THE EPIDEMIOLOGY OF BACK PAIN:
COMPARATIVE STUDIES AND ERGONOMIC INVESTIGATIONS OF RISK FACTORS IN THE NURSING PROFESSION

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ABSTRACT

The aim of the work within this thesis was to i) establish epidemiological parameters relating to the occurrence of back pain amongst nursing personnel and members of the general population, ii) quantify spinal responses to manual-handling, occupational activities and tasks perceived as potentially injurious to nursing personnel, and iii) establish the repeatability of trunk muscle strength assessment and the efficacy of physical training on trunk muscle strength and manual handling capability.

The epidemiological studies established back pain prevalence rates for nursing personnel: point prevalence 24.4%, annual prevalence 58.8% and lifetime prevalence 61.4%. The equivalent prevalence figures derived from non-nursing respondents were 25.1%, 57.8% and 58.9% respectively. The sickness absence caused by back pain symptoms in terms of days off work due specifically to back pain were also comparable. Nurses attributed their back pain to patient handling and lifting activities, in particular, the task of positioning a patient in bed was implicated as causative in the onset of back pain symptoms. It was established that there has been approximately a 40% increase in the prevalence of back pain amongst nursing personnel over a ten year period. There was not a concomitant increase in the quantity of absence from work due to back pain.

Investigations of the compressive loads imposed on the vertebral column utilised the technique of measuring changes in stature. Dynamic lifting tasks, transferring a load from the floor to a height of 76 cm, induced greater loss of stature than either isometric lifting or an asymmetric lifting activity. Subjects with a lifetime prevalence of back pain amongst the nursing sample did not show differences in response to spinal loading compared to asymptomatic individuals. In a separate study, the compressive loads imposed by the repetition of the task of transferring a patient from the bed to chair were investigated. Loss of stature was not influenced by the existence of chronic back pain symptoms amongst nursing personnel.

Reduced strength capabilities have been demonstrated among back pain populations and physical training may help to reduce the incidence of back pain symptoms. The repeatability of apparatus used to assess trunk muscle strength was established using contemporary statistical techniques. Although variability between test and retest was apparent at three angular velocities (1.05, 1.57 and 2.09 $rad.s^{-1}$) particularly at the slowest angular velocity, the magnitude of this variation in comparison with other isokinetic devices could not be established. The assessment of trunk muscle strength may be endorsed at the faster angular velocities and within asymptomatic populations. Improvements in trunk muscle strength and manual handling skills were observed following a 10-week period of physical training. The results demonstrated the beneficial effects of physical training programmes for personnel involved in occupations demanding manual handling.

These research findings indicate that back pain may be ubiquitous within society and that the perceived causes of back pain are not wholly responsible for symptoms. There is a need to differentiate between individuals who do and who do not display signs of disability caused by back pain. Differentiation between the mode of onset of back pain (acute vs insidious) may also aid the identification of predisposing factors.

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Chapter One

Introduction

1 INTRODUCTION

Back pain may be described as one of the major scourges in the United Kingdom and throughout the industrialised nations, with symptoms afflicting an estimated 50 - 80% of the population at some time during their lives (Kelsey and White, 1980). The prevalence of back problems is not limited to contemporary populations; the scriptures of Hippocrates (400 BC) refer to manipulation and traction being used to treat back pain. Lifestyles may have changed greatly since then but back pain still exists despite advances in basic science, diagnostic techniques and treatments for symptoms. In accordance with these changes, it has become acceptable to measure the severity of back problems by the disability caused by symptoms.

Whilst the personal costs borne by the condition are immense there are other factors which indicate the extent and severity of the problem. Apart from the common cold, back pain is the single biggest cause of absence from work in this country. The latest statistics from The National Back Pain Association testify that there were 93 million certified days of incapacity due to back pain within the United Kingdom in 1992-1993. This figure is derived from Sickness and Invalidity Benefit claimants. It demonstrates an increase of 20% on the previous year and represents an estimated loss of £5.7 billion to the UK economy (production costs, the cost of National Health Service provision and Department of Social Security benefits). The true figure is likely to be a great deal worse than these official data suggest as much suffering is endured without certification. In recognition of the scale and consequences of the problem, much research has been initiated into the possible causes and measures of prevention required to curtail the further expansion of symptoms and the disability caused by them.

Back pain is a symptom, the severity of which varies from minor aches to excruciating pain. Back pain may be regarded by some individuals as a temporary inconvenience, for others the pain may be chronic and severe. Objective assessment of back pain is difficult due to subjective reporting of sensations by sufferers. In addition, the tolerance levels of individuals will vary with respect to pain and such thresholds are prone to influence from social and emotional factors. The relationship between the prevalence of back pain symptoms and radiological evidence of disc degeneration is poor. Pathological abnormalities do not always predispose an individual to suffer back pain and similarly, an individual with an apparently healthy spine may experience severe back pain. The mechanisms underlying this inconsistency have yet to be explained and idiopathic back pain is now recognised as a major health problem.

The multifactorial aetiology of back pain makes the identification and isolation of specific causes of symptoms difficult. In certain cases traumatic antecedents may be identified but more often the aetiology is obscure. When the diagnosis of the cause of pain is unclear, subsequent prognosis is uncertain. However, factors that place individuals at risk or predispose an individual to back pain have been identified (Troup and Edwards, 1985). As posture is a major factor in the onset of pain, it therefore follows that occupational factors are recognised as likely to cause back pain. Epidemiological studies have been conducted among various occupations and members of the general population. The nursing profession has demonstrated relatively high prevalence rates of back pain compared to other occupations (Buckle, 1987). Lifting, particularly in relation to muscular strength and/or endurance, bending and twisting moves, pushing and pulling, static work postures (stooping) and repetitive work have all been proposed as contributory factors to the onset of back pain in the general population (Plowman, 1992). These actions all form part of the routine work of nursing personnel.

Recognition of the relationship between low back pain and occupational factors has generated the need for ergonomic evaluation of working situations. An ergonomics approach to workplace evaluation takes into consideration the workload, the capacity of the worker and the consequences of the workload in terms of health, comfort and safety. Epidemiological information from working populations and data regarding the measurement of the loads imposed on the spine during activities are two complementary approaches applied in order to assess the role of mechanical factors in the occurrence of back pain symptoms from an ergonomics perspective.

Nurses are trained in the performance of lifting procedures. Lifting techniques may vary depending on the size and condition of the patient and the co-operation the patient is able to provide. The number of nurses available to assist in manoeuvres and the working environment (the equipment provided, for example, hoists and the area in which work is performed) are also factors associated with the selection of a lifting technique. It is therefore difficult to simulate all aspects of nursing work under laboratory conditions. Nevertheless, controlled experiments incorporating selected nursing tasks or their component actions do yield biomechanical information regarding posture and the loads acting on the human spine.

Measurement of the changes in stature induced by acute loading conditions has been validated amongst healthy individuals as a reliable method of quantifying the load placed on the spine during activities *in-vivo* (Corlett et al., 1987). Changes in stature represent loss of disc height within the vertebral column due to compression. The non-invasive measurement technique has been applied to assess the acute consequences of the performance of both occupational (Foreman and Troup, 1987) and sports activities (Boocock, 1988). The relationship between changes in stature and low back pain has not been investigated extensively. However, the application of the methodology as a diagnostic tool for patients suffering ankylosing spondylitis has been demonstrated in terms of reduced diurnal variation in stature being associated with this condition (Hindle et al., 1987).

The benefits of physical activity to chronic low back pain patients in terms of rehabilitation are well documented but perhaps more important is the application of physical training in the prevention of back pain symptoms. Muscular strength has been demonstrated as a significant factor in the prevention of and rehabilitation from musculoskeletal dysfunction such that without adequate trunk muscle strength and stabilisation of the ligaments, injury or loss of optimal function may result (Smidt et al., 1991). Investigations of trunk muscle strength and training have been directed towards the rehabilitation from, diagnosis or prediction of back pain, but the efficacy of muscle strength training within an occupational context is less well documented. Few studies have attempted to determine the consequences of muscle strength training on lifting capability and the performance of dynamic movements. In occupations demanding manual-handling and lifting activities, the health and productivity of the worker are of prime importance and it is possible that training programmes may help to reduce the incidence of back pain symptoms.

The identification of weakness in the trunk musculature as a risk factor in the incidence of back pain and/or injury has highlighted the application of pre-employment screening for individuals undertaking manual handling at work. Among the methods utilised to detect weakness of the trunk musculature, are psychophysical lifting tests and isokinetic dynamometry. Functional assessment has implications for the identification of individuals capable of performing manual handling manoeuvres but for the results of functional assessments to be interpreted correctly, the assessment technique should be deemed repeatable/reliable.

It is the purpose of this thesis to investigate the severity and implications of back pain and back injury amongst the nursing profession. In combination with comparative studies and ergonomic investigations, risk factors such as lifting/handling that may predispose individuals to back injury/pain will be examined. These will result in the formulation of recommendations in order to reduce the escalating impact of back pain disability amongst occupational groups involved in the manual transfer of loads.

Chapter Two

Aims and Objectives

2 AIMS AND OBJECTIVES

Multidisciplinary investigative strategies have been adopted within this thesis in order to fulfil the following aims:-

i) Establish the incidence and prevalence of back pain in nursing personnel and non-nursing members of the population.

ii) Quantify spinal responses to manual-handling, occupational activities and tasks perceived as potentially injurious to nursing personnel.

iii) Explore the relationship between spinal shrinkage and physiological responses to selected lifting tasks.

iv) Establish the reliability of functional assessment relating to human trunk musculature.

v) Establish the efficacy of physical training on muscle strength and manual lifting skills.

vi) Attempt to interpret the result of the above studies with regard to the problem of back pain amongst the nursing profession.

Fulfilment of these aims will not only determine the magnitude of the problem of back pain in nursing personnel, but also help to identify the risk factors associated with nursing work with respect to the incidence of back pain.

These aims will be fulfilled by the following objectives:-

1 a) The design of two questionnaires for distribution among i) nursing personnel, and ii) non-nursing members of the population.

1 b) The design of an interview procedure to establish tasks perceived by nursing personnel to be stressful.

2. The application of computer-aided stadiometry to measure changes in stature following static and dynamic lifting activities and occupational tasks.

3. Utilise heart rate as an indicator of physiological strain in order to examine correlations between spinal responses to static and dynamic lifting activities and changes in heart rate.

4. The collection of isokinetic data relating to the strength of the trunk musculature.

5. The design and implementation of a 10-week muscle strength training programme incorporating progressive resistance exercises.

6. The collation of research findings with a view towards their synthesis.

The complex nature of back pain in terms of its recognition, causes, symptoms and prevention is acknowledged within the project. The work will progress from the acquisition of comprehensive epidemiological information to the analysis of the performance of the musculoskeletal system during specific activities (occupational and functional). This advancement will demonstrate the applicability of multidisciplinary research methods to appraise ergonomically the work of nursing personnel with respect to back pain and spinal loading.

Chapter Three

Theoretical and Methodological Background

3 THEORETICAL AND METHODOLOGICAL BACKGROUND

This section will acquaint the reader with the functional anatomy of the spine, the problem of low back pain, and the methodologies that have been applied to assess muscle function and measures of manual handling capability. These topics embody the fundamental background necessary to appreciate the investigative strategies employed in the experimental chapters of this thesis.

Epidemiological aspects of low back pain will be considered following an explanation of the anatomical structure of the human spine. Back pain and/or injuries cannot be fully understood without reference to the composition of the vertebral column and associated structures. These will be examined in detail and are particularly relevant in section 4.3. of the following chapter.

3.1 FUNCTIONAL ANATOMY OF THE SPINE

3.1.1 Anatomical structure and movement of the vertebral column (with particular reference to the lumbar spine)

The human spine (Figure 3.1) is a complex, supportive structure consisting of vertebrae, discs and ligaments. The interaction of these structures with muscles enables the distribution of forces through the body, allows movement of the trunk and provides protection for the spinal cord.

