0196-6011/80/0201-015$02.00/0
THE JOURNAL OF ORTHOPAEDIC AND SPORTS PHYSICAL THERAPY

The Relationship Between Subjective and Objective Measurements of Strength*

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INTRODUCTION

Manual muscle testing is utilized by physicians and physical therapists to aid in the diagnosis and evaluation of pathology.[8] The basis of a diagnosis or the modification of a treatment program is dependent upon the clinician's perception of a patient's strength. This inherent subjectivity of manual muscle testing often leads to questionable findings in a medical examination.[1,6] Factors such as sex, age, height, and weight serve only to increase the subjectivity of this evaluation.[4]

This study demonstrates the use of a new manual muscle testing unit (MMTU) to quantify muscle strength objectively. The results of the MMTU were compared to a clinician's subjective evaluation of the stronger limb. In addition, the data obtained with the MMTU were analyzed to investigate further what constitutes a significant strength deficit. The MMTU's ability to differentiate strength differences and deficits demonstrates how manual muscle testing can assume a refined role in the evaluation of muscle strength.

MATERIALS AND METHODS

The MMTU (Fig. 1) is an electromechanical device (Krystal Instruments, King's Island, NY), which consists of three components: a piezoelectric load cell (with an accuracy of ±1%) which converts mechanical energy into electrical energy; a charge amplifier which amplifies the input signal and converts it into a voltage signal; and a peak analog indicator which reads and freezes the peak voltage signal and displays it as a function of mechanical units of force (kilograms).[7]

The manual muscle tests performed were the hip abduction and hip flexion tests.[2,5] Both tests were administered to 219 subjects yielding a total of 438 individual tests. The characteristics of the population according to sex, age, height, and weight are described in Table 1.

For the hip abduction test, the subject was placed in a side-lying position. The leg to be tested was on top with the contralateral leg flexed at 90° at the hip and knee for stability. The subject was instructed to hold onto the edge of the table as he or she abducted the leg, such that the foot was raised 40 centimeters above the table. With the load cell positioned between the tester's hand and the subject's leg, a manual force in the hip abduction direction was applied just superior to the lateral malleolus.

In the hip flexion test, the subject was seated with the distal legs hanging over the edge of the table. The subject was instructed to flex at the hip until the knee rose approximately 20 to 25 centimeters above the table. A manual force was applied in the direction of hip extension, with the load cell interposed between the tester's hand and the subject's limb, just proximal to the superior pole of the patella.

Prior to each test, the subject was informed that a manual force would be applied in the opposite direction when the leg was raised. Each subject was instructed to maintain this position while resisting the force pushing the leg to the table. The tester increased the applied force to the limb until the subject could no longer maintain the position. The peak force indicated by the peak analog indicator was recorded.

Upon completion of a given test, a researcher recorded the magnitude of force (kilograms) and the therapist's subjective evaluation of the stronger limb. The therapist did not know in advance the subject's dominant side or medical history, nor did he read the objective force from the peak analog indicator.

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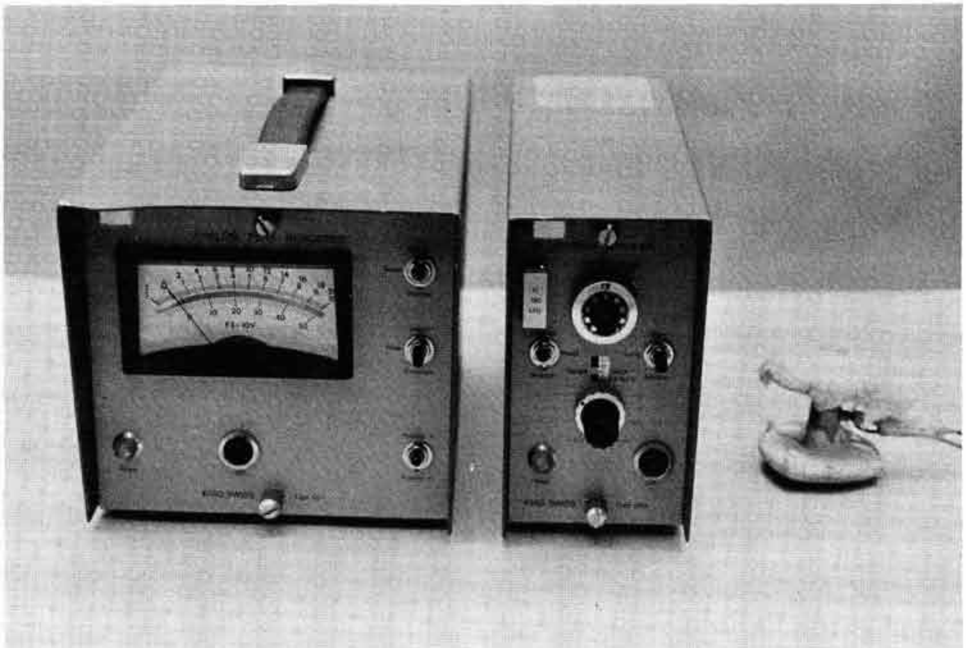

