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Does a Muscle Strength Index Provide Complementary Information to Traditional Disease Activity Variables in Patients with Rheumatoid Arthritis?

GEROLD STUCKI, JOSEF SCHÖNBÄCHLER, PIUS BRÜHLMANN, STEFAN MARIACHER, THOMAS STOLL, and BEAT A. MICHEL

ABSTRACT. *Objective.* To develop a muscle strength index (MSI) and determine whether it provides complementary information to traditional disease activity variables in patients with rheumatoid arthritis (RA).

Methods. The MSI was developed on the basis of practical and empirical aspects and statistical considerations. Intra and interobserver reliability was assessed on the data from 3 observers on 2 strength measurements in each of 10 patients. The association of the MSI with variables of disease activity and severity was assessed in univariate analysis. The contribution of the MSI in the explanation of physician's global disease activity after accounting for the effect of traditional measures of disease activity was assessed in multiple linear regression models.

Results. Eight strength measurements (extension and flexion of knee and elbow joints) obtained with a hand held pull gauge were aggregated into the MSI as the mean of the standardized scores. In 65 patients with RA, the MSI had a high internal consistency (Cronbach's alpha 0.95) and intra and interobserver reliability (Pearson correlation coefficient 0.94 each). The MSI correlated moderately with traditional measures of disease activity and strongly with physical functional disability and radiological damage. In contrast to grip strength, the MSI explained additional variation of physician's global assessment of disease activity if added to variables of pooled activity indices.

Conclusion. The MSI is a reliable and valid measure of disease activity and severity and may improve the content validity of pooled disease activity indices. (*J Rheumatol* 1994;21:2200-5)

Key Indexing Terms:

MUSCLE STRENGTH INDEX
DISEASE ACTIVITY INDICES

MUSCLE STRENGTH
RHEUMATOID ARTHRITIS

GRIP STRENGTH
CLINIMETRICS

The optimal method for assessing disease activity in rheumatoid arthritis (RA) remains a matter of debate. Since there is no single best variable for measuring disease activity, composite indices including laboratory variables, clinical findings and symptoms have been advocated¹⁻⁵. With respect to examination measurements, there is general agreement on the inclusion of an articular index¹⁻⁵. It is striking that no other examination measurement has been included in some of the most recently developed composite indices of disease activity²⁻⁴. Although the value of grip strength in the long-term evaluation of individual patients in clinical practice has

been appreciated⁶, its inclusion in a disease activity index is controversial, and it has been included in few such indices¹⁻⁵. Major problems with the use of grip strength in composite indices for clinical trials is the difficulty of obtaining measurements in patients with significant hand deformities⁶. No strength measurement other than grip strength has been considered for inclusion in a disease activity index.

Impaired muscle function is frequently observed in patients with RA and has been attributed to pain, inactivity, psychological factors, myopathy and deformity⁷⁻⁹. Histochemical, electron microscopic and electromyographic evidence of skeletal muscle pathology in patients with RA have been provided¹⁰⁻¹². Historically, subjective ordinal scales have been used by clinicians to assess muscle strength. Because of the insensitivity of these scales to 20-25% changes in muscle strength¹³, a number of devices have been developed and tested for their reliability¹⁴. Hand held instruments have been of specific interest¹⁴ since they are cheap and allow the assessment of muscle strength in clinical practice. They may be as reliable as fix installed isokinetic measurement instruments (Cybex)¹⁴.

We hypothesized that muscle strength can be measured reliably with a hand held pull gauge and that a muscle strength index can provide complementary information to measure-

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ments currently used in pooled indices of disease activity. To test these hypotheses, we developed a muscle strength index (MSI) and examined its metric properties, intra and interobserver reliability and validity. We then examined whether the MSI explained additional variation in disease activity after accounting for the effect of a variety of traditional disease activity measures.

MATERIALS AND METHODS

Patients. Consecutive patients with RA fulfilling the American Rheumatism Association (ACR) 1987 revised criteria¹⁵ attending the outpatient clinic of rheumatology, University Hospital Zurich. An interobserver study was performed by 3 physicians on a subsample of patients representing a wide spectrum of disease activity twice during one morning.