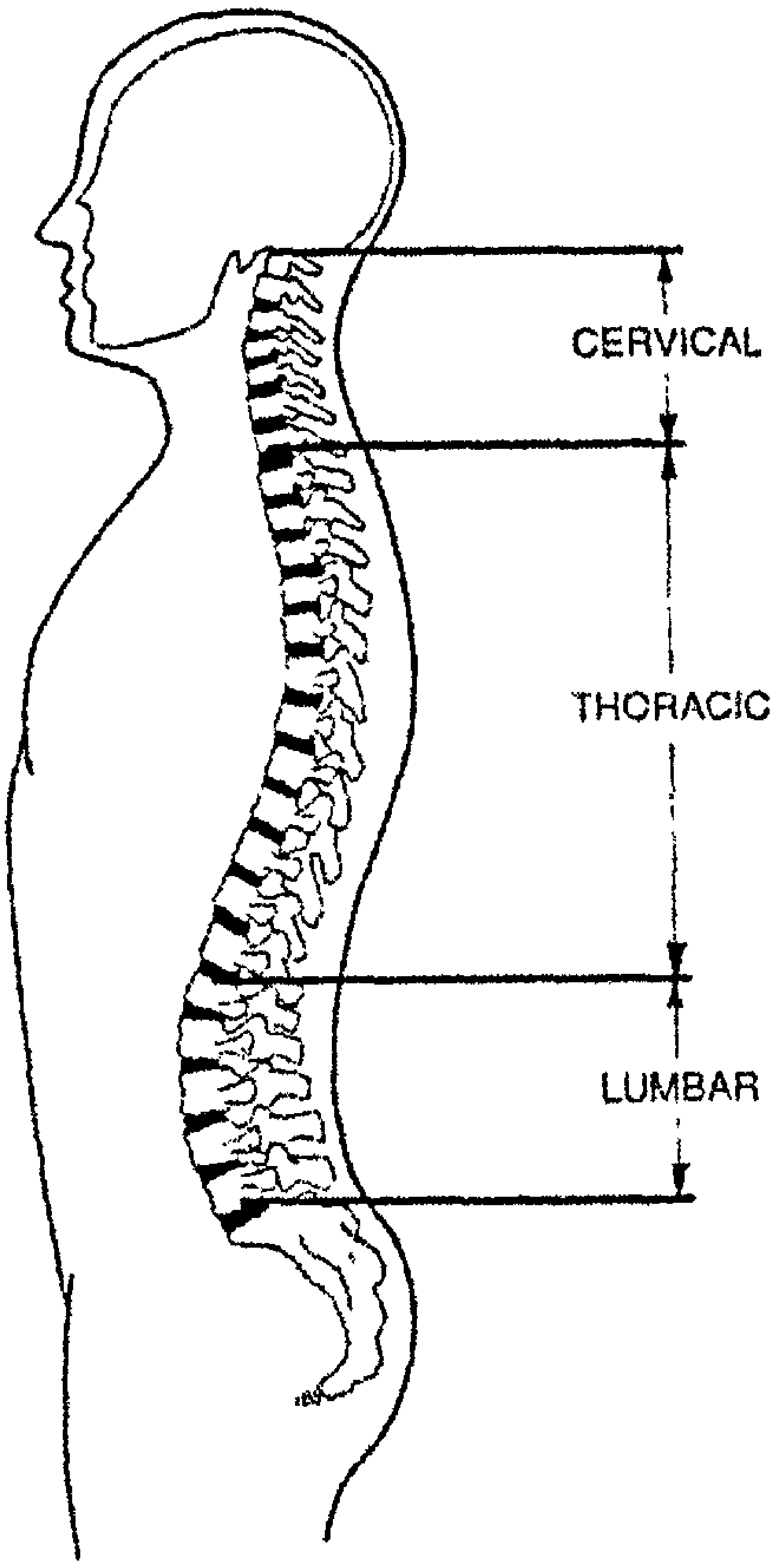


Figure 3.1 The vertebral column

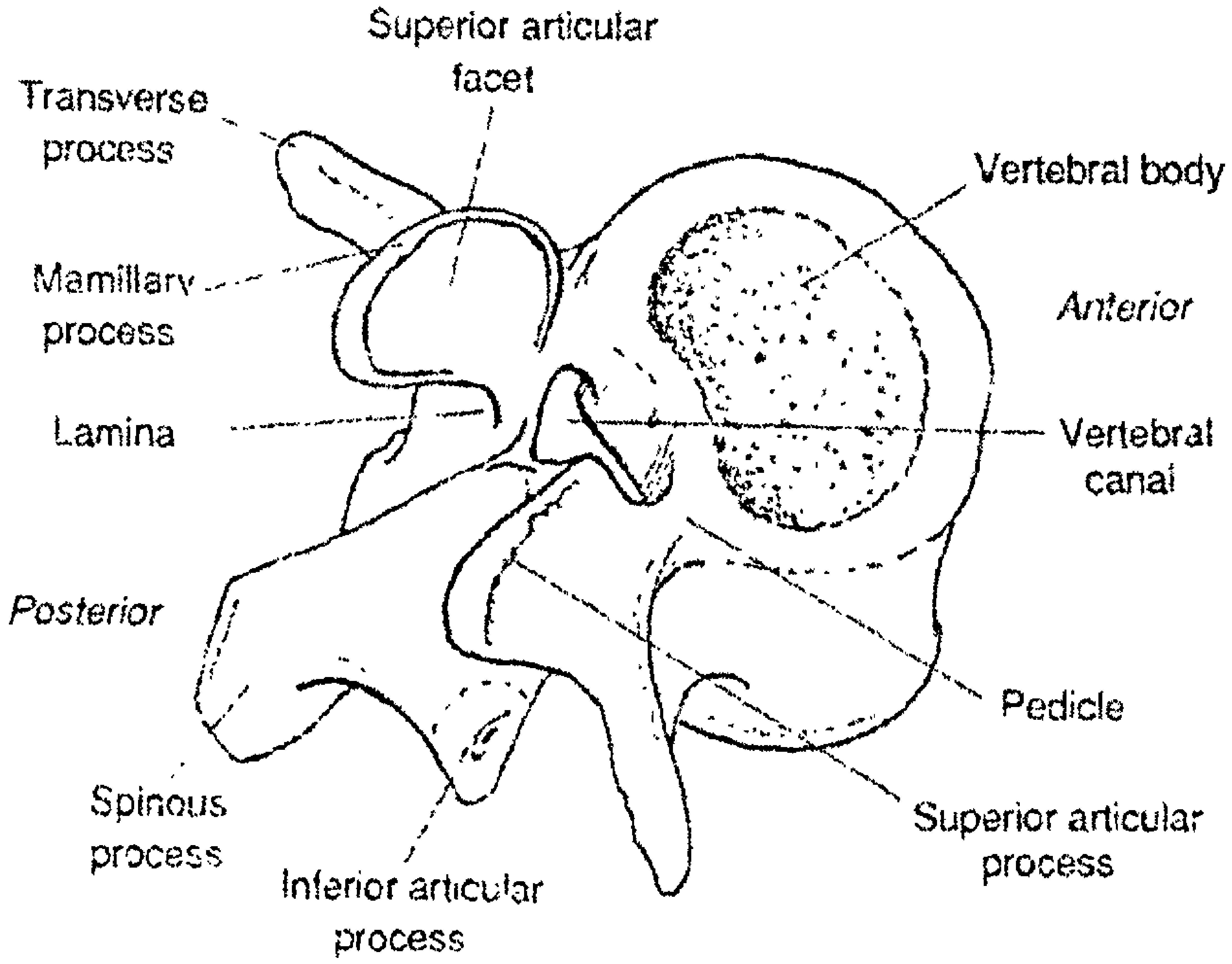


Figure 3.2 A typical lumbar vertebra

Laterally, the vertebral column displays five curves in the upright posture: two cervical (the upper curve is concave, occiput-axis; the lower curve is convex, axis-T2), thoracic (concave, T2-T12), lumbar (convex, T12-lumbosacral junction) and the anterior concave curvature of the sacrum and coccyx. The curves assist in the dissipation of vertical compressive forces acting on the spine as the ligaments play a shock-absorbing role. Twenty-four articulating vertebrae comprise the cervical, thoracic and lumbar regions of the spinal column. The vertebrae are inter-connected by ligaments and intervertebral discs; the discs comprise approximately one fifth of the length of the spine. The sacrum and coccyx are formed from five and four fused vertebrae, respectively. These structures form the posterior wall of the pelvis which articulates with the hip bones through the sacroiliac joints.

All the vertebrae and intervertebral discs have similar basic structures but with small variations at each level. These differences reflect the various functions of the vertebral column. It is beyond the scope of this thesis to describe each vertebral and disc type in detail; the features of functional importance for the cervical and thoracic spines are mentioned below although the intervertebral discs will be mentioned to a greater extent in the following section (3.1.2):

The *cervical* spine is designed primarily for mobility; it enables positioning and weight-bearing of the skull. The intervertebral discs below C2 contribute to more than a quarter of the length of the cervical region and are an important factor in allowing considerable movement of the neck. Within the lordotic curve, the discs are wedge-shaped with greater depth anteriorly.

The *thoracic* region is the least mobile area of the vertebral spine due in part to its protective function with associated structures (rib cage and sternum) surrounding major organs. The thinner intervertebral discs are also restrictive due to structural differences in the collagen framework of the annulus fibrosus (Koeller et al., 1984).

The five lumbar vertebrae are the largest moveable vertebrae. The characteristics of a typical lumbar vertebra are displayed in Figure 3.2. The lumbar vertebrae sustain greater stresses than other vertebral structures and therefore display characteristics particular to this function. There are also several anatomical features of the intervertebral discs and vertebrae that contribute to the lordosis of the lumbar region. Firstly, the vertebral body of the fifth lumbar vertebra and the L5/S1 intervertebral disc are wedge-shaped whereby the anterior depth is greater than the posterior by approximately 6-7 mm. In addition to this, the L1-L4 vertebrae are inclined posteriorly in relation to the vertebra below.

A typical lumbar vertebral body (L1-L4) is wider transversely than anteroposteriorly in addition to the increased anterior height. The posterior arch (formed by the pedicles, laminae and articular processes) is larger than in the thoracic region but smaller than in the cervical. In L5, the articular processes are further apart as a result of the greater lumbosacral angle in this region. The transverse processes and lateral pedicles give rise to the strong, dense ligaments stabilising the lumbar spine to the pelvis.

Longitudinally oriented ligaments are found along the whole length of the spine: anterior and posterior longitudinal ligaments and the ligamenta flava. The primary function of these ligaments is mechanical and they maintain a compressive force along the axis of the spine throughout the whole range of flexion and extension (Aspden, 1995). These ligaments therefore help to stabilise the spine. Interspinous and supraspinous ligaments have lesser roles, providing little resistance to flexion and extension of the spine, respectively.

The muscles of the back, when contracted, also exert a compressive effect on the spinal structures. Most of the muscles are arranged more or less longitudinally, in three layers. It is not necessary to describe the points of origin and insertion of these muscles, moreover, the functional role of particular muscles is displayed in Table 3.1.

Table 3.1 The muscles associated with movements of the trunk

Movement	Muscles
Extension of the trunk	Erector spinae, multifidus, semispinalis quadratus lumborum, interspinales.
Flexion of the trunk	Psoas major, psoas minor. Abdominal muscles: obliquus externus abdominis, obliquus internus abdominis, rectus abdominis.
Rotation of the trunk	Obliquus internus abdominis, multifidus, obliquus externus abdominis, rotatores, semispinalis
Lateral flexion of the trunk	Obliquus externus abdominis, rectus abdominis, obliquus internus abdominis, erector spinae, multifidus, quadratus lumborum, intertransversarii.

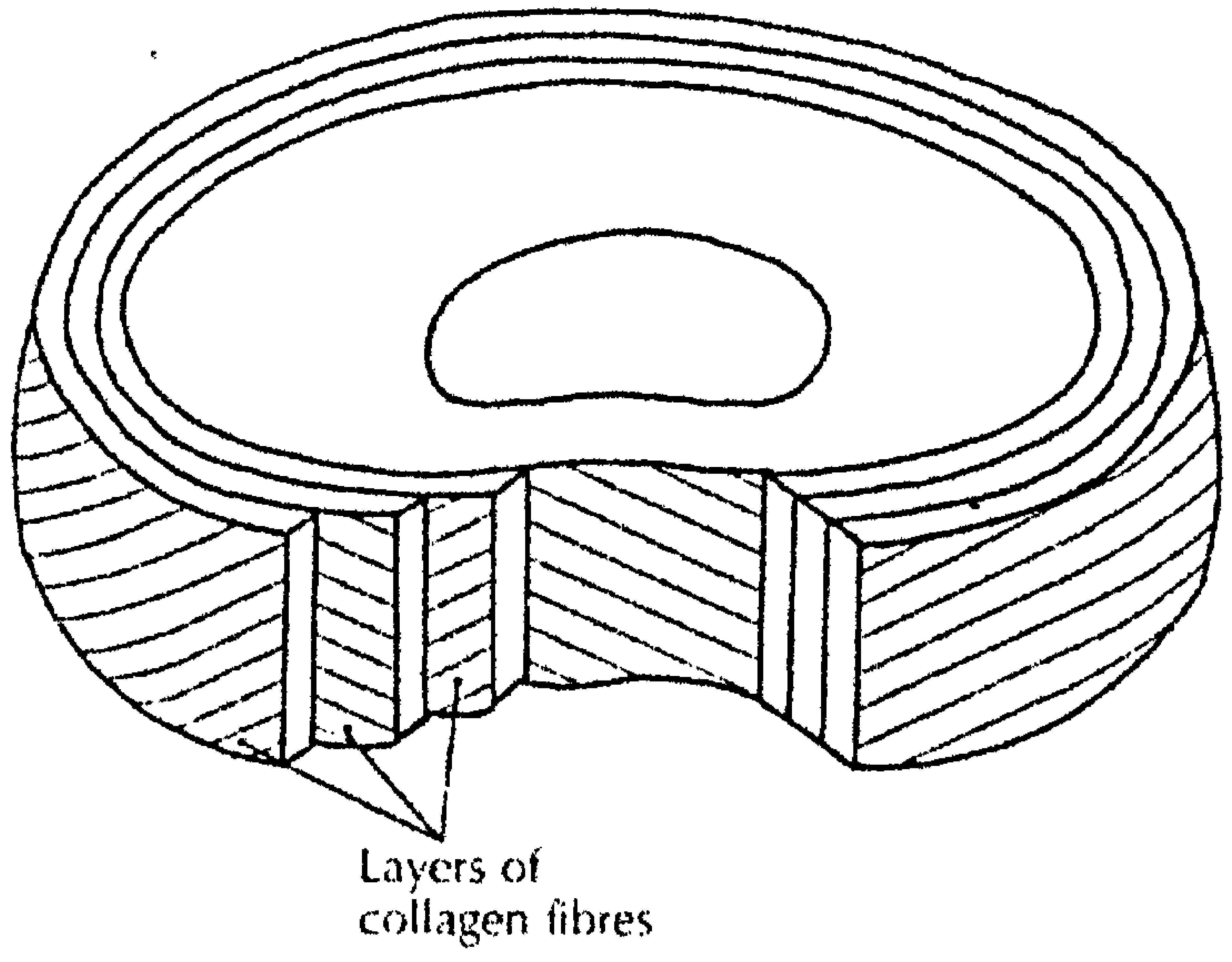


Figure 3.3 Schematic horizontal section through an intervertebral disc

3.1.2 The motion segment as a functional unit of the spine

The motion segment represents an intervertebral disc and the adjoining vertebrae above and beneath. The major role of the intervertebral discs is mechanical. The linked system of intervertebral discs and vertebral bodies enables loads to be transmitted throughout consecutive motion segments in the spinal column, and their flexibility allows the spinal column to bend, flex and twist.

The intervertebral discs and cartilage endplates of the vertebrae are composed of a matrix consisting mainly of collagen fibres in a proteoglycan-water gel which is produced by small numbers of cells within the tissues. The intervertebral discs lying between the vertebral endplates consist of two parts: a central area is known as the nucleus pulposus and there is an outer matrix, the annulus fibrosus (Figure 3.3). The matrix of the annulus fibrosus is arranged into a series of concentric rings. The bundles of collagen fibres within adjacent rings change their line of orientation relative to the vertical. This arrangement permits the discs to respond to sagittal (flexion-extension) movements and asymmetric lateral flexion movements. The laminated arrangement of the fibres also help to provide stability in response to shear and torsion forces. Control over movements involving rotation is provided by the fibres positioned in the direction of the rotary movement while those fibres opposite would be relaxed. Within the annulus the angle of the fibres from the horizontal varies between 40-70°. The ability of the fibres to alter their orientation enables the annulus to demonstrate elastic properties upon loading of the vertebral column. The nucleus pulposus is less fibrous and these fibres conform to a more random arrangement than in the annulus.

The arrangement of the collagen fibres is not uniform within the intervertebral disc or for discs in different regions of the vertebral column. Fibres of the annulus extend to approximately half the disc circumference and within the posterior annulus, the fibres are noted to be more parallel in their arrangement. The collagen lamellae also appear thinner, more tightly packed and bound by less proteoglycan gel in the posterior region. The anterior and lateral regions of the annulus in lumbar vertebrae are approximately twice as thick as the posterior portion. Therefore the posterior annulus may be deemed a weak area which predisposes the intervertebral disc to injury and degenerative change. In the upper regions of the lumbar spine, the posterior annulus is thicker and stronger, yielding greater protection to the vertebrae in this region. The range of motion of the motion segment is partially governed by the height of the intervertebral disc. Greater ranges of flexion, extension and lateral flexion are possible where the discs are thicker.

The inner annular fibres are anchored to the vertebral endplates and prevent the nucleus bulging into the vertebral body. Peripherally, the annulus is secured to the epiphyseal ring of the cortical bone; the inner lamellae join to the endplates directly above and below. The anterior and posterior longitudinal ligaments also attach to the surface of the annulus fibrosus. The vertebral endplates form a permeable barrier which allow water and nutrients to pass from the nucleus pulposus and cancellous bone of the vertebral bodies. The endplates are, however, the most common site of failure under conditions of high compressive loading and may be considered the weakest part of the disc.

Water is the main component of the discs and endplates. The proteoglycan molecules within these structures exhibit a highly anionic charge (side-chains attached to a protein core). This property attracts water and results in the formation of an important gel-like substance, essential for the normal functioning of the disc and cartilage. The collagen fibres restrict the amount of water absorbed within the matrix. The water content of the nucleus, annulus and endplate is 77%, 70% and 55% respectively (Roberts, 1995). The semi-fluid nucleus pulposus may be deformed under pressure without a reduction in volume; it is this property that enables movement and load-bearing capability. The water-binding capacity of the nucleus pulposus is therefore influenced not only by the concentration of the proteoglycans, but by changes in intradiscal pressure.

As mentioned in section 3.1.1 there is always an intrinsic pressure within the intervertebral discs as a result of the compressive but stabilising effect of the ligamentum flavum. Whilst the individual is standing still, the compressive force on the lumbar discs is approximately 500 N (Nachemson, 1981), 380 N of which is due to body weight. When external loads are applied to the body or when the motion segment is flexed, the pressure within the discs rises, partially as a result of increased muscular activity (the generation of large extensor moments). The compressive forces due to muscle tension during forward bending and lifting can rise by 5 to 10 times (Dolan and Adams, 1993).

