Low back testing by dynamometry

A report by the

National Health Technology Advisory Panel

September 1989

Australian Institute of Health

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Any comments or information relevant to the subject matter of this report would be welcome. Correspondence should be directed to:

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The National Health Technology Advisory Panel

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Executive Summary

Low Back Pain

- Low back pain (LBP) affects a significant part of the population and has a great social and economic cost to the community.

- The annual incidence for LBP is 2-5% of the population; with 80% of individuals having an occurence at least once in their lifetime.

- The Panel estimates that there could be 40,000 work-related back injuries each year. Worksafe Australia has estimated that back injuries are costing Australia $600 million a year in compensation costs, lost working days, lowered productivity and increased industrial disruption.

- There has been a general absence of programs and measures to prevent or reduce the incidence and adverse effects of LBP. A National Strategy for Prevention of Occupational Backpain has now been developed by Worksafe Australia.

Dynamometers

- Force measuring devices called dynamometers have been developed to assess muscle performance. Testing of the major joints of the extremities by dynamometry has become widespread. They are also being used in the assessment and rehabilitation of patients with LBP.

- The incorporation of microprocessor technology in dynamometers in recent years has enabled more efficient acquisition, analysis and display of data. The technology has expanded the capacity to study dynamic muscle function.

- Dynamometers are usually operated by qualified physiotherapists with referral of patients by medical practitioners.

Testing of the Limb Muscles

- There are over 50 sites using this technology in Australia for testing limbs, usually in the context of sports medicine and physiotherapy.

- Some recent reports have questioned the quality of measurements obtained from dynamometers. The Panel considers that there is a need for operators to be aware of the limitations of the data obtained from dynamometric measurements.

Testing of the Back Muscles

- Over the last two years dynamometers for low back testing have become available in Australia with about 13 in use. Their capital cost ranges from $80,000 to $270,000.
- The literature on the clinical use and benefit of dynamometers is still limited. The Panel sees a need for operators to document and publish their clinical experience with these machines.
- The various machines available make use of different testing protocols, patient stabilisation systems, patient postures, assumed axes of movement and data bases. The results obtained from the different machines are not comparable.

The Panel considers that:

- Dynamometers are devices with a potential to usefully contribute to the assessment and management of LBP.
- When properly used, these machines can provide a quantitative measure of a patient's progress in a program of rehabilitation. Some machines may be more appropriate than others in providing a measure of fitness to undertake real life tasks.
- Dynamometers may also be capable of providing useful information on diagnosis and prognosis of a spectrum of conditions contributing to LBP. However, with the current status of the technology, additional work is needed on these applications, to define and improve levels of reliability. Further normative data for different types of subject and a range of normal and pathological conditions are required.
- The evaluation of different types of dynamometers should be encouraged and supported by users of the technology, employer groups and insurance agencies.
- The use of dynamometry to identify persons suspected of malingering is not supported in view of the uncertainties as to the reliability of the technology and data interpretation. Research should be undertaken to objectively define patient effort during testing.
- Use of the technology should be integrated with appropriate health services required to manage back-injured persons.

Introduction

Low back pain (LBP) caused by musculoskeletal injury is a major medical disorder which affects a significant part of the population and has a great social and economic cost to the community. Musculoskeletal back injuries are the most frequent work-related injuries (1) and have direct costs associated both with compensation payments and lost production,in addition to adverse consequences for quality of life.

The fundamental tool for the quantitative assessment of muscle function is the dynamometer, a force measuring device. Dynamometers have been used for a number of years in the assessment of limb muscles. Recently, dynamometers capable of evaluating the trunk muscles have become available in Australia. Potentially they could have a significant role in the assessment and rehabilitation of patients with LBP. The Victorian Accident Compensation Commission has requested the National Health Technology Advisory Panel (NHTAP) to undertake an evaluation of their technical performance and benefits.

Following a preliminary study of the subject (2), the Panel decided to undertake an assessment on the use of these machines in the evaluation of back injury, with some reference to their use with limbs.

Statistics on low back pain

Low back pain is a common problem in the community, with an annual incidence of 2-5% of the population, and with 80% of individuals having an occurrence at least once in their lifetime (3). Two recent overseas studies, based on large populations with low back problems, found that approximately 90% of these patients returned to work within six weeks (3).

Only 1-2% of LBP cases will eventually require surgery (4). It has been estimated that 7-10% of the total population of LBP patients eventually become chronic sufferers and consume about 80% of the money spent on low back disorders(4).

In Australia, information on the occurrence of occupational back pain is largely restricted to compensation-based statistics which have some severe limitations including reporting biases (5). For example,back pain is readily recognised as a work-related condition and may be over-reported in comparison with other conditions. Conversely, not all workers are included in worker compensation systems. Australian compensation-based statistics (5) indicate that :

- in 1984-85 back injuries accounted for 23% of all compensated injuries in Queensland, 24% in New South Wales and 28% in South Australia;

- 62% of all compensated back injuries in NSW during the same period arose as a result of work which included manual handling.

Economic cost of low back pain

In the USA, the annual cost of LBP (medical expenses, lost wages and compensation) has been estimated at $US16 billion (6), approximating to 0.5% of Gross Domestic Product (GDP).

A report to the British Department of Health and Social Security in 1979 indicated that more than 375,000 people a year in the UK experienced a period of certified incapacity because of back pain (7). The financial cost to the country in lost output and NHS services was estimated at almost £300 million (representing 0.2% of GDP). However, most married women and the elderly were not represented in the data considered, which therefore provide a substantial under-estimate of the problem. More recent figures suggest that the cost of back pain to the NHS is at least £156 million a year and the cost to the country in terms of lost industrial output is at least £1000 million a year (8), representing 0.5% of GDP.

Figures recently released by Worksafe Australia show that back injuries are costing Australia $600 million a year in compensation costs, lost working days, lowered productivity and increased industrial disruption (9), representing 0.7% of GDP.

In Victoria during 1984, there were 34,352 notifiable occupational injuries that required 5 or more days off work, of which 9,909 (28%) were occupational lower back injuries. The average cost in workers' compensation was $7,900 per case (10). If the national annual incidence of work-related back injury is similar to the incidence in Victoria in 1984 (2,477 per million population), then the number of these injuries in Australia could be in the region of 40,000 annually.

Because of the economic and social implications, Worksafe Australia has developed a national strategy to achieve a significant reduction in the occurrence of occupational back pain (5).

Management of low back pain

Despite the common occurrence of LBP it has been reported that in most cases a specific diagnosis cannot be established, and often the anatomic structure that causes the pain is not identified (4). However, certain risk factors predisposing to LBP have been identified. It has been reported that the strength and endurance of back and abdominal muscles have been shown to be inferior in back-injured persons and it has been suggested that this weakness predisposes the patient to LBP (4).