Fig. 1. *The electromechanical device.*

TABLE 1

Characteristics of population

Group	Mean age (yr)	Age range (yr)	Mean height (cm)	Mean weight (kg)
Male (N = 147)	19.8	13–68	173.7	70.2
Females (N = 72)	19.8	13–66	163.1	57.4
Combined (N = 219)	19.8	13–68	170.2	66.0

The data obtained with the MMTU were compared to the therapist's subjective assessments of the stronger limb. Correct and incorrect assessments were determined, with a correct assessment denoting an agreement between the therapist's subjective and the MMTU's objective determination of the stronger limb, an incorrect assessment denoting no agreement. A χ^2 analysis was done to evaluate the discrepancy between observed and expected frequencies of correct and incorrect assessments.

Mean strength differences were calculated for both hip flexion and hip abduction. A strength difference was defined as the absolute difference between two extremities (expressed in kilograms) of a particular muscle group.

The MMTU data also were divided into three raw strength ranges: 0 to 18 kilograms, 18 to 25 kilograms, and >25 kilograms (Table 2), to more accurately assess significant strength deficits. A strength deficit was defined as the relative strength between two extremities (expressed as a percentage) of a particular muscle group, computed by the following formula:

$$1 - \frac{\text{smaller strength value}}{\text{larger strength value}} \times 100\%$$

or

$$\frac{V_L - V_S}{V_L} \times 100\%$$

Linear regression analysis determined the relationship of raw strength outputs to significant deficits.

RESULTS

In 50 cases, the therapist was unable to make a subjective assessment of the stronger limb because the applied force was insufficient to overcome the subject's resistance. These tests were omitted from the study; hence, the results are based on the remaining 388 tests.

A correct assessment of the stronger leg was achieved in 83% of the hip abduction tests and 80% of the hip flexion tests. Overall, a correct assessment was obtained in 82% of the cases. Table 3 shows the correct assessments by the individual muscle groups and by sex.

In the correct assessments (Table 4), the mean strength differences were 4.0 kilograms (20.5%)

TABLE 2

Mean percentages of deficit by test and by range of strength outputs

Range of strength output (kg)	Hip abduction			Hip flexion		
	N	% deficit	SE	N	% deficit	SE
0–18	133	21.8 ± 13.8*	1.2	23	18.5 ± 12.3	2.6
18–25	89	17.1 ± 10.9	1.2	58	17.2 ± 11.6	1.5
>25	16	7.4 ± 5.4	1.3	56	9.3 ± 7.6	1.0

* Mean ± SD.

TABLE 3

Correct and incorrect assessments by test

Test	No. of tests	No. of correct assessments	No. of incorrect assessments	% correct assessments	Level of significance (*P*)
Hip abduction					
Male	145	117	28	81	<0.001
Female	77	68	9	88	<0.001
Total	222	185	37	83	<0.001
Hip flexion					
Male	83	69	14	83	<0.001
Female	83	63	20	76	<0.001
Total	166	132	34	80	<0.001
Combined	388	317	71	82	<0.001

TABLE 4

Analysis of correct assessments

	Difference (kg)			% deficit*		
	Male	Female	Combined	Male	Female	Combined
Hip abduction	4.1 ± 2.8†	3.7 ± 2.4	4.0 ± 2.7	19.0 ± 12.6	22.9 ± 13.3	20.5 ± 13.0
Hip flexion	4.4 ± 3.7	4.5 ± 3.0	4.4 ± 3.4	14.5 ± 13.9	18.1 ± 10.1	15.9 ± 11.0

* Defined as the relative strength of a muscle group between two extremities.

† Mean ± SD.

TABLE 5

Analysis of incorrect assessments

	Difference (kg)			% deficit*		
	Male	Female	Combined	Male	Female	Combined
Hip abduction	1.5 ± 1.3†	2.0 ± 1.9	1.6 ± 1.5	7.0 ± 5.9	14.3 ± 12.9	8.8 ± 8.6
Hip flexion	2.2 ± 2.2	2.9 ± 2.7	2.2 ± 2.6	4.0 ± 4.2	8.1 ± 7.3	6.4 ± 6.5

* Defined as the relative strength of a muscle group between two extremities.

† Mean ± SD.

for hip abduction and 4.4 kilograms (15.9%) in hip flexion. In contrast, differences of only 1.6 kilograms (8.8%) in hip abduction and 2.2 kilograms (6.4%) in hip flexion were obtained for the incorrect assessments (Table 5) (abduction, $P < 0.001$; flexion, $P < 0.03$). Therefore, the incorrect assessments were made when both legs were almost equal in strength.

