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Validation of Manual Muscle Testing and a Subset of Eight Muscles (MMT8) for Adult and Juvenile Idiopathic Inflammatory Myopathies

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Abstract

Objective—To validate manual muscle testing (MMT) for strength assessment in juvenile and adult dermatomyositis (DM) and polymyositis (PM).

Methods—Seventy-three children and 45 adult DM/PM patients were assessed at baseline and reevaluated 6–9 months later. We compared Total MMT (a group of 24 proximal, distal, and axial muscles) and Proximal MMT (7 proximal muscle groups) tested bilaterally on a 0–10 scale with 144 subsets of six and 96 subsets of eight muscle groups tested unilaterally. Expert consensus was used to rank the best abbreviated MMT subsets for face validity and ease of assessment.

Results—The Total, Proximal and best MMT subsets had excellent internal reliability (r_s:Total MMT 0.91–0.98), and consistency (Cronbach's α 0.78–0.97). Inter- and intra-rater reliability were acceptable (Kendall's W 0.68–0.76; r_s 0.84–0.95). MMT subset scores correlated highly with Total and Proximal MMT scores and with the Childhood Myositis Assessment Scale, and correlated moderately with physician global activity, functional disability, magnetic resonance imaging, axial and distal MMT scores and, in adults, with creatine kinase. The standardized response mean for Total MMT was 0.56 in juveniles and 0.75 in adults. Consensus was reached to use a subset of eight muscles (neck flexors, deltoids, biceps, wrist extensors, gluteus maximus and medius, quadriceps and ankle dorsiflexors) that performed as well as the Total and Proximal MMT, and had good face validity and ease of assessment.

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Conclusions—These findings aid in standardizing the use of MMT for assessing strength as an outcome measure for myositis.

Introduction

The idiopathic inflammatory myopathies (IIM) are systemic autoimmune diseases comprised of subgroups differentiated by clinical, histopathologic and immunologic findings. The IIM primarily affect skeletal muscle, causing chronic inflammation, scarring and atrophy, resulting in muscle weakness and impaired functional ability. Adult polymyositis (PM), dermatomyositis(DM), and juvenile dermatomyositis (JDM) are among the most frequent of the IIM (1;1;1;2).

The IIM primarily involve proximal muscles (3;4). A recent study verified that weakness is symmetric, that proximal extremity weakness is greater than distal, and that neck flexors are significantly weaker than extensors in PM, DM and JDM (5). In that study, the target muscles most affected were the neck flexors; hip abductors, extensors and flexors; and the deltoid (5).

Manual muscle testing (MMT) of proximal muscle groups or a Total MMT score involving proximal, distal and axial muscles, has been used as a major endpoint for IIM therapeutic trials and in clinical practice to follow patients longitudinally (6;7). Traditionally, MMT has been assessed using five point MMT scales, including the Medical Research Council Scale. An expanded 0 –10 point MMT scale (8) has also been used in recent therapeutic trials and a natural history study (6;7) and is postulated to be more sensitive in delineating weakness. The International Myositis Assessment and Clinical Trials Group (IMACS) and the Pediatric Rheumatology Clinical Trials Organization (PRINTO) have incorporated MMT according to the Kendall 0 –10 point scale as a core outcome measures for therapeutic trials (9;10).

The MMT has been validated in some neuromuscular and musculoskeletal disorders (11;12). The 0 –10 point MMT scale has been shown to have good reliability in juvenile idiopathic inflammatory myopathy (JIIM) (3). However, full validation of the 10 point MMT in PM/ DM and JIIM to include proximal, distal and axial muscle groups has not previously been demonstrated.

The primary aim of this study was to validate Total and Proximal MMT scores by demonstrating internal reliability, convergent construct validity, and reliability and responsiveness of these scores in assessing strength in patients with adult and juvenile DM/ PM. We also examined subsets of unilateral muscle groups to determine whether a subset of six or eight muscle groups that contain axial, proximal and distal muscle groups (MMT6 and MMT8) would have similar or better performance characteristics than the Total MMT score in terms of responsiveness and reliability.