Early evaluation, treatment and rehabilitation have been advocated for the management of patients with LBP to provide rapid relief of pain, early return to normal activities and the prevention of chronic back pain (4,11). It has been observed that the chance of rehabilitation rapidly deteriorates with longer periods of absence from work. Workers absent for six months have a 50% chance of returning to work and, after 12 months' absence the chances are only 25% (12). Back pain becomes chronic when it has persisted for several months and has become associated with behavioural changes which interfere with lifestyle (12).

In the early management of back pain, active therapeutic intervention and physiotherapy are seen as important (11). In chronic back pain a comprehensive, multidisciplinary approach is advocated taking into account the physical, social, psychological and vocational aspects of lost function. A detailed account of this approach is provided by Ganora (12). As a part of this approach, the assessment of physical capability and biomechanical function is considered essential.

An understanding of the cause of back pain requires a knowledge of the anatomy and nerve supply of the spinal and lumbar regions (13-15). The lumbar area is the most commonly affected site (11). A brief discussion on how skeletal muscles produce movement is given in Appendix 1.

Dynamometers for measurement of muscle function

Parameters and units of dynamometric measurements

In measuring muscle function by dynamometry a number of parameters (derived from Newtonian physics) are used. These parameters are described in Appendix 2. The most commonly used parameters in the literature on dynamometry are force, torque and angular velocity.

Types of dynamometer

Dynamometry basically involves three interacting elements: the patient, the coupling device to the dynamometer, and the load. The patient is required to do work against the load and the work done is recorded. There are major differences between manufacturers in the approach taken to design of the load system.

The program of movement can be isokinetic (the velocity of movement is maintained at a constant value) or isotonic (the applied force is constant). A number of machines use hybrid programs in an attempt to simulate normal movements of muscles. Some machines are capable of measuring only concentric movement while others permit both concentric and eccentric movements.

Many types of dynamometer have been developed to assess muscle function. A useful review of dynamometers used mainly for the assessment of the limbs has been prepared by Mayhew and Rothstein (16). Appendix 3 provides brief descriptions of those machines.

The incorporation of microprocessor technology in dynamometers in recent years has made it possible to measure dynamic muscular performance in real time. This technical development allows assembly, analysis, storage, display and correlation of the data obtained from dynamometric testing.

Low back testing dynamometers

Early techniques in the quantification of trunk muscle performance relying on table tensiometers and other static dynamometers gave equivocal and often controversial results (17). Until recently, testing of the trunk muscles has been conducted largely in laboratories using devices constructed by the investigator. Dynamometers are now commercially available to measure flexion/extension, lateral flexion and rotational trunk muscle performance. Mayer and Gatchel have reviewed the most widely used trunk assessment devices in the USA (18).

The Panel understands that four companies, all based in the USA, have so far placed dynamometers in Australian clinics. Several other companies are in the market. Table 1 gives details of low back testing machines available in Australia and descriptions of these machines are given in Appendix 4.

The Australian Society of Orthopaedic Surgeons has suggested that it is highly likely that these types of machines would be used extensively, particularly when viewed against the background of the interest they have created in the USA and the large orders that have been placed there (19).

TABLE 1

DYNAMOMETERS AVAILABLE IN AUSTRALIA FOR THE ASSESSMENT OF THE LOWER BACK

Dynamometer	Manufacturer	Distributor in Australia	Cost ($A)	Number in Use	Type of Muscle Contraction Measured
Cybex Back System	Cybex, Division of Lumex Inc. Ronkonkoma, New York USA	T K Morgan Seaford, Victoria			
- Trunk Extension/ Flexion Unit			108,000	0	isometric, concentric
- Torso Rotation Unit			78,000	0	isometric, concentric
- Liftask Unit			87,000	0	isometric, concentric
Kin-Com (with back attachment)	Chattecx Corporation Chattanooga, Tennessee USA	Chattanooga Australia P/L Hawthorn, Victoria	80,500	5	isometric, concentric, eccentric
IsoStation B-200	Isotechnologies Inc. Hillsborough, North Carolina USA	Electroglo P/L Toorak, Victoria	100,000	7	isometric, concentric
Merac System (with back attachment)	Universal Gym Equipment Inc., Cedar Rapids, Iowa USA	Universal Gym Equipment Balwyn, Victoria	76,000	1	isometric, concentric

Sources: Data supplied by Australian distributors and users.

Dynamometry in the assessment of limb and low back function

Assessment of limb function

The use of isometric devices such as cable tensiometers has provided little information on the dynamic qualities of muscular contraction. The development of isokinetic dynamometers in the late 1960's enabled the collection of data about muscle load and limb velocity throughout a range of joint movement. These machines were used primarily for rehabilitation of the knee following sports injury. It enabled patients to undergo their rehabilitation in a manner which could easily be correlated with their ability to perform sporting activities.

Recent application of microprocessor technology has greatly expanded the capacity to study muscle function. The use of isokinetic dynamometers in exercise, testing, rehabilitation and research has become widespread. Most data in the literature describe isokinetic muscle testing not in non-athletic subjects or injured workers but in trained athletes (20). However, reports have been published describing isokinetic measurement characteristics in aged patients, children, stroke patients and those with neuromuscular disease (16,21,22).

The Panel understands that in some States in the USA dynamometry testing of the limbs is mandatory prior to resumption of work following rehabilitation after work-related injury.

Assessment of trunk muscles

Dynamometers for the assessment of the back do not measure the performance of individual muscles, but rather the performance of the functional thoracolumbar segments, which are involved in transmitting loads from the shoulder girdle to the pelvis (23). Forward flexion against resistance primarily involves the vertical abdominal muscles and hip flexor muscles, while trunk extension involves hamstring, gluteals, thoracolumbar erectors, and oblique/latissimus muscles acting through the lumbodorsal fascia. Rotation involves the abdominal oblique and obliquely oriented paravertebral muscles.

The following discussion considers the Kin-Com and IsoStation B-200 machines, which are the most commonly used dynamometers in Australia for the assessment of the musculature of the back.

The Panel is not aware of any reports in the literature on the use of the Kin-Com in the assessment of low back injury. However, the Mount Medical Centre in Perth has used the machine clinically in this way for chronic work-related LBP patients, sportspersons with or without LBP and other chronic LBP patients.

The Panel was informed that successful treatment results have been achieved using isokinetic dynamometry in these groups of patients, and in particular for the first group as part of an overall rehabilitation program (Edwards, personal communication).

The Centre has provided details to the Panel on three pilot courses of its Spinal Injury Rehabilitation Programme (SIRP) conducted during 1987. The SIRP is a multifaceted program comprising history taking, physical examination, assessment on the Kin-Com at three speeds, assessment of lifting and push/pull capability through attachments to the Kin-Com, work simulation, general fitness restoration, back school lectures, psychological assessment and rehabilitation counselling. A total of 21 patients participated in the program. All were referred by either orthopaedic specialists or specialist physicians and represented the "bottom line" in terms of rehabilitation prospects.

Nineteen patients completed the program and early results indicated that approximately 60% would return to their former employment. However, the Centre commented that provision of more meaningful data from the program would take at least two years and would require support from both employers and insurance companies. The Centre considers that the SIRP is an effective way of treating LBP and is cost effective in terms of returning the injured employee to work.

