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FUNCTIONAL IMPROVEMENT OF THE SPASTIC HEMIPLEGIC ARM AFTER COOLING

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ABSTRACT. To investigate the effect of cooling on the function of the spastic arm and hand, 24 spastic hemiplegics were studied with an upper extremity function test (4) before and after immersion of the involved arm in cold water. All patients reached higher functional scores after cooling than before, the difference being statistically significant in 17 patients. The improvement was most marked in the fine movements of the index finger, the middle finger and the thumb. The study shows that cooling of the arm and hand is followed by a functional improvement, detectable in a functional test.

Several clinical reports confirm the old observation that cold reduces spasticity, e.g. in multiple sclerosis, hemiplegia and quadriplegia (1, 2, 6, 10, 11, 14, 19, 20). This report attempts to extend these observations. Because the theoretical background of this effect of cold is still under discussion, a short review of some earlier experimental findings should be given.

The normal tendon reflex, as also the muscular tone necessary for the maintenance of the upright position, is dependent upon afferent impulses, inducing efferent discharges in the anterior horn motor neurons of the spinal cord. Normally supramedullary centres exert an inhibiting influence on the discharge of the motor neurons. In spasticity in which hyper-reflexia, muscle hypertonia and clonus are the cardinal signs, the inhibiting influence of supramedullary centres is presumed to be decreased.

Matthews (13) reported that the firing of the amphibian muscle spindle slows under cooling. In studies on the crayfish Burkhardt (3) showed that the sensitivity of the isolated stretch receptor organ was altered by temperature changes. Eldred, Lindsley & Buchwald (8) showed that cooling of sensory receptors in the gastrocnemius muscle of the cat induced slowing in discharge of sensory afferents, reduction of monosynaptic reflexes and decrease of decerebrate rigidity. Confirming these findings in healthy man, Petajan & Watts (18) showed that the parameter of reflex change they had chosen, namely the half-relaxation time of the triceps surae reflex, increased after cooling and that the amplitude of the reflex response also declined significantly. The effect lasted for at least $7\,^{1}/_{2}$ hours. They also found a decreasing effect of cooling on clonus in spasticity.

Studying subjects with spasticity Miglietta (15) found a reduced number of motor units in the quadriceps muscle being activated by a standard stretch stimulus after cooling. The effect was rapid after the application of cold and also rapidly decreasing after removal. Hartviksen (9) studied the effect of cooling of the gastrocnemius in subjects with spasticity and clonus. He also measured the subcutaneous and intramuscular temperatures and found that spasticity was rapidly reduced at the same time as the subcutaneous temperature decreased, but before the intramuscular temperature decreased. The reduction of spasticity, however, remained for many hours after the cold had been withdrawn and the temperature in skin and muscle had returned to normal. The author concluded that the relaxation of the spastic muscles was at first due to cooling of the skin receptors and later to cooling of the muscle spindles.

Miglietta (16) reported that the clonus frequency was found to decrease and, in some patients, to disappear altogether after immersion of the spastic extremity in a cold bath for 15 min. The effect was long-lasting, persisting for 4–12 hours. The discharges of clonus, demonstrated through skin electrodes, showed a definite reduction in their amplitude.

Studying multiple sclerosis patients, Watson (19) found decreased spasticity in subjects in which the body temperature was lowered by immersion of the body in cold water. As the improvement of the spastic patient coincided with the lowering of the body temperature, he thought that reduced body temperature was essential for improvement. Newton & Lehmkuhl (17), however, showed in anaesthetized cats that the frequency of action potentials in the spindle afferent discharge was reduced substantially during cooling, and that this reduction was most significant when the body was kept at normal temperature during the direct application of cold to muscle.

Cooling reduces neural conductivity. Zankel (21) using cold packs found a significant reduction of conduction velocity of the ulnar nerve. According to Douglas & Malcolm (7) the susceptibility of the various types of nerves to cooling varies with the diameter of the nerve. The afferent γ-fibres have a small diameter and are relatively susceptible to cooling. The thicker efferent α-fibres offer a high resistance to cooling. If a decreased spasticity without a decrease in muscular strength should be attained, then cooling temperatures should be chosen that will not reduce the conductivity of the motor nerves.

Thus the experimental findings indicate that many factors are involved in the effect of cold on spasticity, but that this effect is due "at least in part, to a lowering of the excitability of the muscle spindles" (12). However, to date, an analysis of the clinical effects of this modality is still lacking. Carroll (4) designed an upper extremity function test (U.E.F.T.) and in a subsequent paper he applied the test to hand function in hemiplegia (5). The method was found to be useful for determining which functions of the upper extremity are impaired and need treatment. It can also be used to measure changes in hand function with advancing disease or after treatment. The purpose of the present study is to investigate if U.E.F.T. can be used to study the functional improvement of the spastic hemiplegic arm after cooling.