Data collection procedures. A physician performed the strength measurements with a handheld pull gauge. The patient was then evaluated clinically by another physician who was unaware of the strength measurements, laboratory tests were performed and radiographs taken.

Measurements. Muscle strength was recorded for the shoulder, elbow, wrist, hip, knee and ankle joint. For each joint but the shoulder, the measurement included extension and flexion; for the shoulder, strength of abduction and adduction was recorded. For each measurement, the patient was placed in a position that excluded the effect of gravity (Figures 1 and 2). A nonelastic band was connected to a pull gauge with a continuous scale (range 0–50 kp, model DPPH, Chatillon Inc., Greensboro, North Carolina). The observer kept the pull gauge in a stable position against a bar, the examination table, or his body. The patient was instructed to increase muscle strength gradually to his/her limit.

Clinical findings recorded were ACR functional class¹⁶, swollen and tender joint count, grip strength (mean of both sides), and morning stiffness. Laboratory assessment included erythrocyte sedimentation rate (ESR),

C-reactive protein (CRP), hemoglobin (Hb), Singer-Plotz titer. Radiological assessment included radiographs of the hands and feet; radiological damage was graded according to the Larsen radiological scoring system¹⁷. Patient self-report was used for the measurement of pain [numerical rating scale, 0–10 (NRS)], physical functional disability [health assessment questionnaire (HAQ)¹⁸] and global health (4 point Likert scale). Overall disease activity was measured as physician's global assessment (NRS) and through aggregation of variables in pooled indices [disease activity score (DAS)⁴, Mallya index¹, Van Riel index³].

Development of the muscle strength index. First, the distribution of each muscle measurement was studied. In several patients, muscle sites where it was not possible to obtain a strength measurement for anatomical reasons (fusion, pseudoparesis) were excluded from further consideration. To adjust for the different weight of the different muscles and to provide an interpretable figure, we transformed the original scores into standardized scores by expressing every strength measurement as the percentage of the maximal strength observed in the sample [(strength observed/maximum sample strength)*100]; the higher value of both body sides was used for corresponding measurements. An overall strength score was then calculated as the mean of the individual standardized scores. In the case of missing or nonobtainable measurements, this approach has the advantage that the mean can still be calculated from the remaining variables without important distortion as long as the number of measurements ensures stability of the index. In a next step, the number of measurements was reduced. The goal was to select enough measurements to maintain sufficient statistical stability and internal consistency as assessed with Cronbach's coefficient alpha, but to avoid redundancy due to collinearity. In univariate analysis (using nonparametric statistics) we evaluated the influence of patient characteristics such as age, sex, weight and height on the muscle strength indices.

Reliability. To assess intra and interobserver reliability, 3 observers evaluated 10 patients representing a wide spectrum of disease activity twice during one morning. The patients were examined in random order. In measuring muscle strength, the observers followed a standardized procedure after



Fig. 1. Measurement of isometric flexion and extension strength of the knee joint with a pull gauge.

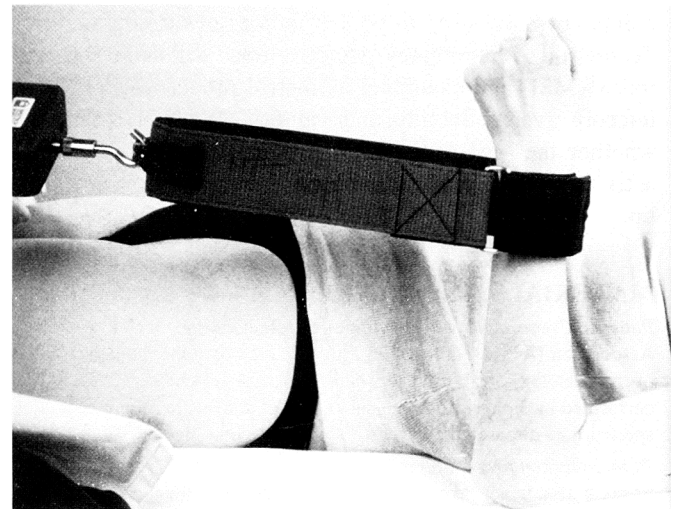
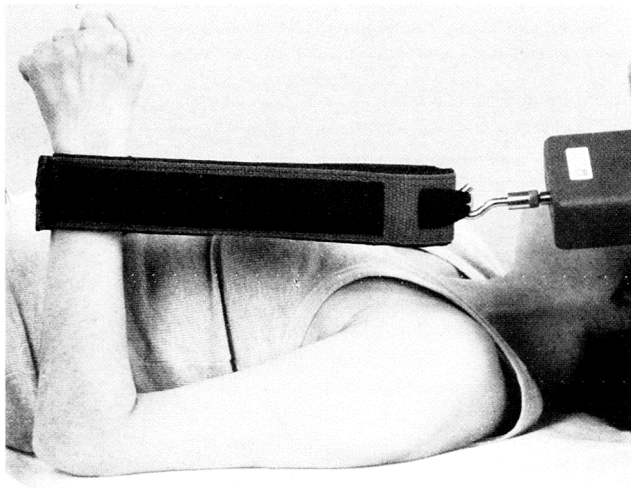


