0363-5465/80/0803-0181$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 8, No. 3

Neurophysiologic inhibition of strength following tactile stimulation of the skin*

JAMES A. NICHOLAS,† M.D., MEREDITH MELVIN, M.Ed., AND ANTHONY J. SARANITI, R.P.T., *New York, New York*

From the Institute of Sports Medicine and Athletic Trauma and the Department of Orthopedic Surgery, Lenox Hill Hospital, New York, New York

ABSTRACT

A modified shoulder abduction manual muscle test was incorporated in this study to demonstrate strength changes following tactile stimulation of the skin. Resistance was applied to the distal radioulnar joint and the stimulus (scratching) was applied inferior to the clavicle on the clavicular head of the pectoralis major muscle after maximum contraction. An electromechanical device quantified the isotonic (eccentric) measurements. A standard dynamometer system (Cybex II) was used to measure isometric strength. The nondominant side was used as the "control." Two populations, a normal (random) and a strong (athletic) group, were studied. Twenty-three persons (52% women, 48% men; mean age, 27 years; mean height, 67 inches (170 cm); and mean weight, 147 lb (66.7 kg)) were in the "normal" group and 17 persons (100% men; mean age, 25 years; mean height, 74 inches (188 cm); and mean weight, 215 lb (97.5 kg)) were in the "strong" group. The random population showed a 19% decrease in strength following tactile stimulation as measured by the manual muscle testing unit; the athletic population showed a 17% decrease in strength. With the isometric measurements, the random population had an 8% decrease in mean strength following the scratch but the athletic population showed no significant decrease. The capability to quantify objectively manual muscle tests is discussed in relation to the importance of the proximal musculature.

Mott and Sherrington[1] (1895) abolished all voluntary movement in the limb of a monkey by sectioning the posterior roots of spinal nerves to eliminate sensation. Their work has been followed by numerous studies demonstrating the extreme importance of cutaneous sensation for purposive movement.[2, 3] Hagbarth[4, 5] worked with spinal and decerebrated cats (1952), as well as with humans (1960), to document the facilitation and inhibition of different muscles by the stimulation of specific skin areas.

Clinically, cutaneous afferent stimulation has been incorporated in physical medicine and rehabilitation treatments for developmental disabilities and neuromuscular disorders. Cutaneous afferent stimulation is used as a component of proprioceptive neuromuscular facilitation techniques to restore flexibility, strength, and to improve sensory-motor integration.[6] These techniques encompass irradiation patterns basic to the principle of neuromuscular function stated by Jackson,[7] "nervous centers know nothing of muscles, they only know of movements." Gellhorn[8] (1950) and Gellhorn and Johnson[9] (1950) have shown that stimulation of an isolated point on the motor cortex produces a muscular response in many muscles in a pattern not the contraction of a single muscle. Proprioceptive neuromuscular facilitation techniques recapitulate neurologic development, cephalocaudal and proximal to distal, by strengthening the entire linkage between the proximal and distal segments of a limb.

The concept of linkage has historically provided a foundation for kinesiology and rehabilitation principles as well as the biomechanical basis for understanding motion dynamics in sports. This concept is useful when one describes the role of muscles, bones, tendons, and ligaments in force transmission and summation from one segment (joint) to the next.[10, 11] The musculature of both the pelvic and shoulder girdles and the trunk and spine provide the key chains in the linkage system. These muscle groups are responsible for the transmission of force from the trunk and spine to the extremities which assures stabilization, fixation, and neutralization forces essential for normal mechanics in distal limb segments. In previous pa-

*Presented at the Fifth Annual Meeting of the American Orthopaedic Society for Sports Medicine, Innisbrook, Florida, July 9 to 12, 1979.

† Address correspondence to: James A. Nicholas, M.D., Director of the Institute of Sports Medicine and Athletic Trauma, Lenox Hill Hospital, 130 East 77 Street, New York, New York 10021.

pers,[12,13] we documented strength deficits in the proximal leg musculature secondary to orthopaedic pathology in distal limb segments. For these reasons, we routinely assess the strength of the proximal musculature in screening athletes for residual weakness which may predispose their distal joints to injury and prescribe preventive strengthening programs when they are indicated.[14]

The synthesis of both our clinical and research experience has led us to the design of an electromechanical device which can objectively quantify a manual muscle tester's subjective assessment of strength in the proximal musculature.[15] The purpose of this study was to investigate our observation that cutaneous afferent stimulation of the proximal musculature could cause a change in the strength of distal segments and to document that change with our device.

