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Comparison of the IEMG Activity Elicited During an Isometric Contraction Using Manual Resistance and Mechanical Resistance

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Published: 01 January 2011

Ibnosina J Med BS 2011, 3(1):9-14

Received: 12 April 2010

Accepted: 31 October 2010

This article is available from: <http://www.ijmbs.org>

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Abstract

Introduction: Quantification of muscle strength is an essential component of assessment and treatment in rehabilitation. Considering the measurement of the muscle strength, mostly two methods are used. They are qualitative and quantitative measures. Maximum voluntary isometric contraction (MVIC), measured using dynamometer and manual muscle testing (MMT) are the most common measurement techniques used in the clinical and research setting. **Objectives:** This study's aim was to observe, if greater activity is produced using mechanical instruments for torque measurements (since the resistance is adjusted to subject's maximum capacity) or if tests, position of MMT, and resistance offered by trained physiotherapist are effective. We compared the IEMG (Integrated electromyography) output between manual and mechanical testing during maximal voluntary isometric contraction. **Subjects and Methods:** Forty normal healthy subjects including 20 males and 20 females were selected for the

study. The measuring system comprises an EMG (Noraxon USA, INC, Scottsdale, Arizona) and HUR 5340 (Kokkola, Finland) leg extension/curl computer controlled machine for isometric evaluating peak torque. MVIC of the Vastus medialis oblique (VMO), Vastus lateralis (VL), Rectus femoris (RF), Semitendinosus (ST) and Biceps Femoris (BF) were measured from dominant leg using SEMG and then subjects were seated on HUR with hip flexed and chest, pelvis, thigh stabilized. The axis of rotation of HUR aligned with the joint axis and moment arm is fixed for every subject. Each subject performed maximal contraction of 10sec at 60° of test angle to get the peak torque and myoelectrical activity are also recorded while performing the same. **Result:** Paired t-test analysis were used to see the difference between MMT and HUR IEMG amplitude and the results show significance difference ($p < .05$) for each muscle when comparing between the EMG amplitude between MMT and HUR. **Conclusion:** HUR system has very good reliability in measuring muscle strength of

the knee extensors and flexors as compared to the MMT, suggesting that it will be useful in clinical applications, especially for professional athletes or physically powerful populations.

Key Words: Muscle strength, IEMG, Isometric contraction

Introduction

Quantification of muscle strength is an essential component of assessment and treatment in rehabilitation. Muscle strength is the force exerted by a muscle or group of muscles to overcome a resistance in one maximal effort. For the measurement of the muscle strength, mostly two methods are used. They are qualitative and quantitative measures. Quantitative measures are those that are not dependent primarily on the judgment of the examiner. Such measures typically involve the use of instrumentation like dynamometers and are expressed in real numbers. On the other hand, measures like manual muscle testing, which involves the judgment of the examiner, is considered as qualitative. In assessing muscle strength, it is essential to describe the conditions surrounding the muscle contraction to interpret the data properly. In this study maximum voluntary isometric contraction (MVIC) is considered. Isometric muscle tests are the most common as they are the simplest to perform and reproduce. The test conditions are well defined, they are the most appropriate for comparing results within a population (1). MVIC, measured using dynamometer and manual muscle testing are the most common measurement techniques used in the clinical and research setting (3–5). Both have advantages and disadvantages. The simplest and most common method of assessing muscle strength is the manual muscle testing. Manual muscle testing is a procedure for evaluating strength and function of an individual muscle or a muscle group in which the patient voluntarily contracts the muscle against gravity load or manual resistance (1,2). MMT is an inexpensive method of testing strength that requires little equipment and personnel training but some studies have shown that MMT lacks the sensitivity to detect small but potentially important changes in muscle strength (5–8). Dynamometer provides interval data (typically in units of kilograms or Newtons of force) that are more objective than manual muscle testing and is a safe and simple method of assessing muscle strength. Dynamometric testing is not suitable for weak muscles when movement against resistance cannot be performed, as often occurs in the case of peripheral nerve lesions (9). Adding electromyography (EMG) during the muscle strength assessment method adds