During flexion the posterior annulus stretches and become thinner (Figure 3.4). This reduces the distance between the nucleus and the outer annular fibres as the nucleus moves posteriorly (during extension, the nucleus moves anteriorly) (Shepperd, 1995). Upon repeated flexion, the annular fibres and nucleus distort; the nucleus deforms posterolaterally (Adams and Hutton, 1985). The reverse occurs during extension of the vertebral column, whereby the nucleus moves anteriorly. The movements of lateral flexion and rotation also cause rises in intradiscal pressure and nucleus deformation. The laminated arrangement of the annular fibres play a significant role during rotation as mentioned earlier in this section.

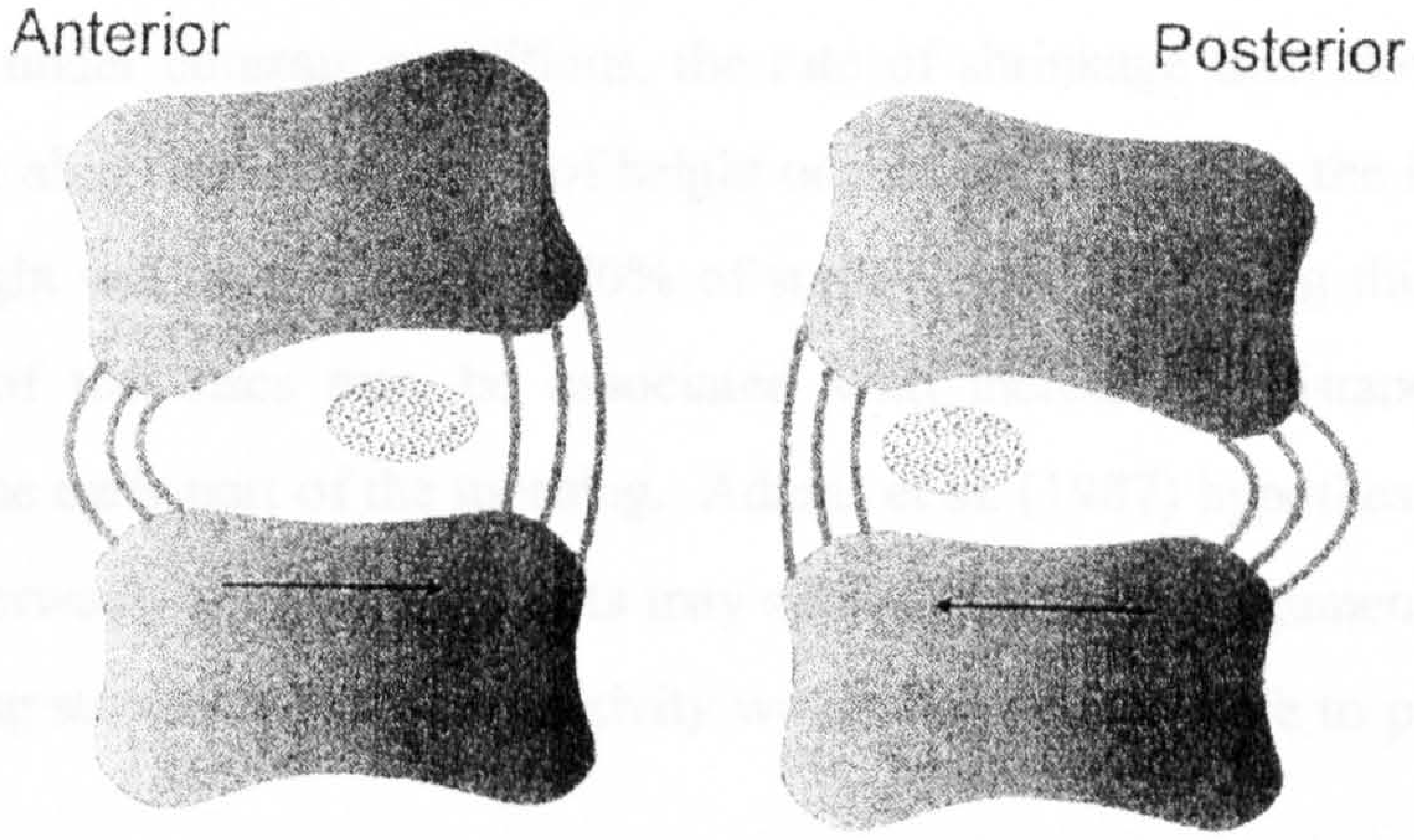


Figure 3.4 The nucleus moves posteriorly in flexion and anteriorly in extension

Vertical loading of the spine results in the radial distribution of stresses to the annulus fibrosus and vertebral endplates. The direction of the annular fibres allows these stresses to be absorbed. After prolonged loading, the bulging of the annulus increases and deformation of the cancellous bone and bulging of the endplates into the vertebral bodies may occur as a result. The disc is also known to 'creep' when vertical loads are maintained. Creep is the gradual loss of fluid from the intervertebral disc into the vertebral bodies and surrounding tissues; it occurs at a decelerating rate until the disc is in equilibrium with the applied load. The rate and magnitude of creep is dependant not only upon the load (the heavier the load, the faster the rate of creep) but also the proteoglycan content of the disc.

There is a diurnal variation in stature amounting to approximately 1% of total body height (Reilly et al., 1984); this is principally attributed to loss of fluid from the intervertebral discs. Height is lost throughout the day and regained during bed-rest at night. Rapid loss of stature occurs in the first hour of rising, accounting for as much as 50% of the total diurnal loss and under constant conditions, the rate of shrinkage then slows throughout the day (Reilly et al., 1984). Recovery of height occurs rapidly during the first four hours of bed-rest at night with approximately 70% of stature regained during this period. This hyperhydration of the discs may be associated with increased resistance to bending stresses during the early part of the morning. Adams et al. (1987) hypothesised that in the early morning, forward flexion movements may subject the lumbar ligaments and discs to damaging bending stresses. The same activity would be perfectly safe to perform later in the day.

The consequences of loss of disc height through compression may include symptoms of discomfort and alterations to normal range of movement. As the disc bulges, the vertical and transverse dimensions of the intervertebral foramen are reduced. The apophyseal joint surfaces are brought closer together which may reduce the range of axial rotation. Conversely, with loss of disc height, increased laxity of the disc and ligaments has been postulated (Adams et al., 1987). Increases in *in-vivo* flexion range of movement (5°) were observed over the course of a day. This was attributed to a decrease in spinal stiffness following fluid-loss induced disc narrowing and the subsequent ligament laxity.

Unloading the spine results in recovery of disc height. This may be achieved by adopting the lying position which reduces the compressive load on the spine and results in fluid imbibition. The flexed resting posture of the Fowler position (lying supine, legs raised and supported with knee angle of 45°) assists in the transport of metabolites to the discs but at the slight expense of an increase in intradiscal pressure (Adams and Hutton, 1986).

3.1.3 The motion segment, degeneration and low back pain

Characteristic slow, destructive changes of the vertebral column with age and degeneration due to exposure to mechanical stresses are often indistinguishable although the two processes are not synonymous (Oliver and Middleditch, 1991). Loss of trabecular and cortical bone throughout the skeleton is associated with ageing; trabecular bone loss in the vertebrae is typical. The height of the vertebral bodies declines in old age as a result of this loss of transverse trabecular bone. Changes in the vertebral end plates occur with age and degeneration. Articular cartilage is gradually replaced by bone which decreases the shock absorbing capacity of the intervertebral disc. Lumbar end plates in particular demonstrate bulging into the vertebral bodies.

The proteoglycan content of the nucleus pulposus and annulus fibrosus decreases with age. Therefore the water-binding capacity of the intervertebral disc is reduced. There is also a gradual increase in the relative proportion and nature of the collagen in the nucleus and annulus. In combination, these affect the normal load bearing capability of the disc and it becomes a more rigid structure. Greater deformation of the annulus and nucleus occurs per given stress when the disc degenerates (Hutson, 1993). Mechanical strains may also be placed upon the apophyseal joints as a result of increases in the height loss of the intervertebral discs.

There appears to be an increase in the slope of the hysteresis curve concomitant with the increased stiffness of the intervertebral discs (Stevens et al., 1982). The magnitude of hysteresis is dependent upon the state of hydration of the disc, the proteoglycan and collagen content of the discs and the condition of the annulus fibres. The result of hysteresis is a delay in the loss of height induced by compression or the capacity of the motion segment to recover from compressive loading which may mask the consequences of an increase in the stiffness of the disc.

Most discs show signs of degeneration with ageing and following maximal compression or repeated submaximal compression; loss of disc height, disc bulging and microfractures of the end plates are characteristic. The latter condition causes irreversible height loss of the intervertebral disc and is thought to contribute to the further development of degenerative changes of the motion segment (Brinckmann, 1985). The annulus fibrosus of the intervertebral disc and the marrow of the vertebral body are innervated structures. van Dieën and Toussaint (1993) express the opinion that there is a relationship between compression induced damage to the motion segment and the aetiology of low back pain. However, degenerative changes may occur within the discs of individuals who do not experience symptoms of back pain (Frymoyer et al., 1984; Greenough, 1995).

3.1.4 The measurement and validity of changes in stature as a measure of load on the spine

Changes in stature may be attributed predominantly to fluid exchange and structural deformation of the intervertebral discs, although compression of the lower extremities accounts for very small body height decreases. Furthermore, compression of the soft tissue structures beneath the calcaneus can account for approximately 4 mm of shrinkage upon weight-bearing. This occurs within a short period of time (approximately 2 min according to Foreman and Linge, 1989), and should be taken into account when using 'spinal shrinkage' as a method of measuring spinal load. Heel pad equilibrium has implications for the timing of test measurements; two minutes standing in the measurement position should be allowed before valid measures of stature will be obtained.

Changes in stature vary between individuals and may be induced by a loading situation, the duration of loading and the time of day. In order to assess the effect of these conditions, equipment capable of measuring stature very precisely and accurately is required. Body height measurements made in medical clinics using traditional equipment may only be accurate to within 10 or 20 mm and demonstrate poor repeatability. However, equipment has been developed to detect very small changes in stature that may be accurate to within 1.0 mm. Individuals must be able to maintain posture during the reference measurement and subsequent measures in order for comparative experimental studies to be conducted successfully.

The measuring device constructed for the experimental work is a modified model of the stadiometer used by Eklund and Corlett (1984). The stadiometer (Plate 3.1) consists of a central pillar set at right angles to a base plate and is inclined backwards by 13 degrees from the vertical to assist both subject relaxation and maintenance of posture in the measurement position. The procedure for the measurement of stature has been standardised by Boocock et al. (1988). Weighing scales are inset into the base plate in order for weight distribution to be standardised during measurements and a heel rest controls the position of the feet. Attached to the central pillar are six adjustable fittings with microswitches These are positioned to contact the prominent points of the spine and support spinal curvature as listed below:

i) Sacral base-plate
ii) Lumbar switch
iii) Two thoracic switches (left and right, between scapular and vertebral column)
iv) Cervical spine
v) Occipital switch

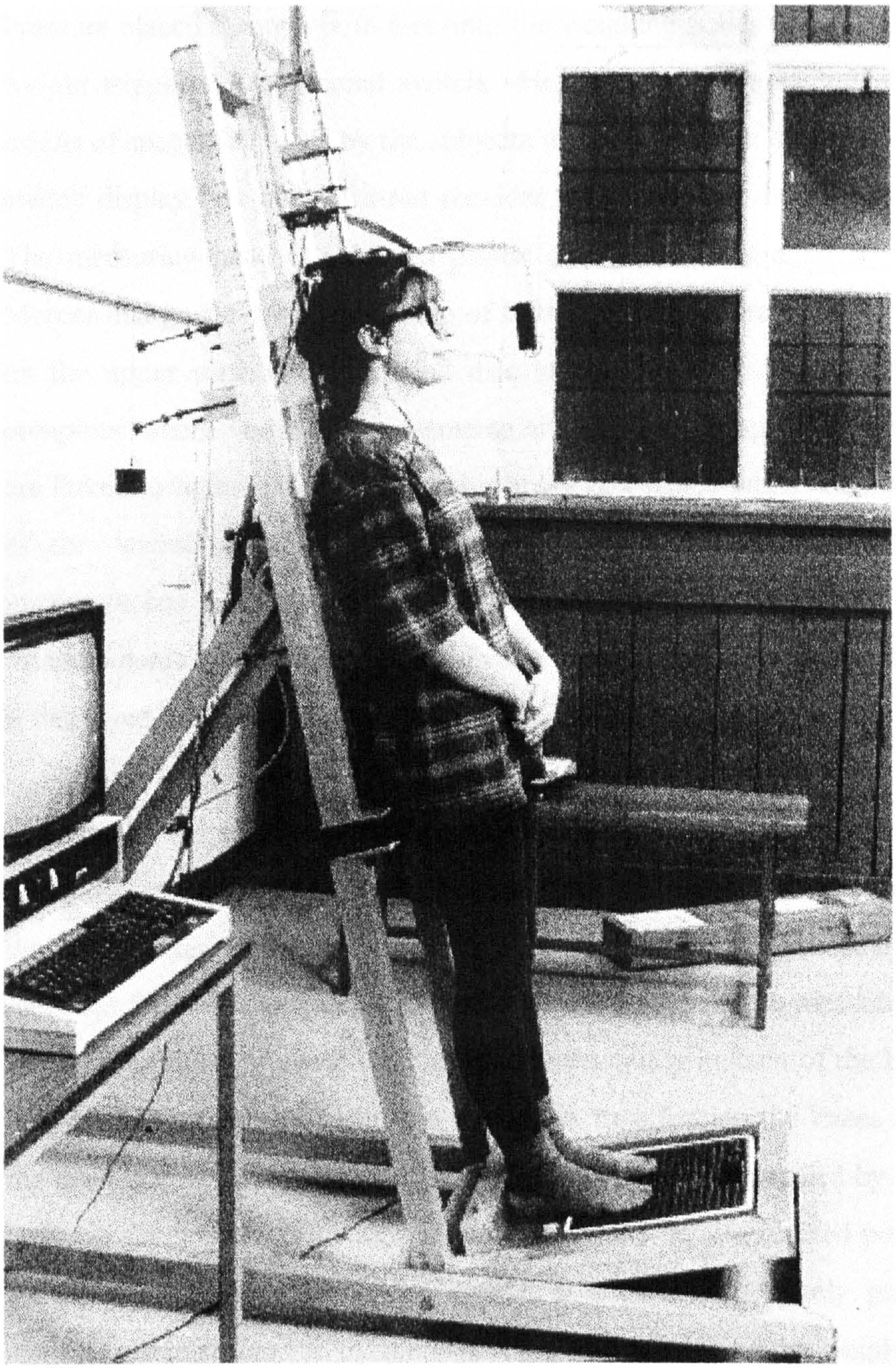


Plate 3.1 The stadiometer used for the measurement of stature

Pressure placed through both feet onto the weighing scales equivalent to 40% of the body weight triggers an additional switch. Head angle in the sagital plane is controlled by means of spectacles worn by the subjects which contain an infra-red emitter; an adjustable switch display box and infra-red receiver are positioned directly in front of the subject. The measuring head is a 15 cm plastic disc, with a travel of 50 mm, connected to a Mercer dial gauge with a precision of 0.01 mm. The voltage from the two strain gauges on the upper surface of the head disc is transferred via an amplifier unit to a micro-computer where vertical displacements are displayed graphically. All the microswitches are linked to lights within the switch display box which when illuminated allows feedback of the desired posture to the subject. An audible signal is emitted when all the microswitches are triggered, indicating that posture should be controlled and that measurements will be taken over a five second period. The mean of these measurements is displayed.