MATERIALS AND METHODS

A modified shoulder abduction manual muscle test was incorporated in this study to demonstrate strength changes following tactile stimulation of the skin overlying the pectoralis major muscle. Isotonic (eccentric) assessments were made by an electromechanical device and isometric strength assessments were made by the Cybex II dynamometer system.‡

The electromechanical device for quantifying manual muscle tests, a manual muscle testing unit (MMTU), consists of three components (Kristal Instruments)[16] (Fig. 1). The first component is a piezoelectric cell that converts mechanical energy into electrical energy. The second component is a charge amplifier which amplifies the input signal and converts it to a voltage signal. The third component is a peak analog indicator, which reads and freezes the peak voltage signal and displays it as a function of mechanical units of force in kilograms.

The standard dynamometer system used in this study to measure isometric strength was the Cybex II. The armbar was set in the horizontal plane, the input shaft was in alignment with the axis of rotation for shoulder abduction at 90°, and peak torques (ft-lb) were recorded.

With the use of modified manual muscle test procedure for shoulder abduction (the resistance applied to the distal radial ulnar joint), we obtained strength measurements before and after tactile stimulation of the skin (by scratching) inferior to the clavicle on the clavicular head of the pectoralis major muscle (T2-T3 dermatome) (Figs. 2 and 3). Our variable (the scratch) was applied to the dominant side, while the nondominant side served as our control; we measured strength outputs with the MMTU and the Cybex.

Two populations, a normal (random) and a strong (athletic) population, composed the group of 40 subjects in this study. The normal group (n = 23; 52% women, 48% men) had a mean age of 27 years, a mean height of 67 inches (170 cm), and a mean weight of 147 lb (66.7 kg). The strong (athletic) population (n = 17; 100% men had a mean age of 25 years, with a mean height of 74 inches (188 cm), and a mean weight of 215 lb (97.5 kg).

‡ Although the Cybex system is an isokinetic device, strength measurements were assessed isometrically.

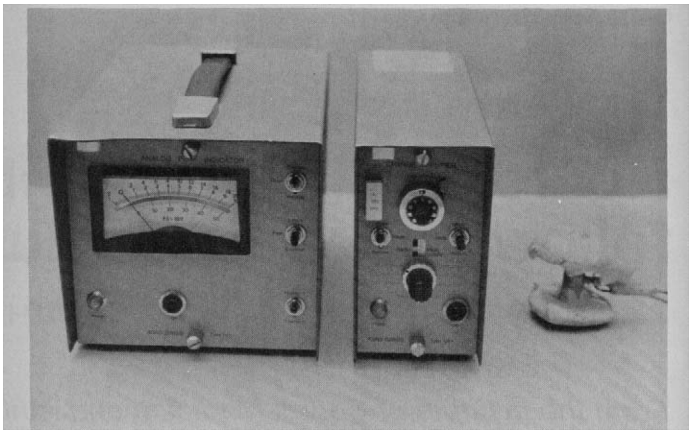

Fig. 1. *Photograph of the MMTU. An electromechanical device designed by Kristal Instruments.*