precision to the quantification method. It has long been recognized that mechanical tension and electromyographic (EMG) amplitude are directly related during isometric contraction (10-12). Lippold and Bigland demonstrated that during a voluntary contraction, the tension is proportional to the measurable electrical activity under isometric contractions (10,11,13,14). With an increase in the voluntary force more motor units are recruited and can be picked up by the surface electrodes. It is common practice to normalize the force (or torque) with respect to maximal isometric force that a subject can generate at the monitored joint. EMG normalization is frequently used to improve reliability by decreasing variation within and between individuals in EMG studies. The most common method of normalization is to compare the myoelectrical activity of a given contraction to the activity of Maximal voluntary isometric contraction (MVIC). In the very process of normalization in EMG study researcher uses the method of eliciting a MVIC. The position used to elicit this MVIC is a matter of controversy because at different knee joint angles the muscle is capable of producing different torque outputs. Researchers commonly use the position and angles described in the standard textbooks and procedures for eliciting manual muscle testing used in physical therapy to grade the strength of a muscle. Thus, this study was to observe, if greater activity was produced using mechanical instruments for torque measurements (since the resistance is adjusted to subject's maximum capacity) or if tests, position of MMT, and resistance offered by trained physiotherapist are effective. The study is designed to compare the IEMG output between manual and mechanical testing during maximal voluntary isometric contraction.

Methodology

Subjects

Forty normal healthy subjects including 20 males (age 22.65 ± 2.45 yr, height 170.6 ± 5.8 cms, weight 67.45 ± 10.36 kgs) and 20 females (age 21.3 ± 1.89 yr, height 162.24 ± 5.16 cms, weight 54.72 ± 7.39 kgs) were selected for the study. All were right leg dominant and were not involved in any type of resistance training. They had no history of knee; hip or lower back pathology or surgery. Before testing, informed consent was obtained from each subject. The study was approved by ethical committee for research, GNDU Amritsar and a formal consent was obtained from all participants.

Equipments

The measuring system comprised of a 4-channel Myosystem

1200 electromyography (EMG) unit (Noraxon, USA Inc) and bipolar Ag-AgCl surface electrodes, measuring 1cm in diameter with a center to-center distance of 2.5 cm to record the myoelectric activity. The EMG signals were amplified by the amplifier system. Driver line with the input impedance of 10 milliohm. Gain (fixed) =1 000 Hz, 12-bit A/D Converter ± 5 mV input range, Bandwidth- 10-500 Hz with no notch filter.

HUR 5340 leg extension/curl computer controlled machine is an isoinertial dynamometer, which was used for evaluating isometric peak torque. This machine was the result of research project at the University of Technology in Helsinki, Finland.

Procedures

Skin impedance was reduced by shaving hair around the electrode site and wiping the skin with 70% of ethyl alcohol before applying the surface electrode. All the impedance level was below 5kOhm before data collection started. Pairs of surface electrode with diameter of 1cm and center to center spacing of 2.5cm were applied to the dominant limb. The electrodes were covered with an electrically conducting gel and were positioned over the VMO, VL, RF, ST & BF of the lower limb under evaluation; and were attached using adhesive tape to avoid the movement artifact. For the VMO, the electrodes were placed on the VMO muscle belly, approximately 4 cm proximal to the superomedial border of the patella. For the VL, the electrodes were applied over the VL muscle belly, approximately 8 cm proximal to the lateral joint line of the knee. For the RF, the electrodes were placed at 50% of the distance from the anterior superior iliac spine to the superior pole of the patella (15). For Semitendinosus (ST), the electrodes were placed at 50% of the distance from the ischial tuberosity to the medial condyle of the femur. For Biceps femoris, the electrodes were placed at 50% of the distance from the ischial tuberosity to the lateral condyle of the femur. All electrodes were placed parallel to the corresponding muscle fiber. A ground electrode is placed on the proximal surface of tibia. After the preparation and positioning of electrode each subject warmed up on a stationary bicycle for five minutes. Soon afterwards, they performed sustained passive stretching of the hamstrings and quadriceps: two series of 30 seconds with an interval of 30 seconds. The purpose was to reduce any discomfort experienced by the subject during the MVIC and to reduce the intensity and duration of any post exercise muscle soreness. Data was recorded while each subject performed a MVIC (Maximum Voluntary Isometric Contraction) against fixed