PATIENTS AND METHODS

Patients

Patients with probable or definite PM/ DM or JIIM confirmed by Bohan and Peter criteria (13) were seen at the National Institutes of Health (NIH) Clinical Center and five participating centers. Patients and/or their parents provided written informed consent and were enrolled in NIH institutional review board-approved studies of myositis. Seventy-three patients with JIIM participated in a multi-center observational study over 7–9 months (14), and 45 adult patients with DM/PM were screened for therapeutic trials of fludarabine or methimazole, 24 of whom entered into a trial and had a 6 month reevaluation assessment (15;16) (Table 1). Juvenile IIM patients were ≥ 4 years of age.

Manual Muscle Testing (MMT)

Patients were examined by an adult or pediatric physical therapist and rheumatologist experienced in evaluating myositis patients. Patients underwent a standardized MMT evaluation by a physical therapist using Kendall's 0 –10 point scale as previously described (5;8). All therapists were provided a standardized set of MMT commands, including a standardized order of testing and instructions to perform the examination and score the strength of each muscle group. Therapists at the NIH either attended a seminar on the 0 –10 point MMT scale presented by Dr. Florence Kendall or viewed videotapes of her instruction in performing the examination. Therapists from other centers were guided on the instructional materials through telephone conversations with a physiatrist/rheumatologist (JEH). The Total MMT score included 2 axial, 7 proximal and 4 distal muscle groups tested bilaterally, with a maximum potential value of 240 (5). The Proximal MMT score included 7 proximal muscle groups tested bilaterally, with a maximum potential score of 140. Physical therapists recorded whether a particular muscle group could not be tested accurately due to lack of cooperation, limited range of motion, calcinosis, or pain. These muscle groups were then excluded, and when possible, a contralateral muscle was substituted. Only patients who completed testing for at least 20 of the 24 muscle groups were included.

On the basis of established symmetry and patterns of weakness (5), we examined whether abbreviated subsets of muscles tested unilaterally on the right side could be validated in order to identify a more efficient strength evaluation than the Total MMT score. We generated the following types of subsets: (a) 144 subsets of six muscle groups (MMT6 scores) with a potential range of 0 – 60, which included 1 axial, 3 proximal (1 upper, 2 lower extremity), and 2 distal muscles (1 upper, 1 lower extremity); and (b) Ninety-six subsets of eight muscle groups (MMT8 scores) with a potential range of 0 – 80, which included 1 axial, 5 proximal (2 upper extremity, 3 lower extremity), and 2 distal muscles (1 upper, 1 lower extremity).

Secondary Outcomes

Outcome measures, including physician global activity, serum levels of muscle enzymes, physical function assessed by the Childhood Myositis Assessment Scale (CMAS) and the Childhood Health Assessment Questionnaire (CHAQ) in children and the modified Convery activities of daily living (ADL) scale for adult subjects, were included as previously described (9;17;18). Physician global activity and the CMAS were assessed by the rheumatologist. A videotape demonstration and detailed instructions for the CMAS were provided to each, as well as training at an investigators' meeting (17). Axial short tau inversion recovery and T1 magnetic resonance images (MRI) were obtained in 31 juvenile and all patients with adult DM/PM and scored as described in (19).

Statistical Analysis

Data were analyzed using StatView (SAS Institute, Inc., Cary, NC), except that Cronbach's α and Kendall's W were computed using a program written with 4^{th} Dimension software (4D, Inc., San Jose, CA). MMT scores were ordinal and summarized by median and inter-quartile ranges for each muscle group. Summed MMT data were expressed as a percentage of the maximum possible score to allow for comparisons among MMT6, MMT8 and Proximal MMT subscores with the Total MMT score. $P < 0.05$ was considered significant and adjustment for multiple comparisons was not performed in this hypothesis generating study.

Internal reliability of muscle subsets was examined by correlating the 144 MMT6 subsets and 96 MMT8 subsets with the Total MMT score. Cronbach's α, an estimate of the internal consistency of constituent muscles in a subset, was calculated for the MMT6 and MMT8