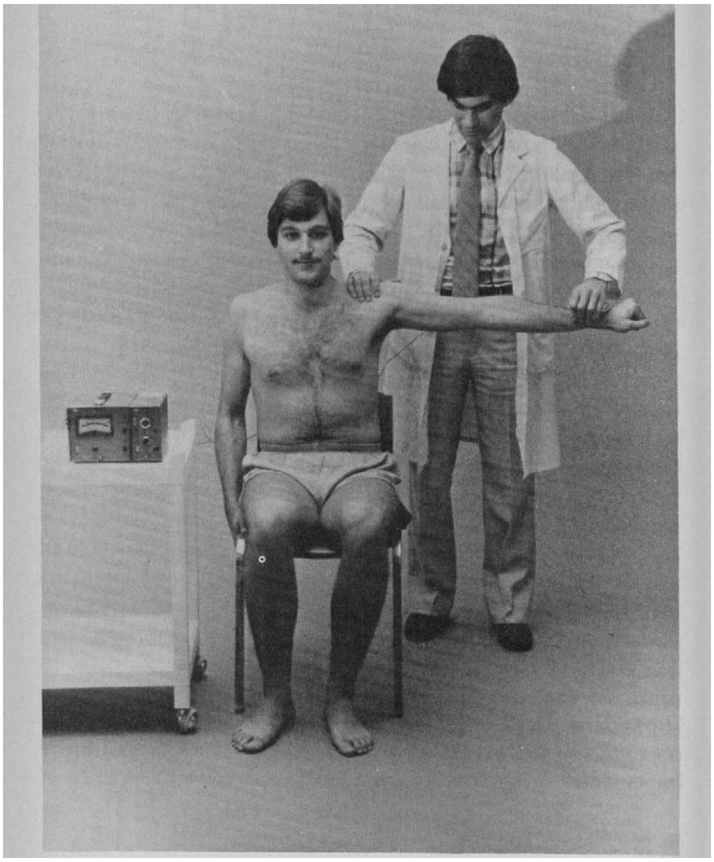

Fig. 2. *Photograph depicting testing with participant seated in a hardbacked chair with arm positioned at 90° of shoulder abduction and the therapist with the MMTU interposed between his hand and the participant's arm.*

All participants in the study were tested according to a standard protocol on both their dominant and nondominant sides. None had previous significant history of upper extremity or spinal injuries.

PROTOCOL

The nondominant side (control) was tested with the MMTU first. Each participant was placed in a hardbacked chair in the upright seated position with the arm held at 90° of abduction. Each was asked to elicit a maximal eccentric contraction with the words "don't let me push you down." The examiner pushed down with the load cell interposed between his hand and the person's arm until the resistive abduction was "broken." The peak force of resistive strength was recorded (PU 4) (Fig. 4). After a 5-sec rest, the participant repositioned his arm in 90° of abduction for another maximal eccentric contraction against manual resistance (PU 5). Finally, after 15 sec of rest with the arm at his side, the participant was asked to position his arm in 90° of abduction and the third maximal eccentric contraction was elicited and broken with the peak force recorded (PU 6).

When we tested the dominant side with the MMTU, we followed the same protocol except that, in the 5-sec rest period following the original measurement of strength (PU 1), the examiner stimulated (scratched) the participant's skin over the ipsilateral clavicular head of the pectoralis major muscle. The subject was asked to reposition his arm in 90° of abduction and elicit a maximal eccentric contraction. The peak force was recorded (PU 2). After a 15-sec rest period the third and final maximal eccentric contraction was elicited and recorded (PU 3).

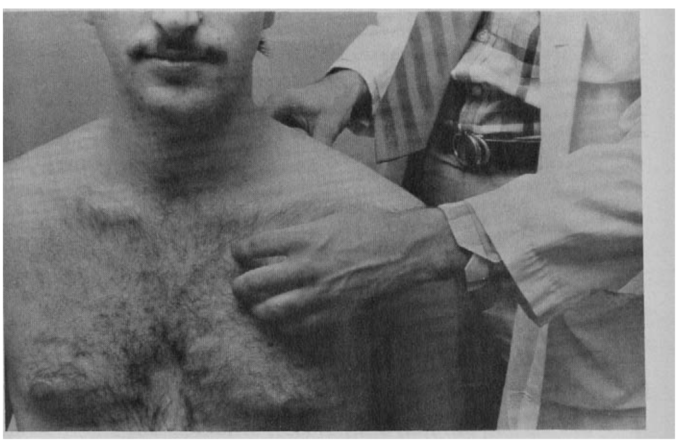

Fig. 3. *Close-up photograph of tactile stimulation (scratch) of pectoralis major muscle.*