Training in the technique to measure stature is necessary in order to obtain accurate sequential and/or interval measurements. The microswitches used for postural control on the stadiometer may be adjusted to accommodate each individual and body weight is recorded for even distribution though the feet during stature measurements. The subjects lean against the instrument with hands clasped gently in front of the body below the waist. The feet are placed just ventral to the pelvis, thus forcing the knees into extension. Once the head disc is lowered, the angle of the head can be controlled by wearing the infra-red emitting glasses. At this stage the subject should be in a relaxed posture with all control switches illuminated except the weight control. Immediately prior to measurement, subjects are instructed to exhale and relax, and to activate the weight control switch until the signal is heard. This position is held for five seconds.

Subjects are considered "trained" at maintaining posture when ten consecutive measurements have a standard deviation of 0.5 mm or less. Test conditions require five measures of stature to be recorded, again with a standard deviation of 0.5 mm or less. The experimenter can view the sequential stature measurements and has the option to eliminate a measure, for example if the subject has altered his or her posture unduly or not maintained posture for five seconds. In order to achieve adequate reproducibility of measurements, the cooperation of the subject is of great importance. The length of time required for training varies between individuals and good coordination does benefit the training process. A small number of individuals will need to undergo considerable training (>1.5 h) although it is usual for subjects to attend at least one familiarisation session of approximately 35 min duration.

The validity of the use of changes in stature as a measure of the load imposed on the spine has been examined in relation to psychophysical factors. The measuring technique appears to be positively correlated to subjective ratings of functional load, such as ratings of discomfort, perceived exertion, relaxation and comfort (Troup et al., 1985).

Large inter-subject variability of stature changes have been observed. A number of factors contribute to the clinical status of the motion segment (age, congenital anomalies, degeneration) which affect the stiffness and state of hydration of the discs. These are difficult to measure or control for in a group of subjects unless expensive, sophisticated scanning techniques are applied to assess the structures of the vertebral column.

Stature loss has been shown to be dependant upon load in practical lifting situations (Tyrrell et al., 1985). In situations such as this, the exact quantification of the loads on the spinal column is not feasible. Postural aspects need to be taken into consideration, for example flexion of the spine causing wedging of the discs, the influence of shear and torsion forces in addition to compression. Flexing of the motion segment causes an increase of height loss and fluid expulsion (Adams and Hutton, 1983). However, these factors are accepted as limitations to such a non-invasive measuring technique.

Height loss of the intervertebral disc is partially an osmotic process and dependant on intradiscal pressure (van Dieën, 1993). Intradiscal pressure is determined by the compression and disc area and so it follows that disc area may have an influence on height loss. Indeed, a linear relationship between lumbar disc area and loss of height was demonstrated by Althoff et al. (1992), although the relationship was weak. The compressive stress of the disc is inversely proportional to the disc cross-sectional area. Therefore, height decrease of the discs at a given load should be inversely proportional to the disc area.

The intervertebral discs themselves vary in anatomical structure throughout the regions of the vertebral column as mentioned in Section 3.1.1. The stadiometer is designed to assess the changes in stature derived from the external loads and trunk muscle forces along the entire vertebral column. This does have implications for the validity of comparing stature loss following different loading situations. It is not known whether the distribution of compression forces and other factors influencing loss of height can be considered constant throughout the regions of the spine in different situations.

The application of the stadiometer in the measurement of stature changes is well established (Corlett et al., 1987; Reilly et al., 1991) and it does provide a repeatable, non-invasive method of estimating the compressive loads acting on the spinal column. Considerable work has been performed investigating the processes involved in spinal loading *in-vitro* and a great deal of information can be postulated from this. The validity of the measurement technique has been established in terms of psychophysical parameters and external load (Troup et al., 1985; Tyrrell et al., 1985) although there is scope for further validation in terms of the influence of lumbar disc area and the observation of changes in disc height in different regions of the spinal column.

3.2 EPIDEMIOLOGY OF LOW BACK PAIN

Back pain is a very subjective complaint. The perceived distribution of symptoms does not often indicate the precise location of structures causing pain. In the majority of cases, the exact underlying cause remains uncertain even after full clinical investigation; this makes the classification of back pain difficult and has given rise to a large proportion of symptomatic individuals whose condition may be described as "idiopathic". In addition, retrospective survey methods employed to collect epidemiological data, rely upon the recall of individuals and may not provide completely accurate information.

The multifactorial aetiology of back pain encompasses a variety of causative or contributory factors; the interaction of these affect the duration of symptoms and the prognosis for recovery. This section will provide a general outlook regarding epidemiological aspects of back pain amongst general populations and related predictive factors. More specific information regarding back pain in the nursing profession will discussed in the Chapter 4.

3.2.1 The magnitude, prevalence, incidence and disability of low back pain

It is generally agreed, despite methodological dissimilarities in the epidemiological data collected, that low back pain should be considered a major health problem. There appears to have been an increase in the magnitude of the problem in industrialised nations in terms of absence from work due to back pain (Biering-Sørensen, 1995). Waddell (1987) reported the number of days of absence per 1000 inhabitants with low back pain in Great Britain to be around 420 in 1954; The equivalent figure for 1981 was 1750. Raspe (1993) also reported upon evidence that the number of people afflicted by back pain symptoms has increased within the last 40 years.

In epidemiological studies, various frequency estimates are used. The incidence rate reports the number of people who for the first time experience back pain during a specified time period, for example 1 year (annual incidence). The prevalence is the number of people who experience symptoms at a particular point in time (point prevalence) or during a defined time period (period prevalence). This information is usually gained from population surveys where people are asked "Have you experienced low back pain during the past year?" (annual prevalence) or "Have you EVER experienced back pain?" (lifetime prevalence). Raspe (1993) reported "current" rates of back pain amongst general populations as about 40% for the point prevalence of symptoms, annual prevalence rates to be around 75% and lifetime prevalence to be greater than 80%.

Although prevalence rates for men and women are generally similar, there may be marked gender differences within various age groups. Biering-Sørensen (1982) reported the peak in low back pain prevalence (lifetime, annual and point) in men to be at the age of 40 years. The equivalent figures for women demonstrated a steadily rising trend with increasing age; Raspe (1993) supported this tendency. Raspe (1993) also concluded that an unequivocal effect of gender can only be demonstrated for chronic and/or severe back pains which have been experienced significantly more often by females.

The impact that back pain has on society may be measured in terms of disability. Disability has been interpreted in economic terms (sickness absence) or an inability to perform certain activities (walking 5 km, stooping, lifting). Anderson (1986) examined the certified sickness absence records of 2684 men in a range of occupations. It was estimated that the annual loss of work time was approximately 15 million days (1661 days per thousand workers). The true figure would undoubtedly be greater if all cases of uncertified sickness absence were taken into consideration. Self-certification by postal workers (Anderson, 1980) did show an increase in the disability caused by back pain: 1735 days per thousand postmen.

3.2.2 Risk factors in low back pain

Within local population studies, risk factors have been identified which predict the first time experience of back pain and which also predict the recurrence of symptoms. A previous history of low back pain is noted to be one of the strongest predictive factors for further episodes of pain (Biering-Sørensen, 1989; Troup at al., 1987). The length of back pain history, the number and duration of attacks are all important variables to be considered within the natural history of symptomatic individuals.

The risk factors for predicting a first attack of back pain are less distinct (Biering-Sørensen, 1984). A variety of risk indicators has been described: Raspe (1993) listed risk factors/indicators relating to biomedical and mechanical factors including childbirth, whole-body vibration, driving, heavy work with bending twisting and lifting. The consequences of cigarette smoking may include an increased risk of experiencing back pain symptoms (Frymoyer et al., 1983). It has been postulated that smoking is associated with a defective fibrinolytic enzyme in the blood (Jayson, 1992). This may cause a reduction in vertebral body blood flow and subsequently affect the diffusion of nutrients from the vertebral endplates into the intervertebral discs and disturb the metabolism of the disc (Frymoyer et al., 1983).

Psychological, lifestyle and social factors are also considered important factors to consider when obtaining information regarding back pain. They are particularly important for clinicians who need to obtain a thorough history of the conditions presented by each individual. Troup (1995) identified a population who display signs of socio-economic problems; these are individuals in whom back pain symptoms have become persistent, they have failed to respond to treatments and have been forced to adapt their lifestyles in accordance with the pain. It would appear therefore that psychological variables incorporate extremely complex interactions with lifestyle and social factors. Such factors are associated with low back disability as opposed to a risk for the acute onset of symptoms (Frymoyer and Cats-Baril, 1991).

3.3 MEASURES OF MANUAL HANDLING, LIFTING PERFORMANCE AND MUSCLE FUNCTION

In practise, it is rare for an individual to undergo any form of work-related pre-employment screening for a job demanding the manual handling of loads or repetitive lifting. Employers rely upon the workers to consider themselves fit and capable of performing the work required of them. The guidance on the Manual Handling Operations Regulations (Health & Safety Executive, 1992) state that an employer shall:

> "so far as is reasonably practicable, avoid the need for his employees to
> undertake any manual handling operations at work which involve a risk
> of their being injured"

Regulation 4 continues to describe the necessity for the performance of risk assessments where employees cannot avoid manual handling operations at work which involve a risk of their being injured. In certain situations it is not easy to predict whether a task does involve the risk of injury; additionally, individual differences in the capability of employees may mean that what is "safe" for one individual may be potentially harmful for another.

The implementation of the manual handling regulations does not eliminate the need to assess individual capability, the two may complement each other. What is important is that the need for control over workplace activities has been recognised, this in turn may help to reduce the incidence of occupational-related musculoskeletal injury.

This section will examine the established techniques used to assess manual handling capability, lifting performance and muscle function. Whilst their applicability within industrial settings can only be postulated, they do enable the assessment of individuals with regard to their ability to perform particular tasks.

3.3.1 Isometric and dynamic lift dynamometry

i) Isometric lift dynamometry. Lifting tasks do contain component elements where isometric contraction of the activated musculature is necessary. Isometric contractions occur primarily during the initial and final phases of the lifting action, particularly if the load is a stationary object. The measurement of static strength therefore has implications with regard to the maximum weight of loads that may be lifted by individuals and the risk of sustaining injury from the performance of tasks requiring maximal effort.

The measurement of maximal isometric lifting strength (MILS) has been derived and standardised by Caldwell et al. (1974) and Chaffin (1975). Maximal isometric lifting strength is dependent upon the height of the origin of the lift and the technique employed to perform the action; different muscle groups are recruited for specific tasks. The standardised heights of lift include: the height of the knuckle, knee, waist and shoulder height. In the performance of all static lifts, maximal effort should be reached within three seconds in order to eliminate jerking movements which may produce erroneously elevated peak forces and are potentially injurious to the user. Chaffin (1975) also noted the importance of distinct and standardised instructions to be given to subjects.

Troup et al. (1987) applied a comprehensive physical test battery to 2891 men and women from a variety of occupations. Maximal isometric lifting strength from knee height was significantly reduced amongst individuals (male and female) who reported mild symptoms of low back pain. However, MILS and all the other physical tests constituting the test battery were not of value in predicting a new experience of low back pain. The application of isometric lifting as a form of pre-employment screening was therefore not endorsed although its value within ergonomics in the design of work tasks was suggested.

Birch et al. (1994) reported on the construction and validation of an isometric lift dynamometer. Maximal isometric lifting strength at knee height demonstrated a significant association with both back and leg strength measured on separate devices; both muscle groups make a major contribution to the squat lifting posture. The handles were positioned marginally in front of the body and so the posture adopted on the isometric lift dynamometer meant that the peak force achieved may not have been the highest possible in an ideal lifting posture. Table 3.2 displays the MILS leg lift measurements obtained in a number of studies.

Table 3.2 Maximal isometric lifting strength (N) at knee height in healthy male and female subjects. Standard deviation values are given in parentheses where available

	Males	Females
Keyserling (1978)	1118	520
Griffen et al. (1984)	903 (285)	471 (177)
Zeh et al. (1986)	1148	598
Troup et al. (1987)	991	491
Birch et al. (1994)	1290 (284)	--

Leskinen et al. (1983) demonstrated that the adoption of the leg lift technique generated lower peak lumbosacral compressive loads compared with lifting from the floor with straight legs. The use of this lifting technique may be endorsed and be of advantage to the low back only if the horizontal distance between the load and the low back is small. Therefore, the isometric leg lift technique may be considered safe if standard procedures are fulfilled and clear instructions are given to subjects.

Dynamic lift dynamometry. A number of systems for lifting have been developed which enable the evaluation of isometric and dynamic lifting tasks using the same item of equipment. The measurement of dynamic strength is complex and these lifting devices enable the measurement of strength under controlled conditions; actual lifting tasks may be simulated, the speed of lift controlled and the load of the lift may be adjusted. Sophisticated computer software programs provide immediate graphical and tabulated feedback regarding the load lifted, velocity and acceleration parameters.

Garg and Beller (1994) compared dynamic (isokinetic) lifting strength with static (isometric) strength. The authors noted that dynamic strength was highly dependant upon the speed of lifting; at the slow speed (0.41 m s^{-1}) mean isokinetic strength was equal to isometric strength. It was also concluded that isometric and dynamic strength were independent of each other and that the estimation of one type of strength (e.g. isometric) from another strength measure (e.g. dynamic) was not possible. Box width and the speed of lift were both shown to have a significant effect on dynamic lifting strength.

Zinzen et al. (1995) conducted a comprehensive evaluation of a three-dimensional lifting system. The isometric and dynamic lifting strength measurements obtained from the device were shown to be repeatable. However, the validity of the strength measurements was not confirmed due to inconsistencies in force measurement between the left and right lifting handles. The manufacturers of this instrumentation were advised of the problem and have subsequently modified the apparatus.

The practical application of these devices includes establishing job-specific norms, job design and pre-employment screening/selection of individuals to match the physical strength requirements for the job (Porterfield et al., 1987; Garg and Beller, 1994). However, their actual use within industrial locations does not appear to match the verve with which the potential of these devices is proclaimed.

3.3.2 Isokinetic assessment of the trunk

The assessment of trunk muscle strength provides a measure of an individual's physical capabilities and is feasible with the use of isokinetic equipment. The application of such equipment is more specific than isokinetic lift dynamometry as it enables a more clinical and functional investigation of the trunk musculature; assessment positions include flexion:extension (sagittal plane), trunk rotation (transverse plane) and trunk lateral flexion (frontal plane). The application of isokinetic strength testing in relation to its application as a measure of disability will be discussed in Chapter 4.

Trunk muscle strength may be assessed in the seated, standing or prone position. The standing position has received the most attention in terms of research and a considerable amount of normative data is available from sagittal plane assessments in this position. Tests may be performed at a range of angular velocities (usually between 1.02 rad.s^{-1} and 2.09 rad.s^{-1}).

The assessment of the trunk flexors and extensors (Section 3.1.1.) in the standing position does require the stabilisation of the lower limbs and pelvis as far as possible to minimise contribution of muscles acting on the hip (e.g. iliopsoas). Values of peak torque have been shown to decrease with increases in angular velocity of movements during the test; measurement position (standing, seated) also influenced peak torque values (Perrin, 1993). Peak torque is frequently expressed as a percentage of total body weight in studies comparing men and women. Men tend to produce more torque relative to body weight than women for the trunk flexors and extensors; this difference decreases with increases in test angular velocity.