resistance for each muscle. MVIC of all muscles were recorded in manual muscle testing position in accordance with standard physical therapy guidelines (16). Subjects were in lying position on the treatment table/ stable base during all muscle testing and recordings. After recording the myoelectrical activity during MMT and then subjects were made sit on the chair of the HUR leg extension/curl with hip flexed at 110° and chest, pelvis, thigh stabilized. Before the final performance on the HUR, the activity was demonstrated to all the participants and they were made to practice the task and familiarize with the task for accurate readings. This was done before recordings the signals to ensure proper performance. The muscles were divided into two groups VMO, VL, & RF in first group and ST & BF in the second group.

The axis of rotation was aligned with the lateral condyle of the femur, and the moment arm is fixed for every subject. Test angles were presented in the midrange (60°) of knee flexion and extension. Each subject performed only one maximal contraction for 10 seconds in extension direction and then in flexion, to get the peak torque for the quadriceps and hamstrings. The myoelectrical activity was also recorded while performing the same. All subjects were given consistent verbal encouragement during the maximal excursion.

Statistical analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS, Chicago, version 16.0). We utilized the peak EMG amplitude of HUR trials as the baseline, expressing the peak EMG amplitude of MMT trials as a ratio to that of HUR trials. Paired t-test was then used to test the changes in EMG peak amplitude between the MMT trials and HUR trials. The change in EMG amplitude for each muscles (VMO, VL, RF, ST, & BF) was calculated by subtracting the average amount of amplitude in the MMT trials from the average amount of amplitude in the HUR trials. The p value was set at the level of 0.05.

Before analyzing the EMG recordings the raw signals were full wave rectified and smoothed. This approach was based on the finding that the amplitude of rectified and smoothed EMG signals is qualitatively related to the amount of force developed by the muscles. The signals during peak of contraction were analyzed. The full wave rectified and smoothed signals were analyzed with the root-mean-square (RMS) processing technique.

Results

To compare the output of two methods, 40 normal subjects

Table 1. Electromyographic (EMG) amplitude (μ V) ratio between MMT and HUR maximal isometric testing of Quadriceps and Hamstrings in women and men. All Data are presented as mean \pm standard deviation.

Muscles Groups	Gender	EMG amplitude in MMT	EMG amplitude in HUR	MMT/HUR
Vastus Medialis Oblique	Women	544 \pm 184	722 \pm 166	0.782 \pm 0.306
	Men	722 \pm 331	1089 \pm 277	0.683 \pm 0.306
Vastus Lateralis	Women	816 \pm 393	1298 \pm 695	0.721 \pm 0.300
	Men	924 \pm 424	1245 \pm 678	0.782 \pm 0.212
Rectus Femoris	Women	625 \pm 234	830 \pm 396	0.806 \pm 0.231
	Men	873 \pm 390	1106 \pm 606	0.845 \pm 0.295
Semitendinosis	Women	396 \pm 211	581 \pm 161	0.735 \pm 0.456
	Men	875 \pm 393	1245 \pm 248	0.717 \pm 0.353
Biceps Femoris	Women	412 \pm 166	541 \pm 115	0.777 \pm 0.303
	Men	574 \pm 188	801 \pm 200	0.726 \pm 0.228

Table 2. Paired t test analysis of differences in electromyographic parameters between maximal manual testing and HUR maximal isometric testing in women and men.