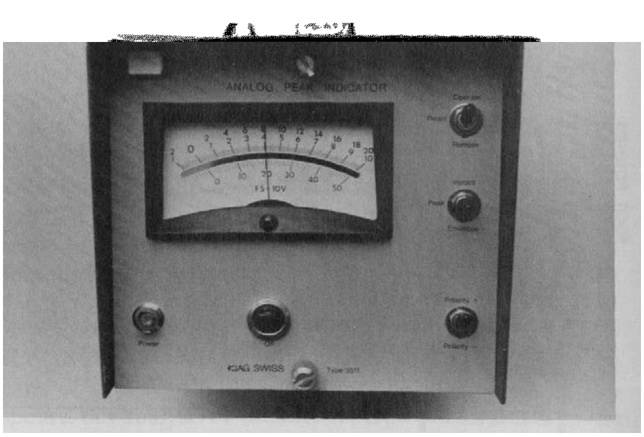

Fig. 4. *Photograph showing peak analog indicator frozen at the peak value.*

Adhering to the same intervals in the protocol used for the MMTU, we measured the nondominant and dominant sides on the Cybex II dynamometer system. Each person was seated in a stool with the input shaft of the dynamometer in alignment with the axis of rotation for shoulder abduction at 90°. The armbar was fixed in a horizontal position parallel to the floor, and the length of the armbar was adjusted so that the participant would be applying his force to the same point of the distal radial ulnar joint that the MMTU force had been applied (Fig. 5). The subject was instructed to "push up" as hard as he could so that maximal isometric contractions were elicited and peak torques recorded, CY 1, CY 2, and CY 3 on the dominant side and CY 4, CY 5, and CY 6 on the nondominant side.

An analysis of variance for repeated measures was performed and in the presence of significant F ratios individual treatment means were compared with Dunnett's T-tests.[17]

RESULTS OBTAINED WITH THE MMTU

Normal population

On the nondominant side, in the strong population, the mean eccentric strength value (PU 4) was 21.7 kg. After the 5-value was 10.8 kg. Following the standard 15-sec rest, the mean value (PU 6) was 10.4 kg (Fig. 6).

The mean value of the normal population for the MMTU measurement of strength on the dominant side before the scratch (PU 1) was 12.6 kg. Following the scratch, the mean value of eccentric strength (PU 2) was 10.2 kg. After the 15-sec rest, the mean value obtained by the eccentric contraction (PU 3) was 12.0 kg (Fig. 6). This represents a transient 19% decrease in mean strengths before and after the scratch between PU 1 and PU 2.

Strong population

On the nondominant side, in the strong population, the mean eccentric strength value (PU 4) was 21.7 kg. After the 5-sec rest, the mean value (PU 5) was 21.9 kg. After 15 sec, the mean value (PU 6) was 21.1 kg (Fig. 7).

On the dominant side, the mean value for eccentric strength before the scratch (PU 1) was 23.0 kg. Following the scratch, the mean value (PU 2) was 19.2 kg. After the 15-sec rest, the mean eccentric strength value (PU 3) was 22.6 kg (Fig. 7). This represents a 17% decrease in mean strength before and after the scratch between PU 1 and PU 2.