The Centre has stated that there is a necessity to collect a large sample of normative data for males and females and to correlate this with age, height and weight to enable judgements to be made in diagnostic terms.

The Australian College of Rehabilitation Medicine (ACRM) has cautioned that there are major difficulties in the fixation of the trunk using this equipment and questions the usefulness of any information obtained from its use (24).

The published literature on the clinical use of the IsoStation B-200 is limited. However, many presentations on its use have been made at conferences in the USA during the last 2 years.

IsoStation B-200s are being used in Australia in a variety of settings. The Panel has been informed that where these machines are being used clinically, close consultation is maintained with other health disciplines (Grundy, personal communication).

The South Brisbane Centre of the Workers' Compensation Board of Queensland began using this dynamometer in December 1988. The equipment is being used within an overall rehabilitation service to provide base line data for individual patients (25). The Centre aims at providing work assessments and early intervention work conditioning programs for moderately injured workers who appear to have the potential to return to work within four to six weeks (25). All client management is undertaken by muli-disciplinary teams.

The Cedar Court Physical Rehabilitation Hospital, Melbourne has been using the B-200 for over two years. The Panel understands that the machine is used as part of an individualised program (involving appropriate health disciplines), for initial assessment, rehabilitation and monitoring of progress.

Limitations of dynamometry

Assessment of limb function

A number of recent reports have critically examined the clinical uses of isokinetic measurements (16,26). Rothstein et al consider that therapists in the USA should be aware of how they can and cannot use isokinetic measurements in their clinical settings, particularly in view of the increased emphasis from third-party insurers and from the medical community for documentation of effectiveness of physical therapy services (26).

The following issues have been raised in relation to testing of the limbs, and to an extent may also apply to back testing.

Isokinetic movement

A number of authors have questioned isokinetics as a concept in that isokinetic limb movements do not occur normally (16,26). Pure isokinetic movement is physically impossible, starting from a rest position: the mass must be accelerated from rest until the desired velocity is reached and similarly decelerated to rest towards the end of the range of movement (2). Only the centre portion of the movement is at constant velocity, and at high velocities, only a fraction of the range of movement is available. In an assessment of the measurement characteristics of two constant velocity dynamometers, Murray and Harrison concluded that recordings are rarely generated under conditions of true constant angular velocity due primarily to the servomechanism's slow response frequency and suggested that the term "isokinetic" is a misnomer (27).

Calibration

An important consideration in dynamometric measurements is whether data obtained from one machine are the same as those that would be obtained with another.It has been stated that inter-machine reliability has never been documented (16). Rothstein et al found that different machines yielded different torque values (16). Each machine was observed to have consistent error that could be compensated for with a linear regression equation specific to that machine. They recommended calibration procedures suggested by Olds to minimize the potential error caused by inter-machine variability. Olds concluded that it was necessary to calibrate the dynamometer every testing day and at every test speed.

Damping

When a freely accelerating limb is abruptly inhibited from further acceleration there is an impact between the accelerating mass and the resisting lever arm. This causes large oscillations which appear as overshoot in the torque tracing until the limb reaches the machine's pre-set velocity. Damping is used on the recorders to minimize this overshoot and to facilitate the identification of peak torque which is one of the parameters used to assess muscle performance (28). It has been stressed that damping must be kept constant during clinical evaluation to avoid erroneous clinical conclusions (28). For example, failure to use the same damping could lead to results that give the illusion that patients are improving (if the damping is lowered) or not improving (if damp setting is increased) (28). Murray has commented that suggestions for damping by the manufacturers may not always be appropriate (27).

Patient positioning

Rothstein et al have pointed out that this topic is one of the most important issues in clinical isokinetic measurements (26). Whenever the axis of rotation of the limb and the machine are not aligned the torque measurements obtained will not reflect accurately the performance of the muscles. The more incongruent the two axes, the greater the error. Additional errors can be introduced through changes in axes of rotation as the limb segments move, regardless of the stabilization methods used. This is particularly applicable to the more complex joints such as the ankle and shoulder (26).

Gravitational error

In vertical movements the limbs are not only working against the dynamometer but also are either aided or opposed by gravity. Winter and coworkers demonstrated the magnitude of errors in the mechanical work done by the leg at various flexor and extensor speeds when there was no correction for gravity (29). They found errors in work measurements exceeding 500% and errors in torque exceeding 79%. More recent dynamometers are interfaced with microprocessors which have software to correct for the effects of gravity. However, the methods used for this correction have not been described (26).

Mis-use of scientific terms

The Panel has noted that in the dynamometry literature there is a continuing misuse of scientific terms and units of measurement. Mayhew and Rothstein have reviewed the literature in this area and noted the use of terms that are less than precise (16,26). They urged that clinicians critically examine the jargon associated with isokinetic testing.

Assessment of trunk muscles

Need for normative data

Before the results of low back testing by dynamometry can be used in diagnosis and prognosis, they must be interpreted in the light of normative data from both normal subjects and patients with known abnormalities. At this time, the available normative data are very limited.

Some patient data for the IsoStation B-100 have been published. Seeds et al presented torque and range of motion data for 160 asymptomatic individuals (110 males and 50 females) collected as part of preplacement screening for local service and industry (30). Males outperformed females in all tests. There was some correlation of torque output to height and weight, which appeared to improve with increased resistance. Seeds et al urged further research to determine the significance of this correlation.

They also noted that graphs presenting secondary axes torque and range of motion data coincided with the patterns for the flexion/extension axis and were reproducible. This effect (which they called 'crosstalk') became less consistent or disappeared with controlled or guarded effort. They suggested that crosstalk might be an indication of patient effort. They urged that this effect be further researched as a possible determinant of effort level.

In a follow-up study, Seeds et al presented torque and range of motion data on 172 symptomatic low back patients (143 males and 29 females) who were two to seven days post-injury (31). They compared results with those obtained in the previous study. There were significant differences in all parameters between normal and abnormal patients. They observed reduced crosstalk effect which they again suggested might be an indicator of effort level. The Panel is not aware of any more recent work in this area.

The data obtained in these studies were limited by the size and lack of characterisation of the samples. The standard deviations cited for most values show an overlap in the data distributions of normal and abnormal populations considered.

Normative data for the B-200 are beginning to appear in the literature. Levene et al recently evaluated data from the B-200 on 200 males and 100 females with no prior history of LBP (32). The data were analysed for significant patterns and differences between the two populations. Males demonstrated greater range of motion values and higher isometric strength values than any in the female population. A coupling pattern (crosstalk) was observed for both males and females. The authors concluded that further normative studies are warranted to expand the knowledge base, value and accuracy of discrimination.

