay in that circuit. They hypothesized that temperature change of the circuit's muscles and neural components modified the delay and thereby changed the tremor frequency and amplitude.

Literature is scarce on the effect of limb temperature in PD. It is not uncommon though, to hear from PD patients subjectively that their rigidity, bradykinesia, and walking are worse during winter, and better during summer.

## SUBJECTS

Twenty patients with ET (8 men and 12 women; ages, 57-84 years; duration of symptoms, 1-6.5 years), and 20 patients with PD (12 men and 8 women; ages, 62-87 years; duration of symptoms, 8 months-3.5 years) were recruited and completed this study (Table 1). All subjects gave informed consent for this study, which was approved by the Mayo Foundation Institutional Review Board, and the study was funded by Mayo Foundation.

Inclusion criteria for subjects were a diagnosis of ET or PT, as follows, and age between 30 and 90 years:

- Patients with ET, as diagnosed by a neurologist at the Mayo Clinic Scottsdale, Scottsdale, Arizona; whose tremors did not have another etiology; who had at least a +2 action or kinetic tremor (see item 21 of the Unified Parkinson Disease Rating Scale [UPDRS], Appendix C) of one or both upper limbs for at least one year; and who had a family history of ET.
- Patients with PD, as diagnosed by a neurologist at the Mayo Clinic Scottsdale, Scottsdale, Arizona, of Hoehn and Yahr Stage 2 or 3 (see Part V of the UPDRS, Appendix C), who had at least a +2 rest tremor of one upper limb (as gauged by the UPDRS); and

Exclusion criteria for subjects were:

- Pregnancy
- Sensory loss in the upper extremities
- Dermatologic lesions in the upper extremities
- Known history of sensitivity to heat or cold (i.e., heat or cold urticaria)

TABLE 1. Patient Characteristics

	Mean	Range
Patients with ET:		
Age (years)	74 (SD 8)	57 to 84
Duration of symptoms (months)	250 (SD 220)	12 to 790
Sex:		
Female	12 (60%)	-
Male	8 (40%)	-
Patients with PD:		
Age (years)	71 (SD 6)	62 to 87
Duration of symptoms (months)	82 (SD 97)	8 to 420
Sex:		
Female	8 (40%)	-
Male	12 (60%)	-

- Medical diagnoses that could cause tremor (e.g., multiple sclerosis)
- Severe, disabling action or rest tremor (i.e., greater than +3 on the UPDRS; Appendix C)
- Severe bradykinesia or reduction in alternating motion rate, defined as stage 4 on the Hoehn and Yahr scale (Part V, Appendix C)

## METHOD

A single-blind, randomized crossover study design was implemented for each of the two study groups (patients with ET and patients with PD). Each subject's more symptomatic upper extremity (i.e., the hand with the greater tremor or functional impairment) was tested. Each subject was assessed at baseline for:

- Arm temperature (using the same thermistor placed at the first dorsal web space for each subject).
- Upper extremity function using subtests 2, 3, 4, and 5 of the Jebsen hand function test,<sup>16</sup> a standardized test of hand function (Appendix A). The Jebsen hand function subtests were administered in the following order: card turning, small common objects, simulated feeding, and checkers.
- A drawing of an Archimedes spiral (Appendix B).
- The UPDRS motor scale (items 20-25 for PD and item 21 for ET; Appendix C). (Results related to UPDRS scores are being reported elsewhere).

The subject's arm was then immersed in cold water (15°C = 59° F) or warm water (44° C = 111.2° F) for five minutes, by randomized assignment. The same tests were performed. Following return of arm skin temperature to within 1° of baseline, the arm was then immersed in water of the opposite temperature, then retested. Since this was a single-blind, randomized, crossover study design, the tester (C.C.) was blinded to subjects' arm temperature and assignment sequence throughout the data collection process.

## Data Analysis

The aim of the primary analysis was to determine whether there was a treatment effect, warm vs. cold, on the basis of the outcome measures within each of the two study groups, ET and PD. The difference in performance following cooling and following warming was assessed using the Wilcoxon signed rank test. Tests for a carryover effect were performed to ensure that the first treatment did not appear to influence performance during the second. To test the carryover effect, the sum of the period 1 and period 2 values for each outcome measure were compared between the two treatment sequence groups (cold first, warm first) using the Wilcoxon rank sum test. In addition to comparing the effects of warm and cold temperatures, the effect of warming or cooling was assessed against the

TABLE 2. Baseline Values

	Mean	(SD)
Patients with ET:		
Cards (sec)	11	(6)
Objects (sec)	11	(5)
Feeding (sec)	25	(33)
Checkers (sec)	17	(21)
Spiral	2.4	(0.9)
Patients with PD:		
Cards (sec)	13	(6)
Objects (sec)	11	(2)
Feeding (sec)	15	(7)
Checkers (sec)	12	(12)
Spiral	1.2	(1.1)

baseline measures using the Wilcoxon signed rank test. The distributions of preferences were compared between study groups using the Fisher exact test. For this study, a finding was considered significant at  $p < 0.05$ . Table 2 shows baseline values.