MATERIAL

The patient population consisted of 27 hemiplegics. Two of the subjects could perform no part of the test and one could perform all of the test. As the testing scale, thus, was not adapted to the loss of function of these subjects, these 3 were excluded from the study. The remaining 24 patients had the following pertinent characteristics.

They were 22–77 years old. The onset of hemiparesis was from 3 months to 10 years before the time of testing. In 15 subjects the hemiparesis was located on the right side and in 9 on the left. The involved arm showed hypertonia and hyper-reflexia in all cases. In a few, finger flexor clonus was also found. The patients were all able to understand the instructions needed for the test.

METHOD

The spastic arm was tested with the upper extremity function test (U.E.F.T.) (4.5) was immersed in cold water and was then again tested with U.E.F.T.

The test is performed with the patient seated in front of a test table with different objects. The objects, listed in the table, are wooden blocks of different sizes, iron pipes, a slate, a wooden ball, a marble, ball bearings of different diameters, a washer, a smoothing-iron, a pitcher and glasses. The patient is asked to take the objects with the involved hand and to move them to determined positions on a shelf in front of him, and to pour water from the pitcher to glasses and back again. The patient is also asked to place his involved hand behind his head, on top of his head and to move his hand to his mouth. The tasks represent the basic functions of the upper extremity, and are designed to test these functions. There are four grades for each of the 32 tests, giving scores from 0 to 3:

Grade 0: The patient is unable to perform any part of the task.

Grade 1: The patient completes part of the task. For example, this grade is given when the patient is able to pick up or lift the item from the table, but is unable to place it in its correct position.

Grade 2: The task is completed, but slowly or very clumsily.

Grade 3: The task is performed normally.

The scoring according to this test has been shown to be correlated to the results in conventional tests for activities of daily life. The standard error of the single test was found to be 2.5 points, when 23 patients with chronic stable hand impairments were re-tested by one investigator.

In this study, the task of writing one's own name has been excluded as this part of the test may be impossible to grade accurately.

After the first U.E.F.T. the tested arm was immersed in cold water up to two-thirds of the upper arm for 15 min. The temperature +12°C was chosen, as the patients were uncomfortable at lower temperatures. During the time of cooling the temperature of the water increased to +13°C. As soon as possible after cooling another U.E.F.T. was performed and the scoring was made by the same investigator. The whole investigation lasted about 40 min.

Table I. *Total scores of 24 spastic hemiplegic patients before and after cooling of the arm*

Basic function		Scores: Before cooling	After cooling	Difference
Grasp	1. Block 100 mm	28	41	13
	2. Block 75 mm	37	43	6
	3. Block 50 mm	45	50	5
	4. Block 25 mm	43	48	5
Grip	5. Pipe 43 mm	40	47	7
	6. Pipe 19 mm	41	47	6
Lateral prehension	7. Slate 25 × 15 × 100 mm	28	42	14
Pinch	8. Ball 75 mm	36	44	8
	9. Marble 15 mm: index finger and thumb	32	42	10
	10. Marble 15 mm: middle finger and thumb	25	30	5
	11. Marble 15 mm: ring finger and thumb	18	21	3
	12. Marble 15 mm: small finger and thumb	11	14	3
	13. Ball bearing 11 mm: index finger and thumb	23	34	11
	14. Ball bearing 11 mm: middle finger and thumb	17	28	11
	15. Ball bearing 11 mm: ring finger and thumb	13	20	7
	16. Ball bearing 11 mm: small finger and thumb	8	10	2
	17. Ball bearing 6 mm: index finger and thumb	20	25	5
	18. Ball bearing 6 mm: middle finger and thumb	17	25	8
	19. Ball bearing 6 mm: ring finger and thumb	9	14	5
	20. Ball bearing 6 mm: small finger and thumb	6	9	3
	21. Ball bearing 4 mm: index finger and thumb	18	24	6
	22. Ball bearing 4 mm: middle finger and thumb	13	20	7
	23. Ball bearing 4 mm: ring finger and thumb	10	13	3
	24. Ball bearing 4 mm: small finger and thumb	6	9	3
Placing	25. Washer over nail	26	39	13
	26. Iron to shelf	19	22	3
Supination and pronation	27. Pour water from pitcher to glass	23	31	8
	28. Pour water from glass to glass	27	32	5
	29. Pour water back to first glass	24	29	5
	30. Place hand behind head	36	38	2
	31. Place hand on top of head	38	41	3
	32. Hand to mouth	50	52	2
Total		787	984	197

RESULTS

All the 24 patients studied reached higher scores after cooling than before, when the scores of all the different parts of the function test for each patient were summed. The scores of a few parts of the test, however, were lower after cooling in a few patients. The mean total score for one patient before cooling was 33, range 5–89; after cooling the mean was 41, range 10–95. The greatest increase after cooling for any patient was 31, and the smallest was 3. In 17 patients the difference was statistically significant, in 8 at the 5% level and in 9 at the 1% level.

