†PREDICTORS OF MUSCLE STRENGTH USING QUANTITATIVE MUSCLE TESTING FOR HAND MUSCLES IN YOUNG INDIAN ADULTS

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Abstract :

Background: *Quantitative Muscle Testing (QMT) is well known for its accuracy & precision as compared to Medical Research Council (MRC) grading system. QMT provides the normal reference while the MRC cannot, and these values can be a target value for rehabilitation program.*

Objectives: *To establish normal reference value for selective hand muscles using "break" test, and to present a case study to demonstrate the clinical application of Quantitative Muscle Strength.*

Method: *A cross sectional study – using a convenience sample of 102 healthy Indian adults (51 male, 51 female), age from 20 to 40 years representing 14 states of India. Maximal Isometric strength of ADM, I DI, APB and ECRB (bilaterally) was measured using a Micro FET3[1] a hand-held dynamometer.*

Results: *Age, gender and body mass index were identified to be a best predictor of the muscle strength and these variables accounted for 61-75% of variability in muscles strength. For each muscle, predictive regression models using age, gender and BMI are proposed.*

Conclusion: *This study established a normative database for Indian adults' between 20 to 40 years for four hand muscles. This may help to compare the strength over time between subjects, thus effective tool to evaluate efficacy of therapy.*

Key words : Isometric contraction, Quantitative muscle testing, Hand function, Predictive strength equation.

INTRODUCTION

Any trauma to hand causes a strength deficit of the intrinsic muscles. Clinically, the intrinsic hand muscles are most often evaluated using MMT. Currently used MRC scale is a 6-point numeric scale, with grades, 0 as complete paralysis, 3 when the limb segment can be moved actively against gravity, and grade 5 as normal. MRC scale seems to indicate a constant distance between grades. It will be more appropriate to use terms such as normal, good, fair, trace, and paralyzed as compared to a grading of 0–5. Another drawback with using the ordinal MRC scale is that the higher part of the scale (grades 4 and 5) occupies by far the largest part of total range. As a result, in these ranges the MRC scale will not be able to detect clinically relevant changes in muscle strength (Brandsma et al 2001, Schreuder et al 2006 & Durfee W. K et al 2006).

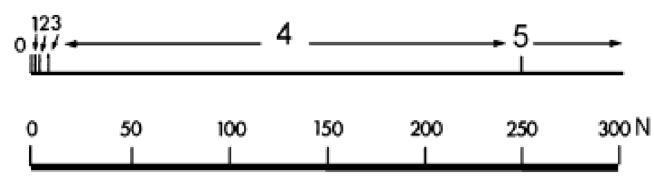

Figure 1: *Comparison of the MRC scale (upper line) with the scale of the dynamometer (bottom line) in the case of male elbow flexor*

Many muscles need only 15% to 30% of their maximum voluntary contraction potential to move a limb or limb segment through its full range without resistance (grade 3). In other words, force needed to grade the muscle or movement as having "some" resistance (grade 3+, 4-) or "almost normal" resistance (grade 4+, 5-) may vary between 15% and almost 100% of the maximum force the muscle is able to generate. This is the "range" in which sensitivity and responsiveness of the test is clinically very important. Thus, manual muscle strength grading can be misleading as it is nonlinear and ordinal. Hence precise testing of muscle strength using Quantitative Muscle Testing (QMT) was done.

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A hand-held dynamometer (HHD) is easy to use and helps to measure muscle strength quantitatively with accurate measurements of isometric muscle strength than MMT. There are various commercially available strain gauge dynamometers. The MicroFET3 developed by the Hoggenhealth Company is a battery-operated, electromechanical device. It measures, freezes, and displays the peak force and time duration of muscle testing. The MicroFET3 model is sensitive even to 0.8 lb.

Statement of the problem

No reference values are available for quantitative hand muscle strength for Indian population. Although various factors that influence muscle strength have been studied earlier, but the extent of this influence are yet to be determined.

Objectives

- To establish normative values for selective hand muscles using "break"
- A case study to demonstrate the clinical application of Quantitative Muscle Strength.