A co-investigator (V.G.H.E.), who was blind to the temperature and sequence of each Archimedes spiral drawing, determined the scores of these drawings using a scale from 0 to 3 (0 = no tremor; 1 = barely visible tremor; 2 = readily apparent tremor; 3 = severe tremor).<sup>17</sup>

## RESULTS

### Subjects with Essential Tremor

The Archimedes spirals, captured from a video, of six subjects with ET are shown in Figures 1 through 6. Changes from baseline performance scores are shown in Table 3. Treatment effects for performance scores are shown in Table 4.

- Scores for Archimedes spiral ( $p < 0.001$ ), card turning ( $p = 0.04$ ), simulated feeding ( $p < 0.001$ ), and stacking checkers ( $p < 0.001$ ) were significantly lower following cold water than at baseline (Table 3).
- Scores for Archimedes spiral ( $p = 0.044$ ) and card turning ( $p = 0.008$ ) were also significantly lower following warm treatment than at baseline (Table 3).
- Subtest scores for Archimedes spiral ( $p = 0.045$ ), simulated feeding ( $p = 0.004$ ), and stacking checkers ( $p = 0.007$ ) were statistically significantly lower (improved) following cold water than warm water (Table 4).
- Scores for patients who had cooling first followed by warming were statistically better for Archimedes spiral ( $p = 0.041$ ) and stacking checkers ( $p = 0.038$ ) than scores for those in the other sequence (Table 5), indicating that the treatments during the first period may have influenced the results during the second period. If such a carry-

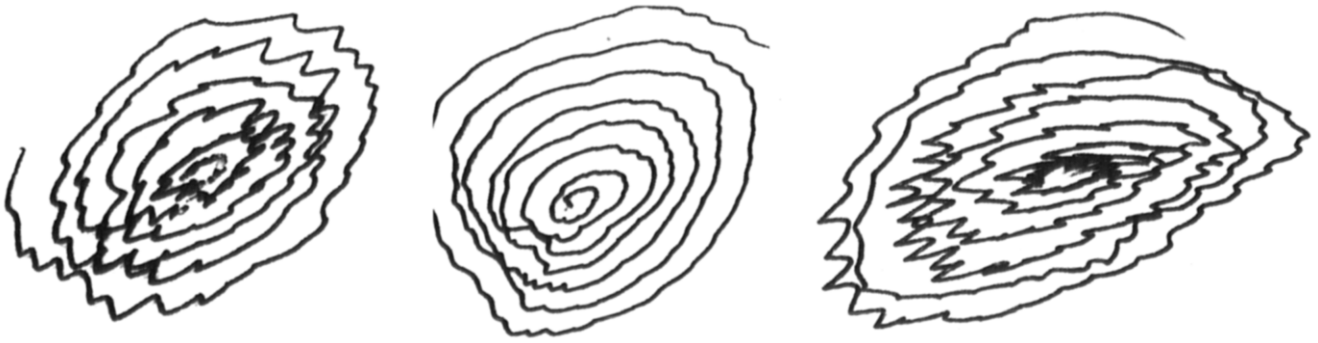


FIGURE 1. Archimedes spirals for subject ET1. Left, baseline. Middle, cold. Right, warm.



FIGURE 2. Archimedes spirals for subject ET5. Left, baseline. Middle, cold. Right, warm.

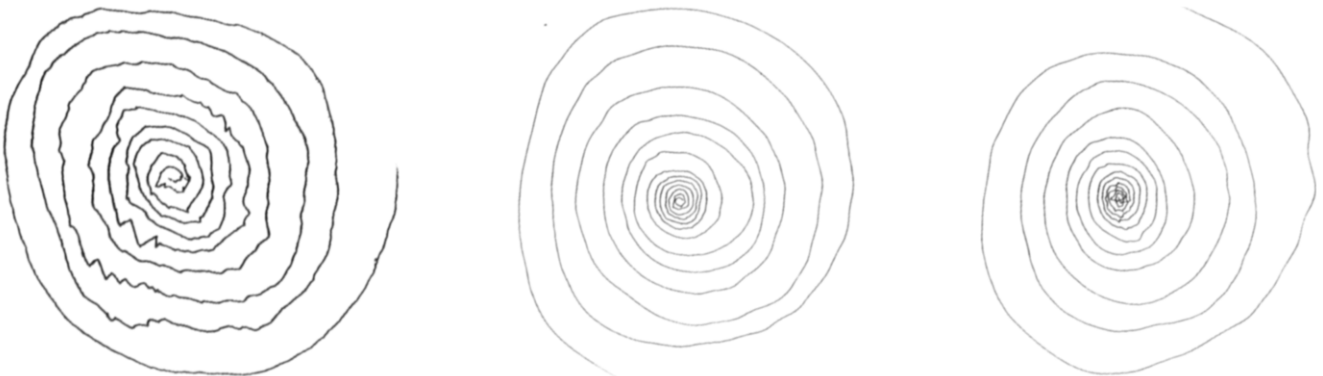


FIGURE 3. Archimedes spirals for subject ET13. Left, baseline. Middle, cold. Right, warm.



