Scand J Rehab Med 22: 93–99, 1990

REPRODUCIBILITY OF ISOKINETIC MUSCLE STRENGTH MEASUREMENTS IN NORMAL AND ARTHRITIC INDIVIDUALS

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ABSTRACT. The serial reproducibility of an individual's isokinetic torque was assessed in order to establish a reliable baseline value for future comparison. Thirty-two controls and twenty arthritic patients were tested for their peak isokinetic torque on knee flexion and extension and hip flexion at three velocities on five occasions, at fortnightly intervals. The first test was found to provide a reliable baseline for controls and subjects who could generate a peak torque of 54 Newton meters (Nm) or more. The second test was found to be more representative of the series for groups containing weaker subjects. Variation related to torque: for subjects who generate a peak torque of 54 Nm or more, a range of ±20% accommodates the variability of 95% of tests. We conclude that a ±20% range applied to either the first or second test, depending on the nature of the group to be studied, serves as a representative baseline value.

Key words: exercise, muscle strength, isokinetics, arthritis.

In contrast to the numerous reports on pharmacological aspects of management of chronic rheumatic disease, there are very few critical studies on the equally important area of physical therapy. In certain forms of arthritis, exercise programmes are prescribed with the dual aims of maintaining or improving both the range of joint movement and muscle strength. However, there is little evidence to show that the exercises prescribed produce any objective benefit or even that the rheumatic patient is capable of responding to exercise in the same way as a normal individual (6, 7, 8, 19, 20, 21).

The Cybex isokinetic dynamometer has been extensively employed as an instrument with which to measure muscle strength. Most studies investigating inter-test variability have used as subjects young, healthy, active males and females (10, 11, 15). While some studies have included the elderly (3) and children (1, 17, 18), only one has investigated baseline variability in older patients with painful disability (4). Before using the Cybex to evaluate the effect of exercise in rheumatic patients, it was essential to determine, in non-athletic controls and rheumatoid arthritis (RA) patients, guidelines which would establish a reliable baseline measurement.

The present study was undertaken with three aims: first to determine whether a variation in performance becomes apparent when the same test is repeated at intervals of two weeks; second to establish the first test in the series which matches most closely the mean of the remainder of the series and, third, to establish the standard deviation which can be expected for the individual in a series of tests.

METHODS

Fifty-two patients were studied: 20 patients with rheumatoid arthritis (12 females aged 48–78 years, mean 62.2 years; 8 males aged 55–75 years, mean 66.9 years) and 32 non-athletic controls (20 females aged 23–65 years, mean 45 years; 12 males aged 23–64 years, mean 43.1 years).

The arthritic group was drawn from the Outpatients Clinic of the Department of Rheumatology.

The patients had definite or classical RA by ARA criteria (23) with or without previous knee joint involvement but none had had prosthetic knee or hip joint surgery. Treatment was unrestricted with respect to drug therapy and intra-articular steroid, if required, was used no more frequently than three monthly.

The control group comprised volunteers from the community and hospital staff; none had clinical evidence of joint disease nor were they participants in organised training programmes although the majority undertook social sporting activities such as lawn bowls and tennis.

Subjects were tested for isokinetic strength using a Cybex II isokinetic dynamometer linked to an IBM PC-XT with Isoscan software (Isotechnologies, Hillsboro, N. Carolina, USA, 1986) in which the torque signal receives no damping. Knee flexion and extension and hip flexion were assessed at the angular velocities of 60, 120 and 180 deg/s for the knees and 45, 90 and 135 deg/s for the hips. Each subject was instructed as to the basic principles of isokinetic assessments and requested to perform 5 maximal repetitions without pause at each of the testing speeds. Three minutes rest was