Implications of the study

Normative values can serve as a reference value. The extent of a patient's impairment can be established by comparing measurements of that patient's performance with normative values obtained. The predicted value can help detect small changes early as compared to MRC grading. It will hence help in monitoring the effectiveness of various interventions aimed at improving muscle strength.

METHODOLOGY

Cross sectional study design

Setting

Department Occupational Therapy, Kasturba Hospital, Manipal

Participants

Convenient sample of 102 healthy men (n=51) and women (n=51) aged 20 to 40 years.

Inclusion criteria

- Healthy young Indian adults aged 20 to 40 years who are able to understand and perform the testing procedures.
- Everyone who had a muscle power 5 according to MRC.

***Exclusion criteria*:**

Any inflammatory or other disease involving joint or muscle pathology

1. Any report of pain that might affect maximal strength testing results
2. Elite athletes or individuals were sedentary because of chronic medical illness
3. Cardiac and Vascular
   a. Post MI
   b. High Blood Pressure (>160/95)
   c. Known Aneurysms
   d. Certain Arrhythmias
   e. Heart Failure
   f. Any condition for which a strong Valsalva is contraindicated
4. Biomechanical force
   a. Uncertainty regarding Fracture status
   b. Acute Strains and Sprains
   c. Certain immediate status post (Surgical conditions, those where stress may cause injury)
   d. Osteoporosis, Tumors, Metabolic Diseases
   e. Fusion Uncertainty

Instruments used:

MicroFET3 & its attachments:

- Digit pad for fingers and toes
- Curved pad for rounded surface

Testing Procedure for Muscle strength measurements using MicroFET3

The test was carried out in distraction free, well illuminated & ventilated room by well trained examiners. Standard table and chair was used for all the subjects. Prior to actual data collection examiners practiced on 10 subjects with standardized procedure. A trial of the test was performed before the actual test. To increase the accuracy of the measurement the instruments were calibrated prior to use

The Break Test

The break test for different muscles was performed using MicroFET3. The break test is repeated three times for each muscle group and the average of three values is reported, similar to the ASHT clinical evaluation recommendation.

This test was performed on following four muscles: *Abductor Digiti Minimi* First Dorsal Interossei Abductor Pollicis Brevis &Extensor Carpi Radialis Brevis.

Statistical Analysis using SPSS 11.5 was done.

RESULTS

Table-1
Subjects Characteristics

Characteristics	Men (n=51)	Women (n=51)	Total (n=102)
Age (yrs)	29.4±6.0 (20-40)	27.6±6.4 (20-40)	28.5±6.2 (20-40)
Weight (kg)	67.6±12.4	53.8±8.0	60.4±12.4
Height (cm)	170.8±7.0	157.1±5.9	163.9±9.4
Body Mass Index (kg/M^2)	22.96±3.87	21.82±3.34	22.39±3.64
Right Dominance	47 (46%)	51 (50%)	98(96%)

Note: Values are Mean ± SD or as otherwise indicated

Table-2A
Strength Reference Value for Men and the Influence of Dominance

Muscle	Side	Men (n=51) (mean ± SD) lbs	t score	CI (95%)	P-value (2-tailed)
ADM	Dominant	9.3±1.6	-1.81	-.079 – 0.15	.07
	Nondominant	9.6±1.9			
1DI	Dominant	15.2±1.9	5.25	0.60 – 1.85	<.001
	Nondominant	13.9±1.9			
APB	Dominant	15.8±3.0	1.91	-0.18 – 1.11	.06
	Nondominant	15.4±3.1			
ECRB	Dominant	34.3±5.2	4.85	0.72 – 2.49	<.001
	Nondominant	32.7±5.0			

Table-2B
Strength Reference Value for Women and the Influence of Dominance

Muscle	Side	Women (n=51) (mean ± SD) lbs	t score	CI (95%)	P-value (2-tailed)
ADM	Dominant	6.5±1.4	4.35	0.17 – 0.72	<.001
	Nondominant	6.0±1.2			
1DI	Dominant	11.0±2.2	6.61	0.65 – 1.54	<.001
	Nondominant	9.9±2.0			
APB	Dominant	10.1±2.1	4.03	0.22 – 1.11	<.001
	Nondominant	9.5±2.1			
ECRB	Dominant	21.3±2.8	6.29	0.72 – 1.80	<.001
	Nondominant	20.1±2.8			

