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THE RELATIONSHIPS OF FUNCTIONAL CAPACITY, PAIN, AND ISOMETRIC AND ISOKINETIC TORQUE IN OSTEOARTHROSIS OF THE KNEE

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ABSTRACT. Thirty-nine patients suffering from osteoarthrosis of the knee were repeatedly measured. The relationship was studied for two groups of variables. The first group consisted of subjective assessments of functional capacity and pain and a walking test. The second group consisted of isometric knee extension torque and isokinetic knee flexion and extension torque at 30°/sec, 60°/sec, 120°/sec and 180°/sec. High correlations between each of the static and dynamic torque values were found. Multiple regression analysis showed that isometric and isokinetic torque measures are unsatisfactory predictors of functional capacity, since only 23–35 % of the variation of functional capacity, pain and walking test variables was explained by the variation of torque variables. Dynamic torque measurements had very little advantage over static torque tests. It is concluded that outcome measures in studies of osteoarthrosis should be problem-oriented and include direct assessments of functional capacity, pain and walking ability.

Key words: Functional capacity, measurement theory, osteoarthrosis, outcome study

In recent years increasing emphasis has been placed on measurement theory in the evaluation of therapeutic regimens in joint disease (3, 4, 7). Important issues are validity, reliability, objectivity and sensitivity (22). Validity is probably the most important item, but it is the most difficult to assess. The concept of validity is concerned with the question whether a (set of) measurement(s) measures what it is intended to measure. In the assessment of osteoarthrosis of the knee measurements of static muscle strength have been used (19). When discussing validity the central question is: what is the goal of rehabilitation? The best answer is probably: better functional performance. Hence, measurements of muscle strength are valid as outcome measures, if and only if they correlate well with functional capacity.

In a previous study in patients suffering from osteoarthrosis of the knee we found the correlations between isometric muscle strength and functional variables to be unsatisfactory (13). Measurement of dynamic muscle performance seemed to be more promising regarding validity, because many activities in daily life, which depend on lower extremity function, are dynamic rather than static. For more than a decade, a method of isokinetic muscle testing has been available (18). Conflicting reports have been published, however, about the relationships of static (isometric) and dynamic (isokinetic) muscle strength measurements (2, 10, 11, 12, 16, 20). Although this has received little attention until now, pain can also be expected to play a role in functional performance in degenerative joint disease. We therefore undertook a study of the relationships of functional capacity, pain, and isokinetic and isometric muscle strength.

METHODS

Patients

Forty-two consecutive patients (9 men, 33 women, mean age 62.4±10.4 years) with osteoarthrosis of one or both knees entered the study. All patients had a typical history (knee stiffness after a period of immobility and knee pain) and the typical physical findings (crepitus and a decreased range of motion), satisfying the criteria for osteoarthrosis of the knee proposed by Altman et al. (1). Twenty-five left knees and thirty-two right knees were affected, amounting to a total of fifty-seven knees. Radiological examination showed a joint space narrowing without osteophyte formation in 29 knees and a combination of joint space reduction and osteophytes in 28 knees (stage II and III according to Kellgren & Lawrence (8)). The mean duration of symptoms was 27.5±36.0 months. All patients were able to walk (with or without aids). Patients with other than degenerative joint disease were excluded from the study.

Measurements

Five groups of variables were used. The first group consisted of four questions about functional capacity (related to lower extremity function) experienced during the past week. For each aspect the patient indicated an appropriate number on a 0- to 10 point Numerical Rating Scale (0: minimal functional capacity; 10: maximal functional ca-

Table I. *Results of the set of measurements*

	Mean	SD
Functional capacity (units on the 0- to 10-point scale)		
Rising from a chair	5.2	3.1
Standing	5.3	2.9
Walking	5.5	2.9
Stair climbing	4.2	3.0
Mean functional capacity score	5.0	2.4
Pain (units on the 0- to 10-point scale)		
General	5.9	2.4
At night	3.8	3.3
After inactivity	6.0	2.8
Sitting	2.6	3.0
Rising from a chair	5.3	3.0
Standing	5.5	2.8
Walking	5.4	2.7
Stair climbing	5.9	2.7
Mean pain score	5.0	2.1
Walking, stair climbing		
Walking time (sec)	44.4	21.8
Number of steps	77.8	19.4
Stair climbing up (sec)	11.4	7.5
Stair climbing down (sec)	12.1	8.1
Pain during test (0- to 10-point scale)		
Walking time	4.0	3.3
Stair climbing up	4.8	3.1
Stair climbing down	5.1	3.1