Fig. 2. Measurement of isometric flexion and extension strength of the elbow joint with a pull gauge.

receiving instructions with respect to order of measurements and techniques. The test-retest reliability (intra and interobserver) of the muscle measurements was assessed with Pearson's product moment correlation coefficient.

Validity. To assess construct validity, we tested the hypothesized relationship with other disease activity variables, pooled disease activity indices (DAS, van Riel, Mallya), physical functional disability (HAQ) and joint destruction (Larsen score). For all correlations we used Spearman correlation coefficients to account for the nonnormal distribution of most variables.

Contribution of the muscle strength index in explaining variation in disease activity. To assess the contribution of the MSI in explaining disease activity, we selected the physician's global disease activity assessment to be the dependent variable. In multiple linear regression models, controlling for age, sex and body height, we examined whether the MSI explained additional variation in models which contained articular indices (swollen and tender joint count) and ESR or CRP. We then analyzed whether muscle strength explained additional variation in models together with variables of disease activity index (DAS: Ritchie articular index, swollen joint count, ESR, global health; van Riel: morning stiffness, tender joint count, hemoglobin and ESR; Mallya: morning stiffness, pain, Ritchie articular index, grip strength, hemoglobin and ESR). Finally we used grip strength instead of the MSI in the above analyses.

RESULTS

Patients. Sixty-five patients were enrolled in the study. The interobserver reliability was assessed on a subsample of 10 patients. The baseline characteristics of the 65 patients are shown in Table 1.

Development and testing of strength indices. All muscle measurements were moderately skewed towards higher strength. The strength measurements could not be performed for patients lacking mobility in the right wrist (extension: 5 patients out of 65; flexion: 4/65), the left wrist (extension: 2/65; flexion 1/65), the right shoulder (abduction: 10/65; adduction: 10/65) and the left shoulder (abduction: 9/65; adduction: 9/65). All the other muscles had no or one nonobtainable measurement. Shoulder and wrist were thus excluded

Table 1. Baseline demographic and clinical characteristics of the 65 patients with RA

	Number of Patients (N = 65)	Percent
Sex		
Male	23	35.4
Female	42	64.6
Age group		
≤ 50	18	27.7
51 to 60	10	15.4
61 to 70	20	30.8
> 70	17	26.2
Functional class ACR		
I	10	15.4
II	19	29.2
III	34	52.3
IV	2	3.1
Rheumatoid factor (Singer Plotz, N = 64)		
Negative	31	48.6
Positive	33	51.6

from further consideration. After standardization of individual scores, the index was calculated as the mean of the standardized scores. The internal consistency of this index was 0.97, which we considered higher than required. We therefore dropped 2 joints from the lower extremity to balance the number of measurements of the upper and lower extremities. Because measurements of the knees were easier and faster to obtain than for the hip and ankle joints, the knee was selected. The internal consistency of this full MSI measuring the strength of the knee and elbow joints (flexion and extension, both sides; 8 measurements) was 0.95. The correlations of the selected muscle strength measurements of the

full version are shown in Tables 2 and 3. As an alternative to the full MSI, we also tested a short version using only measurements from the right side (elbow and knee, extension and flexion; 4 measurements). The internal consistency was 0.92 and the correlation between the measurements ranged from 0.64 (between flexion of the knee and extension of the elbow) to 0.85 (between flexion and extension of the elbow).