FIGURE 4. Archimedes spirals for subject ET18. Left, baseline. Middle, cold. Right, warm.

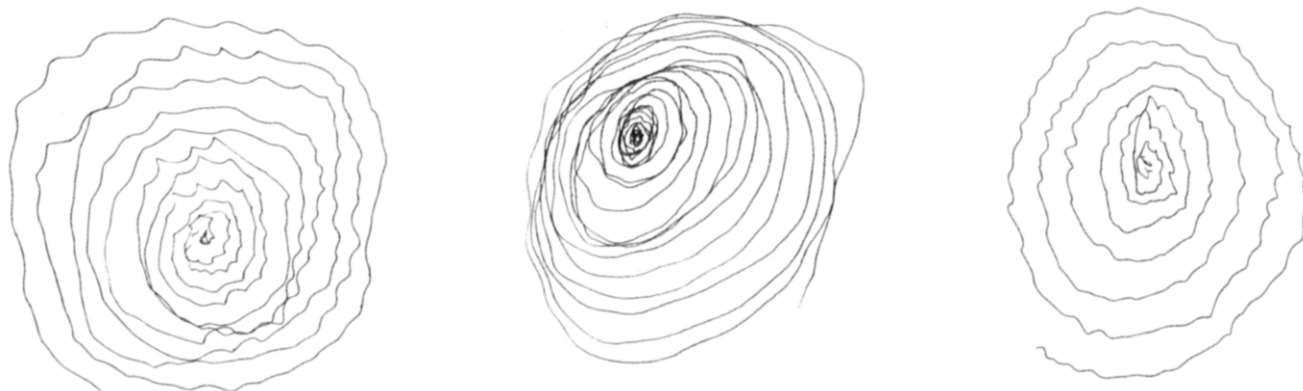


FIGURE 5. Archimedes spirals for subject ET19. Left, baseline. Middle, cold. Right, warm.



FIGURE 6. Archimedes spirals for subject ET20. Left, baseline. Middle, cold. Right, warm.

over effect was present, the actual difference between warm and cold may have been greater than it appeared in the study.

### Subjects with Parkinson Disease

No statistically significant differences were noted between treatments or from baseline except the score for small common objects ( $p = 0.04$ ), which was lower (improved) following warm water than at baseline (Table 3).

### Patient Preferences

Regarding preferences (Table 6) among patients with ET, 13 patients (65%) preferred cold, 3 (15%) had no preference, and 4 (20%) preferred warm.

Regarding preferences among patients with PD, 3 patients (15%) preferred cold, 2 (10%) had no preference, and 15 (75%) preferred warm.

The distribution of preferences for patients with ET differed significantly from the distribution for patients with PD ( $p < 0.001$ ). A majority of the patients with ET preferred the cold treatment, and a majority of the patients with PD preferred the warm treatment. Results related to UPDRS scores are being reported elsewhere.

## DISCUSSION

Traditional therapies to improve tremulous hand function, such as those making use of weighted implements, long-handled devices, and other adaptive devices, are effective for some patients. A broader selection of medications that can be adjusted and modified to improve function are available for PD than for ET.

Patients with ET and patients with PD, however, report that they have trouble tolerating their medications. Identifying additional ways to decrease tremor, even temporarily, will help patients with ET and PD perform basic ADLs that they may not otherwise be able to accomplish. The results of this study suggest that practical strategies to cool the hand of patients with ET may maximize their function and minimize the social isolation and embarrassment associated with tremor. For hand therapy patients with ET, this may make it possible to accomplish an otherwise impossible hand therapy function, such as donning or doffing a hand splint. Easy ways to implement the study findings include holding an iced beverage or immersing the hand in cool water prior to using a writing implement, donning or doffing a splint, tying shoes, eating, or such. An ice pack or gel mitt may also be easy to use. Our results do not support use of the same strategy for patients with PD.