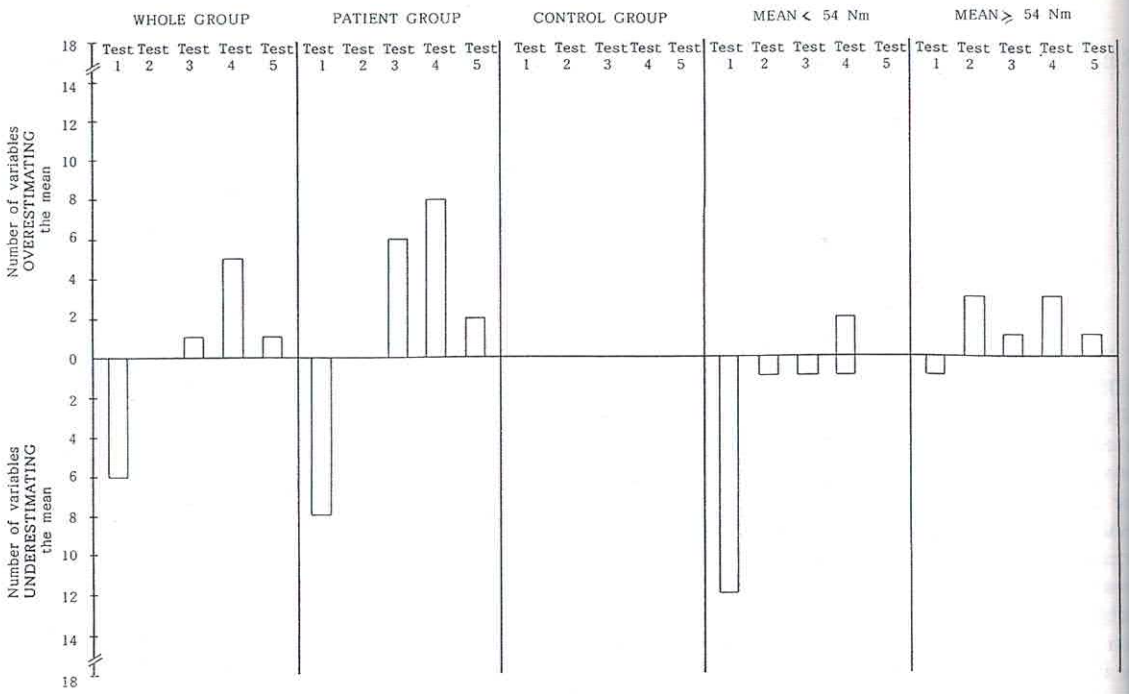

Fig. 1. The number of variables in each test found to underestimate or overestimate the mean of the remainder of the series.

given between testing at each speed. For each movement and speed combination (18 measurements), the peak torque was recorded for analysis. No compensation was made for limb segment weight. Assessments were repeated at fortnightly intervals.

Knee extension and flexion were tested with the patients seated with the hip in 105 deg of flexion. The lever-arm length as measured from the crossbar of the resistance arm to the motion centre at the time of the first test was recorded and used on subsequent tests. The movements were initiated from 90 deg of knee flexion.

Hip flexion was assessed in the supine position; knee movement was not restricted and again no compensation was made for limb segment weight. To increase stability and support, the patient was instructed to rest the foot of the contralateral limb on the table so that the knee and hip were flexed. The movement was initiated with the knee and hip fully extended. Hip extension was not measured.

In the initial test the subjects were given the opportunity to familiarise themselves with the movement prior to each speed or position change. This practice was not repeated at subsequent testing sessions. All testing was administered by one person (B. G.) who, during the test, encouraged the subjects to perform maximally. A constant testing pattern was maintained: both knees tested before the hips; right side before the left.

Testing was carried out on five occasions at fortnightly intervals without any intervening physical activity programme. Subjects were given no feedback on the results of previous tests, but were encouraged to utilise the visual display of torque on the dynamometer as motivation to maximise their performance. Testing was carried out at a uniform time of day to prevent a diurnal effect. A daily calibration was performed in accordance with the instructions of the Isoscan software.

Statistical analysis: data were analysed using the statistical package SPIDA (14). The *t*-test was used to compare the performance of each individual on each variable across the five tests. The individual variation of serial isokinetic testing was assessed by using the coefficient of variation (CV) defined as:

$$CV = (\text{standard deviation}/\text{mean}) \times 100$$

The significance level for each test was set at $p < 0.05$. With a large number of statistical tests, this may result in 5% false positives.

RESULTS

Selection of a representative test

The first task was to determine which test in the series could be viewed as a reliable baseline figure. Using the *t*-test, the mean peak torque of each test was compared with the mean of the remaining four in the series, i.e. Test 1 was compared with the mean of the peak torque of Tests 2 to 5; Test 2 was compared with Test 1 and Tests 3 to 5, etc. This was carried out on