Sample population data have been compiled by Isotechnologies Inc. for the B-200 (33). The data were obtained from two studies on non-symptomatic populations. One population consisted of 42 males, whose ages ranged from 24 to 45 years, and the other of 33 females with the same age range. Each subject performed a total of 25 tests which included range of motion,isometric testing and dynamic testing during flexion/extension, rotation and lateral flexion at various resistances. For each resistance value, percentile distributions of the test results are given for each parameter (range of motion, maximum and average velocity, average torque and power).

The Panel has some reservations on the clinical usefulness of these data, because of the small sample size, limited characterisation of the population and the wide range in ages of the subjects. Performance is known to vary with a number of factors including age (Henke, personal communication) and, as far as the Panel is aware, such variation has not been taken into account.

The population data included in the standardised protocol referred to as the Occupational Orthopaedic Center (OOC) System (34) for the B-200 (used to determine whether the various test parameters of performance are acceptable) presents similar difficulties. Some details of the OOC system are given in Appendix 4.

It has been stated that the approach used in the OOC System simplifies both the development of a useful normative data base, and the interpretation of test results (34). The use of the percentage-based resistances, and ratios for characterisation of back dysfunction, is said to reduce the variation between subjects and approximates the power of a large normal data base of absolute values for test comparison.

The System was based on analysis of information collected on

103 subjects (51 normal and 52 abnormal). The discriminant function found was the best fit for that data set and contingency analysis on the same data set showed sensitivity of 86%, specificity of 88% and accuracy of 88%.

Advice tendered to the Panel (S Bennett, personal communication) suggests that the disciminant function would not be expected to perform as well on other samples as the results of the contingency analysis might indicate. In addition, as some of the ratios do not appear to have intrinsic meaning, performance of the discriminant function is made less certain. The population base upon which the System is based is small and requires better characterisation.

The ACRM has advised that the St George Hospital, Sydney is carrying out research with this machine to establish basic epidemiological data (24). The College considers that data on individual pathological conditions may not be available for some time. The College stresses that testing of the lower back is primarily for the establishment of clinical status as a base line against which clinical progress may be measured.

The Illawarra Rehabilitation Centre, Wollongong has also stated that there are at present, insufficient normative data and the results of testing in back injury remain impossible to interpret, either in terms of diagnostic or prognostic implication (35). At best, the measurement, if reliable, can serve as a baseline measure of function, measuring change after intervention.

There is evidence to suggest that inter-test variabilty of dynamometric measurements, as expressed by standard deviation, varies for athletes by up to 5%, for the normal population between 5%-15%, and for badly back-injured persons increases to over 50% (Henke, personal communication). Increased variability of performance for back-injured patients has also been observed by Seeds et al (31). The Panel is not aware of statistical analyses of measurements taken of groups of patients in the short or long term.

Mayer and Gatchel have commented that one of the limitations of quantification of spinal function is the small number of subjects available in the normative data base (18). They consider that ultimately large groups of normal subjects must be tested and job, age, gender and weight specific data must be collected. They also pointed out some of the difficulties in the use of weight-normalised data. They recommended additional research in these areas.

The Australian Physiotherapy Association has informed the Panel that most of its membership using low back testing dynamometers considered that the equipment is still an 'unknown quantity' and that further testing was necessary (36).

The Panel considers that much larger data sets for both normal subjects and individual types of abnormality must be developed before dynamometry can be used reliably either for diagnosis or prognosis.

Dynamometric parameters as predictors of function

An important question raised by muscle performance testing is whether measurements from such testing can be used to predict function. With regard to limb testing Mayhew and Rothstein have stated that critical levels of power and torque have not been determined for any activity (16).

In relation to the low back, Mayer and Gatchel have commented that current protocols do not address the issue of worker performance through the course of a full day of work (18). They suggest the development of specific endurance protocols for the spine/abdominal musculature ; once these endurance profiles are known for workers in specific job categories, the hope is that it would be possible to better gauge a worker's readiness for return to work.

The Panel considers that further work is required to identify and determine the parameters that could be used to assess whether a person is ready to resume work.

Portability of results

Machines currently available test muscle performance under a variety of conditions such as isometric, isokinetic and isoinertial, and in a variety of positions. Different types of muscle contractions are also tested (isometric, concentric and eccentric contractions). These differences together with the different mass characteristics of each type of machine make comparability of results impossible.

As new manufacturers enter the market, new normative databases for their products will need to be established and the necessary level of experience and skill to operate them will need to be acquired. Testing protocols for the same machines at different centres need to be the same to enable comparability of results.

Assessment of patient effort

It has been suggested to the Panel and reported in the literature (23) that variability and inconsistencies of curve shape (the graphical representation of torque generated by the patient plotted against angular displacement) help to evaluate patient effort.

It is argued that it is extremely difficult to produce consistent curves with submaximal effort. It is possible that dynamometry could be seen as a means to identify those patients deliberately attempting to falsify results. This interpretation of curve shape has been challenged in relation to limb testing (16,20).

The Panel considers that judgements concerning assessment of patient effort during testing are fraught with difficulty. A number of factors such as anxiety, depression, neuromuscular inhibition,fear of reinjury or fear of pain may cause patients to perform poorly or inconsistently during testing (23,18). Patients with such conditions should of course not be considered as part of the minority wanting to falsify results (23,18).

Mayer and Gatchel have stated that limitations of effort are only infrequently the result of conscious attempts by the patient to mislead the examiner and misrepresent true abilities (18). They consider that there is a need to clarify effort more objectively (18). They point out that although the principle that consistency of performance on multiple repetitions establishes good effort appears to have face value,it has also been shown that a trained individual, given optimum circumstances, may "beat the system". They conclude that performance variability produced by sub-optimal effort needs to be defined with specific protocols and that numerical limits of curve variability in large normal populations have yet to be defined (18).

The OOC System for the B-200(34) provides specific rules for determining whether the test results represent an individual's maximum effort. Tests showing such effort are classified by the OOC System as 'physiological', while tests which do not show maximal effort consistent with normal test behaviour are classified as 'non-physiological'. The distinction between a physiological and a non-physiological test is made by comparing different parameters and by examining changes in values from the first to the second test sequence. However the identification of a non-physiological test does not explain why the patient exerted a sub-maximal effort.

The Panel has not seen the results of any studies which are able to show effort levels.

The ACRM has expressed anxiety concerning the use of dynamometry to detect "malingering" patients. The College has pointed out that there are no published data that demonstrate that back dynamometry can determine whether or not a person is malingering (24). Smith has submitted that the concept that it is possible to distinguish between real and imaginary disability, or organic or functional disability, by the use of this technology is simplistic (37). Smith considers that there are functional differences between patients with illness behaviours, patients with organic disc disease, patients with muscular strains and sprains of the back and patients with psychological or chronic pain syndromes.

The Panel considers that more research is required to objectively define effort and believes that the use of this technology to detect "malingering" patients should be resisted.

Patient stabilization, positioning and posture

For trunk muscle evaluation, motion should be restricted to the area of interest. During testing the motion involves many articulations of the body including the hip joint, the lumbosacral junction, the lumbar intervertebral joints, the thoracic spine and the rib cage. Different types of dynamometers use different stabilization systems to reduce the unwanted movement. There appears to be a need for studies to determine whether there is adequate reproducibility of results using the various stabilization systems.