pacity) (5). The second group consisted of questions regarding eight aspects of knee pain experienced during the past week. Also a 0- to 10 point Numerical Rating Scale was used (0: no pain; 10: unbearable pain). The third group of variables consisted of a walking and stair-climbing test under standardized conditions. The fourth group consisted of torque measurements. Peak torques (maintained for 1 sec) were recorded for isometric knee extension (at 90° of knee flexion) and for isokinetic knee flexion and extension. The tests were performed on a Cybex II apparatus (Cybex II, Lumex Inc., New York) under standardized conditions. Patients were tested at four different speeds (30°/sec, 60°/sec, 120°/sec and 180°/sec) with resting intervals of 2 min between the tests. Finally the pain felt during the walking and stair-climbing test and each of the torque measurements was scored on the 0- to 10 point pain scale immediately after each test. The complete set of measurements was done six times, initially twice with an interval of one week and subsequently after 1, 2, 3 and 4 months.

Statistical methods

From the data a Pearson correlation matrix was computed. Subsequently a multiple regression analysis was done in order to analyze the predictive values of torque measurements and pain on functional variables (9).

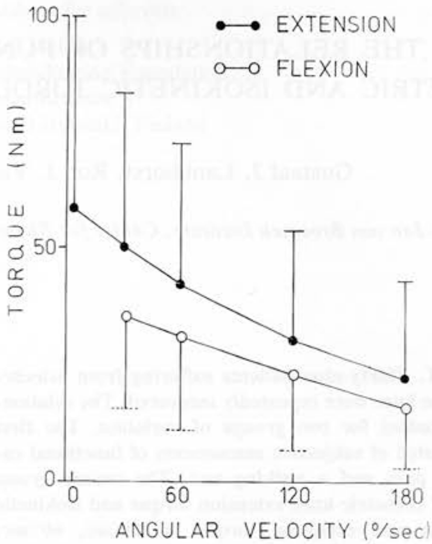

Fig. 1. Torque velocity relationships.

RESULTS

Thirty-nine of the forty-two patients completed the study. Three patients dropped out, because they refused to continue the measurements.

Results of the measurements

The data show a substantial amount of variation for all groups of variables (Tables I and II). The force-velocity relationship for the torque variables is shown in Fig. 1. Peak torques on the affected side were 65–83% of those on the normal side (Table II).

Results of the correlation analysis

High correlations were found between isometric and isokinetic knee extension torques at different velocities (Table III) and also high correlations between isokinetic flexion and extension torques (0.84–0.87). Very small negative correlations were observed between torque at any velocity and pain during that specific torque test (−0.04 to −0.16).

Results of the multiple regression analysis

Multiple regression is a statistical technique by which one can analyze the relationship between a dependent or criterion variable and a set of independent or predictor variables (9). In our analysis the data from the Walking Test and Functional Capacity and Pain Scores were used as dependent

Table II. *Results of the set of measurements: torque and pain score during the torque test for osteoarthrotic knees (n=54). Comparison with torque values of normal knees (n=24)*

	Normal knees Torque (Nm)		Osteoarthrotic knees Torque (Nm)		Pain during test (0- to 10-point scale)	
	Mean	SD	Mean	SD	Mean	SD
Isometric knee extension	90.7	52.3	59.7	40.3	2.9	3.1
Isokinetic knee extension						
30°/sec	76.3	40.8	49.9	33.1	3.9	3.1
60°/sec	63.8	36.6	42.2	30.2	3.5	3.1
120°/sec	45.5	28.8	29.6	23.6	3.1	3.1
180°/sec	31.8	23.1	22.1	20.2	3.0	3.2
Isokinetic knee flexion						
30°/sec	42.8	21.4	35.3	20.1	3.6	3.1
60°/sec	41.4	24.0	30.6	20.3	3.3	3.1
120°/sec	30.1	19.6	22.9	16.8	2.9	3.0
180°/sec	23.1	18.1	15.3	14.4	2.8	3.1

variables. Isometric and isokinetic torque values, as well as pain scores during torque testing were used as independent or predictor variables. Table IV lists, in the order in which they emerged from the multiple regression analysis, those independent variables which were found to be significant.