RESULTS OBTAINED WITH THE CYBEX

Normal population

Measurements on the nondominant side of the normal popu-

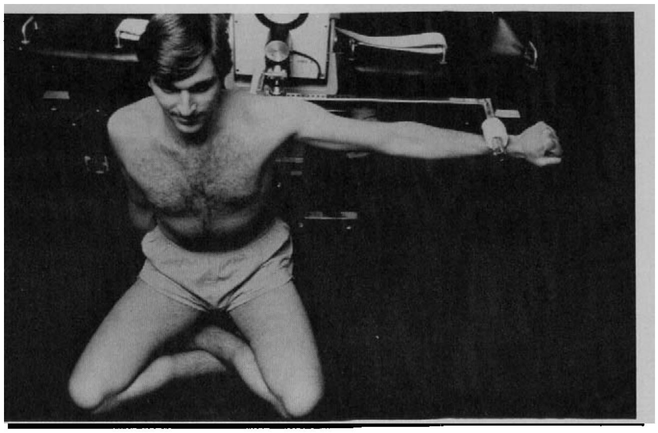

Fig. 5. *Photograph depicting Cybex set up for isometric measurements.*

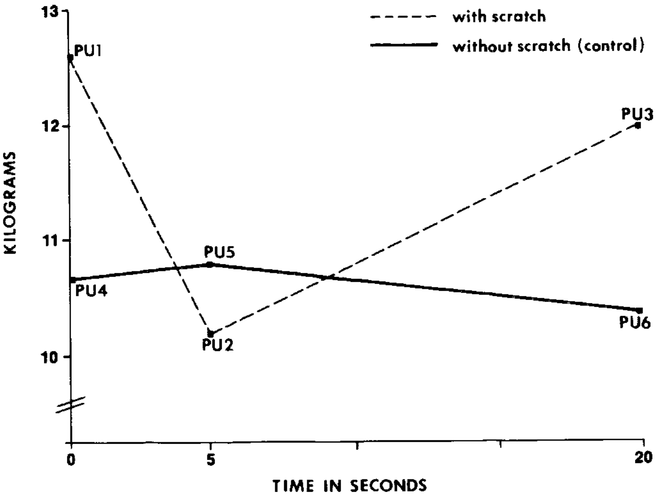

Fig. 6. *Graph of the eccentric strength assessments with and without scratch. Normal population.*

lation revealed a mean isometric strength value (CY 4) of 26.8 ft-lb. Following the standard 5-sec rest, the mean isometric value (CY 5) was 27.3 ft-lb. After a 15-sec rest, the mean isometric value (CY 6) was 26.9 ft-lb (Fig. 8).

On the dominant side, measurements with the Cybex taken before the scratch (CY 1) revealed a mean isometric value of 28.6 ft-lb. Following the scratch, the mean value (CY 2) was 26.2 ft-lb (Fig. 8). This represents an 8% decrease in mean strengths between CY 1 and CY 2. After the 15-sec rest, the mean isometric value (CY 3) was 27.6 ft-lb.

Strong population

On the nondominant side, the mean isometric strength value was 66.7 ft-lb (CY 4) for the strong population. Following the 5-sec rest, the mean value (CY 5) was 65.7 ft-lb. After the 15-sec rest, the mean isometric strength value (CY 6) was 63.7 ft-lb (Fig. 9).

For the strong population, on the dominant side, the mean value for isometric strength (CY 1) was 74.4 ft-lb. Following the scratch, the mean value (CY 2) was 71.2 ft-lb (Fig. 9). This represents a 4% decrease in mean isometric strength between CY 1 and CY 2. Following the 15-sec rest, the mean value (CY 3) was 71.8 ft-lb.

STATISTICAL SIGNIFICANCE OF THE RESULTS

Measurements of strength on the nondominant side served as our control in representing a fatigue pattern for the shoulder abductors. The results were analyzed statistically to verify that the scratch, not fatigue, was responsible for the loss of strength in the dominant side. An analysis of variance for repeated measures was performed on all of the strength data from eccentric and isometric measurements. A significant F ratio was obtained in all cases except before and after scratch measurements of isometric strength for the strong population. A posthoc comparison of the difference between individual treatment means by Dunnett's T-test indicated strength means were significant at the α, equal to 0.05 level of probability.

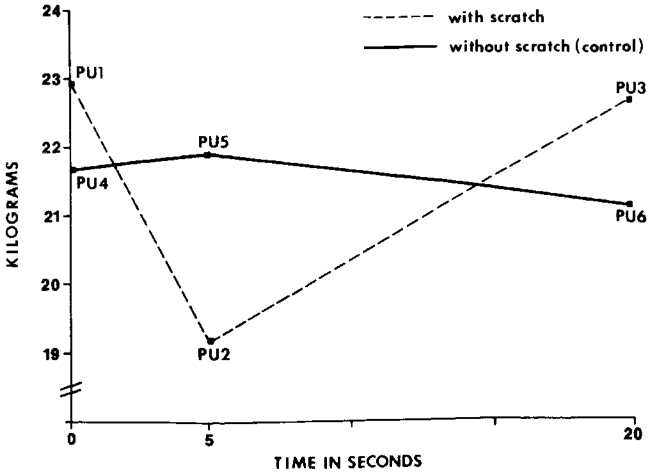

Fig. 7. *Graph of the eccentric measurements with and without scratch. Strong population.*