**TABLE 3. Changes from Baseline Performance Scores**

	<i>Cold minus Baseline</i>			<i>Warm minus Baseline</i>		
	<i>Mean</i>	<i>(SD)</i>	<i>p Value*</i>	<i>Mean</i>	<i>(SD)</i>	<i>p Value*</i>
Patients with ET:						
Cards (sec)	-1.0	(7.2)	0.04	-2.0	(3.4)	0.008
Objects (sec)	-0.4	(2.7)	0.52	-0.5	(3.5)	0.33
Feeding (sec)	-13.0	(30)	< 0.001	-4.0	(34)	0.21
Checkers (sec)	-9.0	(20)	< 0.001	0	(25)	0.16
Spiral	-0.95	(0.76)	< 0.001	-0.50	(0.95)	0.044
Patients with PD:						
Cards (sec)	-1.4	(4.2)	0.23	-0.9	(5.1)	0.28
Objects (sec)	-0.3	(1.9)	0.50	-0.9	(1.9)	0.04
Feeding (sec)	-2.2	(6.2)	0.07	2	(22)	0.14
Checkers (sec)	-3.0	(11)	0.47	-3	(11)	0.12
Spiral	0.1	(0.85)	0.79	0.20	(0.83)	0.42

\*P values are from the Wilcoxon signed rank test.

**TABLE 4. Performance Scores for Treatment Effects**

	<i>Warm</i>		<i>Cold</i>		<i>Warm minus Cold*</i>		
	<i>Mean</i>	<i>(SD)</i>	<i>Mean</i>	<i>(SD)</i>	<i>Mean</i>	<i>(SD)</i>	<i>p Value†</i>
Patients with ET:							
Cards (sec)	9.2	(4.4)	10	(7)	-1.0	(6.3)	0.79
Objects (sec)	11	(4)	11	(3)	-0.1	(2.3)	0.88
Feeding (sec)	21	(24)	12	(4)	9	(22.0)	0.004
Checkers (sec)	17	(25)	7.8	(2.4)	9	(24.0)	0.007
Spiral	1.9	(1.2)	1.4	(0.9)	0.45	(0.83)	0.045
Patients with PD:							
Cards (sec)	12	(8)	11	(6)	0.5	(3.5)	0.59
Objects (sec)	10	(4)	11	(3)	-0.5	(2.1)	0.23
Feeding (sec)	16	(23)	13	(5)	4	(20.0)	0.67
Checkers (sec)	8.3	(5.1)	9.0	(3.6)	-0.7	(4.4)	0.08
Spiral	1.4	(1.0)	1.4	(0.9)	0.10	(0.79)	0.78

\*The difference between the score following warming and the score following cooling was calculated for each patient.

† P values are from the Wilcoxon signed rank test.

Hand therapists may treat patients with concomitant diagnoses, including movement disorders, that affect their upper extremity function. As noted above, tremor can dramatically interfere with daily activities such as handwriting, dressing, and eating. Such tasks as eating soup or salad and writing checks are frequently reported as impossible. In fact, patients with tremor commonly describe social isolation that results from their wish to avoid embarrassment in public. The tremor is not always corrected by use of traditional therapy, such as use of weights and self-stabilization techniques.

A hand therapist may notice tremor when treating a patient for another problem, such as arthritis or a fracture. The tremor may become apparent as the patient attempts to don or doff a splint or to practice a home exercise program or it may be reported in terms of difficulty with daily function such as handwriting, dressing, or eating.

Prior to this study, the only findings in the litera-

ture addressing the effects of temperature on tremulous hand function were anecdotal. The significant findings from this study support therapeutic use of cooling to temporarily decrease tremor, thereby improving hand function among patients with ET.

A limitation of the study was that tests at room temperature were performed only at baseline. The crossover design compared the findings for warm treatment with those for cold treatment but did not make a concurrent comparison of findings for warm or cold treatment with findings at room temperature. Changes from baseline could have been caused, at least in part, by factors other than temperature, such as the patient's having practiced the tests at baseline.

This study showed that temperature has an effect on tremor. But there are several ways to get a better measure of how much the cold treatment helps. One way would be a crossover design with a cold/control sequence and a control/cold sequence. Another would be a parallel design in which the change from baseline