Early studies of isokinetic trunk assessment did not have the facility to correct peak torque measurements for the effects of gravity (Davies and Gould, 1982; Thompson et al., 1985). As the trunk constitutes more than 50 % of the body, gravity effects may be considerable, especially when the trunk is assessed from the standing position. In studies where a gravity correction procedure has not been implemented, trunk extensor strength has exceeded flexor peak torque at the slower velocities; as angular velocity increases however, trunk flexion torque values exceed extension torque. Table 3.3 provides normative values for trunk flexor and extensor torque at a range of test velocities. These studies were performed with subjects in the standing position, without gravity correction procedures.

Table 3.3 Normative values of trunk flexion and extension peak torque (Nm) at angular velocities 1.02, 1.57 and 2.09 rad.s^{-1}

		Extension (rad.s^{-1})			Flexion (rad.s^{-1})		
		1.05	1.57	2.09	1.05	1.57	2.09
Davies & Gould	M	271	239	149	247	236	219
(1982)	F	182	159	135	160	156	149
Thompson et al.	M	260	249	243	249	254	254
(1985)	F	149	142	140	148	145	143

3.3.3 Psychophysical measures of performance

Tests of psychophysically acceptable lifting capacity have been developed not as screening methods, but in order to design work schedules which do not strain or cause the lifter to become fatigued (Snook, 1978). Isometric and isokinetic lifting tasks do not incorporate the subjective responses of the individual performing the task. This alternative approach takes into consideration a number of factors associated with the performance of the task including the duration of the working period and the frequency of the lifting activity.

The psychophysical method enables an individual to select the maximum weight of load acceptable for a particular work period, with lifts being performed at a set frequency over the period of time and through a constant distance/height. Subjects are able to adjust the load lifted during the lifting and to adopt freestyle lifting techniques/postures. The load lifted by an individual may be termed the "maximal acceptable load" (MAL) or "rating of acceptable load" (RAL); this may be either submaximal or a comfortable maximal lift performed once only (one repetition maximum) over the defined distance/height. The repeatability of these tests has been demonstrated in healthy individuals (Griffen et al., 1984; Snook, 1985).

Troup et al. (1987) applied psychophysically acceptable lifting tasks within a comprehensive test battery administered to 2891 men and women employed in a range of occupations. The rating of acceptable load was closely associated with the experience of low back pain and the perception of workload. These results advocate the use of such tests within ergonomics and studies within the workplace. They are repeatable and easy to administer.

3.4 SUMMARY

This chapter has incorporated a number of essential components relevant to later sections of this thesis. The functional anatomy of the spine has been described with particular reference to the motion segment and the mechanisms associated with compression of the intervertebral discs. These include bulging of the annulus fibres, loss of fluid and the consequent height loss of the intervertebral disc. It is clear that degeneration of the intervertebral discs is not necessarily associated with back pain although degenerative processes do occur as a result of compressive loading of the discs.

The application of precision stadiometry in the measurement of stature changes is now well established. It provides a repeatable, non-invasive method of estimating the compressive loads acting on the spinal column. Adherence to the standardised measurement procedure is essential for the collection of valid data.

Back pain may afflict as many as 80% of a population at some time during their lives and the severity of reported symptoms varies widely. The impact that back pain has on society may be measured in terms of disability or the sickness absence attributed to symptoms. Risk factors associated with the onset or recurrence of back pain symptoms have been identified; these include twisting, lifting and a previous history of back pain.

Isometric and isokinetic dynamometers have been applied to assess individual lifting performance and trunk muscle function. Maximal isometric lifting strength and peak torque of the trunk extensors and flexors may be reduced in symptomatic individuals. Psychophysical lifting tasks have also been applied to evaluate lifting capability; these tests incorporate the subjective response of the lifter and have been shown to be closely associated with the experience of back pain and the perception of workload.

Chapter Four

Review of Literature

4 REVIEW OF LITERATURE

The previous section provided fundamental information regarding the functional anatomy of the spine, the epidemiology of back pain and measures of manual handling, lifting performance and trunk muscle function. It is the purpose of this literature review to examine how these issues and other methodologies have been applied in relation to the measurement of the problem of back pain and to review the research which has been conducted with reference to the nursing profession.

4.1 LOW BACK PAIN

4.1.1 Low back pain in nursing personnel

The nursing profession has been the subject of studies worldwide to establish the prevalence and incidence of back pain (Stubbs et al., 1983; Heap, 1987; Ryden, 1989), to determine the costs associated with its morbidity (Stubbs et al., 1980) and to identify risk factors associated with occupational duties which may predispose nurses to back pain symptoms (Harber et al., 1988; Stobbe et al., 1988; Garg and Owen, 1992;).

The epidemiological surveys conducted amongst nurses demonstrate inconsistencies comparable to those associated with similar investigations of the general population. Methodological dissimilarities between studies dictate the parameters reported and the range of figures presented with regard to the prevalence and incidence of pain. Studies may be of various design (prospective or retrospective, cross-sectional or longitudinal), with different grades of staff surveyed and with varying definitions of back pain provided. Therefore, interpretation and comparison of the data is complex. Table 4.1 presents the data collected from a selected number of retrospective, cross-sectional questionnaire surveys.

Table 4.1 Epidemiological data for back pain in nurses

Authors/year/country	Sample	Results
Stubbs et al. (1983) U.K.	Nurses (n=3912)	Point prevalence 17% Annual prevalence 43.1% Annual incidence 7.7%
Videman et al. (1984) Finland	Nursing Aides (NA) n=318 Qualified Nurses (QN) n=562	Lifetime prevalence (NA) 85% (QN)79%
Harber et al. (1985) U.S.A.	Nurses (n=550)	6 month prevalence 52% 2 week prevalence 44%
Arad and Ryan (1986) Australia	Nurses (n=831)	Lifetime prevalence 87% Annual prevalence 67% 1 month prevalence 38% Point prevalence 13%
Larese and Fiorito (1994) Italy	Nurses General Hosp. (GH) n=425 Oncological Dept. (OD) n=198	Annual prevalence (GH) 48.2% (OD) 32.8%
Smedley et al. (1995) U.K.	Nurses (n=1659)	Lifetime prevalence 60% Annual prevalence 45%

To overcome the difficulties associated with the recall of pain experience, retrospective surveys have selected a number of differing time bands. Buckle (1987) suggested that where surveys have generated prevalence data of more than one type, the validity of the data increases. This is because respondents may wish to register the existence of symptoms despite the occurrence of pain outside the specified time period. Similarly, point prevalence data is often utilised as does not rely upon the recall of past symptoms.

It may be seen that just within the sample of studies reported in Table 4.1, considerable variation does exist with regard to the annual prevalence figures (33% - 67%). Stubbs et al. (1983) did not specify a definition of back pain and subjects indicated the site of pain on a diagram; pain in the low back was reported by 77.9% of respondents indicating pain in some region of the back. Arad and Ryan (1986) asked "Have you ever had low back pain?". Smedley et al. (1995) defined back pain as lasting for longer than a day in an area between the twelfth ribs and the gluteal folds, a diagram was provided showing the exact location. Making direct comparisons between studies is not recommended because of the discrepancies in definitions used. In addition, methodologies differ in terms of distribution of the questionnaires, the pursuit of non-responders and the nursing populations considered.

Lifetime prevalence data should also be considered a valid epidemiological measure; an episode of back pain at some point during a lifetime ought to be a memorable experience. It is when questions are asked about the severity of the pain and symptoms (such as sciatica) in relation to pain that the validity of data should be a serious concern.

The consequences of back pain amongst the nursing profession have been examined in terms of the disability caused by symptoms. Sickness absence figures from Stubbs et al. (1983) indicated that 9.5% of the sample of NHS nurses took 1 or more days of sick leave due to back pain during 1979. The sick leave taken for back pain in comparison to absence for all causes was 16.2%. Within the sample investigated by Smedley et al. (1995) 10 % of nurses had been absent from work because of back pain for a cumulative period exceeding four weeks.

A prospective survey of 180 low back injuries to nursing staff was carried out by Heap (1987) over a five year period. It was reported that, on average, 2055 days were lost per year by 36 injured individuals in one Health District; this is equivalent to the loss of 20 full time nursing staff during one year. These figures illustrate the severity and size of the problem even without accounting for nursing personnel reluctant to report incidents that have caused back pain or staff suffering intermittently.

Stubbs et al. (1980) studied the mode of onset of back pain in nurses and found a preponderance of episodes of acute onset as against cases in which the pain came on insidiously. Thirty-six percent of all episodes of back pain were associated in their onset with patient handling procedures. Further analysis of these data identified the specialities of general medicine, geriatrics, orthopaedics and district nursing such that nursing work in these specialities may be regarded as heavy as compared to accident and emergency, obstetrics and outpatients.

Investigations comparing the prevalence of back pain amongst different grades of nurse have also revealed distinctions. Heap (1987) noted the injury rate in the sample population to be highest in nursing auxiliaries (now known as Health Care Assistants), followed closely by student nurses and then by staff nurses. Videman et al. (1984) reported that less qualified grades of nurse were exposed to a greater amount of patient handling than their more experienced colleagues. Arad and Ryan (1986) noted greater prevalence and incidence rates of back pain amongst registered and student nurses in Australia compared to nurses with more administrative and educational roles. Stubbs et al. (1983) and Smedley et al. (1990) did not note any significant difference in the experience of back pain symptoms (point or annual prevalence) between nurses of different status. Nurses may change grade as their career progresses and this further adds to the complexities associated with identifying possible risk factors of experiencing pain amongst the nursing profession.

Attempts to identify nursing specialities where nurses are more at risk of developing back pain symptoms have also proved futile (Stubbs et al., 1983; Harber et al., 1985). Similarly, although Smedley et al. (1995) observed that an annual prevalence of back pain was reported less frequently than the average by paediatric nurses, there were no clear patterns by department. Nurses may frequently change occupational speciality during their career and this may negate particular risks associated with back pain symptoms whilst working in a specific area.

Stobbe et al. (1988) conducted a retrospective survey of three grades of nurse, collecting data relating to back injuries reported to a hospital medical centre over a 40 month period. They reported that the risk of back injury was a function of the number of lifts performed and three reasons were given to justify the apparent association. One suggested that that repetitive exposure of the tissues to the “mini-traumas” induced by lifting ultimately resulted in restricted motion of joints and ligaments and/or chronic pain. A second rationale was that pain occurred as a consequence of a single event, such as an over-exertion, slip or fall. Incorporating both explanations, a third proposal was that the cumulative effect of the “mini-traumas” reduced the tolerance level of tissues, resulting in tissue damage and pain following a (not necessarily stressful) single exertion. These speculations were discussed in an attempt to explain a positive association between lifting and back injury rates. Stobbe et al. (1988) suggested that back pain may be attributed, in part to one of the explanations proposed. The study emphasised the necessity to prevent injury by reducing the exposure of nurses to lifting tasks.

The exposure of nurses to lifting was the subject of a separate study conducted by Jensen (1990). Six studies that had previously investigated the relationship between patient handling and back pain or injury were examined and data extracted to provide comparable information for exposure to lifting and the experience of back pain. Larger prevalence rates of back pain amongst those nurses frequently handling patients were observed consistently. However, the exposure variables from each individual study were not constant and relied upon the subjective reporting of the quantity of lifting performed as opposed to that observed by independent assessors (the number of lifts performed per shift, estimates of the load lifted or estimates of the number of patients lifted per week). The analysis did demonstrate a relationship between frequent exposure to lifting and the prevalence of back pain although specific patient handling tasks were not identified in relation to large exposure/repetitive performance. Smedley et al. (1995) found significant associations between back pain and the frequency of manually moving patients around on the bed, manually transferring patients between bed and chair and manually lifting patients from the floor.

Harber et al. (1987) performed an observational investigation of sixty-three work shifts within hospital units. The study demonstrated the high incidence of static postures during the normal working duties of nursing personnel (10.3 per hour). These actions were defined as actions involving patient contact in which the nurse maintained an antigravity position potentially stressing the back for at least 30 s. Static activities may also require the adoption of awkward postures for the duration of the isometric action. Activities not involving the handling or transfer of patients were also observed to be performed regularly (pushing equipment, carrying supplies). It was not identified whether the nursing staff associated the performance of these activities with symptoms of back pain.

Patient handling tasks perceived to be most stressful by nursing assistants were identified by Owen and Garg (1989). The tasks ranked as the most stressful were those that involved the lifting and transferring of patients from one destination to another. These findings corroborate the results of Stobbe et al. (1988) whereby nursing personnel believed back stress to occur as a result of the lifting of patients. Static tasks were not included within the sixteen patient handling task categories which had been drawn up from a list of 153 tasks suggested by the study participants as being the most stressful to perform. Therefore, although Harber et al. (1987) observed that static activities were regularly performed by nurses, they may not be perceived as stressful.

Despite differences in the methodologies of the epidemiological studies conducted amongst nursing personnel, it is apparent that nurses attribute back pain symptoms to the patient-handling activities routinely performed. A relationship is also evident between exposure to lifting tasks and the prevalence of back pain. Nurses report a preponderance of pain with an acute onset although a rationale has been proposed incorporating the consequences of repetitive exposure to submaximal "trauma". It is difficult to differentiate between acute and non-acute injury/pain as it is logical to associate the occurrence of pain with a particular causative event. Exposure to repetitive lifting may lead to the insidious onset of pain. However, pain may only be evident after the performance of one lift in particular; this may be perceived as an acute onset of symptoms.

Although observational studies have helped in quantifying the proportion of nursing work-shifts in terms of exposure to lifting and patient-handling, the relationship between specific nursing tasks and the prevalence of pain has not been investigated in great detail. This applies particularly to static postures. In addition, the majority of epidemiological studies have failed to identify nursing grades and specialities which may place individuals at increased risk of experiencing pain. This is most likely to be due to changes in grade and speciality during the course of nursing career.

4.1.2 Trunk muscle strength and back pain

Controversy exists as to whether reduced muscle strength is an aetiological or predisposing factor in the incidence of back pain. Battié et al. (1989) found only a slight association between isometric lifting strength and the development of back pain symptoms in a four year follow-up study of industrial workers. Biering-Sørensen (1984) reported weak trunk musculature to be more pronounced among subjects who experienced recurrence or ongoing low back trouble during a follow-up period of twelve months. Isometric endurance time of the trunk muscles in men was indicated as a predictor for first time experience of low back trouble. Forces in maximal voluntary contraction of the trunk musculature either in flexion or extension were not significant variables in the stepwise discriminant analysis of predictive variables for the first time experience of pain.

Kumar (1994) measured isometric and isokinetic strength in flexion, extension, lateral flexion and axial rotation in control and chronic back pain patients. The symptomatic group had been off work due to back pain for three months. The patients were significantly weaker than the normal controls ($P<0.01$). In addition, Lee et al. (1995) found average peak torque values of the trunk and lower extremities to be reduced significantly in a low back pain group compared to asymptomatic individuals. In a further study of peak abdominal strength and trunk extensor endurance by Smidt (1983), normal subjects demonstrated 48-82% greater strength values compared to patients with chronic low back dysfunction.

It would appear that in studies where the trunk strength of back pain populations has been compared to peak torque values of asymptomatic populations, the former group clearly demonstrate lower strength capabilities. Therefore, a relationship exists between trunk muscle strength parameters and the prevalence of back pain symptoms. Lee et al. (1995) attributed this to i) either generalised muscle weakness resulting from disuse atrophy or poorly endowed musculature by nature, or ii) psychological factors such as fear of injury or malingering during the test. This latter issue was indirectly confounded by Rissanen et al. (1995) who demonstrated that the intensity of momentary low back pain during the strength test procedure did not correlate with isokinetic trunk extension peak torque. However, there is probably scope for the implementation of isokinetic dynamometry as a diagnostic tool. It is only with the implementation of longitudinal studies that the relationship between trunk muscle strength parameters and the incidence of back pain may be fully established. These would endorse or counter the use of isokinetic strength tests to predict the experience of symptoms.

