An evaluation of the dynamic qualities of isometric grip strength

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SUMMARY A strain gauged torsion dynamometer linked to a microprocessor was used to assess the dynamic qualities of isometric grip strength in patients with rheumatic diseases. Maximum grip strength, time to maximum grip, and percentage fatigue provide independent information on the grip. Time to maximum grip does not appear to be an objective correlate of subjective stiffness. The usefulness of these dynamic variables for the assessment of stiffness appears limited in arthritic disease, where pain may interfere with the maximum voluntary effort of the test.

Key words: rheumatic diseases, microprocessor.

Isometric grip strength is used in rheumatic diseases as a measure of improvement where change over a period is expected to occur. Traditionally this is measured with a Davis bag, which is essentially a pneumodynamometer. Although this system is cheap and portable, it is an imprecise measure of grip, and readings may vary according to the position of the hand on the bag.

In an attempt to improve the precision and utility of this system modifications were made which enabled an analysis of the grip/time curve to be obtained.¹ As a result of this analysis it was suggested that the rate of development of grip is the objective correlate of subjective stiffness and thus may be a more sensitive indicator of change in hand function than the maximum grip strength.²

We previously described a strain gauged torsion dynamometer which allows an objective measurement of grip strength without the problems inherent in a device which measures pressure. We linked the torsion dynamometer to a microprocessor for analysis of a 4-6 second timed squeeze and showed this system to be acceptable to a group of patients with rheumatoid arthritis.³ Reproducibility was acceptable for the group, though individual reproducibility of dynamic variables was poor. Of these dynamic variables, only maximum grip strength, time to maximum grip ($t_{\max}$), and percentage fatigue ($F\%$: the fall in sustained grip over the timed period

expressed as a percentage of the maximum grip) appeared to provide independent information on the grip. The aim of the present study was to confirm the suggestion that time to maximum grip is related to the subjective symptom of stiffness, and to assess the usefulness of these dynamic variables as indicators of hand dysfunction in rheumatic diseases.

In this study we have continued to measure $t_{\max}$ instead of rate of development of grip. These two variables are related by the following formula: $t_{\max} = \text{maximum grip} / \text{grip rate}$.

Theoretically, in normal subjects, $t_{\max}$ should be constant irrespective of maximum grip, so that a plot of grip versus grip rate would show a positive linear correlation. On the other hand, there should be no relation between $t_{\max}$ and maximum grip. As shown previously $t_{\max}$ is independent of maximum grip. We confirmed the relation between maximum grip and grip rate in a study in which 45 consecutive squeezes of eight seconds' duration in a normal population were observed: Pearson's r correlation coefficient was 0.41 between these two variables. Thus we feel that grip rate does not provide truly independent information and have adhered to the use of time to maximum grip in this study.

Methods

DYNAMIC VARIABLES IN DIFFERENT RHEUMATIC DISEASES

Dynamic variables were measured on a single occasion in patients with rheumatoid arthritis (RA)

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and other rheumatic diseases. Patients with RA were subdivided into four groups on the basis of changes in the third metacarpophalangeal (MCP) joint of the hand employed in grip strength measurement. Although this may seem an arbitrary subdivision, other indices of disease activity, such as Ritchie articular index, erythrocyte sedimentation rate, and global hand x ray score, were in agreement with the local classification. The four groups were as follows: active RA (66 patients), inactive RA (32), those with a subluxed MCP joint (32), and those who had had arthroplasty (five). Six patients with pure, symptomatic osteoarthritis were also studied and four patients with painful inflammatory psoriatic arthritis were included.

These patients were compared with 30 patients waiting to see the doctor in a general practitioner's waiting room. None of these patients complained of pain or stiffness in the hands, and the age range of this group was similar to that of patients with rheumatoid arthritis.

EFFECT OF A SINGLE ORAL DOSE OF IBUPROFEN

Eight patients with RA were studied. After informed consent had been obtained all non-steroidal anti-inflammatory drug (NSAID) treatment was discontinued for 48 hours before the start of the study. On the day of the study patients were given 800 mg of ibuprofen on an empty stomach, and grip strength was measured for six hours thereafter to coincide with the known pharmacokinetic profile of ibuprofen.

On each occasion subjective pain and stiffness were each assessed with a horizontal 100 mm visual analogue scale. Both scales were unmarked apart from the end stops, which were clearly labelled as 'no pain' (or stiffness) and 'worst pain ever'. Patients were asked to choose a point on the continuum which best represented the intensity of the symptom at that time. Access to the previous selection was given.

CIRCADIAN VARIATION

Fourteen patients with RA were investigated. Patients agreed to stop all NSAID treatment for 24 hours before the measurements. Grip strength was measured at three-hourly intervals for 24 hours starting at 9.00 am.

On each occasion subjective pain and stiffness were assessed using a horizontal 100 mm visual analogue scale.