In most evaluations of the trunk muscles it has been assumed that all motion occurs about the L5-S1 axis. Some workers have placed the mechanical axis at the L2-3 junction, or the greater trochanter or the hip and it has been suggested that a single L5-S2 axis can be used (16). More recently, a study using a computerised simulation of motion of the lumbar spine concluded that the fixed axis of the testing machine should be placed at the L3 position and that further research is required to determine how much motion of the hips and thoracic spine is permitted (38).

The Panel believes that the results obtained from the different assumed mechanical axes of rotation will yield different measurements and their relationship and significance to functional tasks in real life situations is unclear. It is also important that the correct alignment of the assumed axis of motion be achieved consistently on an individual machine.

Patient testing is generally carried out in either the sitting or standing positions. It has been suggested that the advantages of the standing position are that it maintains the normal orientation of the spinal curves, reflects functional vertebral body positioning and simulates the way muscle groups act together in normal functional activities.

The Panel considers that further research is required on patient posture and stabilisation, and elucidation of the level of the spine about which motion is assumed during testing.

Operation and siting

The installation of low back testing machines presents few problems; in general the machines require a substantial base, a power supply of about 30 A single phase at 240 V AC, and sufficient space for patient handling, the machine itself and the computer console and printer.

The use and interpretation of results obtained from dynamometers require considerable practical experience. The Panel notes that, at present, most practical experience is gained from the USA where their use has been more extensive.

The Panel considers that an operator-in-training would need to examine at least 100 subjects, both normal and back injured, before any confidence could be developed in interpreting results.

Low back testing machines are usually operated by qualified physiotherapists, with referral of patients by medical practitioners. The Panel considers that it is essential that users of dynamometers work in close liaison with other health professionals, not necessarily on the same site, to provide an integrated evaluation and rehabilitation service. The Panel has noted the risk that these machines could be installed in establishments without reasonable access to the health professionals so essential for the evaluation and treatment of the back injured person. The Panel believes that such developments should not be encouraged.

Cost considerations

Capital and operating costs in dynamometry

The capital costs of these machines range from $80,000 to $270,000 (Table 1).

The following estimates of costs are based on the use of the IsoStation B-200. Table 2 sets out the main cost elements in operating the dynamometer. In estimating the operating cost the Panel has assumed that a physiotherapist is engaged full time to operate the B-200.

A typical back examination on a B-200 takes about one hour. An additional one hour is required for interpretation of results and report writing. The Panel has been informed that, in a private clinic, 800 assessments per year are possible using this machine (39).

Using this throughput and the calculated annual operating cost, the cost per test is estimated to be in the range $110-$125. This does not provide for return on investment.

TABLE 2

ESTIMATED ANNUAL OPERATING COST RANGE FOR THE ISOSTATION B-200

	$
Annualised Capital charges	19,400(a) - 31,100(b)
Salary of Physiotherapist	36,000
Salary On-costs	7,200
Equipment Maintenance	10,000
Space Rental	14,400
Administration Costs	1,000
Total annual operating cost range =	88,000 - 99,700

(a) Based on capital cost of $100,000, repaid over 10 years at 15% interest. No adjustment is made for inflation or tax deductions on interest.

(b) Based on capital cost of $100,000, repaid over 5 years at 19% interest. No adjustment is made for inflation or tax deductions on interest.

Potential national cost of dynamometry

To estimate the potential national cost of dynamometry, it would be necessary to have information on the number of persons likely to be tested and the number of tests per person. If 20,000 persons per annum (half those with work-related back injuries) were tested by dynamometry, three times each, about 75 machines would be required.

The potential cost of testing with these machines could be in the region of $6.6 to $7.5 million a year. More frequent testing per patient could increase this cost. If each patient was treated four times, the national cost would rise to between $8.8 to $10 million and about 100 machines would be required.

Benefits of dynamometric testing

It has been found both in Australia and in the USA that structured programs of rehabilitation requiring periods of several hours a day for about three weeks have had marked success (2). Success is defined as re-entry into the work place, or, where this was not a factor, resumption of an acceptable lifestyle. Early results from the spinal injury rehabilitation program in Perth indicates that a 60% success rate is feasible (Edwards, personal communicaiton).

However, in such programs there are many components to the rehabilitation program. It would be very difficult to attribute a particular contribution to the use of the dynamometer in terms of dollars saved .

The Panel is not aware of any reports which quantify the benefits of dynamometry in muscle testing generally in money terms.

Safety aspects

The Panel is not aware of any reports in the literature of injuries sustained by patients while being tested by low back testing dynamometers. It has been reported that muscle soreness has occurred after testing and patients are instructed to avoid jerky exertion during testing.

There is evidence to suggest that musculoskeletal injuries occur predominantly during eccentric activities (Edwards, personal communication). The Panel suggests that operators using machines capable of testing eccentric contractions adequately brief their patients and ensure that the testing protocol takes this matter into account.

Some dynamometers have extensive restraint systems used to minimize unwanted movements during testing. Discomfort may be experienced if there is excessive tensioning of the restraining straps. There is a potential for respiratory embarrassment or the adoption of a posture dissimilar to that assumed in performing the real life task which is being simulated.

Over the years dynamometers have been increasingly computerised with sophisticated software controlling the testing protocol. A general question arises about the safety of patients attached to automatic equipment. Opportunities for malfunctions arise from at least three different areas, the hardware used in the equipment, the controlling software and the performance of the operator. With increasing sophistication of these devices, there will be a growing need for operators and professional bodies involved in rehabilitation to be aware of the safety issues involved in the mechanisation of muscle and joint testing programs.

Conclusions

Low back pain continues to be a massive health problem in Australia, with major costs to the community. While preventative strategies should have a high priority in dealing with this condition, technologies which can assist in the diagnosis and management of back injured patients are also of major importance.

Dynamometers have the potential to assist in this area. There is continuing development of this technology and significant advances have occurred through the use of microprocessor-assisted data analysis and display.

However, the Panel notes that in their present state of development, there are limitations on the clinical usefulness of dynamometers. In particular, their usefulness in the diagnosis and prognosis of low back injury is limited by uncertainties in the interpretation of results.

As yet, there are insufficient normative data on different types of person and their performance on each machine. Those data that exist are based on small series of subjects which are not well defined. There is a lack of rigorous published studies in the literature, defining the reliability of dynamometric measurements in different populations and for different types of disability. In addition, a number of technical difficulties are inherent in the application of dynamometry to low back injury. While there has been extensive work in meeting these through design of new machines, not all have yet been resolved. Other limitations include the lack of portability of results between different types of machine. The Panel considers that further work is needed in all these areas.

Given the limitations of dynamometry in its current state of development, there would appear to be dangers in its use in a medico-legal sense to detect so called malingering patients. The interpretation of results is an area that requires further research, particularly in relation to interpretation of patient effort.