4.1.3 Physical exercise and back pain: rehabilitation and prevention

Research conducted to investigate the possible advantages of participating in physical exercise or training with regards to the incidence and prevalence of back pain have concentrated upon the strength of the trunk musculature. The majority of these studies may be differentiated according to distinct objectives: i) to reduce the severity of back pain symptoms (Elnaggar et al., 1991; Rissanen et al., 1995); ii) to identify predictive variables associated with the risk of experiencing pain (Chapter 3.2.2), and iii) to establish relationships between muscular strength and lifting capabilities to possibly reduce the incidence of back pain symptoms (Asfour et al., 1984).

Rissanen et al. (1995) investigated the effects of an intensive physical rehabilitation programme on the trunk extensor muscles in patients with chronic low back pain (14 men, 16 women); both the strength and structure of the musculature were investigated. The results of muscle biopsies of the multifidus and isokinetic parameters of the trunk were reported at baseline and after 3 months of rehabilitation. The rehabilitation programme incorporated home exercises followed by 3 weeks of intensive in-house rehabilitation (strength and aerobic training, spinal flexibility). A further period (6-7 weeks) of home training completed the protocol. Trunk extensor peak torque increased significantly ($P<0.05$) at the post-training assessment. The Type II muscle fibres (Type IIc and Type IIb not differentiated) within the multifidus in male subjects increased by 11% ($P<0.05$), suggesting that it is possible to reverse the selective atrophy associated with chronic back pain. However, in females, the slight increase in Type II fibres was not significant. It was suggested that women may need a longer training period than men to achieve significant structural changes in their back muscles. Pain and disability were reduced within the sample although these subjective symptoms showed no statistically significant association with strength improvement or the hypertrophy of Type II fibres in the back.

Elnaggar et al. (1991) also demonstrated a reduction in the reporting of low back pain symptoms following flexion and extension exercises of the trunk; an increase in sagittal mobility was also observed. Two treatment groups undertook either flexion exercises or activities involving extension of the trunk. Home exercises and in-house treatments were administered over a two week period. There was no significant difference between the exercise prescriptions in terms of reduction in the severity of back pain symptoms.

It has been suggested that in order to decrease the incidence of work-related musculoskeletal disorders either the loads lifted during work should be reduced, or the lifting capability of the worker be increased (Asfour et al., 1984). Whilst an ergonomic approach would favour the former, it was with the latter recommendation in mind that Asfour et al. (1984) conducted a study investigating the effects of endurance and strength training on lifting capability. A training programme of 6 weeks duration was designed. The programme incorporated activities to influence flexibility, muscle strength and endurance and cardiovascular endurance; progressive resistance exercises were performed to increase muscle strength. Ten male subjects participated in the study; all were asymptomatic of back pain at the time of the study. The training programme resulted in significant increases (percentage indicated in parentheses) in the maximum acceptable weight lifted (average 65% increase for three different lifts), isometric back (30%), arm (36%), leg (19%) and shoulder (14%) strengths of the subjects. Maximal oxygen uptake also increased significantly (23%). Isometric strength and endurance increased after only 10 exercise sessions. The study demonstrated the benefits of physical training in terms of muscle strength although the beneficial consequences of increased muscle strength (e.g. a reduction in the incidence of work-related back injuries) were not established.

Genaidy et al. (1990) designed an endurance training programme for symmetrical and asymmetrical manual lifting tasks. Sixteen sessions of training were undertaken by sedentary male subjects inexperienced in manual handling. Endurance time for the symmetrical and asymmetrical lifting improved significantly 248% and 46% respectively. The latter task requires greater muscle activation and may be considered a more complex task to perform. The subjects did not usually engage in physical activity before the study, therefore the improvements in the performance of endurance lifting tasks may not be directly applied to those experienced individuals who are required to perform manual handling tasks at work.

The efficacy of physical training to improve measures of muscular strength and reduce pain intensity in symptomatic individuals has been demonstrated. Although psychophysical, isometric and isokinetic tests of manual handling capability and muscle strength have been applied to assess the effectiveness of physical training in asymptomatic individuals, few studies have examined a female population. Occupational-related studies do not appear to have included samples with the relevant manual handling experience; individuals who are inexperienced in the performance of complex lifting tasks will undoubtedly demonstrate a learning effect during the course of repeated testing. The testing of control subjects would provide the opportunity to examine the consequences of familiarisation, unfortunately, there appears to be insufficient use of control groups to differentiate between the changes in performance measures due to actual improvements in strength or adaptations due to task familiarisation.

4.2 SPINAL LOADING

4.2.1 Axial compression and *in-vivo* stature changes

The influence of static and axial compression has been described by a number of authors (Troup et al., 1985; Corlett and Eklund, 1986; Tyrrell et al, 1985; Althoff et al, 1992). Axial (or as close to as possible) compression of the vertebral column was achieved by the placing of a weight bar on the subjects shoulders, or the wearing of a backpack or weighted vest. Troup et al. (1985), Tyrrell et al. (1985) and Althoff et al. (1992) demonstrated a linear relationship between stature loss and the load applied. Tyrrell et al. (1985) observed a 11.2 mm (mean) loss in stature following 20 min of loading with a 40 kg barbell; the mean loss in stature for a 10 kg load over the same time period was 5.14 mm. The stature loss induced by wearing a 10 kg rucksack was similar to that induced by the barbell (5.45 mm).

More recent work on a modified stadiometer with a refined measurement procedure to accommodate the normal diurnal variation in stature loss has been conducted by Althoff et al. (1992). It was proposed that the amount of stature loss due to a given load depends on previously imposed loads and hence on the time of day. The technique involved fitting an exponential to the pre-test stature data to predict the normal diurnal variation. Following the 30 min test (lifting) period (stature measures every 5 min), a second exponential was fitted to the difference of the data taken during the subsequent test period minus the prediction. The net change of stature was the difference between the two exponentials. The pre-test period experimental session was of between 25 - 40 min duration. Stature was measured between 20 and 40 s following the interruption/completion of the load bearing task. This does not account for the influence of heel pad thickness and the 2 min period for equilibrium of the heel to be established (Foreman and Lingo, 1987). Nevertheless, an investigation demonstrated that a decrease in stature was proportional to the quasistatic load on the spine (shoulder load 0-30 kg).

4.2.2 Dynamic lifting and *in-vivo* stature changes

Tyrrell et al. (1985) again observed the effect of load on stature changes. Repetitive lifting (12 lifts per min for a period of 20 min) of 10 and 40 kg loads induced 6.90 and 14.49 mm loss of stature respectively; the difference between the loads was highly significant. van Diën and Toussaint (1993) commented upon this greater loss of stature following dynamic as opposed to axial loading tasks. They suggested that the greater loss of stature observed following dynamic lifting tasks could not be attributed to different reactions of the spine to dynamic and static lifting. Although different compression forces act on the spine during the performance of dynamic lifting and static tasks, it is uncertain whether the greater stature loss observed following dynamic lifting is in contrast with the linear relationship between load and shrinkage in axial loading. It would appear appropriate to consider the consequences of dynamic lifting in combination with the effects of axial compression. The influence of compression resulting from flexion and the subsequent posterior stretching of the annulus fibrosus is difficult to quantify but is an important consideration in the overall magnitude of the stature loss observed.

Stålhammar et al. (1989) studied the effect of self-paced and fixed-pace lifting. Subjects performed 30 min of repetitive lifting following 15 min in the Fowler position. Self-paced and fixed-pace stature changes were not significantly different: 6.8 mm and 5.8 mm respectively. The time at which stature measurements were taken was not specified. Therefore the stature loss values include the normal diurnal loss over the test period in addition to the loss induced by the compressive loading of the activity.

van Diën et al. (1994b) compared the load imposed on the low back during two lifting techniques: the leg lift and back lift. No differences in the stature loss induced by the lifting techniques were observed. The creep curves for loss of stature were plotted (similar to Althoff et al. 1992) thus controlling for the diurnal variation in stature.

Large inter-individual differences have been observed within a number of studies even when activity prior to the test measurements is controlled (van Diën et al., 1994a and b). Therefore it may be suggested that the measurement of stature changes to assess the compressive loading effects of lifting tasks is applicable by both current measurement techniques i) time series/curve fitting techniques, or ii) by standardising prior activity and time of day, as long as the same subjects are used in all situations studied or if a large number of subjects are available.

4.2.3 Unloading the spine

The benefits of the adoption of postures to unload the spine have been documented briefly in Section 3.1.2. Recovery of the height of the motion segment following compressive loading may be achieved by a number of means. Postures adopted to facilitate hydration of the intervertebral discs include the Fowler position (Leatt et al., 1985; Tyrrell et al., 1985; Stålhammer et al., 1989), standing/walking (Tyrrell et al., 1985; Reilly and Peden, 1989; Helander and Quance, 1990) and gravity inversion (Leatt et al., 1985; Boocock et al., 1988; Boocock et al, 1990).

Tyrrell et al. (1985) compared standing recovery against recovery in the Fowler position following experiments involving static and dynamic loading. The regains in stature increased with respect to the increase in load and with respect to the amount of shrinkage that had occurred during the load bearing tasks. The authors reported a maximum recovery of 79% in 10 min standing after 20 min of axial loading (10 kg) and a maximum recovery of 128% in 10 min of Fowler position (100% being full recovery of the pre-exercise value). Therefore the Fowler position may be considered a more effective method of promoting disc height recovery.

Leatt et al. (1985) compared the effects of adopting the Fowler position to regain losses in stature with a gravity inversion system. Ten male subjects were inverted at 90°, 70° and 50° to the vertical. After 30 min of the 50° inversion, the greatest mean increase in stature occurred (5.57 mm); the corresponding value for the Fowler position was 3.58 mm. The magnitude of the stature changes induced by the acute unloading conditions in comparison to the normal circadian variation were relatively small: 20% and between 25 -30% of normal variation (19 mm) for the Fowler position and gravity inversion respectively. Leatt et al. (1985) proposed that the gravity inversion procedure offered a marginal advantage over the Fowler position in terms of unloading the spine. In addition, during the first 10 min of the treatment approximately 60% of the total gain in stature had occurred. Therefore, although further, slight increases occur over a prolonged period of time, a 20 min unloading period would be considered adequate.

The effects of unloading have been demonstrated to be relatively transient (Leatt et al., 1985; Boocock et al., 1990). Following post-exercise gravity inversion, 30 min of standing resulted in measurements of stature equivalent to those obtained following a similar regimen which substituted standing for gravity inversion (Boocock et al.; 1990). The potential benefits to the intervertebral discs following periods of unloading in terms of fluid flow and disc nutrition are well documented (Adams and Hutton, 1983). It would appear that following periods of unloading, there is a rapid return to the normal disc responses for time of day. This has implications for the programming of work-rest schedules of activities which may impose compressive loads on the spine: brief sessions of work interspersed with periods of approximately 20 min unloading.

Helander and Quance (1990) examined the relationship between duration and frequency of rest intervals and changes in stature. Subjects simulated keyboard work in the sitting posture for periods of 4 hours; forty minutes of rest break were permitted during this period. Four different rest conditions were imposed during the work schedules; eight breaks of 5 min, four breaks of 10 min, two breaks of 20 min, or a single break of 40 min at the end of the work session. Rest periods (standing/walking) of 20 min and 40 min resulted in significantly less loss of stature at the end of the four-hour working period. The 40 min rest period was scheduled at the end of the work period and the final measurement of stature was taken immediately upon cessation of this. In addition, the results may be explained by the relationship noted by Leatt et al. (1985) and Boocock et al. (1990) that changes in stature are dependent upon the duration of both the period of loading and the period of unloading (up to approximately 20 min).

4.2.4 Nursing activities and stature changes

Foreman and Troup (1987) investigated the relationship between loss of stature and the workload of eleven nurses. Measurements of stature and workload were investigated during two working shifts (07.45-16.30 hours and 11.30-20.30 hours) and stature was measured in ten of the subjects between 08.00 and 20.30 hours during a day off. Workload was assessed using real-time observation coding to record the frequency and duration of work activities and postures. The mean total loss of stature for the early and late shifts were 10.2 mm and 9.8 mm respectively; the difference between the shifts was not significant. During the day off work (12 hr), mean loss of stature was 8.1 mm. Correlation analyses between workload variables and stature changes during work-shifts revealed a relationship in the late shift between i) loss of stature and the duration of activities involving lean/stoop postures, and ii) between loss of stature and total lifting duration. Measurements of stature were taken at intervals during each shift (before and after meal/coffee/tea breaks). Further analysis of these periods actually identified relationships between workload and loss of stature which were stronger during the early shift.

The authors reported that the duration for which the spine was off-loaded (standing and sitting without load) was inversely related to loss of stature. These off-loading activities occur intermittently throughout shifts and would affect the magnitude of stature loss, especially if measurements of stature were taken immediately following a period of rest. The study did demonstrate that nursing work induced stature losses greater than those observed during a day off work. Although periods of off-loading could not be controlled during the working shifts of nurses, relationships between the duration of lifting, lean/stoop postures and loss of stature were observed.

4.2.5 Spinal loading and back pain

Few studies have implemented the non-invasive technique of spinal shrinkage to measure changes in stature among symptomatic populations. Hindle et al. (1987) conducted a clinical study to investigate diurnal stature variation amongst patients with ankylosing spondylitis. Patients matched against asymptomatic controls exhibited significantly reduced diurnal variation in stature: 0.34% of total body height in the symptomatic patients, 0.68% of total body height in the controls. This reduced diurnal variation was attributed to ankylosing spondylitis; features of the condition include ossification of the outer collagen layers of the annulus fibrosus. It was postulated that the deposition of this bone would stiffen the motion segment thus reducing the mobility of the intervertebral disc. This would reduce the response of the vertebral column to the compressive loads associated with gravity and habitual activity. The diurnal variation observed in the asymptomatic individuals was lower than values previously reported (Reilly et al., 1984). Differences in the time over which stature measurements within the studies cited were obtained would account for these discrepancies.

Garbutt et al. (1990) compared the changes in stature observed in two groups of long distance runners with and without low back pain; no differences between the two groups were observed after 15 and 30 minutes of running. Spinal loading was not strictly standardised in the study as subjects were running at percentages of their marathon times. Runners with severe symptoms of back pain did not participate in the study. The experimental group was therefore able to train and compete with mild symptoms; the prevalence of back pain, may not have been a strong enough indicator to predict that these subjects would demonstrate stiffening of the motion segment due to compression.

4.3 SUMMARY

Back pain and its associated disability within the nursing profession have been widely attributed to the manual handling that the job entails. A large number of retrospective surveys has been conducted worldwide but the different prevalence rates reported can not be directly compared due to differences in the methods of investigation. This does highlight the need for replication of previous studies so that current figures regarding back pain and measures of disability may be obtained.

Although the relationship between the exposure of nurses to lifting tasks and the experience of back pain has been established, the identification of specific occupational tasks implicated as causative has received less attention. Studies have attempted to quantify the duration and frequency both patient-handling and non-patient-handling tasks but there is still a need to identify actual tasks perceived as stressful to perform.

There are difficulties associated with the identification of grades of nurse and nursing speciality with regard to the incidence and prevalence of symptoms. Controversy exists as to whether the nurses performing a more manual role (Health Care Assistants) do experience symptoms to a greater extent compared to nurses of a higher grade.

Chronic back pain patients demonstrate reduced trunk muscle strength compared to asymptomatic individuals but it is not yet clear whether weak trunk musculature directly causes back pain or whether atrophy occurs as a result of the inactivity associated with symptoms. There also appears to be a relationship between the performance of physically demanding work and back pain. Improvements in muscle strength have been demonstrated after just ten physical exercise sessions or tasks simulating occupational lifting activities and this endorses the application of training within occupational contexts.