subgroups and compared with the Total and Proximal MMT scores. A value > 0.7 indicates acceptable internal consistency (20;21). Intra-rater reliability for MMT was assessed by using an average of the pairwise Spearman rank (r_s) correlations obtained from two separate assessments of 10 JIIM patients by a single physical therapist. Inter-rater reliability for MMT performed by physical therapists on nine JIIM patients was evaluated using Kendall's W among each of the four pairs of raters, as previously described (3). A Kendall W value of ≥ 0.7 represents very good to excellent inter-rater reliability (21). Convergent construct validity was determined by examining Spearman rank correlations (r_s) of the Total MMT, Proximal MMT, and MMT6 and MMT8 subsets with measures of strength, function, and disease activity. Spearman's correlations > 0.70 were defined as strong, between 0.40 and 0.70 as moderate, and < 0.40 as poor (21). The standardized response means (SRM) over time were calculated by dividing the observed change by the standard deviation of the change. Responsiveness of the MMT subsets relative to Total MMT was examined using relative efficiency, defined as the square of the ratio of the Student's t statistics of each measure to be compared (22;23). A value > 1.0 was considered to indicate greater responsiveness than the Total MMT score.

Nominal Group Technique (NGT) to Rank Best MMT Subsets

A group of 12 adult and pediatric rheumatologists and physical therapists gathered for an NGT consensus formation exercise to discuss and rank order the eight subsets that performed at least as well as the Total MMT score for potential use in therapeutic trials and other outcome studies. These clinicians practiced rheumatology for a mean of 14.7 ± 9.5 years and saw an average of 37 IIM patients annually. After reviewing the MMT performance data before the session, participants silently rank-ordered their top five choices among the eight subsets. Participants were asked to consider the following factors in determining their rank order for these subsets based on the data presented and clinical experience: (a) Face validity: Are the muscle groups in the subset often affected in myositis? (b) Impact on function: Do the muscle groups in the subset have important effects on physical function when strength is impaired? (c) Performance characteristics: does the MMT subset perform well in both juvenile and adult DM/PM? (d) Ease of testing: are these muscle groups easy to test, including frequency for test position change in the subset, fatigability, and in younger children, cooperation issues. (e) Rater reliability: is there good inter- and intra-rater reliability of the subsets and of individual muscles contained in the subset? (f) Limitations: would joint contractures limit strength testing ability of individual subset muscle groups? After an open round-robin discussion of each person's top three choices and why their reasons for excluding other subsets, participants silently re-ranked their top three choices based on their preference for using these MMT subsets in therapeutic trials and other outcome studies. A videotape demonstrating the performance of the top-ranked MMT8 subset is available on the International Myositis Assessment and Clinical Studies Group internet site at http://www.niehs.nih.gov/research/resources/collab/imacs/diseaseactivity.cfm. This site also contains the MMT commands, 0 –10 point scale, and standardized positions for testing patients.

Results

Degree of Weakness

Adult IIM patients were weaker than JIIM patients based on their Total and Proximal MMT scores (Table 2), as reported previously (5). The Proximal MMT score indicated a slightly greater degree of weakness than the Total MMT score in both juvenile and adult patients, based on the percentage of maximum potential score. Among the MMT subsets that best approximated the Total MMT score, all but one indicated a greater degree of weakness

based on the percentage of maximum potential score in patients with JIIM (Table 2). In adult DM/PM, four abbreviated subsets, MMT8#55, MMT8#58, MMT8#133 and MMT8#136, exhibited a greater relative degree of weakness than the Total MMT score.

Internal reliability and internal consistency

All 144 MMT6 subsets and 96 MMT8 abbreviated subsets significantly correlated with the Total MMT score in juvenile and adult IIM patients ($r_S > 0.70$, $P < 0.0001$). Of the top one-third subsets with the strongest correlation, 18 MMT6 and 19 MMT8 subsets were common to both juvenile and adult IIM patients and selected for further analyses. Among the top eight abbreviated subsets in the NGT exercise, r_S ranged from 0.95 – 0.99, and r_S was 0.96 in juvenile and 0.91 in adult IIM between Proximal and Total MMT scores ($P < 0.0001$ for all, Table 3).

Sixteen of 18 MMT6 and all 19 MMT8 subsets had Cronbach's α values between 0.70 and 0.91 (Table 3), suggesting good internal consistency. Cronbach's α values were higher in the top eight abbreviated subsets, with values ≥ 0.78 and even higher in Total and Proximal MMT (0.93 – 0.97).