TABLE 5. Performance Scores for Each Period in Each Sequence Group

Sequence	Baseline		Period 1		Period 2		p Value*	
	Mean	(SD)	Mean	(SD)	Mean	(SD)		
Patients with ET:								
Cards (sec)	Cold/Warm	9.8	(5.5)	8.2	(3.2)	8.3	(4.5)	0.19
	Warm/Cold	13	(6)	10	(4)	12	(10)	
Objects (sec)	Cold/Warm	11	(6)	11	(4)	10	(4)	0.79
	Warm/Cold	12	(3)	11	(4)	11	(3)	
Feeding (sec)	Cold/Warm	15	(6)	12	(4)	24	(32)	0.85
	Warm/Cold	35	(45)	18	(12)	12	(5)	
Checkers (sec)	Cold/Warm	10	(2)	7.0	(1.7)	7.9	(2.6)	0.038
	Warm/Cold	23	(29)	25	(34)	8.6	(2.7)	
Spiral	Cold/Warm	2.2	(0.8)	1.0	(0.8)	1.4	(1.3)	0.041
	Warm/Cold	2.6	(1.0)	2.4	(0.8)	1.9	(0.9)	
Patients with PD:								
Cards (sec)	Cold/Warm	12	(5)	11	(6)	11	(8)	0.47
	Warm/Cold	14	(7)	13	(8)	11	(6)	
Objects (sec)	Cold/Warm	12	(3)	11	(4)	10	(5)	0.85
	Warm/Cold	10	(1)	9.6	(2.2)	9.8	(1.9)	
Feeding (sec)	Cold/Warm	17	(9)	12	(4)	11	(2)	0.91
	Warm/Cold	13	(5)	22	(32)	13	(6)	
Checkers (sec)	Cold/Warm	8.7	(4.0)	9.3	(4.1)	7.4	(2.8)	0.79
	Warm/Cold	15	(17)	9.2	(6.7)	8.8	(3.3)	
Spiral	Cold/Warm	1.0	(1.1)	1.4	(1.0)	1.6	(1.1)	0.97
	Warm/Cold	1.5	(1.1)	1.3	(0.9)	1.3	(0.9)	

\*P values are from the Wilcoxon signed rank test.

to cold treatment is compared with the change from baseline in a control group. Also, more detailed studies could be designed to explore how different amounts of cooling affect tremor amplitude and frequency.

Thermistor reliability was not measured. However, each patient served as his or her own control for comparisons of performance. Since patients were assigned to the sequence groups at random, thermistor reliability was not expected to bias the conclusions.

A follow-up study is being planned, to survey how the patients with ET in this study are implementing these findings. Future studies are needed to compare the effectiveness of different methods of cooling at different temperature, and to determine the duration of the therapeutic effect of cooling on hand function in patients with ET. Future studies with a crossover design should use a longer washout period between the two treatment periods to reduce the chance that the effect of treatment in the first period may influence results in the second period.

TABLE 6. Subject Preferences

	Cold	None	Warm
Essential tremor	13 (65%)	3 (15%)	4 (20%)
Parkinson disease	3 (15%)	2 (10%)	15 (75%)

## CONCLUSIONS

Therapeutic cooling of the hand may improve hand function of patients with ET. Neither cooling nor warming significantly affects the hand function of PD patients.

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APPENDIX A  
*Jebsen Test of Hand Function*

**SUBTEST 2: CARD TURNING (simulated page turning)**

*Procedure:* Five 3" x 5" index cards, ruled on one side only, are placed in a horizontal row 2" apart on the desk in front of the patient. Each card is oriented vertically 5" from the front edge of the desk. This distance is indicated on the side edge of the desk with a piece of tape. Timing is from the word "go" until the last card is turned over. No accuracy of placement after turning is necessary.

*Instructions:* "Place your (left or right) hand on the table, please. When I say 'go,' use your (left or right) hand to turn these cards over one at a time as quickly as you can, beginning with this one (indicate card to extreme right if starting with left hand). You may turn them over in any way that you wish, and they need not be in a neat pattern when you finish. Do you understand? Ready? Go."

**SUBTEST 3: SMALL COMMON OBJECTS**

*Procedure:* An empty 1-lb coffee can is placed directly in front of the subject, 5" from the front edge of the desk. Two 1" paper clips (oriented vertically), two regular-sized bottle caps (each 1" in diameter, placed with the inside of the cap facing up), and two U.S. pennies are placed in a horizontal row to the left of the can (if using the left hand). The paper clips are to the extreme left, and the pennies are nearest the can. The objects are 2" apart. Timing is from the word "go" until the sound of the last object striking the inside of the can is heard.

*Instructions:* "Place your (left or right) hand on the table, please. When I say 'go,' use your (left or right) hand to pick up these objects one at a time and place them in the can as fast as you can, beginning with this one (indicate paper clip on the extreme left). Do you understand? Ready? Go."

**SUBTEST 4: SIMULATED FEEDING**

*Procedure:* Five kidney beans approximately 5/8" in length are placed on a board clamped to the desk in front of the subject, 5" from the front edge of the desk. The beans are oriented to the left of the center, parallel to and touching the upright of the board, 2" apart. An empty lb coffee can is placed centrally in front of the board. A regular teaspoon is provided. Timing is from the word "go" until the last bean is heard hitting the bottom of the can.