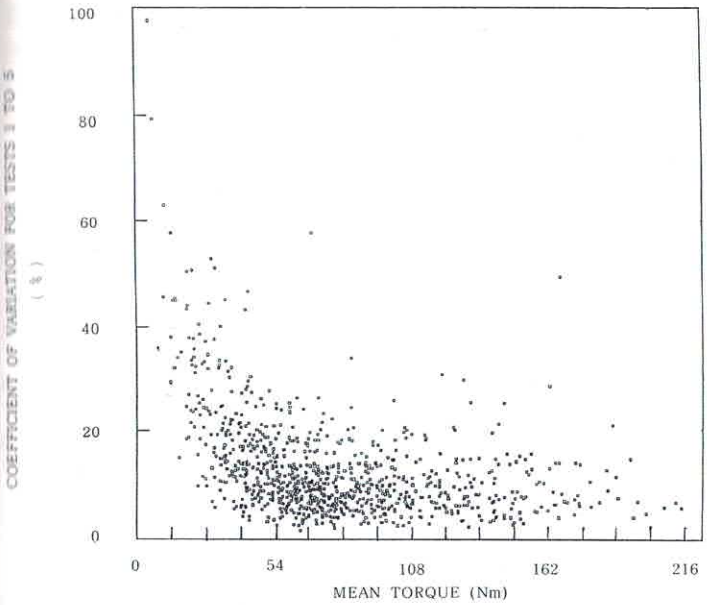

Fig. 2. The coefficient of variation plotted against the mean peak torque for Tests 1 to 5. Every subject is represented for each of the 18 variables.

the subject group as a whole, on patients and controls separately, and then on the group in which mean torque fell below 54 Nm and on the group in which the mean peak torque exceeded 54 Nm. The number of variables which were significantly different from the mean of the series was tallied (Fig. 1).

Fig. 1 shows that Test 1 variably underestimates the mean of the series for the patient group and for those whose peak torque exceeded or fell below 54 Nm. It also shows that in Test 1 for the patient group, 8 of 18 variables underestimate the mean of the remainder of the series; for patients and controls (considered as a group) with a peak torque less than 54 Nm, 13 of 18 variables fell below the mean of the series while for

Table I. *Mean peak torque (Nm) for all variables of Tests 1 to 5 and Tests 2 to 5 for comparison (dominant and non-dominant sides combined)*

	Controls		Patients	
	Mean of mean torque Tests 1–5	Mean of mean torque Tests 2–5	Mean of mean torque Tests 1–5	Mean of mean torque Tests 2–5
Knee extension				
60 deg/s	130.8 ± 40.0	131.0 ± 40.4	73.5 ± 31.5	74.0 ± 31.6
120 deg/s	107.3 ± 35.8	107.7 ± 36.3	58.2 ± 28.8	58.6 ± 28.3
180 deg/s	89.2 ± 32.8	89.9 ± 33.5	46.6 ± 25.1	46.4 ± 25.0
Knee flexion				
60 deg/s	80.4 ± 22.3	80.9 ± 23.6	49.6 ± 17.1	50.6 ± 16.8
120 deg/s	74.3 ± 19.9	74.7 ± 20.0	44.5 ± 17.0	45.4 ± 17.1
180 deg/s	68.6 ± 19.9	69.1 ± 20.2	38.9 ± 16.2	38.8 ± 15.8
Hip flexion				
45 deg/s	108.2 ± 35.9	108.6 ± 35.9	58.2 ± 20.0	59.4 ± 19.8
90 deg/s	95.6 ± 34.9	96.1 ± 35.6	49.4 ± 18.6	50.9 ± 18.8
135 deg/s	81.7 ± 33.3	82.5 ± 34.7	38.1 ± 16.0	39.5 ± 16.7