EFFECT OF PHYSIOTHERAPY

Informed consent was obtained from 10 patients with active RA and 10 with inactive RA. As before,

definition of activity was based on local changes in hand joints only. The 10 patients with active disease were given 20 minutes of cryotherapy in the form of cryogel packs at -10°C applied in a cloth to both sides of the hand. After a rest of 10 minutes they were then given 20 minutes standard hand exercises. The patients with inactive disease had 20 minutes faradic stimulation using a Triodyne Mark III stimulator. After a 10 minute rest they then performed similar exercises to those performed by the patients with active disease. Grip strength measurements were made before each treatment and after the completion of hand exercises, and concurrent subjective assessments of pain and stiffness were obtained.

EFFECT OF ARTHROPLASTY

Three hands were tested in two subjects undergoing Swanson arthroplasties of their MCP joints. Arthroplasty was indicated to correct deformity (joint subluxation with marked ulnar deviation) and pain. Measurements were made 24 hours before operation and three months afterwards.

Results

DYNAMIC VARIABLES IN DIFFERENT RHEUMATIC DISEASES

Fig. 1 presents the results of this part of the study in a bar chart. Patients with hand arthropathy from whatever cause had a marked reduction in maximum grip strength. In the patients with RA this was particularly so in the presence of MCP joint subluxation and after arthroplasty (both groups where functional disability is pronounced). The highest grip strength was found in the group with inactive disease.

Where pain was a predominant feature of the hand arthropathy $t_{\max}$ was prolonged. The fact that this variable was prolonged in patients with osteoarthritis and psoriatic arthritis suggests that the time to reach maximum grip is not solely a function of associated muscle disease. The group with artificial MCP joints, though small, had the shortest $t_{\max}$ values, whereas the active RA group, in which pain was prominent, had the longest values for $t_{\max}$.

As muscle fatigue is a function of training it might have been expected that patients unable to use their muscles because of pain or anatomical disorganization of the hand would have shown the greatest increase in fatigue. The results broadly supported this thesis except in the case of the osteoarthritic group; possibly their normal fatigue reflected the intermittent character of their pain.

IBUPROFEN

Fig. 2 displays graphically the effects of a single dose

Fig. 1 Grip strength variables in different rheumatic diseases. Inact. RA=inactive RA; sublux. MCP=subluxed MCP joints; MCP repl.=arthroplasty group; OA=osteoarthritis; PsA=psoriatic arthritis.

of ibuprofen. The changes in subjective pain and stiffness roughly followed the time course of the pharmacokinetic profile of oral ibuprofen, where peak serum values are obtained after one to two hours but peak intrasynovial values occur at four

hours. The improvement seen in maximum grip strength suggests that this variable is a function not only of muscle disease but also of pain and stiffness in the hand. The changes in t_{max} and fatigue ($F\%$) showed no particular pattern and did not relate to the subjective scores.

Fig. 2 The effect of 800 mg ibuprofen orally on dynamic grip variables. $F\%$ =percentage fatigue; max=maximum grip; T_{max} =time to maximum grip; VAS stiff=stiffness as measured by visual analogue scale; VAS pain=pain as measured by visual analogue scale.

CIRCADIAN VARIATION

In this study the analysis adopted was similar to that used by Yung *et al.*⁴ For each patient the following statistic was calculated for each measurement:

$$C_i = (x_i - \bar{x}) / \left(\sum_{i=1}^9 (x_i - \bar{x})^2 \right)^{1/2}$$

where x_i is the value at time i and $\bar{x}$ is the mean value for the patient over the 24 hour period. The values of C_i thus obtained for each variable were found to be distributed normally with a mean of zero. Thus 95% confidence limits for each variable were calculated with which individual values of C_i could be compared.

Fig. 3 plots the values of C_i for each variable over the 24 hour period. The 95% confidence limits are included. None of the values of C_i achieved statistical significance. For maximum grip there was

Fig. 3 Circadian variation of dynamic grip variables. The calculation of C_i is explained in the text. The dotted lines represent 95% confidence limits.

suggestion that the highest values occurred at 6 00 pm and the lowest values at 3 00 and 6 00 am. This is in accordance with previous work.⁵ The highest values for $t_{\max}$ were also obtained at 6 00 pm and the lowest values at 6 00 am. For fatigue the maximal values occurred at 9 00 pm and the minimal at 9 00 am.

Most of these patients complained of early morning pain and stiffness and it might have been expected that the maximal values for $t_{\max}$ would have occurred simultaneously, but there was clearly a discordance between the time of maximum objective score and the time of greatest symptomatic stiffness.