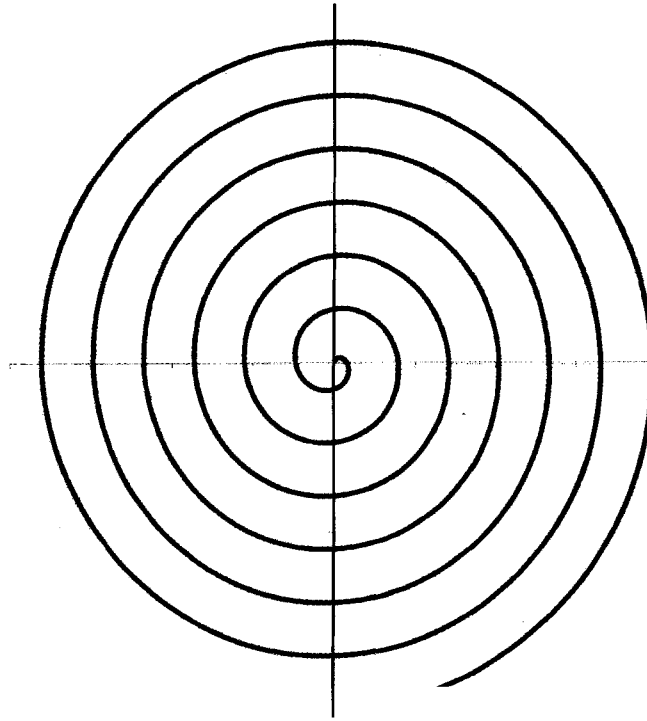
*Instructions:* "Take the teaspoon in your (left or right) hand, please. When I say 'go,' use your (left or right) hand to pick up these beans one at a time with the teaspoon, and place them in the can as fast as you can, beginning with this one (indicate bean on the extreme left, if starting with right hand). Do you understand? Ready? Go."

**SUBTEST 5: CHECKERS**

*Procedure:* Four standard-sized (1-1/4" diameter) red wooden checkers are placed in front of and touching a board clamped to the desk in front of the subject, 5" from the front edge of the desk. The checkers are oriented two on each side of the center in a 0000 configuration. Timing is from the word "go" until the fourth checker makes contact with the third checker. The fourth checker need not stay in place. The procedure is repeated with the dominant hand.

*Instructions:* "Place your left [or right] hand on the table, please. When I say 'go,' use your left [or right] hand to stack these checkers on the board in front of you as fast as you can, like this, one on top of the other. [Demonstrate.] You may begin with any checker. Do you understand? Ready? Go."

APPENDIX B  
*Spiral of Archimedes*



APPENDIX C  
*Unified Parkinson Disease Rating Scale*

**I. MENTATION, BEHAVIOR, AND MOOD**

**1. Intellectual impairment**

0 = None.

1 = Mild. Consistent forgetfulness with partial recollection of events and no other difficulties.

2 = Moderate memory loss, with disorientation and moderate difficulty handling complex problems. Mild but definite impairment of function at home with need for occasional prompting.

3 = Severe memory loss with disorientation in time and often in place. Severe impairment in handling problems.

4 = Severe memory loss with orientation preserved to person only. Unable to make judgments or solve problems. Requires much help with personal care. Cannot be left alone at all.

**2. Thought disorder (due to dementia or drug intoxication)**

0 = None.

1 = Vivid dreaming.

2 = "Benign" hallucinations with insight retained.

3 = Occasional to frequent hallucinations or delusions; without insight; could interfere with daily activities.

4 = Persistent hallucinations, delusions, or florid psychosis. Not able to care for self.

**3. Depression**

1 = Periods of sadness or guilt greater than normal, never sustained for days or weeks.

2 = Sustained depression (one week or more).

3 = Sustained depression with vegetative symptoms (insomnia, anorexia, weight loss, loss of interest).

4 = Sustained depression with vegetative symptoms and suicidal thoughts or intent.

**4. Motivation/Initiative**

0 = Normal.

1 = Less assertive than usual; more passive.

2 = Loss of initiative or disinterest in elective (nonroutine) activities.

3 = Loss of initiative or disinterest in day-to-day (routine) activities.

4 = Withdrawn, complete loss of motivation.

**II. ACTIVITIES OF DAILY LIVING (for both "on" and "off")**

**5. Speech**

0 = Normal.

1 = Mildly affected. No difficulty being understood.

2 = Moderately affected. Sometimes asked to repeat statements.

3 = Severely affected. Frequently asked to repeat statements.

4 = Unintelligible most of the time.

**6. Salivation**

0 = Normal.

1 = Slight but definite excess of saliva in mouth; may have night-time drooling.

2 = Moderately excessive saliva; may have minimal drooling.

- 3 = Marked excess of saliva with some drooling.  
4 = Marked drooling, requires constant tissue or handkerchief.