Evidence presented to the Panel indicates that dynamometry has a significant role as a means of monitoring progress in the rehabilitation of the back-injured patient. Successful rehabilitation programs have economic benefits for society as well as benefits to individuals in terms of quality of life, through returning patients to normal lifestyle when otherwise they would probably remain incapacitated and unable to work. In assessing these benefits, it would be difficult to quantify the contribution of dynamometry, which would depend on its integration with physiotherapy and other services. This difficult area deserves further study.

At this stage, it would be premature to rely solely on dynamometry in the assessment of a back-injured patient's readiness to return to work. Further protocol development is needed before the technology would give reliable results in this area.

Finally, there appears to be a need to further define appropriate protocols for positioning and handling patients being evaluated by dynamometry and for operators and the professional organisations involved to consider the safety issues involved in operation of these automated machines.

Dynamometry is a potentially useful technology in an area of major concern to Australian society, but requires further work if its full potential is to be realised.

The Panel considers that:

- Dynamometers are devices with a potential to usefully contribute to the assessment and management of LBP.

- When properly used, these machines can provide a quantitative measure of a patient's progress in a program of rehabilitation. Some machines may be more appropriate than others in providing a measure of fitness to undertake real life tasks.

- Dynamometers may also be capable of providing useful information on diagnosis and prognosis of a spectrum of conditions contributing to LBP. However, with the current status of the technology, additional work is needed on these applications, to define and improve levels of reliability. Further normative data for different types of subject and a range of normal and pathological conditions are required.

- The evaluation of different types of dynamometers should be encouraged and supported by users of the technology, employer groups and insurance agencies.

- The use of dynamometry to identify persons suspected of malingering is not supported in view of the uncertainties as to the reliability of the technology and data interpretation. Research should be undertaken to objectively define patient effort during testing.

- Use of the technology should be integrated with appropriate health services required to manage back-injured persons.

APPENDIX 1

MUSCULOSKELETAL MOVEMENT

Detailed descriptions of the muscular system and how skeletal muscles produce movement are provided in the many textbooks on anatomy and physiology. For the purposes of this report a brief description of how skeletal muscles produce movement and the types of muscle contractions producing those movements is given.

Skeletal muscles produce movements by exerting force on tendons, which in turn pull on bones. Most muscles cross at least one joint and are attached to the articulating bones that form the joint. When such a muscle contracts, it draws articulating bone toward the other. The two articulating bones usually do not move equally in response to the contraction. One is held nearly in its original position because other muscles contract to pull it in the opposite direction or because its structure makes it less movable.

In producing a body movement, bones act as levers and the joints function as fulcrums of these levers. The mechanical advantage gained by a lever is largely responsible for a muscle's performance and range of motion. The muscle performance and range of motion both depend on the placement of muscle attachments relative to the joint.

Most muscle movements are coordinated by several skeletal muscles acting in groups rather than individually. A muscle that causes a desired action is referred to as the agonist or prime mover. Simultaneously with the contraction of the agonist, another muscle, called the antagonist, is usually relaxing. Other muscles called synergists or fixators, assist the agonist by reducing undesired action or unnecessary movements in the less mobile articulating bone. Many muscles are, at various times, prime movers, antagonists, or synergists, depending on the action.

In describing movements occurring at joints a number of terms are used. Flexion decreases the angle between parts of the body by moving the adjacent parts together. The action of extension is the opposite of flexion. Using the hand as an example,the fingers are flexed in making a fist. The extensor muscles of the fingers open or straighten out the closed fist. Abduction moves a part away from the body and adduction moves a part closer. In the hand,abduction spreads the fingers and adduction brings them back together. Rotation turns a part of the body around a pivotal point.Circumduction is an action in which a cone is circumscribed by the movement of a part,such as moving the hand in a circle. Pronation and supination are actions limited to the forearm and hand. Pronation turns the palms downward and supination turns the palms upward. Inversion and eversion are limited to actions of the foot. Inversion turns the sole inward toward the body and eversion does the opposite action.

There are three types of muscle contractions classified according to the external load, direction of action and magnitude; these are isometric, concentric and eccentric.

Isometric contraction occurs when there is no change in joint angle with muscle contraction. An example of such a contraction is when one pushes against an immovable wall.

Concentric contraction refers to the type of contraction that occurs when the muscle shortens while moving a load. The term describes the situation in which the net movement is in the same direction as the change in the joint angle.

Eccentric contraction describes the situation when the muscle is forcibly lengthened as it is contracting. An example of this contraction type is the lowering of a weight. As the forearm extends, the elbow flexor muscles will lengthen under tension. Such contractions are typically used in resisting gravity or when running or walking down inclines. A large percentage of injuries are acquired during eccentric movement.

Isotonic contraction occurs when a muscle is providing a constant force to an external load. The characteristics of real life tasks in the presence of gravity are such that true isotonic contraction never occurs.

Human movements are limited by two external factors: these are (i) the mass of the parts being moved, and (ii) the gravitational forces acting on these masses. For both factors, the movements are mass-limited. To move a limb from position A to position B, starting and finishing at rest, a force must first be applied in the appropriate direction, which will accelerate the limb in proportion to the force applied (Newton's Second Law). Having accelerated it to an appropriate velocity (over about half the total distance to be travelled) a decelerating force in the reverse direction must then be applied, until the limb is brought to rest as desired.

This process usually occurs in the Earth's gravitational field, so that the gravitational forces acting on the limb may often be used in part to substitute for muscular forces. Accelerations of 10 metres per second per second (ms^{-2}) against gravity, and 30 ms^{-2} with gravity are typical: humans were evolved to operate in a 10 ms^{-2} (one g) gravitational field.

When a human being is operating on an external object, the situation is complicated by the characteristics of the object: it may consist of a mass only, or a manipulandum (such as a car steering wheel) with the characteristics of viscosity and stiffness (as in a spring) as well as mass. Even if the object has mass only, if it is resting on a horizontal surface, there are two components involved in moving it: (i) an upward force equal to the force of gravity acting on its mass must be applied, to produce any movement at all and (ii) an additional upward force must be applied, to accelerate it upward according to Newton's Second Law.

APPENDIX 2

PARAMETERS AND UNITS OF DYNAMOMETRIC MEASUREMENTS

The parameters used to describe muscle performance are derived from Newtonian physics using the basic quantities of mass, length and time. Table 3 gives the units for the basic quantities and parameters commonly used for linear measurements. Two systems of units are used in dynamometry the FPS (Practical Unit) and the preferred system of scientific units, the Systeme Internationale (SI).

For many movements, it is better to treat the system as rotational, pivoted about a point. In such a case moment of inertia replaces mass, angular movement replaces linear movement, and angular viscosity and stiffness replace linear viscosity and stiffness. Table 4 gives the units for rotational movements.

Other parameters and terms used in the evaluation of muscle performance are:

Range of Motion:	the total angle through which movement has been undertaken.
Maximum Torque:	the greatest quantity of torque recorded during a given period of time.
Average Torque:	the average of all the torques recorded during a given period of time.