As expected, body height was a moderate correlate of both strength indices ($r = 0.33$, $p < 0.01$). Sex did not reach statistical significance (full version: $p = 0.12$; short version: $p = 0.19$). Age and weight were not correlated with strength in our population.

Test-retest reliability. The average intraobserver reliability of the individual muscle measurements was 0.94 ($p < 0.01$) with a range of 0.84 to 0.98. The average interobserver reliability was 0.94 ($p < 0.01$) ranging from 0.78 to 0.98.

Validity. The correlation of the full MSI with variables of disease activity and disease activity are shown in Table 3. The correlations of the short index were virtually identical and differed less than 5% from the full index. The MSI was most strongly correlated with grip strength ($r = 0.61$, $p < 0.01$) (Table 4). The correlation with variables of disease activity was moderate and ranged from 0.24 (swollen joint count; $p = 0.05$) to 0.37 (ESR; $p < 0.01$). The correlation with pooled indices of disease activity was -0.68 ($p < 0.01$) for the Mallya index and -0.37 ($p < 0.01$) for the DAS. Correlations with the Larsen score were 0.51 ($p < 0.01$) and 0.63 ($p < 0.01$) with the HAQ.

Contribution of strength in explaining variation of disease activity. Muscle strength was a significant variable ($p <$

0.01) when added to a model with swollen and tender joint count (raising the R-square of the model from 32 to 40%), with physician's global disease activity assessment as the dependent variable. Muscle strength was also significant ($p < 0.05$) when added to a model with the 2 articular indices and ESR or CRP and increased the variation of overall disease activity explained from 37 to 43% and from 36 to 43%, respectively.

In a model that included the variables of the DAS, the MSI strength was a significant correlate ($p < 0.05$). The addition of the MSI to the model increased the explained variation from 52 to 56%. In a stepwise forward selection process of the DAS variables and the MSI, the Ritchie articular index was chosen first and explained 27% of the variation of disease in addition to the variables forced to stay in the model (age, body height and sex; explaining 9% of the variation). The MSI was selected second and explained an additional 10%. ESR was selected third and explained an additional 5% resulting in a model R-square of 53%. Global health and swollen joint count did not reach statistical significance.

When grip strength instead of the MSI was added to the model, this was not statistically significant. In a stepwise forward selection together with the 4 DAS variables, grip strength was not selected (variables selected included the Ritchie articular index, ESR and global health explaining 51% of the variation of physician's activity estimate).

The MSI but not grip strength was a significant explanatory variable ($p < 0.05$) when added to a model with the variables from the van Riel index (increasing the R square of the model from 36 to 40%). In a stepwise forward selection of the van Riel variables, the MSI was selected second (after tender joint count) explaining 10% of the variation of disease activity.

Table 2. Correlations between muscle strength measurements of the right side

Joint	Function	Right Knee		Right Elbow	
		Extension	Flexion	Extension	Flexion
Right knee	Extension	1			
	Flexion	0.81	1		
Right elbow	Extension	0.68	0.64	1	
	Flexion	0.77	0.73	0.85	1

All Spearman correlations have a p value < 0.01 .

Table 3. Correlations between muscle strength measurements of both body sides

Joint	Function	Right Knee		Right Elbow	
		Extension	Flexion	Extension	Flexion
Left knee	Extension	0.81			
	Flexion	0.87	0.90		
Left elbow	Extension	0.70	0.65	0.87	
	Flexion	0.74	0.65	0.57	0.69

All Spearman correlations have a p value < 0.01 .