#### **7. Swallowing**

- 0 = Normal.  
1 = Rare choking.  
2 = Occasional choking.  
3 = Requires soft food.  
4 = Requires nasogastric tube or gastrostomy feeding.

#### **8. Handwriting**

- 0 = Normal.  
1 = Slightly slow or small.  
2 = Moderately slow or small; all words are legible.  
3 = Severely affected; not all words are legible.  
4 = The majority of words are not legible.

#### **9. Cutting food and handling utensils**

- 0 = Normal.  
1 = Somewhat slow and clumsy, but no help needed.  
2 = Can cut most foods, although clumsy and slow; some help needed.  
3 = Food must be cut by someone, but can still feed slowly.  
4 = Needs to be fed.

#### **10. Dressing**

- 0 = Normal.  
1 = Somewhat slow, but no help needed.  
2 = Occasional assistance with buttoning, getting arms in sleeves.  
3 = Considerable help required, but can do some things alone.  
4 = Helpless.

#### **11. Hygiene**

- 0 = Normal.  
1 = Somewhat slow, but no help needed.  
2 = Needs help to shower or bathe; or is very slow in hygienic care.  
3 = Requires assistance for washing, brushing teeth, combing hair, going to bathroom.  
4 = Foley catheter or other mechanical aids.

#### **12. Turning in bed and adjusting bed clothes**

- 0 = Normal.  
1 = Somewhat slow and clumsy, but no help needed.  
2 = Can turn alone or adjust sheets, but with great difficulty.  
3 = Can initiate, but not turn or adjust sheets alone.  
4 = Helpless.

#### **13. Falling (unrelated to freezing)**

- 0 = None.  
1 = Rare falling.  
2 = Occasionally falls, less than once per day.  
3 = Falls an average of once daily.  
4 = Falls more than once daily.

#### **14. Freezing when walking**

- 0 = None.  
1 = Rare freezing when walking; may have start hesitation.  
2 = Occasional freezing when walking.  
3 = Frequent freezing. Occasionally falls from freezing.  
4 = Frequent falls from freezing.

#### **15. Walking**

- 0 = Normal.  
1 = Mild difficulty. May not swing arms or may tend to drag leg.  
2 = Moderate difficulty, but requires little or no assistance.  
3 = Severe disturbance of walking, requiring assistance.  
4 = Cannot walk at all, even with assistance.

#### **16. Tremor (symptomatic complaint of tremor in any part of body)**

- 0 = Absent.  
1 = Slight and infrequently present.  
2 = Moderate; bothersome to patient.  
3 = Severe; interferes with many activities.  
4 = Marked; interferes with most activities.

#### **17. Sensory complaints related to parkinsonism**

- 0 = None.  
1 = Occasionally has numbness, tingling, or mild aching.  
2 = Frequently has numbness, tingling, or aching; not distressing.  
3 = Frequent painful sensations.  
4 = Excruciating pain.

### **III. MOTOR EXAMINATION**

#### **18. Speech**

- 0 = Normal.  
1 = Slight loss of expression, diction and/or volume.  
2 = Monotone, slurred but understandable; moderately impaired.  
3 = Marked impairment, difficult to understand.  
4 = Unintelligible.

#### **19. Facial expression**

- 0 = Normal.  
1 = Minimal hypomimia, could be normal "Poker Face".  
2 = Slight but definitely abnormal diminution of facial expression.  
3 = Moderate hypomimia; lips parted some of the time.  
4 = Masked or fixed facies with severe or complete loss of facial expression; lips parted 1/4" or more.

#### **20. Tremor at rest (head, upper and lower extremities)**

- 0 = Absent.  
1 = Slight and infrequently present.  
2 = Mild in amplitude and persistent. Or moderate in amplitude but only intermittently present.  
3 = Moderate in amplitude and present most of the time.  
4 = Marked in amplitude and present most of the time.

#### **21. Action or postural tremor of hands**

- 0 = Absent.  
1 = Slight; present with action.  
2 = Moderate in amplitude, present with action.  
3 = Moderate in amplitude with posture holding as well as action.  
4 = Marked in amplitude; interferes with feeding.

#### **22. Rigidity (judged on passive movement of major joints with patient relaxed in sitting position. Cogwheeling to be ignored.)**

- 0 = Absent.  
1 = Slight or detectable only when activated by mirror or other movements.  
2 = Mild to moderate.  
3 = Marked, but full range of motion easily achieved.  
4 = Severe, range of motion achieved with difficulty.

#### **23. Finger taps (patient taps thumb with index finger in rapid succession.)**

- 0 = Normal.  
1 = Mild slowing and/or reduction in amplitude.  
2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.  
3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.  
4 = Can barely perform the task.

**24. Hand movements (patient opens and closes hands in rapid succession.)**

0 = Normal.