Reliability

Spearman r_S, a measure of intra-rater reliability, was 0.90 for Total and 0.95 for Proximal MMT in JIIM patients. The top eight MMT subsets had comparable intra-rater reliability, with r_S ranging from 0.84 – 0.93 ($P < 0.01$ for all, Table 3). Kendall's W, a measure of inter-rater reliability, was 0.70 for Total MMT and 0.76 for Proximal MMT in patients with JIIM. Most of the top eight MMT subsets had a Kendall's W of 0.71 – 0.75. A few fell just lower at 0.68 – 0.69 (Table 3).

Convergent construct validity

Total and Proximal MMT scores correlated highly with each other, as well as with physical function assessed by the CMAS, and moderately with physician global activity, functional disability measured by the CHAQ/HAQ, and MRI (a score reflecting an average of activity and damage, Table 4). Total and Proximal MMT scores correlated highly with Distal and Axial MMT scores ($r_S = 0.73–0.88$, $P < 0.0001$ in JIIM; $r_S = 0.40–0.74$, $P < 0.008$ in adult DM/PM). In adult DM/PM, Total and Proximal MMT scores correlated moderately with lactate dehydrogenase ($r_S = −0.45$ - $−0.50$, $P = 0.007–0.016$), and weakly, but significantly, with creatine kinase, aldolase and aspartate aminotransferase ($r_S = −0.30$ - $−0.38$, $P = 0.012–0.055$). MMT scores did not correlate significantly with serum muscle enzymes in JIIM patients. Prednisone dose correlated with Total, Proximal and best MMT subset scores in JIIM ($r_S = −0.33$ - $−0.39$, $P \leq 0.005$), but not in adult DM/PM ($r_S = −0.11$ - $−0.22$, $P > 0.18$).

For the best MMT6 and MMT8 subsets, convergent construct validity was comparable among each other and to the Total MMT score, and was generally equal to or better than the Proximal MMT score (Table 4). In a few instances, the abbreviated subsets did not have as strong a correlation with other myositis assessment measures as the Total MMT score had. This included correlation of the subsets with physician global activity and with serum creatine kinase in patients with JIIM (MMT8#13, MMT8#55, MMT8#58), and with the Convery ADL in adult DM/PM (Table 4). In some cases, subsets correlated better than the Total MMT score, including with physician global activity in adult IIM, with the CHAQ (MMT6#118, MMT8#88), or many subsets and the Proximal MMT score with thigh muscle MRI in adult IIM (Table 4).

Responsiveness

The standardized response mean for Total MMT was 0.56 in JIIM, and 0.75 in patients with adult DM/PM. Using relative efficiencies, the Proximal MMT score was slightly less responsive relative to the Total MMT score in JIIM, but slightly more responsive in adults with DM/PM (Table 5). Several subsets were more responsive than the Total MMT score in both juvenile and adult IIM patients, including MMT8#58, MMT8#88, MMT8#136, and MMT8#142 (Table 5). Only one abbreviated subset, MMT8#13, was slightly less responsive than the Total MMT score in both juvenile and adult IIM, but it had a relative efficiency > 0.90 in both populations. MMT6#18 and MMT8#55 were responsive in the juvenile, but not in the adult IIM cohort (Table 5).

NGT rankings

The top-ranked MMT subset chosen for use in therapeutic trials and interim assessments in clinical studies was MMT8#58, which included neck flexors, deltoid, biceps, gluteus maximus, gluteus medius, quadriceps, wrist extensors and ankle dorsiflexors (Table 6), followed closely by MMT8#13, with iliopsoas substituted for gluteus medius and wrist flexors substituted for wrist extensors. MMT8#55 ranked third, with wrist flexors substituted for wrist extensors. These subsets were ranked highest because they provided the best balance of function between upper and lower extremities; they consisted of muscle groups frequently affected in myositis, including lower more so than upper extremity muscles. The top-ranking subset was more responsive than the Total MMT score, and these subsets performed well in both juvenile and adult IIM.

Discussion

In this study, using a 0 – 10 point MMT scale (8) to test 24 bilateral proximal, axial, and distal muscles, we preliminarily validated the Total and Proximal MMT scores by demonstrating internal reliability and consistency, rater reliability, convergent construct validity, and responsiveness in assessing strength in patients with adult PM/DM and JIIM. Most therapeutic PM/DM trials have used unvalidated five-point MMT scales that include varying sets of proximal muscles and some distal muscle groups (6;24). The lack of consistency in scoring or in the content of specific muscle groups makes it difficult to compare data across studies. More recent trials used the 0 – 10 point MMT of a total score of muscles, because this expanded scale is thought to enhance the sensitivity of strength testing, particularly in the fair to good muscle strength range (8). Inclusion of a uniform set of muscle groups with standardized scoring (5) that has been validated should provide clinicians and researchers with more reliable, standardized MMT data in patients with adult and juvenile DM/PM.