Table 4. Relationship of the muscle strength index (MSI) with disease activity and disease severity variables

Variable	Median (Quartiles)	Correlation with MSI*
Swollen joint count	5 (2;11)	-0.24
Tender joint count	6 (2;15)	-0.31**
Ritchie articular index	18.5 (8;38.5)	-0.29**
Grip strength (kp/cm ²)	0.61 (0.39;0.95)	0.61 [†]
Pain (0-10)	5 (3;6)	-0.42 [†]
CRP (mg/dl)	1.8 (0;4.6)	-0.34 [†]
ESR (mm/h)	18 (12;30)	-0.37 [†]
Physician's activity estimate (0-10)	3 (2;5)	-0.47 [†]
Global health (0-3)	2 (1;2)	-0.42 [†]
Larsen-score (0-40)	10 (8;17.5)	-0.51 [†]
Health assessment questionnaire (0-3)	1.19 (0.25;1.75)	-0.63 [†]
Disease duration (years)	5.2 (1.44;11.6)	0.30**

* Spearman correlation coefficient.

** $p < 0.05$; [†] $p < 0.01$.

If added to a model with all variables but grip strength from the Mallya index, the MSI did not reach statistical significance ($p = 0.08$). In a model of all 6 original Mallya variables (including grip strength), grip strength was not significant ($p = 0.48$). In a forward stepwise selection process, the MSI was selected 4th (after pain, hemoglobin and the Ritchie articular index) but did not reach statistical significance ($p = 0.07$). Grip strength was not selected in a similar process.

DISCUSSION

Muscle strength in patients with RA can be measured reliably with a simple hand held pull gauge. Muscle measurements obtained at different joint sites have a high correlation, and the aggregation of measurements into an index has a high internal consistency. Because of frequent impairment of the wrist and shoulder joints which interfered with the measurement of muscle strength, practical aspects and the goal of balancing the number of measurements of the upper and lower extremity, we suggest that measurements of extension and flexion of the elbow and knee joints be included in the index. A short version with 4 measurements including only one body side had only a slightly smaller internal consistency and may be the optimal compromise between statistical stability and efficiency.

As expected, we found isometric muscle strength to be associated with body height. In our population with relatively little age variation, age was not associated with isometric muscle strength. Sex was not significant in univariate analysis, an indication that other factors such as body height and disease activity were more important. Nevertheless, in studies using muscle strength as an outcome variable involving groups with unequal distribution of these characteristics, it is advisable to control for age, sex and body height.

Muscle strength correlates with generally accepted variables of disease activity and pooled disease activity indices

such as the DAS, the van Riel and the Mallya index. The particularly high correlation with the Mallya index may be explained by the fact that this index includes grip strength.

Using physician's global assessment of disease activity as an external standard, the MSI provides information in addition to articular indices and the ESR or CRP. It also increases the variation in disease activity explained by the variables included in the DAS and van Riel indices. When added to the variables of the Mallya index (without grip strength), the MSI did not reach significance. Whether this is due to a limited power in the small sample or whether the MSI does not provide additional information when morning stiffness and pain are included in a disease activity index cannot be decided on the basis of our data. It is striking that grip strength did not add information to the variables of the DAS, the van Riel or the Mallya index. This finding is consistent with the non-selection of grip strength into the statistically derived DAS.

The MSI therefore may have advantages over grip strength. First, measurements of knee and elbow strength were obtainable in cases where deformities of the hand interfered with grip strength measurement. Even in the case of one immobile joint, the MSI can still be calculated and provides a stable estimate because of the aggregation of standardized measurements. Second, unlike grip strength, the MSI seems to provide additional information when used with composite disease activity indices. Third, the MSI may reflect the systemic nature of RA better than grip strength because it includes measures of both the upper and lower extremity and may thus improve the content validity of a disease activity index. Whether the MSI should be considered for inclusion in a disease activity index is, however, conditional on its sensitivity to change. Prospective data on sensitivity are underway.

Like grip strength¹⁹, the MSI is not exclusively a measure of disease activity but also of disease severity. It may thus be a useful measure of impairment in addition to physical functional disability and radiological destruction in assessing the cumulative impact of disease.

In conclusion, the MSI is a reliable and valid measure of disease activity. Unlike grip strength, it may improve the content validity of pooled disease activity indices and may be a particularly useful impairment measure for the assessment of longterm treatment effects. The external validity in other populations with RA and the responsiveness of the MSI need to be established.

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