The validity and reliability of the measurement of changes in stature have been established. This method has been applied as a tool to reflect the compressive loads imposed on the spine during occupational, lifting and sports activities. The measurement technique does appear to have a clinical application with the reduced diurnal variation observed in patients with ankylosing spondylitis. It is plausible that loss of height of the motion segment as a result of compression-induced degeneration may be associated with symptoms of back pain. Further research is necessary to determine to a greater extent, the diagnostic application of this non-invasive measurement technique. In particular, research is needed to focus on the loads imposed on the spine during occupational tasks in symptomatic individuals compared to samples who report no symptoms of back pain. The performance of epidemiological studies amongst nursing personnel would identify occupational tasks associated with the incidence and prevalence of back pain symptoms and provide information regarding the magnitude and consequences of the problem of back pain within this profession.

Chapter Five

Epidemiological Aspects of Back Pain

5 EPIDEMIOLOGICAL ASPECTS OF BACK PAIN

In this Chapter the problem of back pain principally amongst the nursing profession is examined. The incidence and prevalence of symptoms, the disability caused by back pain and the possible causes and consequences of the problem on job performance are established. These are all important aspects to consider within the discipline of epidemiology in order to define the health problem associated with back pain. Therefore, the studies conducted within this Chapter aim to establish whether a problem does exist within the nursing profession, the nature and importance of the problem and the possible explanations for and consequences of back pain.

5.1 QUESTIONNAIRE SURVEYS OF NURSES AND MEMBERS OF THE GENERAL POPULATION

Aspects of this work have been published in Occupational Medicine, 1995, 45, 263-267, a copy of which appears in Appendix 7.

5.1.1 Introduction

The theoretical background and review of literature enabled a comprehensive discussion of the epidemiology of back pain amongst general and nurse-specific populations. It is apparent that the problem has severe implications on job performance in terms of sickness absence. Within the United Kingdom few cross-sectional, epidemiological surveys have been conducted among nursing personnel (Stubbs et al., 1980, 1983; Smedley et al. 1995) despite the existence of an excess prevalence of back pain amongst the nursing profession compared to members of the general population (Pheasant and Stubbs, 1992).

Mechanical predictive factors for back pain are integral components of normal nursing duties (lifting, twisting, bending). Studies conducted in other industrialised nations have indicated an increase in the magnitude of the problem amongst different populations. In order to be aware of both changes in the severity and consequences of back pain with in the United Kingdom, more recent figures are required from nursing personnel and from non-nursing members of the population.

Hypothesis 1. The prevalence of back pain is greater in nursing personnel than amongst non-nursing members of the population.

Hypothesis 2. There is an increase in the prevalence of back pain in contemporary nursing personnel compared to data collected in the previous decade.

The study was designed to collect epidemiological data regarding back pain from i) nursing personnel and ii) non-nursing members of the population. The prevalence and incidence of back pain was determined in both sample groups. Information regarding the possible causes of back pain in nurses and the effects of the condition on nursing and leisure activities were also ascertained.

It was appropriate to compare the epidemiological data collected from this nursing population with the result obtained from Stubbs et al. (1983). The definition of back pain and direct questions relating to the incidence and prevalence of back pain were alike in the two studies.

5.1.2 Methodology

Two questionnaires were designed for distribution to each of the two sample groups. Back pain is often difficult to define and diagnose and the present study used the term "back pain" without any further definition but asked respondents to indicate the site(s) of pain and state the medical diagnosis of their condition if applicable. This approach has been applied by other researchers (Stubbs et al., 1983).

Psychological and social parameters were not included within either questionnaire. These complex variables are associated with individuals in whom chronic back pain symptoms exist and who would probably demonstrate considerable amounts of disability (Troup, 1995). It was believed that the target samples of the questionnaires would not include a large number of these individuals. In addition, the time taken to complete the questionnaires would rise considerably if psychosocial variables were included and this might have deterred a number of the sample from completing the survey.

5.1.2.1 The nursing personnel questionnaire (Appendix 1)

The questionnaire consisted of three sections and 47 questions in total. The three sections of the form covered 1) personal and professional data; 2) the incidence and prevalence of back pain, possible causes of symptoms/injury and its effect on nursing and leisure activities; 3) limitations to patient-care and the use of assistive devices during patient transfers. All personnel participating in the survey were required to complete sections 1 and 3; the number of applicable questions in the second section varied depending on the prevalence of back pain symptoms.

A pilot study was conducted in December 1992 in one NHS Trust hospital in Liverpool where 50 nurses of various grade and in a number of specialities volunteered to complete the form. Minor alterations were made to the structure of the questionnaire following this survey.

(i) Sample. In total, 2100 questionnaires were issued to five NHS Trust hospitals and one Community (NHS) Trust in Merseyside. Nurses of all grades working in different specialities were requested to complete the form regardless of whether or not they suffered from back pain. The number of forms issued to each of the participating NHS Trusts corresponded to the number of nursing personnel within the specialities. In order to ensure that each speciality was evenly represented in the response, some hospitals were only issued with questionnaires for particular specialities. The specialities included in the survey are displayed in Table 5.1.

Table 5.1 Nursing specialities surveyed by questionnaire

General Surgical	General Medicine
Paediatrics	Geriatrics/Psychogeriatrics
Orthopaedics	Psychiatry/Mental Illness
Theatre	Intensive Care Unit
Community	Accident & Emergency

(ii) Distribution. The questionnaire survey was conducted during January and February 1993. The mode of distribution of the forms varied according to the assistance available from the Director of nursing and hospital support staff; it was not possible to standardise the distribution. In two hospitals the Director of Nursing took responsibility for circulating the questionnaire to Nurse Managers of the appropriate specialities/directorates, where they would be subsequently issued to personnel on individual wards. The Directorate Nurse Managers in two hospitals were willing to issue the forms to nursing personnel in respective specialities and in only one hospital did the form go directly to the individual ward Sister/Charge Nurse. Distribution of the questionnaire to Community nurses/midwives was arranged through the Resource Management Co-ordinator to locality managers within the region and then onto individual personnel.

Questionnaires were collected from the individual who originally circulated the form within each hospital, 3-4 weeks following distribution. Collection of the completed forms from the Community Trust Resource Management Co-ordinator occurred within a slightly longer time period due to the delay in distributing and returning the forms to and from different localities. Due to the confidential nature of the questionnaire it was not possible to identify and follow-up those individuals who had not completed or returned the form.

5.1.2.2 The questionnaire issued to non-nursing personnel (Appendix 2)

This questionnaire was a shorter, modified version of the form the nurses completed. The survey was designed to establish the prevalence and incidence rates of back pain for the purpose of comparison with the nurses' data. Therefore it requested minimal information regarding job/work history and the consequences of back pain symptoms upon work and leisure activities. The questionnaire comprised of two sections and 16 questions in total. Section 1 of the form covered personal and professional data whilst Section 2 enquired about the prevalence and incidence of back pain. All participants were requested to complete section 1 of the form and the number of questions responded to in section 2 varied according to individual experience of back pain symptoms.

A pilot study was conducted whereby 30 volunteers in a range of occupations completed the form. It was not necessary to alter the questionnaire following the pilot study.

(i) Sample and distribution. In order that the questionnaire be circulated to a sample representative of the non-nursing population, personnel managers of a number of established companies in Liverpool were asked to issue the questionnaire to members of staff. Six employers permitted the distribution of the form to a cross-section of their employees or to individuals attending meeting/classes on their premises. It was requested that the questionnaire be distributed predominantly to females to control for gender when making comparisons between the findings of the two surveys. In total, 500 questionnaires were issued and completed forms were returned to the representative of each organisation who had co-ordinated the distribution. These forms were collected 3-4 weeks following their initial deposit.

5.1.2.3 Analysis of data

Statistical analysis of the data generated by both questionnaires was performed using SPSS (version 4.1). The responses of male and female respondents in each sample were pooled and analysed jointly.

The data from each questionnaire were entered separately onto a system file. The SPSS edit command facility was used to perform explorative, descriptive and comparative statistics. Categorical and numerical variables were examined using cross tabulation and chi-square (χ^2) analyses to examine the relationship between two or more variables. Pearson Product Moment correlation analyses (correlation coefficient = r) were applied to normally distributed numerical variables to establish the existence of a linear relationship. Responses to ranked and non-parametric variables were examined for linear relationships using Spearman's rank correlation analyses (correlation coefficient = r_s). The information derived from the questionnaires was predominantly descriptive. The application of multivariate analyses was not considered appropriate to the outcome of the study. The specificity and range of questions regarding particular risk factors would not have been sufficient for a comprehensive and valid multivariate analysis to be performed.

5.1.3 Results

5.1.3.1 Response to questions common to both questionnaires

A response rate of 63% was obtained for the general population survey (n=315). The nurses questionnaire was completed by 54% of the nurses sampled (n=1134).

The non-nursing group included sedentary workers (secretaries, receptionists) and personnel within more active occupations (fitness instructors, teachers). A small proportion of the sample was either retired, unemployed or housewives (4.5%), 56.7% categorised their occupation as "clerical/other" and 20% of the sample described their job as "middle management". The sample characteristics are displayed in Table 5.2.

Table 5.2 Sample characteristics

		Nurses	Non-nurses
Age	(years)	36	32
	(range)	18-64	16-61
Gender	(Female)	90%	83%
	(Male)	10%	17%
Sample size		1134	315

(i) Prevalence and incidence of back pain. The epidemiological data collected from both the general population and nursing personnel samples are displayed as percentages in Table 5.3. Using a chi-squared test of independence, no significant differences were found in the occurrence of back pain between the two samples for each epidemiological parameter described in Table 5.3. (point prevalence χ^2=0.057, annual prevalence χ^2=0.11, lifetime prevalence χ^2=0.561, annual incidence χ^2=2.226, degrees of freedom=1; P>0.05 in all cases).

The anatomical location of back pain amongst both sample groups included multiple sites of pain. Respondents indicated on a body diagram within the questionnaire where they experienced pain; pre-coded anatomical sites were established for analysis (shoulders, mid-back, lumbar region, buttocks/legs and multiple sites). Pain specifically in the low back was reported by 78.2% of those nurses indicating an annual prevalence of back pain. The equivalent figure for non-nursing respondents was 67.6%.

Table 5.3 Back pain and sickness absence figures for nursing personnel and members of the general population

	Nursing personnel (n=1134)	General population (n=315)
Point prevalence	24.4	25.1
Annual prevalence	58.8	57.8
Lifetime prevalence	61.4	58.9
Annual incidence	14.7	11.5
Sickness absence*	14.2	35.1

*number of days absent due to back pain expressed as a percentage of days lost for all causes *(ii) Age.* The age of the non-nursing respondents was significantly correlated to both the point (r=0.12, P<0.05) and annual prevalence (r=0.28, P<0.01) of back pain. For the respondents between the ages of 40 - 49 years, 77% reported an annual prevalence of back pain compared to 68% of nurses in the same age group. The mean age at which the first episode of back pain occurred was 25 years.

The mean age of the nursing sample was 36 (range 18-64) years. Age was significantly correlated with point prevalence of back pain (r=0.11, P<0.01) but there was no significant relation between age and annual prevalence of back pain (P>0.05). The first episode of back pain was reported to be at mean age 27 years.

The relationship between age and the prevalence and incidence of back pain for both sample groups are illustrated in Fig. 5.1 and Fig. 5.2.

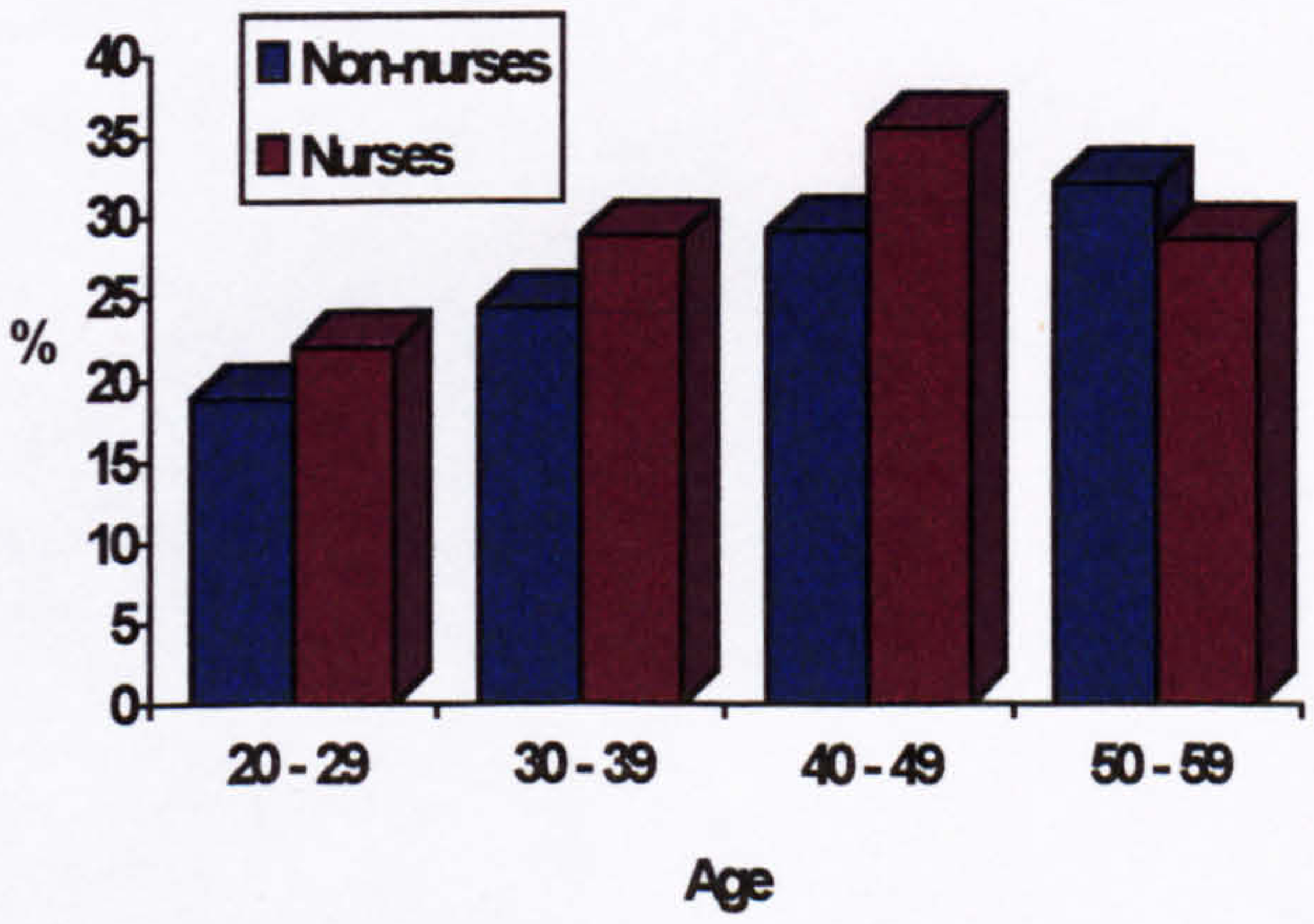


Fig. 5.1 The point prevalence of back pain within age categories in nurses and non-nursing respondents