Muscle Groups	Gender	T	Df	Significance level	Mean difference
Diff_amp Vastus Medialis Oblique	Women	-3.506	19	0.002	-1.784
	Men	-4.61	19	0.000	-3.672
Diff_amp Vastus Lateralis	Women	-4.843	19	0.000	-4.820
	Men	-3.33	19	0.004	-3.211
Diff_amp Rectus Femoris	Women	-3.151	19	0.005	-2.043
	Men	-2.67	19	0.015	-2.876
Diff_amp Semitendinosis	Women	-3.289	19	0.004	-1.840
	Men	-4.13	19	0.001	-3.699
Diff_amp Biceps Femoris	Women	-3.440	19	0.003	-1.279
	Men	-5.67	19	0.000	-2.268

were taken and during the performance of manual and mechanical methods, EMG amplitude were taken and analyzed. Which was presented in the Table (1) shows the result of EMG amplitude ratio of the MMT to the HUR trials of MVIC. The results show that both males and females, elicited greater EMG amplitude while using HUR, rather than when using MMT.

To find the significant difference between the outcome of the two methods, we used the paired t-test and the result is presented in Table (2) which shows significance difference ($p < 0.05$) for each muscle when comparing between the EMG amplitude between MMT and HUR in both males

and females.

Discussion

The purpose of this study is to compare the IEMG output between manual and mechanical testing during maximal voluntary isometric contraction. The findings of the present study showed a significant difference between manual EMG amplitude and mechanical EMG amplitude output of all the flexor and extensor muscles, revealing that mechanical EMG amplitude has an edge over the manual EMG amplitude (table 1). Table 2 represents the significant difference ($p < 0.05$) between the two methods of assessing

the IEMG activity in males and females. However, this method is not used in the clinical practice as frequently as compared to the Manual muscle testing because of the greater consumption of time involved and the cost of the machine itself. A possible reason for our results may be the consistent resistance applied by the dynamometer as compared to the manual resistance. Another possible reason for the greater SEMG activity observed during mechanical resistance could be the greater stability of the subjects on the HUR leg extension/curl. The machine allows for full trunk support and the pelvis is also well stabilized. One of the strength of our study was the sample size, which was more than double as compared to previous study (17). A study conducted by Lin et al. had a contrasting view, stating the manual methods were preferable to mechanical methods because they elicited comparable activity in the quadriceps femoris muscle and did not involve the cost of installation of a machine and the overall time involved in preparation of the patient was also less in manual methods. In this study we chose the angle of knee for the performance of the isometric test of the quadriceps and hamstring as 60° which has been demonstrated to be the angle of maximal isometric force generation (15,18) Lin et al (17) used an angle of 45° for his study, and we believe that it may be this factor which caused the difference in results. The other reason may be that during testing on the HUR machine the hip joint angle is fixed at 110° by the inclination of the seat, offering a better length tension relation for the rectus femoris muscle output as compared to the manual method where the patient is encouraged to keep an upright posture with the hip at 90°.

In a recent study of acute rehabilitation patients, it was found that reliance on manual muscle testing (subjective measures) missed strength deficits 25% of the time (5). On the other hand, quantitative measures have in some cases three potential advantages over qualitative measures: 1) sensitivity, 2) validity, and 3) reliability. The objective measures may require more time and effort than the subjective measures, and also require equipment that may elevate their cost and limit the setting in which they can be applied, yet objective measures are more sensitive or precise than subjective measures. This fact has been documented repeatedly in regard to measures of muscle strength. Beasley, using objective strength measures, demonstrated over 50 years ago that subjective manual muscle testing in children produced "Normal" test results when strength was only 50% of Normal(9). He also demonstrated that differences in strength of 20% to 25% were not detected by manual muscle testing (9,19-21).

In conclusion, the examiner's muscle strength affects the inter-examiner reliability of muscle strength measurements using the MMT. Insufficient examiner muscle strength leads to poor inter-examiner reliability with the MMT. So using HUR, which provides constant output forces, solves this problem by increasing reliability of outcomes. Our study shows that HUR system has very good reliability in measuring muscle strength of the knee extensors and flexors as compared to the MMT, suggesting that it will be useful in clinical applications, especially for professional athletes or physically powerful populations. The limitation of our study is that it included only collegiate population and it allowed only one maximal contraction for both manual and mechanical methods.

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