For Walking Time the best single predictor variable was isokinetic knee extension torque at 30°/sec (Q30), which explains 21% (correlation coefficient $r=-0.46$; $r^2=0.21$) of the variation of the Walking Time variable. The second variable to emerge from the analysis was the pain score during the isokinetic knee extension test at 30°/sec (Pain Q30) which accounts for 2% (r^2 change = 0.02) of additional explanation of variation of Walking Time. Subsequent variables add insignificantly (0.7% or less) to the variation of Walking Time already explained by Q30 and Pain Q30. When all predictor variables are taken together, 26% of the variation of Walking Time is explained, leaving 74%, which is not explained by isometric or isokinetic torque or pain during torque testing. A comparison of Q30 (correlation coefficient with Walking Time: $r=-0.46$) and isometric knee extension (Q0; correlation coefficient with Walking Time: $r=-0.41$) shows that Q0 by itself explains 17% (r^2) of the variation of Walking Time which is slightly inferior to Q30 (21%).

For the Number of Steps a similar pattern was found, but the amount of explained variation was somewhat higher. Q30 explains 33% of the variation of this variable and Pain Q30 adds 2%. Q0 alone explains 27%, which again is slightly less than Q30. 63% of the variation of the Number of Steps is not explained by the combination of torque variables and pain during torque testing variables.

For the Functional Capacity Score isokinetic knee extension torque at 120°/sec (Q120) was the single best predictor variable, accounting for 25% of the variation. The second variable to emerge here from the multiple regression analysis was the pain score during isokinetic knee flexion at 60°/sec (Pain H60), which adds an increment of 6% of explained variation. In this case Q0 and Q30 alone explain 20% and 23% respectively, as opposed to 25% for Q120. The combined torque and pain during torque testing variables account for 34% of the explained variation. This means that 66% of variation of Functional Capacity Score is not explained by this group of predictor variables.

Finally, the pain score during isokinetic extension at 180°/sec (Pain Q180) was found to be the

Table III. *Correlation matrix of extension torque values at different speeds*

	Q0	Q30	Q60	Q120	Q180
Q0	1.00	0.90	0.86	0.84	0.80
Q30	0.90	1.00	0.95	0.91	0.86
Q60	0.86	0.95	1.00	0.93	0.89
Q120	0.84	0.91	0.93	1.00	0.93
Q180	0.80	0.86	0.89	0.93	1.00

Q0: isometric knee extension; Q30, Q60, Q120, Q180: isokinetic knee extension at 30°, 60°, 120°, 180°/sec respectively.

Table IV. *Results of the multiple regression analysis*

Dependent variable	Independent variables	Simple *r*	Multiple *r*	r^2	r^2 change
Walking time	Q30	−0.46	0.46	0.21	
	Pain Q30	−0.05	0.48	0.23	0.02
	(Q0	−0.41		0.17)	
Number of steps	Q30	−0.57	0.57	0.33	
	Pain Q30	−0.05	0.59	0.35	0.02
	(Q0	−0.52		0.27)	
Mean functional capacity	Q120	0.49	0.49	0.25	
	Pain H60	−0.34	0.56	0.31	0.06
	(Q0	0.45		0.20)	
	(Q30	0.48		0.23)	
Mean pain score	Pain Q180	0.48	0.48	0.23	
	Q0	−0.34	0.56	0.32	0.09
	Q30	−0.29	0.57	0.33	0.01
	H60	−0.33	0.58	0.34	0.01
	Pain H30	0.41	0.59	0.35	0.01

Q30, Q120: isokinetic knee extension at 30°/sec, 120°/sec. H60: isokinetic knee flexion at 60°/sec. Q0: isometric knee extension. Pain Q30: pain score during isokinetic knee extension at 30°/sec. Significant contributions ($p<0.05$) to the multiple regression analysis are listed. Wherever Q0 and Q30 did not reach the level of statistical significance their *r* and r^2 values are added between brackets for comparison.

single best independent variable for the Mean Pain Score (23%). Q0 explains 9% of variation not explained by Pain Q180, whereas Q30, H60 and Pain H30 each add one more percent of explained variation. The grand total of 38% leaves 62% of the Mean Pain Score unexplained by the predictor variables.