Similar definitions apply to maximum angular velocity and average angular velocity.

TABLE 3

UNITS AND PARAMETERS FOR LINEAR MEASURE

QUANTITY		DIMENSION	SI UNIT (4)	FPS (PRACTICAL) UNIT
Displacement	(x)	L	metre m	ft
Velocity	($\dot{x}$)	LT^{-1}	metre/sec $m\ s^{-1}$	$ft\ s^{-1}$
Acceleration	($\ddot{x}$)	LT^{-2}	metre/sec^2 $m\ s^{-2}$	$ft\ s^{-2}$
Force	(F)	MLT^{-2}	Newton $N = kg\ m\ s^{-2}$	lb of force (1) (lbf, lbs)
Mass	(M)	M	kilogram kg	lb
Viscosity	(R)(3)	MT^{-1}	$N\ s\ m^{-1} = kg\ s^{-1}$	$lbf\ s\ ft^{-1}$
Stiffness	K	MT^{-2}	$N\ m^{-1} = kg\ s^{-2}$	$lbf\ ft^{-1}$

TABLE 4

UNITS AND PARAMETERS FOR ROTATIONAL MEASURE

QUANTITY		DIMENSION	SI UNIT (4)	FPS (PRACTICAL) UNIT
Angular displacement	(Θ)	dimensionless	radian (r)	deg
Angular velocity	($\dot{\Theta}$)	T^{-1}	$r\ s^{-1}$	$deg\ s^{-1}$
Angular acceleration	($\ddot{\Theta}$)	T^{-2}	$r\ s^{-2}$	$deg\ s^{-2}$
Torque	(T)	ML^2T^{-2}	$N\ m = kg\ m^2\ s^{-2}$	lbf ft (2)
Moment of Inertia	(I)	ML^2	$N\ m\ s^{-2} = kg\ m^2$	$lb\ ft^2$
Angular viscosity	(R')(3)	ML^2T^{-1}	$N\ m\ s = kg\ m^2\ s^{-1}$	$lb\ ft^2s^{-1}$
Angular Stiffness	(K')	ML^2T^{-1}	$N\ m = kg\ m^2s^{-2}$	$lb\ ft^2s^{-2}$

NOTES ON TABLES 3 AND 4

(1) A force of 1 Newton produces an acceleration of 1 m s^{-2} in a mass of 1 kg. However, a pound of force produces an acceleration of 32 ft per s^{-2} in a mass of 1 lb. This causes great confusion in the dynamometry literature, especially as the pound of force is often abbreviated as lbf or lbs, or is simply written incorrectly as lb.

(2) Similarly in angular measure, lbf.ft or lbs.ft is often wrongly written as lb.ft (or ft.lb, which is the unit of work).

(3) In the technical literature, viscosity is usually called resistance. The dynamometry literature wrongly often refers to mass, moment of inertia or even torque as being "resistance".

(4) It would be desirable for all measurements to be expressed in metric units, and most dynamometers give the option of SI or FPS units by means of their attached computers. However, the bulk of the literature is from the USA, where there is a marked preference for feet, pounds and seconds.

Source: Dewhurst, report to the NHTAP, May 1988

APPENDIX 3

DYNAMOMETERS FOR LIMB TESTING

Cable Tensiometers

In 1948 Clarke reported how tensiometers could be used for the measurement of muscle performance (16). One end of a cable is attached to a fixed object and the other end is attached to a limb segment. The tensiometer is placed at some point between the two sites of fixation. As the cable is pulled a force is applied to the tensiometer which is connected to a calibrated gauge. Although cable tensiometers have been used for the evaluation of most movements of the trunk and extremities over the last 40 years, they are not used frequently in clinical practice. Cable tensiometers measure isometric performance.

Strain Gauge Dynamometers

These devices operate on the principle that loads applied to materials cause deformation which leads to a change in their electrical resistance. Loads are usually applied to the surfaces of metal rings or rods. For muscle evaluation the metal ring or rod is attached to an object that the limb segment can either push or pull against thus causing either compressive or tensile strain. Many strain-gauge devices have been described in the research literature but it appears that these are not used often in clinical settings. Strain guages are, however, sometimes included in modern dynamometers. Strain gauge dynamometers measure isometric performance.

Hand-held Dynamometers

Hand-held dynamometers vary in their methods of translating force into units of measurement, but their modes of application are similar. Typically the patient is asked to push the limb under test maximally against the measuring head of the device held by the examiner who resists the patient's movement. A reading is taken when the patient "breaks" that is when the patient is unable to resist the examiner's force. Most often the force of the patient pushing against the device is translated linearly by an oil-filled chamber to a pressure gauge. Strain gauges are sometimes used. A number of these devices are available commercially (16, 40-42).

Hand Dynamometers

Various instruments have been used to quantify the forces generated during gripping. Often the patient is asked to squeeze and hold and the force generated is recorded by a machine strain gauge, spring scale or hydraulic system. are available with adjustable handle widths and diameters (43,44). It has been suggested that grip measurements can be of value in the diagnosis and prognosis of occupation related injuries (43,44). Hand dynamometers provide a measure of isometric muscle contraction.

Isokinetic Dynamometers

The concept of isokinetic (constant velocity) exercise was developed in 1967 (45). In this form of exercise a muscle contracts and shortens against a mechanical braking device at a controlled speed so that the resistance is accommodating to a muscle force at each point in the range of motion. A useful review and bibliography of isokinetic dynamometry has been published by Osternig (46).

The development of the Cybex isokinetic dynamometer in 1967 enabled constant velocity exercise and testing. Subsequent development of commercial isokinetic dynamometers has made the use of isokinetic testing widespread. During the past decade the Cybex II (manufactured by Cybex, Division of Lumex Inc. Ronkonkoma, New York) has been the most commonly used machine for the clinical measurement of muscle performance of the extremities. The use of this machine dominates current dynamometry literature.

The Cybex II consists of a movable lever arm controlled by an electronic servomotor that can be set for angular velocities from 0 to 300 degrees per second. The lever arm is attached to a subject's limb and the subject is then asked to move the limb as fast as possible. When the subject attempts to exceed the pre-set machine speed,the machine resists the movement.

The machine is designed to maintain limb movement at a constant angular velocity and provide accommodating resistance. A hydraulic load cell within the machine measures the resistance needed to keep the limb from exceeding the machine's pre-set speed. Many of the machines have facilities to enable the acquisition of goniometric (joint motion) data. A microprocessor provides a digital printout and calculates variables such as torque, power and work.

Cybex dynamometers for leg injury assessment and rehabilitation are widespread in Australia (at about 40 sites), being used almost entirely in sports medicine. Machines assess concentric muscle contractions.

Recently many other devices, most notably the Kin-Com dynamometer, (Chattecx Corporation, Chattanooga, Tennessee) have been introduced and reports describing their measurement capabilities are now appearing (47-49). The

Kin-Com is primarily designed to assess the musculature of the knee joint. There are about 14 installations in Australia.