The Table shows the total scores of all the patients studied before and after cooling of the arm. As seen, before cooling the lowest scores were found in the parts of the test in which ball bearings should be pinched with the small finger, the ring finger and the thumb. In all the pinch tests, using the thumb and one of the other fingers, the scores increased from the small finger towards the index finger. Low scores were also seen in moving the iron to the shelf, and in some of the pronation–supination movements.

After cooling of the arm the greatest functional improvement was found in grasping the biggest wooden block (side 100 mm), in lateral prehension of the slate and in placing the washer over the nail. Also pinching of the marble and the ball bearings with the index finger and the middle finger showed a marked improvement. The improvement was greater using the index finger and the middle finger than that using the ring finger and the small finger, as is also shown in the figure.

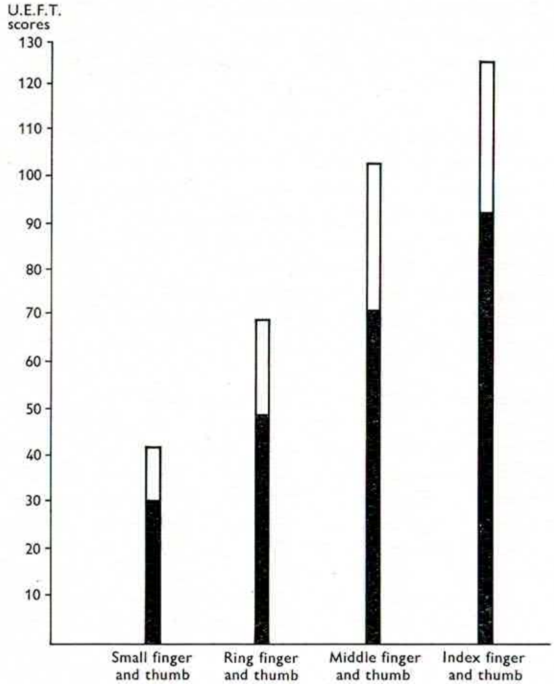

Fig. 1. Scores of 24 hemiplegic patients in U.E.F.T. doing precision movements with the thumb and alternately the small, ring, middle and index finger (*solid bars*). Functional improvement after cooling of the arm (*open bars*). The height of the bars is derived by adding together the scores of the pinch tests (tasks 9–24) in the Table.

DISCUSSION

The study has shown that each single patient investigated reached higher total scores after cooling than before. In 17 out of the 24 patients this increase of scores represents a significant functional improvement, considering the error when patients are re-tested by the same investigator. When the scores found in each single part of the test were summed for all the patients studied (see the Table), higher values were also found after cooling. The findings confirm the observation that a functional improvement in a spastic extremity can be seen as an effect of cooling.

The improvement was most marked in the parts of the test in which the index finger, the middle finger and the thumb were used for lateral prehension of the slate, for placing a small washer over a nail and pinching a marble and ball bearings. All these tests include fine movements of the fingers. The greatest functional improvement should, of course, be expected in the functions using the muscles of the hand and the forearm, as the shoulder was not and the upper arm was only partly exposed to the cold. It may be observed, however, that these fine movements of the fingers are extremely important for hand function and, as a consequence, also for activities of daily living (4). The effect of cold on the fine movements of the hand here observed may therefore be of some interest.

Experimental and clinical investigations have shown that the effect of cold on spasticity can remain for many hours (1, 9, 16, 18). Treatment with cold may therefore be valuable as an adjuvant for better performance during the active hours of the day. It has also been shown that the local application of cold to spastic muscles in conjunction with exercise for several weeks often results in a lasting improvement of the motor functions (12). The technique has also been shown to elicit a larger range of motion in joints with contractures due to spasticity (10).

Cooling of the spastic hemiplegic arm is almost invariably accompanied by a feeling of relaxation and comfort. The results of the present study show that this feeling is combined with a functional improvement, detectable in a functional test.

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