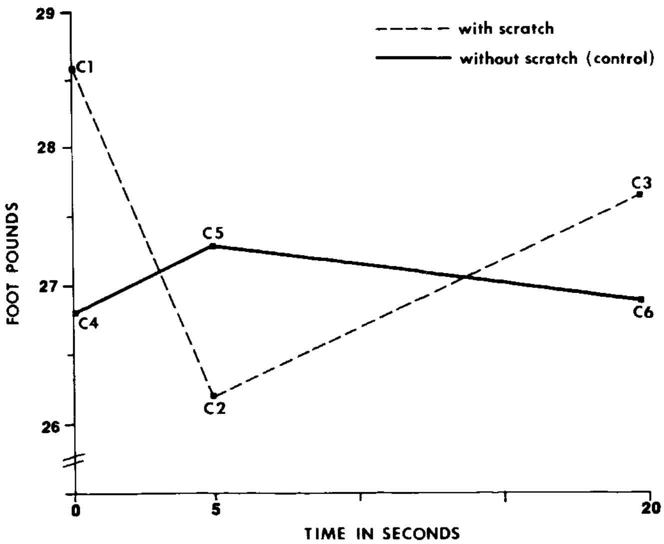

Fig. 8. *Graph of the isometric assessments. Normal population.*

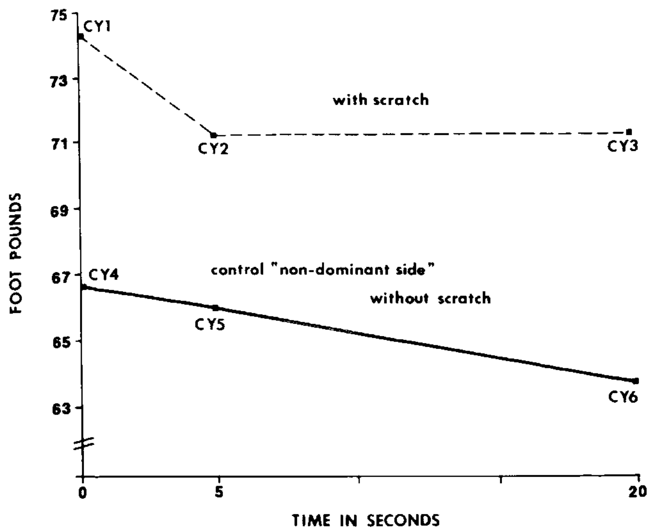

Fig. 9. *Graph of the isometric measurements with and without scratch. Strong population.*

DISCUSSION

One explanation as to why the strong population did not show a significant decrease in isometric strength following the scratch may be found in the effects of their training and motivation. For the athletes, the isometric measurement procedure was not unfamiliar and the motivational effort for a maximal contraction was present for each assessment of strength.

It is important to recognize that the isometric Cybex tests, however, were not performed in the same manner as the manual muscle tests. In the isometric measurements, the subject pushed against the armbar, which was set at 0 degrees/sec until their strength output plateaued. In the manual muscle tests, the peak force was recorded when the arm could no longer resist the examiner's force and the participant's resistance was broken. While the isometric tests require that the participant push up his arm and maintain an angle of 90° of shoulder abduction, the manual muscle test requires that the subject resist an applied force in the direction of shoulder adduction. The isometric tests take less balancing response and adjustment than the manual muscle tests which require that both the examiner and the subject cope with the variables of each others' resistance.

Tactile stimulation (the scratch) was applied to the T2-T3 dermatome and possibly underlying myotome of the clavicular head of the pectoralis major muscle. As the stimulated afferent neuron enters the spinal cord, the neuron bifurcates and then ascends and descends several spinal cord segments. One theory is that the stimulated neurons ascend to C4-C5-C6 and hyperpolarize the lower motor neurons innervation of the deltoid and supraspinatus muscles, momentarily diminishing their ability to recruit strength. Although at this time we have no means of proving the pathways for the mechanism of this response, our analysis of variance for repeated measures on the nondominant arm, which served as our control, revealed that fatigue was not a major contributing factor in the decrease in strength in the manual muscle tests and in most of the isometric tests.