PHYSIOTHERAPY

Fig. 4 displays graphically the results of this study. It can be seen that most of the patients complained of an increase in pain and stiffness on the application of ice and that there was a corresponding prolongation of $t_{\max}$ at this time. This particular investigation illustrates one of the problems in this field: pain and stiffness in rheumatoid arthritis often change simultaneously. It can be seen, however, that after faradic

Fig. 4 Effect of physiotherapy on dynamic grip variables. B=baseline; FAR=after faradism; ICE=after ice; EX=after exercise. Other abbreviations as for Fig. 2.

stimulation of the hands patients perceived an increase in pain but a decrease in stiffness. In this situation $t_{\max}$ showed a slight increase and a further increase after exercise.

ARTHROPLASTY

Arthroplasty, while providing restoration of hand anatomy, also relieves pain. Often subjective stiffness is unchanged or worse after operation. Table 1 shows the changes in grip variables in the three hands studied. At three months there was no improvement in maximum grip, but $t_{\max}$ was markedly reduced. There was a marked increase in fatigue, perhaps reflecting the period of immobilisation that follows surgery.

Table 1 Effect of arthroplasty on dynamic grip variables. Mean values of three hands

	Before operation	Three months after operation
Maximum grip (newtons)	19	19
$t_{\max}$ (seconds)	4.2	0.8
Fatigue (%)	6	19

Discussion

Analysis of the dynamic qualities of isometric grip strength was pioneered in Dunedin using a standard sphygmomanometer bag linked by a pressure transducer to a microprocessor. Sample pressure readings were taken every 20 milliseconds during a two second grip. The rate of development of grip, the time taken to reach maximum grip, and the maximum grip were recorded. These variables were related mathematically to 'work' (as a function of maximum grip strength) and 'power' (as a function of grip rate).¹ Subsequently it was claimed that the rate of development of grip can be accepted as an objective correlate of joint stiffness in RA.⁶ This relation was suggested by the differential early morning response of work, power, and maximum grip strength to the administration of an indomethacin suppository the previous evening. It was suggested that work and maximum grip strength are independent of the time taken to reach maximum grip and more influenced by factors such as pain and strength of the subject. No attempt was made to relate subjective symptoms to objective variables so as to confirm this hypothesis. Furthermore, the Dunedin authors did not present any evidence to suggest that the rate of release, or the fatigue, measured from the grip/time curve, provided any additional information in RA. It was suggested that these variables may be of more use in studying muscular disorders.

Time to maximum grip is undoubtedly prolonged in rheumatoid arthritis, and this is particularly so where the disease is active. To relate this prolongation to perceived dysfunction we have measured this variable in situations where symptomatic stiffness and pain are changing rapidly. Unfortunately, pain and stiffness often change together. Indeed there is some suggestion that patients often confuse pain and stiffness in their joints.⁷ Nevertheless, the results of this study have shown that there is poor correlation between $t_{\max}$ and perceived stiffness after the administration of ibuprofen, over a 24 hour period, and after arthroplasty. After faradic treatment, where stiffness and pain changed differentially, it appeared that $t_{\max}$ was more a function of pain than of stiffness.

Neurophysiology has shown that both subclinical polymyositis and abnormal muscular fatigability are common in rheumatoid arthritis.^{8,9} Fatigue in itself is an index of muscle training and is likely to be prolonged in muscular wasting, whether due to primary disease or secondary changes following disuse and reflex inhibition. In short term studies there is therefore likely to be little change in this variable, and on the whole the results of this study

support this suggestion. It may be that fatigue is a more useful variable in, for example, a longer term longitudinal study of the benefits of physiotherapy. It is difficult to imagine any significant changes occurring without concomitant improvement in the associated arthropathy, however. On the other hand, fatigue and other dynamic variables such as release rate may be more useful in neurological diseases such as myotonia and myasthenia, and possibly when training muscles for gymnastic events.

Isometric grip strength testing relies on a sustained maximum voluntary effort by the subject. In studies comparing voluntary muscle strength with maximum strength produced by tetanic stimulation of the muscle there is little difference between the two results in normal subjects without joint pain.¹⁰ In subjects with arthropathy this may not be so: to achieve a sustained maximal grip subjects may experience considerable pain. This study has shown that variables such as maximum grip, $t_{\max}$, and fatigue are not totally reliable indicators of muscle capacity but are influenced by other factors, such as pain in the joints. In addition, as was shown for maximum grip strength,¹¹ patient/observer interaction probably occurs with the dynamic variables of grip. In normal subjects and in patients with neurological diseases grip strength dynamic variables may be more useful, and further studies in these diseases are indicated.

The electronic strain gauged torsion dynamometer used in this study undoubtedly provides a more precise measure of grip strength. Moreover it is easier to use than the conventional pneumodynamometer and has been shown to be acceptable to a group of patients with rheumatic disease. On line analysis of the dynamic qualities of grip appears to provide little extra information, however: both maximum grip strength and dynamic variables are affected by pain experienced in the rheumatic hand.

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