DISCUSSION

Force–velocity relationships

The force–velocity curve for our group of patients suffering from osteoarthrosis of the knee (Fig. 1) shows a hyperbola-like curvature, which has a shape almost identical to the one found by Aniansson et al. (2) in healthy old-aged people. Perrine & Edgerton (23) described a definitely different force–velocity relationship in healthy volunteers. In their experiments isometric torque and isokinetic torque at 48°/sec were found to be lower than isokinetic torque at 96°/sec. At higher speeds the expected rapid decline of torque was found. They suggested that some neural regulatory mechanism may restrict the maximum voluntary tension level at low or zero speed. This could explain why at low velocity any rise in produced torque is less steep than expected, but it cannot explain why 0°/sec and 48°/sec should actually produce *lower* torque values than at medium range velocity.

We postulated that in a group of patients suffering from knee pain as a result of osteoarthrosis, inhibitory mechanisms could be active during the whole range of speed. We therefore expected the normal relationship of declining torque with increasing angular velocity, which in fact was found. We also expected substantial negative correlations between torque production and pain experienced during torque testing. The results, however, showed very small negative correlations, indicating that the influence of momentary pain on torque production was minimal. Possibly the 'reflex inhibition', which was postulated to play a role in arthrogenous muscle weakness by Stokes & Young (25), is more important than pain during torque testing.

Relationship of isometric and isokinetic torque and functional capacity

The high correlations between isometric and isokinetic torque values observed by Knapik et al. (10, 11) in healthy people have been confirmed in our study for patients suffering from osteoarthrosis of the knee. Because of these high intercorrelations it is not surprising that dynamic torque measurements seem to have little advantage over static torque measures in the prediction of functional capacity in osteoarthrosis of the knee.

Absolute peak torque is not the only muscle function variable which may be considered with regard to functional capacity. Also peak torque at specific angles has been studied, but it is not clear to which angle the most importance should be assigned (11, 25). Other possibilities are (instantaneous) power and endurance (6, 19, 21, 24), though at present there are no good arguments for preferring one of these over peak torque. Furthermore it may be speculated that, unless one group of activities is specifically trained (16), as in athletes, correlations between the various muscle functions will be high, but this needs further investigation.

Measurement of functional capacity and measurement theory

Since torque values explained only 23–35% of the variation related to functional capacity and pain, neither static nor dynamic torque can be considered as good predictors of functional capacity. Torque measurements are sometimes chosen because they are objective (13). However, torque production can be modified by reflex mechanisms but also by the patient at will. Therefore it is semi-objective at the best. In osteoarthrosis of the knee the goal of rehabilitation should probably be defined as better functional capacity and less pain, which are essentially subjective variables. Subjective variables can be measured with good objectivity (14, 17). Here the word *objectivity* is used with reference to the phenomenon that the result of a measurement is independent of the observer. Bellamy (4) states three important criteria in measurement theory: validity, reliability and sensitivity. Meenan (17) adds a fourth criterium: simplicity. Although simplicity is to be preferred wherever possible (and in fact our set of measurements is simple and not time consuming) it is not clear why a more complicated test procedure, if necessary, should be unacceptable. Reliability and sensitivity of outcome measures are, without doubt, important in evaluative research. These aspects have not been the subject of the present study, but in a very similarly designed set of measurements for the outcome of low back pain, reliability and sensitivity have been found to be satisfactory (15).

In conclusion, with regard to validity, outcome measurements in osteoarthrosis of the knee should be directly problem-oriented, i.e. include subjective scorings of functional capacity and pain (which report in a standardized way the patient's perception of these aspects) and semi-objective variables such as a walking test. Dynamic and static torque measurements can give insight into the relationship of torque and functional capacity but they cannot be regarded as valid single outcome measures.

Additional data about the results of the measurements are available from the authors on request.

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