Total MMT testing has several disadvantages, including that testing of 24 muscle groups is time consuming, patients often fatigue during the testing, occasionally experience muscle pain, making muscle testing unpleasant and stressful, and children frequently are not able to cooperate for the entire 24 muscle group test, resulting in incomplete results or inconsistent strength evaluation (18). Testing numerous muscles and changing test positions can add to overall and local muscle fatigue and decrease test reliability due to decreased muscle force. Documenting patterns and symmetry of weakness in our previous study in juvenile and adult DM/PM (5) allowed us to evaluate Total and Proximal MMT scores as measures of strength testing in patients with myositis. In the present study, to approximate the Total MMT score while reducing its disadvantages, we also examined unilateral muscle subsets of six or eight muscle groups that included proximal, distal and axial muscles and more emphasis on proximal and lower extremity muscle groups. We postulated that testing a subset of muscles might be more sensitive to change over time and have better reliability. A validated

abbreviated MMT score that includes fewer muscles and three instead of five test positions is not only more efficient but might also improve testing reliability.

The explicit purposes of developing these abbreviated muscle subsets are for enhancing consistency among international myositis therapeutic trials with adult and pediatric patients and for brief clinical follow-up visits. By NGT consensus formation, we rank-ordered the best eight muscle group subsets containing unilateral representative axial, as well as upper and lower extremity proximal and distal muscle groups (Table 6). These MMT subsets had results comparable to those of Total and Proximal MMT scores for internal reliability, consistency, and construct validity. These eight muscle group subsets were in a comparable range for rater reliability in JIIM patients. They were slightly more responsive than the Total or Proximal MMT score, which is especially important for therapeutic trials. The eight muscle group subsets performed better than the six muscle group subsets, and no six muscle group subsets achieved consensus for replacing the Total MMT score. The top-rated eight muscle group subsets also had acceptable face validity, included frequently involved muscle groups, and were felt to be easier to test, even in patients with joint contracture or calcinosis. However, they require prospective validation, including in therapeutic trials, to further define their performance characteristics in other populations.

MMT has been widely used to test muscle strength in the IIM (25), and is a preferred method of testing strength in patients with IIM because weakness encompasses the full range, from no to full strength, and MMT tests this full range; it is simple, easy to use and available for all examiners internationally; and validated, standardized MMT scales allow comparison between studies (18).

Although validation of the Total MMT and MMT8 subsets in this study is well substantiated, the study has some limitations. Although we included the most common forms of IIM (adult and juvenile PM/DM), we did not include patients with inclusion body myositis and myositis associated with malignancy. Twenty-four of the 45 adult patients were accepted into therapeutic trials for refractory disease and may have been weaker than those regularly encountered in clinical practice. Also, we did not include recently diagnosed, possibly weaker, patients. However, the remaining patients were either adults who did not meet weakness criteria for therapeutic trials or JIIM patients who were enrolled in a natural history study. These patients might be more representative of patients at other centers. Another potential limitation is that our patients enrolled from rheumatology centers that specialize in IIM, where the therapists have many years of myositis testing experience, which could result in better quality data than if they were enrolled at clinics serving fewer IIM patients.

Although the MMT8 has several advantages, the top-rated MMT8 subsets might not yet contain the most representative muscles. The highest ranking subset contained four of the five weakest muscles identified in the IIM (neck flexor, deltoid, gluteus maximus, and gluteus medius), but it did not include hip flexors, the other weakest muscle group in adult and JIIM patients (5). It did include the proximal quadriceps and two distal muscles (ankle dorsiflexors and wrist extensors), which are functionally important (26;27). Clinically, some muscles are easier to test than others; those that require position changes for testing are generally not as popular with clinicians. More research is needed to determine and validate the best MMT8 subsets.