The basic load is provided by a hydraulic torque via a rotating lever arm. The load [from moment to moment] is computer controlled so that by modification of the software isometric, isotonic or isokinetic loads can be simulated The force generated by the subject is measured by a strain gauge mounted on the rotating lever arm. Facilities for the measurement of electrical activity (electromyography) of selected muscle groups are available. This machine is able to assess eccentric as well as concentric muscle contractions.

Attachments are available for these machines that permit almost any body movement to be tested.

APPENDIX 4

DYNAMOMETERS FOR BACK TESTING

Isotechnologies Inc.

The IsoStation B-200 (and its earlier version the B-100) are manufactured by this company. The B-200 was introduced in 1987 and its predecessor in 1984. The B-200 is designed specifically for low back measurements. Only concentric movements are measured. This machine is the most widely used in Australia for evaluation of the trunk muscles.

The IsoStation B200 is a hydraulic unit with three independent axes of motion corresponding to those for flexion/extension, lateral bending and rotation. The axes can be used independently or in any combination. Three separate hydraulic pumps allow the tester to dial (in any axis) a minimal load that must be overcome in order to move the machine. The machine is not isokinetic but is described by the manufacturer as isoinertial.

The machine is isometric (see Appendix 1) to a pre-set load which is set by the operator. Above this load it provides a constant viscosity and hence the velocity of movement produced is proportional to the force being applied by the patient. This is intended to simulate the type of load commonly encountered in every day situations of lifting a load. Eccentric loading is not available. The system is controlled by a microprocessor which also serves to acquire, process, display and store patient data.

The first step in placement of the patient in the machine is the alignment of the machine's flexion/extension and lateral bending axes with the patient's lumbo-sacral interspace (L5/S1). The patient stands on an electrical elevator which is moved up or down and the alignment is approximated by palpation. When the patient is positioned, the patient's thighs, pelvis and thorax are restrained to minimize the contribution of those body parts to the movement. The restraint system can be adjusted to accommodate different body sizes. When the patient is secured the height of the elevator plate is recorded to facilitate patient placement in future testing sessions.

Isotechnologies Inc. has published a back evaluation system developed by the Occupational Orthopaedic Center,Rhode Island, in the USA and is known as the OOC System (34). The OOC System uses a standardised test protocol. Before testing patients are familiarised with the B-200 and the testing procedures. Active tester participation, giving specific directions and encouragement during testing is also important in the OOC System. The test protocol takes about 30 minutes to complete.

Unresisted range of motion in each plane is measured twice; at the beginning of the test and after the first dynamic sequence. The patient is asked to exert an isometric effort about each axis, and the results of the isometric test are used to establish the resistances for two dynamic test sequences. In both the dynamic test sequences the patient is asked to move in each plane as hard and as rapidly as possible. Motions are repeated five times. During the first sequence, the patient works against resistances set at 25% and then at 50% of the maximum isometric torques. The order of the resistances is reversed in the second sequence without informing the patient of the change.

To evaluate back function the OOC System relies on ten parameters from the tests, seven of which consist of ratios. Test results for each parameter are first scored as normal or abnormal according to specific statstically-based rules. Degrees of back dysfunction (mild, moderate or severe) are classified according to the number of occurrences of subnormal test values for certain parameters.Test behaviour is also characterised as physiological or non-physiological (those tests which do not show maximal effort).

The OOC System provides some guidelines on how non-physiological tests should be treated. It points out that an initial non-physiological test should not be construed as indicating malingering. Patients are treated even where there is a high number of non-physiological indicators. After two weeks, these patients are re-tested and if the test shows no improvement or remains non-physiological, initial psychological screening is re-assessed and further testing undertaken. If further psychological screening is positive, patients are requested to undergo councelling and gain psychological clearance before treatment is resumed.

The OOC System also furnishes data called the Baseline Rehabilitation Data on the report printout; these data are a rank percentile range, fifth through ninety-fifth percentile, calculated for some of the variables in the normal database. The printout graphically represents, based on this percentile range, the patient's isometric strength as left and right for rotation and lateral flexion, isometric strength for flexion and extension, maximum velocities and dynamic maximum torque/resistance for both test sequences. Any data below the twentieth percentile are considered abnormal from a functional perspective.

The IsoStation B-200 is the only device currently available that is able to take measurements of trunk muscle performance in the three cardinal axes simultaneouly.

Cybex

Early Cybex dynamometers were unsuited to measurements on the musculature of the low back. The company has adapted its basic isokinetic dynamometer system for this purpose and in 1987 released the Cybex Back System. This consists of three pieces of equipment which include the trunk

Extension/Flexion Unit (TEF), the Torso Rotation Unit (TR) and the Liftask Unit (LT). These units perform testing under isometric and multispeed isokinetic conditions.

Testing with the TEF unit is undertaken with the patient in a standing position, with stabilization occurring across the chest, at the pelvis and above and below the slightly flexed knees. Motion occurs through an axis set at the L5/S1 level. Isometric measurements may be taken at any point along the range of motion and multispeed protocols are available. Gravity correction is available. The unit is connected to a computer which records and provides graphic and numerical analyses of the measurements taken.

Testing with the TR unit is undertaken in the seated hip-abducted position, with an axially mounted dynamometer. Motion occurs at the L5/S1 level. The output obtained is displayed through the same computer system as with the TEF unit.

The LF unit is a lift simulator and comprises a lifting handle on a cable attached to the dynamometer. Because there is no anatomic stabilisation a wide selection of body positons and lifting styles can be used during a test protocol.

Reports of the use of prototypes of these units have appeared in the literature (17,50).

Chattecx Corporation

A back attachment can be purchased for the Kin-Com to enable testing of trunk musculature in flexion and extension in the sitting position. However, fixation of the patient in the machine is not well defined. The machine allows for isometric and multispeed isokinetic measurements. A motor-driven forced resistance capability permits measurement of eccentric as well as concentric contractions. The machine is capable of measuring either flexion or extension at one time only, with the interscapular bar being pushed by the subject in extension.

Risk of injury in the eccentric mode is decreased by a computer controlled "lock out" device that stops the motion of the dynamometer arm when the subject breaks contact with the arm, causing the resistance to drop below a predetermined minimum. A computer provides graphics and calculations of performance parameters of interest. A voice synthesizer provides auditory feedback to operator and subject.

The manufacturers claim that ability to assess trunk muscles eccentrically is unique to this machine. The distributor in Australia has advised that the Kin-Com is not a back testing machine but a machine that can be adapted to provide some facility for back testing.

Universal Gym Equipment

The back flexion/extension module of the Merac system, marketed by this company, attaches directly to the Merac base unit dynamometer. The module allows for testing in a variety of positions from 90 degrees hip flexed to standing. The system offers isokinetic and isotonic testing programs and is interfaced to a computer.

The Panel is not aware of reports in the literature concerning the use of this device.

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