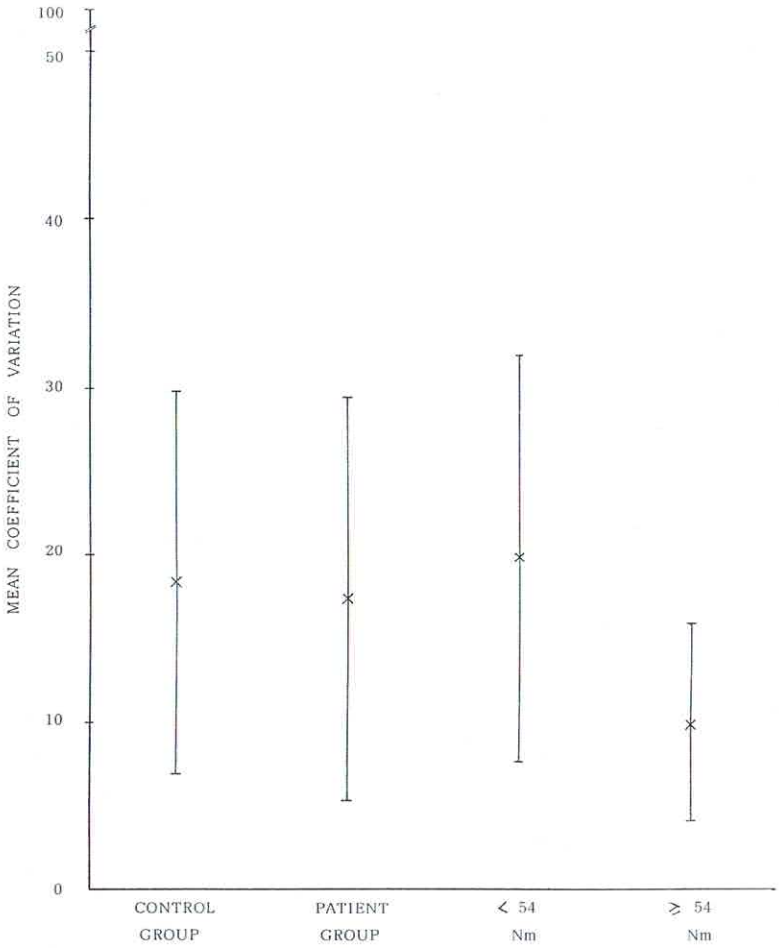

Fig. 3. Mean and standard deviations of the coefficients of variation for all variables combined.

those with a peak torque greater than 54 Nm, only 1 of the 18 variables underestimated the mean of the series.

For the whole group and the patient group, the major contribution towards Test 1 underestimating the mean appears to arise from the effect of tests in which the peak torque was less than 54 Nm. By contrast it should be noted that none of the variables was under- or over-estimated for the control group, most of whom had peak torque values exceeding 54 Nm.

Test 2 shows few variations from the mean of the series for any group studied. Tests 3, 4 and 5 showed minor variations, most notably for the patient group in Test 4, where 8 variables significantly differed from the mean.

Thus, for the individual who generates a peak torque equal to or greater than 54 Nm for each action studied, the initial test proves an acceptable baseline. However, for studies on groups which include individuals who generate a peak torque less than 54 Nm, the second test serves as a more representative baseline figure.

Individual intertest variability

For each individual and for each variable the CV for the five tests was plotted against the mean peak torque. Fig. 2 shows that the greater the mean peak torque, the smaller the CV; conversely there was a rapid increase in the CV for a mean peak torque of less than 54 Nm. Although Fig. 2 shows only the composite CV pattern, this configuration was evident for each variable.

From the above data it is clear that if the mean peak torque of any variable is more than 54 Nm, a range of $\pm 20\%$ accommodates the variability of 95% of tests. Variables in which the mean peak torque fell below 54

Table II. *Mean coefficients of variations for all variables of Tests 1 to 5 and Tests 2 to 5 for comparison (dominant and non-dominant sides combined)*

	Controls		Patients	
	Mean of coefficient of variation		Mean of coefficient of variation	
	Tests 1–5	Tests 2–5	Tests 1–5	Tests 2–5
Knee extension				
60 deg/s	8.3±4.0	6.9±3.6	14.8±10.1	13.3±8.9
120 deg/s	8.2±4.8	7.4±3.7	15.3±11.5	12.6±9.4
180 deg/s	9.3±5.0	8.3±4.2	19.6±15.3	17.7±14.3
Knee flexion				
60 deg/s	11.5±7.5	11.1±8.7	16.1±9.4	12.5±6.1
120 deg/s	10.6±4.4	9.0±4.4	15.8±11.3	12.1±6.2
180 deg/s	10.1±5.0	8.5±4.4	20.3±16.1	18.2±14.1
Hip flexion				
45 deg/s	9.3±6.4	8.9±7.3	13.6±7.9	10.7±4.9
90 deg/s	10.2±5.2	10.1±6.3	16.8±10.0	12.2±6.4
135 deg/s	13.2±6.2	12.2±6.5	23.6±11.9	21.4±12.2

Nm were found to have a wide range of CV of up to 97%. The mean CV for all variables for the control group was 18.3%±11.4 (mean ± standard deviation); for the patient group the mean CV was 17.3%±12; for those patients and controls with a mean peak torque less than 54 Nm the mean CV was 19.8%±12.1 and for those with a mean peak torque greater than 54 Nm the mean CV was 10%±5.8 (Fig. 3).

When the relationship between the CV and mean peak torque in the patient and control groups was compared, a similar pattern was demonstrated for both groups. However, while the mean peak torque exceeded 54 Nm for 92% of control variables, only 65% of the patient variables achieved this peak torque level and hence direct comparison of the two groups must be undertaken with caution.

These relationships were again investigated excluding Test 1. While there was no consistant change in the mean peak torque values (Table I) the CV's were consistently reduced (Table II).