Mean percentage deficits were computed for each of the three ranges of strength (Fig. 2) for both hip abduction and hip flexion. A trend appeared, in which the strength output increased as the average strength deficit decreased. This indicates that a smaller strength deficit may be considered significant in a strong muscle group. Conversely, a greater strength deficit may be considered significant in a weak muscle group. In hip flexion, for example, a 36% deficit is significant below 18 kilograms of force, but, when the strength output is greater than 25 kilograms, the deficit need only be 17%. Linear regression analysis (Fig. 3) indicates a Pearson

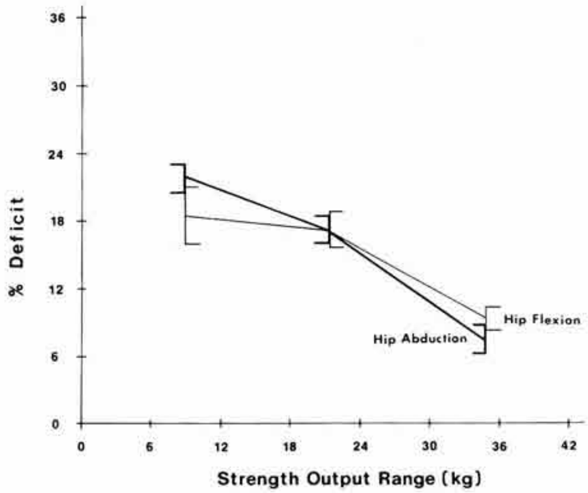

Fig. 2. *Values of strength ranges for hip abduction and hip flexion (mean ± SE).*

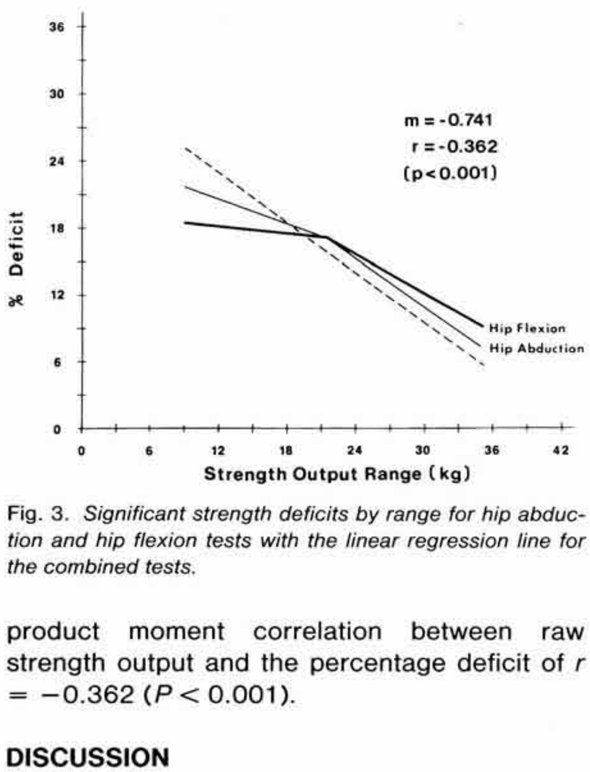

Fig. 3. *Significant strength deficits by range for hip abduction and hip flexion tests with the linear regression line for the combined tests.*

product moment correlation between raw strength output and the percentage deficit of $r = -0.362$ ($P < 0.001$).

DISCUSSION

Historically, manual muscle testing has been limited to a subjective evaluation of muscle strength. This new lightweight electromechanical MMTU now affords the clinician an objective strength output reading. In the hip abduction and hip flexion tests, the MMTU was consistent with the subjective evaluation of the stronger limb in 82% of the cases.

One of the most important factors of the 18% incorrect assessments was the inability of the therapist to detect strength differences when both muscle groups presented almost equal strength bilaterally. The hip abduction test demonstrated a higher percentage of correct assessment of the two tests because the mean percentage deficit in hip abduction is greater than the mean percentage deficit in hip flexion. A greater strength deficit made it easier for the therapist to subjectively assess the relative strength difference between two limbs.

In the disciplines of orthopaedics and physical therapy, the definition of a significant deficit is a controversial issue. In former studies, a strength deficit greater than or equal to 10% was considered significant, regardless of the magnitude of the patient's strength output. However, this finding was based on pathological populations where the side of pathology correlated highly with the strength deficits greater than or equal to 10%.[3, 9] In this study, we found that significant strength deficits are relative to the magnitude of a patient's strength output and that the ≥10% limit is not absolute.

The objective strength output data from the MMTU supplements the function of manual muscle testing. Using this unit, the clinician can better evaluate pathology and design the necessary strengthening programs based on determined deficits. Additionally, the MMTU is simple to use and can give those untrained in manual muscle testing the ability to evaluate muscle strength. With the MMTU, coaches, physical educators, or allied health professionals will be able to recommend exercise programs to correct strength deficits in individuals encountered in their settings. In this way, deficits which might predispose an individual to injury or reinjury can be corrected, thereby potentially decreasing the frequency and/or severity of injury.

The authors wish to gratefully acknowledge the editorial assistance of Philip Witman, MPH.

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