Table-3
Influence of Gender on Muscle Strength

Muscle	Side	Men (n=51) (mean ± SD) lbs	Women (n=51) (mean ± SD) lbs	t score	CI (95%)	P-Value (2-tailed)
ADM	Dom	9.3±1.6	6.5±1.4	-9.49	-3.54 – 2.00	<.001
	Non	9.6±1.9	6.0±1.2	-11.08	-4.37 – -2.69	<.001
1DI	Dom	15.2±1.9	11.0±2.2	-10.40	-5.19 – -3.10	<.001
	Non	13.9±1.9	9.9±2.0	-10.39	-5.18 – -3.00	<.001
APB	Dom	15.8±3.0	10.1±2.1	-11.78	-7.02 – -4.35	<.001
	Non	15.4±3.1	9.5±2.1	-11.18	-7.27 – -4.51	<.001
ECRB	Dom	34.3±5.2	21.3±2.8	-15.62	-15.12 – -10.77	<.001
	Non	32.7±5.0	20.1±2.8	-15.82	-14.69 – -10.51	<.001

Graph 1:
Comparison of mean strength for men and women on dominant hand

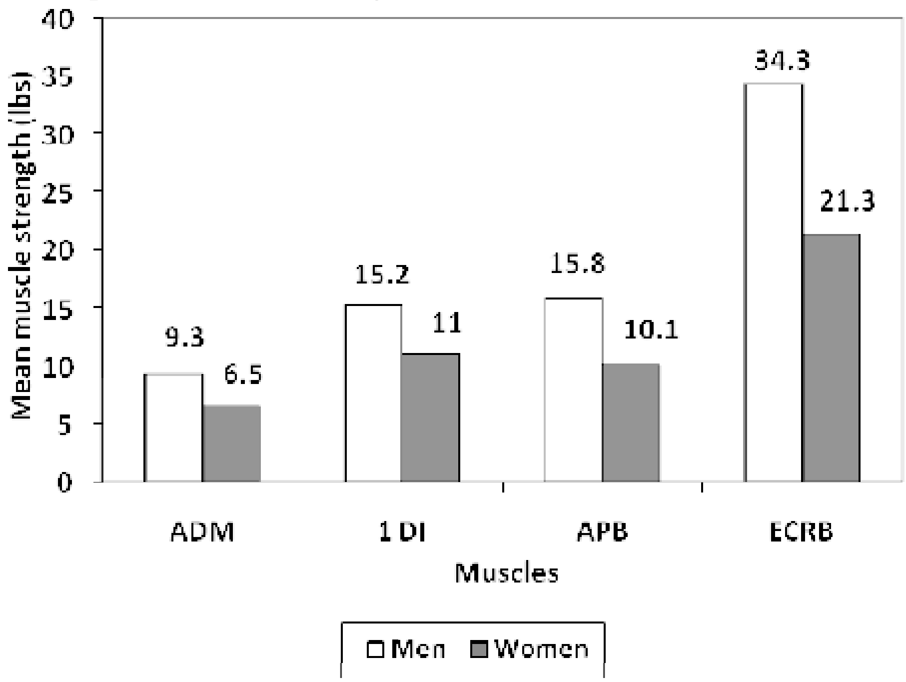

Table-4
Correlation Between Outcome Variables with other Covariates/Predictors

Muscle	Side	Gender		Age		BMI	
		R	P value	r	P value	r	P value
ADM	Dominant	.688	<.001	.487	<.001	.229	.02
	Nondominant	.742	<.001	.434	<.001	.194	.05
1DI	Dominant	.721	<.001	.394	<.001	.340	<.001
	Nondominant	.720	<.001	.276	.005	.370	<.001
APB	Dominant	.745	<.001	.326	.001	.352	<.001
	Nondominant	.745	<.001	.358	<.001	.294	.003
ECRB	Dominant	.842	<.001	.264	.007	.273	.006
	Nondominant	.845	<.001	.278	.005	.272	.006