1 = Mild slowing and/or reduction in amplitude.

2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.

3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.

4 = Can barely perform the task.

**25. Rapid alternating movements of hands (pronation-supination movements of hands, vertically and horizontally, with as large an amplitude as possible, both hands simultaneously)**

0 = Normal.

1 = Mild slowing and/or reduction in amplitude.

2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.

3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.

4 = Can barely perform the task.

**26. Leg agility (Patient taps heel on the ground in rapid succession, picking up entire leg. Amplitude should be at least 3 inches.)**

0 = Normal.

1 = Mild slowing and/or reduction in amplitude.

2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.

3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.

4 = Can barely perform the task.

**27. Arising from chair (patient attempts to rise from a straight-backed chair, with arms folded across chest)**

0 = Normal.

1 = Slow; or may need more than one attempt.

2 = Pushes self up from arms of seat.

3 = Tends to fall back and may have to try more than one time, but can get up without help.

4 = Unable to arise without help.

**28. Posture**

0 = Normal erect.

1 = Not quite erect, slightly stooped posture; could be normal for older person.

2 = Moderately stooped posture, definitely abnormal; can be slightly leaning to one side.

3 = Severely stooped posture with kyphosis; can be moderately leaning to one side.

4 = Marked flexion with extreme abnormality of posture.

**29. Gait**

0 = Normal.

1 = Walks slowly, may shuffle with short steps, but no festination (hastening steps) or propulsion.

2 = Walks with difficulty, but requires little or no assistance; may have some festination, short steps, or propulsion.

3 = Severe disturbance of gait, requiring assistance.

4 = Cannot walk at all, even with assistance.

**30. Postural stability (response to sudden, strong posterior displacement produced by pull on shoulders while patient is erect, with eyes open and feet slightly apart. Patient is prepared.)**

0 = Normal.

1 = Retropulsion, but recovers unaided.

2 = Absence of postural response; would fall if not caught by examiner.

3 = Very unstable, tends to lose balance spontaneously.

4 = Unable to stand without assistance.

**31. Body bradykinesia and hypokinesia (combining slowness, hesitancy, decreased arm swing, small amplitude, and poverty of movement in general)**

0 = None.

1 = Minimal slowness, giving movement a deliberate character; could be normal for some persons. Possibly reduced amplitude.

2 = Mild degree of slowness and poverty of movement which is definitely abnormal. Alternatively, some reduced amplitude.

3 = Moderate slowness, poverty or small amplitude of movement.

4 = Marked slowness, poverty or small amplitude of movement.

**IV. COMPLICATIONS OF THERAPY (in the past week)**

**A. Dyskinesias**

**32. Duration: During what proportion of the waking day are dyskinesias present? (historical information)**

0 = None

1 = 1–25% of day.

2 = 26–50% of day.

3 = 51–75% of day.

4 = 76–100% of day.

**33. Disability: How disabling are the dyskinesias? (historical information, may be modified by office examination)**

0 = Not disabling.

1 = Mildly disabling.

2 = Moderately disabling.

3 = Severely disabling.

4 = Completely disabled.

**34. Painful dyskinesias: How painful are the dyskinesias?**

0 = No painful dyskinesias.

1 = Slight.

2 = Moderate.

3 = Severe.

4 = Marked.

**35. Presence of early morning dystonia (historical information)**

0 = No

1 = Yes

**B. Clinical Fluctuations**

**36. Are "off" periods predictable?**

0 = No

1 = Yes

**37. Are "off" periods unpredictable?**

0 = No

1 = Yes

**38. Do "off" periods come on suddenly, within a few seconds?**

0 = No

1 = Yes

**39. What proportion of the waking day is the patient "off" on average?**

0 = None

1 = 1–25% of day.

2 = 26–50% of day.

3 = 51–75% of day.

4 = 76–100% of day.

### C. Other Complications

40. Does the patient have anorexia, nausea, or vomiting?

0 = No

1 = Yes

41. Any sleep disturbances, such as insomnia or hypersomnolence?

0 = No

1 = Yes

42. Does the patient have symptomatic orthostasis?

(Record the patient's blood pressure, height, and weight on the scoring form.)

0 = No

1 = Yes

### V. MODIFIED HOEHN AND YAHR STAGING

STAGE 0 = No signs of disease.

STAGE 1 = Unilateral disease.

STAGE 1.5 = Unilateral plus axial involvement.

STAGE 2 = Bilateral disease, without impairment of balance.

STAGE 2.5 = Mild bilateral disease, with recovery on pull test.

STAGE 3 = Mild to moderate bilateral disease; some postural instability; physically independent.

STAGE 4 = Severe disability; still able to walk or stand unassisted.

STAGE 5 = Wheelchair bound or bedridden unless aided.

## Reviewers for Volume 13

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