The current study is the only one to validate the bilateral Total MMT score consisting of 24 muscles, a Proximal MMT score including 14 muscle groups, and unilateral eight muscle group MMT subsets, chosen by consensus formation, for patients with adult and juvenile DM/PM. The MMT8 subsets, which take less time and involve less patient effort, performed

as well as or better than Total MMT in terms of responsiveness, content validity, and construct validity. This preliminary validation of Total MMT, Proximal MMT, and an abbreviated subset of eight key muscles can also help standardize the testing and reporting of MMT, an important measure of strength and a core outcome measure (9;10) for myositis clinical studies.

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Table 1

Demographic features, disease characteristics and assessment measures at baseline evaluation for juvenile and adult patients with idiopathic inflammatory myopathy (IIM)*

Characteristic	Juvenile IIM	*N*	Adult IIM	*N*
Diagnosis				
DM	71	73	15	45
PM	2		30	
Age (years)	10.2 [5.6]	73	42 [17.2]	45
Race		73		45
Caucasian	83.5%		73.3%	
African American	6.9%		24.4%	
Hispanic	2.7%		2.3%	
Other	6.9%		0%	
Gender (female)	69.9%	73	77.8%	45
Disease duration (months)	33.2 [52.4]	63	60 [40.8]	
Prednisone dose	0.3 [0.85] (mg/kg/day)	72	12.5 [10.0] (mg/day)	45
Physician global disease activity VAS (0–10 cm)	2.4 [4.0]	73	5.7 [4.0]	44
Physician global disease damage VAS (0–10 cm)	1.1 [1.9]	63	3.8 [2.8]	44
CMAS score (0–52)	45 [11]	69	NA	
CHAQ score (0–3)/ Convery ADL (0–91)†	0.12 [1.12]	58	53 [19.5]	45
CK (0–252 U/l)	80 [73]	73	959 [2097]	45
LDH (0–226 U/l)	238 [111]	41	364 [154]	30
Aldolase (0–7 U/l)	7 [5.2]	49	18 [19.4]	43
AST (0–34 U/L)	27 [12]	72	52 [49]	45
ALT (0–41 U/L)	25 [25]	68	53 [47]	45
STIR + T1 MRI score (0–4)	0.8 [1.7]	31	2.0 [1.0]	45

Abbreviations: IIM, idiopathic inflammatory myopathy; JIIM, juvenile IIM; DM, dermatomyositis; PM, polymyositis; VAS, visual analog scale; CMAS, Childhood Myositis Assessment Scale; NA, not assessed; CHAQ, Childhood Health Assessment Questionnaire; ADL, activities of daily living; CK, creatine kinase; LDH, lactate dehydrogenase; AST, aspartate aminotransferase; ALT, alanine aminotransferase; STIR, short tau inversion recovery; MRI, magnetic resonance imaging

*Values are expressed as the median [interquartile range] unless given as percentage values.

†The CHAQ was assessed in patients with juvenile IIM and the Convery ADL was used in patients with adult IIM.

Table 2

Description of muscle groups and their percentage score strength values in juvenile and adult IIM patients*

MMT Score	Muscles groups included in score	MMT scores in Juvenile IIM (n = 73) Median [25%, 75%]	MMT scores in Adult IIM (n = 45) Median [25%, 75%]
Total MMT	Neck flexors, neck extensors, trapezius, deltoid, biceps, iliopsoas, gluteus maximus, gluteus medius, quadriceps, wrist flexor, wrist extensor, ankle dorsiflexor, ankle plantar flexor	88.3 [79.0, 94.1]	78.2 [73.1, 84.0]
Proximal MMT	Trapezius, deltoid, biceps, iliopsoas, gluteus maximus, gluteus medius, quadriceps	87.6 [78.7, 94.2]	72.4 [66.3, 81.2]
MMT6#118	Neck extensor, trapezius, gluteus maximus, iliopsoas, wrist extensor, ankle dorsiflexor	86.7 [78.0, 94.3]	80.0 [74.3, 85.9]
MMT8#13	Neck flexor, trapezius, deltoid, gluteus maximus, iliopsoas, quadriceps, wrist flexor, ankle dorsiflexor	86.8 [77.1, 92.7]	78.5 [71.7, 81.6]
MMT8#55	Neck flexor, deltoid, biceps, gluteus maximus, gluteus medius, quadriceps, wrist flexor, ankle dorsiflexor	87.5 [76.6, 92.3]	76.8 [70.1, 81.3]
MMT8#58	Neck flexor, deltoid, biceps, gluteus maximus, gluteus medius, quadriceps, wrist extensor, ankle dorsiflexor	86.8 [76.4, 92.5]	76.5 [69.7, 80.9]
MMT8#88	Neck extensor, trapezius, deltoid, gluteus maximus, iliopsoas, quadriceps, wrist extensor, ankle dorsiflexor	87.5 [79.6, 94.4]	79.0 [72.8, 84.1]
MMT8#133	Neck extensor, deltoid, biceps, gluteus maximus, iliopsoas, quadriceps, wrist flexor, ankle dorsiflexor	87.3 [77.1, 94.8]	77.3 [71.1, 81.8]
MMT8#136	Neck extensor, deltoid, biceps, gluteus maximus, iliopsoas, quadriceps, wrist extensor, ankle dorsiflexor	87.3 [76.7, 94.4]	77.3 [70.1, 81.8]
MMT8#142	Neck extensor, deltoid, biceps, gluteus medius, iliopsoas, quadriceps, wrist extensor, ankle dorsiflexor	89.0 [78.4, 94.3]	78.5 [70.3, 83.4]