Table-5
Regression Parameters for Strength Prediction

Muscle	Side	N	Intercept	Age	Gender	BMI	*R*	R^2	SD
ADM	Dominant	102	1.83	.12	2.47	.05	.80	.63	2.02
	Nondominant	102	1.75	.12	3.25	.03	.81	.66	2.40
1DI	Dominant	102	3.74	.12	3.70	.17	.81	.65	2.89
	Nondominant	102	3.74	.07	3.66	.19	.78	.61	2.80
APB	Dominant	102	1.44	.12	5.17	.24	.81	.65	3.83
	Nondominant	102	1.30	.15	5.39	.18	.80	.64	3.97
ECRB	Dominant	102	10.55	.16	12.31	.28	.86	.75	7.72
	Nondominant	102	9.24	.17	11.96	.27	.87	.75	7.50

Male=1, Female=0; BMI= Weight/Height^2

Multiple regression parameters for strength prediction for each muscle are listed in Table 5. Pearson correlation analysis was performed to provide the equation to predict muscle strength for muscles assessed in this study. Age, gender and Body Mass Index were identified to be significantly correlating with outcome variables (Table 4).

DISCUSSION

Table 2a & 2b shows the reference values of muscles tested on dominant & non-dominant hand on men & women respectively. Standard deviations are very close to mean suggesting the reliable findings on muscle strength.

No study exists for comparing strength reference value for all the tested muscles. However, the APB strength in kg (in dominant hand, for men 4.5±0.89, for women 2.84±0.48, in non-dominant hand, for men 4.26±0.79, for women 2.82±0.62) reported on American population by Lie F et al (2000) was lesser both in men & women as compared to our current findings in kgs (in dominant hand, for men 7.16±1.36, for women 4.58±0.95, in non dominant hand, for men 6.98±1.40, for women 4.30±0.95). The differences observed could have several origins. The analyses in several studies on normative strength show a marked variation depending on the country, which can be partly explained by differences in methodological procedures. However differences could have caused by increased finger dexterity, cultural, social characteristics of healthy populations that have been involved in such protocols.

Table 2a shows the performance of dominant hand in men was greater as compared to non dominant hand. However, statistically significant difference is noted mainly for First dorsal interossei (1DI) (p <.001) and Extensor Carpi Radialis Brevis (ECRB) in men (p<.001). The strength of the ADM in nondominant (9.6±1.9) side for men was greater than the dominant side (9.3±1.6). However, the difference is not statistically significant (p .07).

Similarly in women (table 2b) the performance of dominant hand was greater as compared to non dominant hand. Also all four muscles demonstrated the significant difference in muscle strength between dominant and nondominant hand (p<.001).

Even though there is no existing findings about the difference in dominant & non dominant in relation to these specific muscles, Lie F et al 2000 a study on (American population) normative database for Abductor Pollicis Brevis described that there is no significant difference in muscle strength between dominance. These results support our findings especially in Abductor Pollicis Brevis muscle strength in men. On the contrary the findings by National Isometric Muscle Strength database consortium (NIMS 1996), reports, that there is a significant difference in grip strength between dominance in American population. Thus, the reason for the inconsistent results regarding the significant difference between the dominance remains unclear. However, further investigation is needed to resolve this question.

Table 3 suggests that the muscle strength for men both in dominant as well as non-dominant was considerably higher as compared to women. There is a significant difference in muscle strength among men & women in both dominant as well as non dominant (Graph 1). These results are supported by the similar studies done by Liu et al 2000, Boatright et al 1997, Mathiowetz V et al 1985 and Philips BA 2000.

Table 4 presents the Pearson correlations between muscle action and sex, age and BMI. Gender, age and BMI were correlated significantly ($p<.001$) for most of the muscle action. Regression established age, gender and BMI as the best set of independent predictors of the muscle action strength (Table 5). Together these three variables predicted between 61% and 75% of the strengths of the muscle actions tested. Moreover, as assessed by stepwise regression, height and BMI were less predictive variables with respect to age, sex, and weight. The regression coefficients were similar to previous studies with adults. These predictive regression models make it possible to assess the relative weakness of patients. These findings are very much comparable with studies done different population by Hogrel JY et al 2007, NIMS 1996, Bohannan 1997, Andrews 1996 and Philips BA 2000. BMI was included rather than weight and height as separate independent variable (predictor) because of its strong correlation with dependent variable (strength) as compared to weight and height separately. We have proposed for each muscle function a similar predictive regression model performed using age, sex, BMI as NIMS database consortium (1996).