DISCUSSION

Our data allowed three conclusions. First, that in untrained persons, maximal performance was not exactly reproduced when sampled at two weekly intervals, using the Cybex II isokinetic dynamometer as the test system. Second, that the initial test is an acceptable baseline for individuals whose tested actions generate 54 Nm or more, but that in groups which include subjects whose peak torque is less than 54 Nm, the second test is a more representative baseline figure. Third, that variability is related to strength; for variables greater than 54 Nm the use of a 20% range applied to the baseline test accommodates 95% of the remaining tests for the combined patient and control groups. However, because of the large and unpredictable CV it was not possible to establish a reliable range where peak torque value fell below 54 Nm.

In the patient group, the relatively reduced value of several of the Test 1 variables indicates the possibility of a learning effect as previously reported (25). This variation between the first test and subsequent tests was not evident in the control group in our study. In fact our results support previous studies (1, 13, 17, 18) which show insignificant variation between the first test and subsequent tests in active young healthy subjects. However, when standardising a protocol to compare normal individuals with the elderly, the disabled and arthritic subjects, Test 1 may underestimate the torque value and we consider Test 2 serves as a more uniform indicator of baseline strength.

When compared with the 5% variation figure proposed by Johnson et al. (13), our 20% variation seems

large. Indeed it is larger than that reported by most other workers, but comparison is complicated by the different statistical approaches which have been used. We chose to employ the coefficient of variation because we wanted a method which would provide, for each individual, a baseline range against which his or her subsequent performance could be measured. Other studies have used either mean results for a group or have subjected group means to an analysis of variance. By contrast, in a study on RA patients and controls, Danneskiold–Samsoe (4) reported a coefficient of variation of up to 19.9, although she did not relate this to the mean peak torque and her results may include higher individual variations in those with lower peak torque values.

There are several factors which could have contributed to our coefficient of variation: technical effects including the influence of gravity on the use of the Cybex isokinetic dynamometer; the intertest period and the population studied.

We acknowledge several technical problems of reproducibility inherent in the use of the Cybex isokinetic system. These include the influence of impact spike, oscillation (24) and computer sampling error. Peak torque values were collected from the torque production curves manually corrected for the effect of impact spike. The introduction of possible error due to this correction must be acknowledged although the process of interpreting data was performed by the same individual to reduce inter-observer error. A further error may occur with the interpretation of results where oscillations exist due to lack of damping in the system. Finally, the use of an eight bit recording system limits the accuracy of the quantified torque due to the number of samples recorded per second.

The inter-test period in our study is unlikely to contribute greatly to the variation since it falls within the range used in other studies (16). While unexceptional by comparison with previous reports, the time over which the test were taken in our study was long and provided a realistic basis for clinical applications where Cybex II is being used to assess intervention effect.

By contrast, our study group probably contributed significantly to the large coefficient of variation. The population consisted of the untrained in both subject and control groups. As it is likely that people who participate in regular physical training are more accustomed to reproducing their performance than are the untrained, this factor is probably of importance. Furthermore, rheumatoid arthritis shows considerable fluctuations in activity and symptoms even over brief periods of time. Thus the large variation and greater percentage of lower torque values displayed by the rheumatoid group are not unexpected in this chronic and debilitating disease. Previous studies of isokinetic strength in the rheumatoid patient have demonstrated this reduced physical capacity (4, 12). In another chronic weakening condition, Armstrong et al. (2), using isokinetic assessment in patients with multiple sclerosis, acknowledged the importance of changes in the patients' clinical state.

We also noted that a trend existed for increased CV with increased speed. This may reflect the greater likelihood of lower torque values at high speed although the trend did not reach statistical significance and was not noted in the study of Danneskiold-Samsoe (4).

We found the major factor influencing variation between tests was peak torque although the relationship was an interesting one. For mean peak torque values less than 54 Nm the coefficient of variation was large and unpredictable; for mean peak torque values greater than 54 Nm the coefficient of variation fell below 20% and apparently remained steady for the range of peak torque values recorded up to 200 Nm.

While a variation of around 5% may be satisfactory in the analysis of groups of subjects tested over brief periods of time, our data suggest that in most clinical situations, particularly where individuals have disease or disability, reliance on such a narrow range may be misleading. We suggest that either Test 1 or Test 2 be used as a baseline, depending on the nature of the group to be tested. Test 1 represents a satisfactory baseline where peak torque equals or exceeds 54 Nm, while Test 2 should be used for the study of groups which include individuals who produce peak torque values of less than 54 Nm.

ACKNOWLEDGEMENTS

The authors would like to thank Mrs Daphne Castle for her secretarial assistance.

This project received the financial support of the National Health and Medical Research Council.

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