* Abbreviations: IIM, idiopathic inflammatory myopathies; MMT, manual muscle testing score.

Scores are expressed as a percentage of the maximum potential score. For Total MMT, proximal and distal muscle groups are tested bilaterally, and the maximum potential score is 240. For proximal MMT, muscle groups are tested bilaterally, and the maximum potential score is 140. For the MMT subscores, muscle groups are tested unilaterally on the right side. The MMT6#188 has a maximum potential score of 60, and the 8 muscle group subsets (MMT8#n) have a maximum potential score of 80.

Table 3

Internal consistency and reliability of manual muscle testing scores in juvenile and adult IIM*

	Internal Reliability (Spearman-Rank Correlation with Total MMT)†		Internal Consistency (Cronbach's Alpha)		Intra-rater Reliability (Spearman-Rank Correlation Coefficient) ‡	Inter-rater Reliability (Kendall's W) ‡
MMT Score	**Juvenile (n = 73)**	**Adult (n = 45)**	**Juvenile (n = 73)**	**Adult (n = 45)**	**Juvenile (n = 10)**	**Juvenile (n = 9)**
Total MMT	1.0	1.0	0.97	0.93	0.90§	0.70
Proximal MMT	0.96	0.91	0.96	0.93	0.95§	0.76
MMT6#118	0.97	0.95	0.85	0.78	0.93§	0.75
MMT8#13	0.98	0.96	0.89	0.79	0.89§	0.68
MMT8#55	0.98	0.96	0.90	0.78	0.86¶	0.71
MMT8#58	0.98	0.96	0.90	0.79	0.84¶	0.72
MMT8#88	0.98	0.97	0.89	0.84	0.84¶	0.71
MMT8#133	0.99	0.98	0.91	0.83	0.87§	0.68
MMT8#136	0.98	0.97	0.91	0.84	0.89§	0.71
MMT8#142	0.98	0.96	0.90	0.83	0.87§	0.69

*Abbreviations: IIM, idiopathic inflammatory myopathy; MMT, manual muscle testing; MMT6#n or MMT8#n, six or eight muscle group subsets tested unilaterally, as in Table 2.

†$P < 0.001$ for all.

§$P = 0.004 – 0.009$.

¶$P = 0.010 – 0.012$

‡Intra-rater reliability was tested by one therapist on 10 juvenile myositis patients tested in the morning and afternoon. Inter-rater reliability was tested on nine juvenile myositis patients by four pediatric physical therapists, as described in (3).