In our clinical experience with manual muscle testing, we have been able to observe an inhibition of strength following scratching of the lower abdominal and inguinal area when testing hip flexion. Applying tactile stimulation superior to the iliac crest yields a decrease in hip abductor strength, and following tactile stimulation of the dorsal aspect of the forearm, we observed a loss of strength in the intrinsics of the hand as well.

We have observed that this phenomenon, a decrease in strength following tactile stimulation, does not occur if there is any history of pathology present in the limb being tested. The subtleties of spinal adaptation to pain, pathology, and afferent input continue to intrigue us. Facilitation and inhibition of strength can be seen as both protective and detrimental responses. The possibility of neurophysiologic mechanisms such as this one contributing to the etiology of injuries by affecting recruitment remains open to discussion. We hope the additional capability to quantify objectively manual muscle tests will lead us toward understanding the complexities of irradiation and recruitment that transmit strength from proximal to distal segments.

CONCLUSIONS

Our study has demonstrated the neurophysiologic inhibition of strength in the shoulder abductors after tactile stimulation of the skin dermatome overlying the pectoralis major muscle. We documented a 19% decrease in strength with the manual muscle testing unit following the scratch in our random population and a 17% decrease in the athletic population. We also documented an 8% decrease in the mean strength of the random population following the scratch with the Cybex isometric measurements, however, we did not find a significant decrease following the scratch of the athletes tested isometrically.

ACKNOWLEDGMENT

Bernard R. Cahill, M.D., Peoria, Illinois, discussed this paper at the time of its presentation to the American Orthopaedic Society for Sports Medicine, Innisbrook, Florida, July 12, 1979. A revised manuscript was submitted for publication.

REFERENCES

1. Mott FW, Sherrington CS: Experiments upon the influence of sensory nerves upon movement and nutrition of the limbs. *Proc R Soc Med 57:* 481, 1895
2. Lassek AM: Inactivation of voluntary motor function following rhizotomy. *J Neuropathol Exp Neurol 12:* 83–87, 1953
3. Twitchell TE: Sensory factors in purposive movement. *J Neurophysiol 17:* 239–252, 1954
4. Hagbarth KE: Excitatory and inhibitory skin areas for flexor and extensor motoneurones. *Acta Physiol Scand 26:* 1–58, 1952
5. Hagbarth KE: Spinal withdrawal reflexes in human lower limb. *J Neurol Nuerosurg Psychiatry 23:* 222–227, 1960
6. Kabat H: Proprioceptive facilitation in therapeutic exercise. In *Therapeutic Exercise.* Second edition. Edited by S Licht Baltimore, Williams & Wilkins, 1961, pp 327–343
7. Jackson JH: *Selected Writings of John Hughlings Jackson,* edited by J Taylor. New York, Basic Books, 1958
8. Gellhorn E: Validity of the concept of multiplicity of representation in the motor cortex under conditions of threshold stimulation. *Brain 73:* 267–274, 1950

9. Gellhorn E, Johnson DA: Further studies on the role of of proprioception in cortically induced movements of the foreleg of the monkey. *Brain 73:* 513–531, 1950
10. Nicholas JA, Grossman RB, Hershman EB: The importance of a simplified classification of motion in sports in relation to performance. *Orthop Clin North Am 8:* 499–532, 1977
11. Miller DI: Modelling in biomechanics: an overview. *Med Sci Sports 2:* 115–122, 1979
12. Nicholas JA, Strizak AM, Veras G: A study of thigh flexion weakness in different pathological states of the lower extremity. *Am J Sports Med 6:* 241–248, 1976
13. Gleim GW, Nicholas JA, Webb JN: Isokinetic evaluation following leg injuries. *Physician Sportsmed 6:* 75–82, 1978
14. Goldberg B, Nicholas JA: The pre-participation physical examination- a proposed method. Submitted for publication
15. Nicholas JA, Sapega A, Kraus H, et al: Factors influencing manual muscle tests in physical therapy. *J Bone Joint Surg 60A:* 186–190, 1978
16. Saraniti AJ, Gleim GW, Melvin M, et al: The relationship between subjective and objective measurements of strength. Submitted for publication
17. Morehouse CA, Stull GA: *Statistical Principles and Procedures with Applications for Physical Education.* Philadelphia, Lea & Febiger, 1975, pp 293–295