The Table 5 describes the regression parameters (regression coefficients) to predict strength for ADM, IDI, APB & ECRB on both dominant & non dominant hand which was derived using stepwise multiple linear regression analysis. The value intercept under each muscle can be interpreted as when there is no influence of factors like age, gender and BMI on muscle strength, the model predicts that the individual will have for example, in Right ADM on dominant side will be 1.83 lbs. Regression coefficients for age represents the change in muscle strength associated with a unit change in the age, that is if our predictor variable (age) increased by 1 unit (1 year) then our model predicts that .12 lbs of additional strength will be present. For example, if an individual's age is 29, using this model we can multiply .12 with age (29 X .12) to get the variability in strength caused by the factor age. Same explanation is true for other factors like gender and BMI. The value R under each muscle is the correlation between observed value of muscle strength and the values of muscle strength of given muscle predicted by the multiple regression model. R^2 can be interpreted as the amount of variation in the muscle strength that is accounted for by the model. For example if the value is .63 can be interpreted as 63% variability in the muscle strength is caused by the age, gender and BMI of the individual. Remaining 37% of unexplained variation may be due to, of course, to other variables which have not been included in the regression equation (Andy field 2000 & Sundar Rao 1999).

The regression equation for a given muscle: $y=a+bx_1+cx_2+dx_3$

y= muscle strength to be predicted

a=constant indicated as intercept (strength predicted by model when there is no influence of age, gender and BMI)

b=age, c=gender & d=BMI

x_1, x_2, x_3= regression coefficients for age, gender and BMI respectively

Case Study 1

To know the use of normative database, we report a case study to see the sensitivity of the QMT for change in muscle strength. The client a 20 year old, female, student from Kudramukh, was diagnosed with neurofiroma who after the tumor removal developed post surgical brachial plexus injury. She developed paralysis in right upper extremity, proximal more than distal. While undergoing radiotherapy she was also referred to occupational therapy for her upper extremity weakness. She was started on therapy to improve upper extremity strength and hand function. QMT using MircroFET3 was done at baseline and 3 follow-up were performed regularly at 10 days interval. Her contralateral hand strength was used as normal reference value to compute the percentage of weakness of the affected limb. On statistically analyzing the progression of her muscle strength at baseline and during 3 follow-ups, QMT demonstrated steady improvement in all four muscle strength while the MRC scale did not show any change for a period of one month which remained at 3+. ADM showed maximum recovery from 2.1lbs to 3.2lbs, followed by ECRB, 1DI and APB. Degree of improvement was ranged from 30.5% (ADM) to 3.4 % (1DI). This helped us to monitor the progress and communicate with the patient easily about the improvement in muscle strength. This also helped us to evaluate the intervention.

CONCLUSION

This study has led to the development of an isometric strength normative database for Indian young adults by using QMT for hand muscles. Reference values were obtained in this study correlated significantly with age, gender, and BMI in adults from 20 to 40 years of age. There were considerable differences between men and women and between dominant and non-dominant hand. Men demonstrated increased muscle strength as compared to women in all muscle groups. Similarly Dominant hand performed better as compared to non dominant hand. This study establishes reference values for muscles strength which can be used in clinical context. Case study reported in this study demonstrates the sensitivity of QMT to change in muscle strength which could not be detected by the MRC grading.

Limitations of the study

- The sample of subjects used for the database was one of "convenience," i.e., subjects who were readily available and agreeable to the intent of the study were recruited.

- Very few subjects was involved in physical and sports activity (other than exclusion of those subjects at either extreme of an activity level continuum), thus, their influence was not considered for analysis
- No attempt was made to assess mental status, nutritional status, etc. of the subjects
- The predictive equations presented in this study are appropriate only for strength values that have been obtained using testing and stabilization procedures identical to those used here.

Future Recommendations

- Software may be used along with MicroFET to perform QMT to monitor the degree of force generated by the subject while testing.
- Further study can be done with subjects representing all the states in India
- All the muscles may be tested to compare QMT with Dynamometry, to understand the role of each muscle in grip, key pinch and pulp to pulp.

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