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Table 4

Convergent construct validity of manual muscle testing scores with measures of myositis activity and damage[*,†]

	r_s with Total MMT		r_s with Proximal MMT		r_s with MD Global Activity		r_s with CHAQ/ADL		r_s with CMAS	r_s with MRI STIR + T1 average		r_s with CK	
MMT score	**Juvenile IIM (n = 73)**	**Adult IIM (n = 45)**	**Juvenile IIM (n = 73)**	**Adult IIM (n = 45)**	**Juvenile IIM (n = 73)**	**Adult IIM (n = 44)**	**Juvenile IIM (n = 58)**	**Adult IIM (n = 45)**	**Juvenile IIM (n = 69)**	**Juvenile IIM (n = 31)**	**Adult IIM (n = 45)**	**Juvenile IIM (n = 73)**	**Adult IIM (n = 45)**
Total MMT	1.0	1.0	0.96	0.91	−0.54	−0.33[§]	−0.62	0.63	0.70	−0.48[§]	−0.43[§]	−0.16[//]	−0.34[§]
Proximal MMT	0.96	0.91	1.00	1.00	−0.47	−0.34[§]	−0.59	0.70	0.73	−0.48[§]	−0.50[§]	−0.12[//]	−0.38[§]
MMT6#118	0.97	0.95	0.92	0.81	−0.54	−0.31[§]	−0.68	0.61	0.71	−0.49[§]	−0.43[§]	−0.13[//]	−0.36[§]
MMT8#13	0.98	0.96	0.96	0.87	−0.48	−0.39[§]	−0.61	0.55[‡]	0.71	−0.45[§]	−0.45[§]	−0.16[//]	−0.43[§]
MMT8#55	0.98	0.96	0.95	0.91	−0.48	−0.37[§]	−0.62	0.57[‡]	0.69	−0.45[§]	−0.45[§]	−0.13[//]	−0.37[§]
MMT8#58	0.98	0.96	0.95	0.91	−0.49	−0.37[§]	−0.64	0.59	0.70	−0.45[§]	−0.46[§]	−0.13[//]	−0.36[§]
MMT8#88	0.98	0.97	0.95	0.89	−0.50	−0.34[§]	−0.66	0.63	0.73	−0.47[§]	−0.42[§]	−0.12[//]	−0.37[§]
MMT8#133	0.99	0.98	0.95	0.90	−0.51	−0.34[§]	−0.63	0.62	0.69	−0.47[§]	−0.44[§]	−0.14[//]	−0.38[§]
MMT8#136	0.98	0.97	0.94	0.90	−0.51	−0.34[§]	−0.63	0.64	0.69	−0.48[§]	−0.45[§]	−0.15[//]	−0.38[§]
MMT8#142	0.98	0.96	0.94	0.91	−0.49	−0.33[§]	−0.60	0.66	0.67	−0.45[§]	−0.44[§]	−0.15[//]	−0.33[§]

[*] Abbreviations: MMT, manual muscle testing; MD, physician; CHAQ/ADL, Childhood Health Assessment Questionnaire/Convery activities of daily living; CMAS, Childhood Myositis Assessment Scale; MRI STIR, magnetic resonance imaging short tau inversion recovery; CK, creatine kinase; IIM, idiopathic inflammatory myopathy; MMT6#n or MMT8#n, six or eight muscle group subsets tested unilaterally, as in Table 2.

[†] $P < 0.0001$ unless noted otherwise.

[‡] $P = 0.0001 - 0.0009$.

[§] $P = 0.001 - 0.05$.

[//] $P > 0.05$.

Table 5

Relative efficiency of manual muscle testing (MMT) subgroups to total MMT score*

MMT Score	Relative Efficiency to Total MMT	
	Juvenile IIM (n = 49)	Adult IIM (n = 24)
Total MMT	1.0	1.0
Proximal MMT	0.98	1.08
MMT6#118	1.25	0.94
MMT8#13	0.93	0.98
MMT8#55	1.02	0.91
MMT8#58	1.16	1.24
MMT8#88	1.07	1.24
MMT8#133	0.91	1.03
MMT8#136	1.06	1.32
MMT8#142	1.01	1.26

*Abbreviations: IIM, idiopathic inflammatory myopathy; MMT, manual muscle testing; MMT6#n or MMT8#n, abbreviated six and eight muscle group subsets tested unilaterally, as in Table 2.

Table 6

Results of nominal group technique consensus on the rank order of the MMT8 subsets for face validity and ease of use.*

MMT8 Subset	Votes	Rank Order
MMT8#58	18	1
MMT8#13	16	2
MMT8#55	14	3
MMT8#136	11	4
MMT8#142	6	5
MMT8#133	1	6

* For a list of the muscle groups involved, see Table 2. MMT8#, abbreviated eight muscle group subsets tested unilaterally.