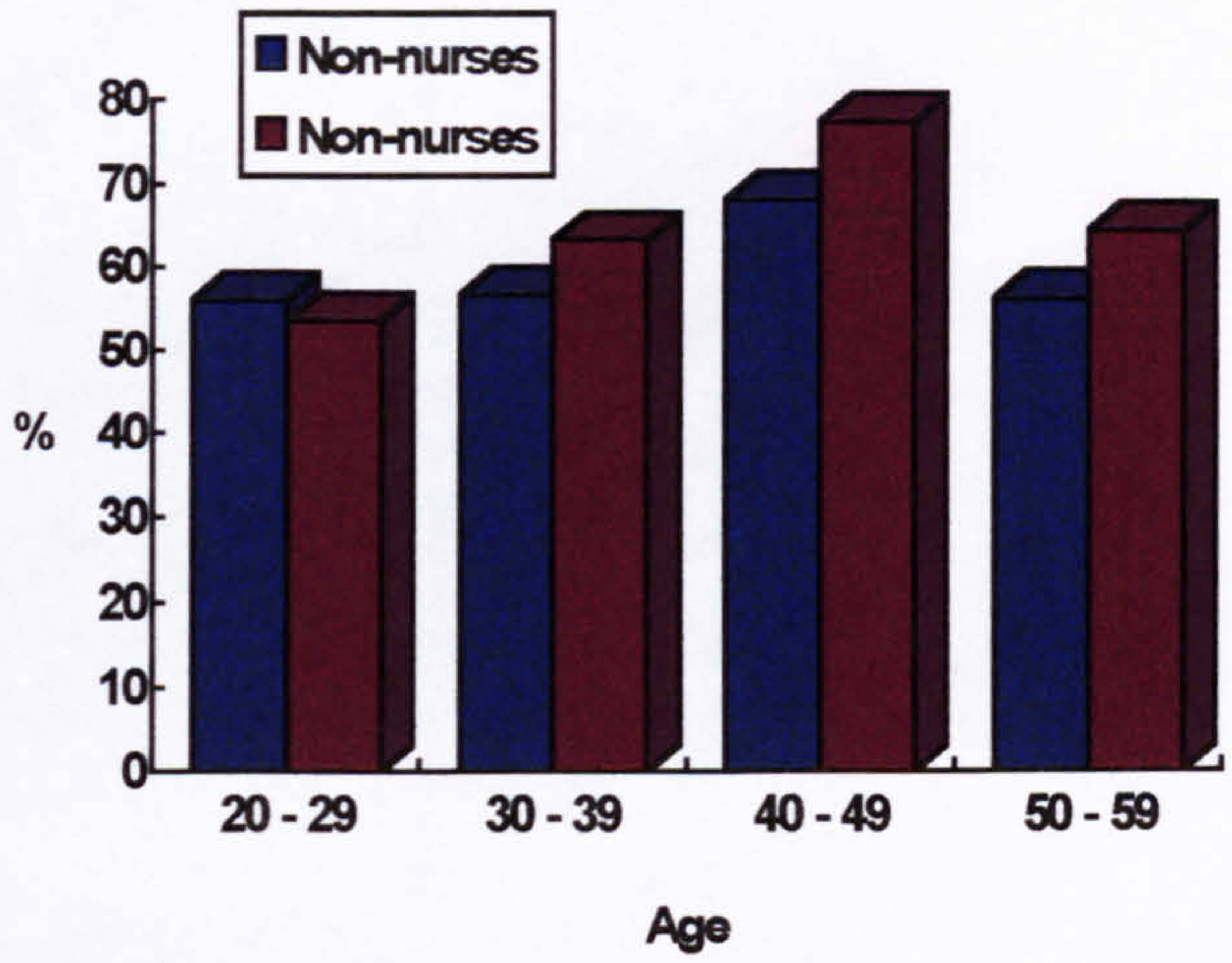


Fig. 5.2 The annual prevalence of back pain within age categories in nurses and non-nursing respondents

(iii) Absence from work. Absence from work due to back pain was reported by 11.3% of the non-nursing respondents who had experienced symptoms during the previous year. The equivalent figure from the sample of nursing personnel was 9.1%.

The non-nursing sample took more sickness absence for all causes than the nurses. Absence rates due specifically to back pain are comparable: 1578 days per 1000 non-nursing individuals and 1495 days per 1000 nurses.

When the sickness absence figures for the non-nursing sample are examined with regard to age, there is no significant difference in the number of days of absence taken by each age group (P>0.05). Amongst the nursing personnel the number of days of sickleave taken for back pain appeared to increase with age although not significantly (P>0.05).

(iv) Medical consultation for back pain. Respondents who had experienced episodes of back pain within one year were asked to indicate with whom treatment had been sought regarding their back pain. The results are tabulated in Table 5.1.4; the results were not significantly different between the nurse and non-nurse respondents (χ^2=5.80, degrees of freedom=5, P>0.05). It was not possible to identify in the analysis the respondents who had consulted more than one of the stated professionals/hospital.

Table 5.4 Proportion of respondents seeking consultation for back pain during one year

Practitioner	% nurses	% non-nurses
Occupational Health Doctor	6.5	1.4
Personal General Practitioner	31.9	33.0
Hospital Accident & Emergency	7.0	5.5
Osteopath	5.5	9.2
Physiotherapist	10.4	15.2
Other Doctor	6.9	10.6

5.1.3.2 Response to questions specific to the nursing personnel questionnaire

The grades of the nurse respondents are listed below and the percentage of the sample working at each grade is given in parentheses:

> Student (5), Health Care Assistant (18), Registered (20), Staff Nurse (30), Sister/Charge Nurse (15), Administrative Nurse (2), Community Nurse (8), Midwife (2).

(i) Precipitating factors. For the nurse respondents reporting an annual prevalence of back pain symptoms, approximately half (n=361) could recall a particular incident which started their back pain or made an existing condition worse. In two-thirds of these individuals the incident occurred whilst lifting or moving a patient and 47.5% of nurses in this group were repositioning a patient in bed as opposed to performing a patient transfer task. Table 5.5 lists the patient handling tasks implicated in the precipitation of the most recent episode of back pain. The proportion of nurses who indicated that they had filed an accident report form following an incident which induced pain numbered 177.

Table 5.5 Proportion of nurses performing different patient transfer procedures at the time of an incident which initiated back pain.

Patient transfer	% nurses*
Positioning patient in bed	47.7
Moving patient from bed	23.4
Moving patient in/out of bath	4.5
Moving patient on/off toilet	4.5
Moving patient from chair	13.1
Moving patient from floor	3.6
Other procedure	3.2

(ii) Risk within the profession. The nurses sampled had worked for a mean of 13.4 (±9) years (range from <12 months to 47 years). Forty-two percent had worked part-time at some stage during the course of their employment. The mean hours (±SD) worked per week was thirty-four (±7). Nurses had experience of working in a number of different specialities.

Of the nurses working in the orthopaedic speciality at the time of the study, 71% indicated that they had suffered back pain symptoms during the year prior to the survey. Nurses working in general medicine, community nursing, intensive care and geriatric nursing also indicated high annual prevalence rates, with 68.6%, 62.5%, 60.9% and 60.7% of the respective staff experiencing symptoms. Only 44.1% of theatre staff reported having experienced symptoms during the previous twelve months; paediatrics (51%), general surgical (48.4), psychiatry/mental illness (50.7), A&E (60%).

Back pain was reported at the time of the survey (point prevalence) by thirty-six percent of nurses working in orthopaedics. Community nurses (33%), nurses in general medicine (30%) and geriatric wards (25%) also reported high point prevalence rates compared to other specialities.

Over 50% of nurses of each grade indicated having experienced back pain symptoms during the previous year. The highest prevalence rate being amongst administrative staff (83%), registered nurses (61%) and health care assistants (59%). With regard to the point prevalence of back pain, administrative staff also indicated the highest prevalence of all the grades sampled (42%). Twenty-nine percent of nurses working in the community and twenty-six percent of healthcare assistants also indicated back pain at the time of the survey.

(iii) The use of assistive devices. Thirty-nine percent of all nurses completing the questionnaire reported that their current ward did have mechanical lifts/hoists. Of the remaining sample, 44% definitely stated that their ward did not have assistive devices. A number of wards did not have the need for these devices (12% of nurses). In response to the question "When do you most often use a lift/hoist to transfer patients" eleven percent of nurses reported that they never used a hoist to transfer patients.

(iv) Reactions to back pain. Regarding the consequences of back pain on nursing activities on those nurses indicating annual or point prevalence, 56.4% reported that back pain had made performing their work slightly more difficult but that all activities could still be continued. Only 2.5% of nurses reported that they had given up some activities. Similarly, 52.8% of nurses indicated that back pain had made activities outside of nursing more difficult although 10% of respondents had been forced to give up some activities. Driving and sport were activities reported to be "never" or "rarely" associated with back pain by over 60% of the respondents for each activity. Occupational tasks such as stooping over a patient, lifting/moving a patient and prolonged standing were indicated by over 25% of the responders to be "always" or "often" associated with back pain.

5.1.4 Discussion

Prevalence and incidence of pain, sickness absence. The prevalence of back pain in nursing personnel did not differ greatly from the data obtained from age and gender matched, non-nursing members of the general population. Within the nursing sample, the number of new cases of back pain during one year was 28% greater than for the general population. Sickness absence due to back pain formed a greater percentage of the days off work compared to the absenteeism (all causes) in the non-nursing group. However, sickness absence rates due specifically to back pain were comparable for the nurses and non-nursing respondents.

The sickness absence figures of the non-nursing sample reflect the demands of a range of occupations where the postures or activities regularly performed will vary considerably and the consequences in terms of a direct relationship with back pain cannot be measured. Therefore, sickness absence may not be a useful criteria for comparing the magnitude of the back pain problem between the two sample groups (Buckle, 1987).

Age. Owen (1986) stated that nurses were more likely to injure their backs at an earlier age compared to industrial workers, but this was not confirmed in the current study. The mean age of first onset of pain amongst the nurses reporting symptoms in the current study was 27 years and this is similar to the mean age reported for non-nursing individuals (25 years). Similarities are also evident between the two questionnaire sample groups with respect to age and peak frequency of back pain. The peak frequency of symptoms in all individuals reporting point prevalence of back pain was during the fifth decade of life. Beyond this age group, the reporting of symptoms diminished in both groups. Nurses demonstrated the same trend with regard to the annual prevalence of back pain whilst the peak frequency of symptoms was observed in the eldest age group of non-nurses. Anderson (1986) commented upon peak prevalence of back pain in workers during the fifth decade of life; attributing a decrease in the prevalence of symptoms amongst older employees to the early retirement of individuals severely affected by back pain. This is an issue which is mentioned later in this chapter, with regard to the involuntary exclusion of nurses from the study who were absent from work due to sickness or on annual leave. In addition, amongst the nursing population, older individuals are more likely to be have a greater administrative role as opposed to being involved in the manual handling of patients on a daily basis (for example, Clinical Nurse Manager, Directorate Manager, Director of Nursing). Although it is evident that these members of staff did experience back pain symptoms which could be attributed to their occupational activities, it is unlikely that the most recent episode could be due to a manual handling incident. The responses of these staff to the questionnaire are more likely to influence the annual incidence of back pain figures. The majority (95.5%) of the non-nursing sample were in employment at the time of the survey and although the type of occupational activities undertaken by this group may be very different to nursing activities, they still comprise a working population and demonstrate characteristics of other working populations (Anderson, 1986).

Risk within the profession. The career path of nurses involves experience working in a number of different specialities and may entail changes in grade as promotion is achieved; therefore risk within the profession cannot be determined with ease. Analysis of the data failed to identify conclusively the nursing grades or specialities that predisposed nurses to an increased risk of experiencing episodes of back pain. Nevertheless, within the specialities of orthopaedics, general medicine, community nursing, intensive care and geriatric nursing, over 60% of the nurses reported having experienced back pain symptoms during the year prior to the survey. Patients in these specialities tend to be heavily dependent upon nurses for mobility due to incapacity or disability. These results support the findings of Pheasant and Stubbs (1992) who added that such areas of nursing were traditionally regarded as heavy work.

Precipitating factors. Stubbs et al. (1980) reported that the most common single activity associated with back pain was moving or supporting a patient. Lifting or moving a patient in bed proved to be the procedure implicated by the majority of nurses who could recall a precipitating incident (41.3%). The results for all the activities listed in the questionnaires bear remarkable resemblance, indicating that changes to the procedures used to perform these tasks and the emphasis in training and the use of hoists has not had a great impact on the perceived causes of back pain amongst symptomatic nurses.

A retrospective questionnaire was implemented by Arad and Ryan (1986) among Australian nurses. Sixty-five percent of nurses could recall an event which precipitated their first attack of pain. A clear relationship was demonstrated between the prevalence and incidence of back pain and the number of occupational lifts performed each working shift (lift rate). Although exposure to lifting was not measured in the current study, almost half of the symptomatic nurses could also recollect an incident precipitating back pain.

Nurse respondents to the survey by Harber et al. (1985) perceived that certain activities were associated with back pain. The tasks of lifting a patient in bed and assisting a patient to get out of bed were associated with back pain in 48% and 30% of nurses respectively. These results support the finding in the current study whereby positioning a patient in bed (47.7% of nurses) and moving a patient from bed (23.4% of nurses) were implicated as precipitating back pain.

The use of assistive devices. Previous research has emphasised the need for mechanical hoists to be available to nurses in order to reduce the loads imposed on the spine during patient transfer tasks (Garg and Owen, 1992). The results of the current survey suggest that a large number of wards did not have assistive devices available for use. There are specialities where hoists are not usually required (paediatric wards). The nurses working within these specialities account for the 12% of the sample who stated that their ward did not have the need for such devices and the similar number who reported never using a hoist to transfer patients. Excluding these individuals, it is apparent that nurses still do not routinely use a hoist. Even where aids are available, time, work-space and staffing levels may dictate their practical use. Lack of training should no longer a valid reason for not using assistive devices and their importance should be emphasised to all nursing personnel. The long-term consequences of using mechanical lifting aids have not been determined with respect to the incidence of back pain symptoms and may influence the results of future epidemiological studies.

Reactions to back pain (nurses). It would appear that despite experiencing symptoms, nurses are able to continue their work duties. A number of activities were reported to always be associated with pain (lifting/moving a patient) which would support the finding that nurses attributed their pain to a patient handling incident. However, the severity of the symptoms did not appear to affect the nurses decision to perform these tasks or encourage them to use assistive devices.

Medical consultation for back pain. It was interesting to note that Occupational Health physicians were rarely consulted by nurses experiencing back pain; fear of being thought incapable of performing their job could influence choice of medical opinion sought. Nurses are aware that being physically capable to perform occupational duties is very important to their career. Symptomatic nurses may rather consult an external clinician than risk it being recorded on their occupational health record that they suffer from back pain.

Occupational Health departments are not available through all employers. This may account for the small proportion of the non-nursing respondents consulting Occupational Health physicians.

Comparison of nurses data. For the purposes of comparison, the incidence and prevalence of back pain in nurses detected in the present study and figures reported by Stubbs et al. (1983) are displayed in Figure 5.3. The latter researchers employed a similar method of data collection and the specific questions designed to elicit information enabling the calculation of figures relating to the prevalence and incidence of back pain in the current study were modelled upon those in the earlier questionnaire. Similarities in the characteristics of the two nursing samples exist, particularly the mean age of the nurses (36 years and 35.8 years) and the proportion of male respondents (10% compared to 11.5%) in the current study and the figures from Stubbs et al. (1983) respectively.

It is difficult to make direct comparisons between epidemiological data collected by different research groups. Within this discussion comparisons between studies have only been made where a similar questionnaire has been applied and the sample characteristics appear homogenous. The response rate attained by the nurses questionnaire in this study may be considered low and the existence of a response bias can not be eliminated. Nevertheless, all questionnaire studies are subject to response bias and the consequences of missing a proportion of the original sample are not clear (Raspe, 1993). Within this limitation, comparison of the results of the current surveys with the data from studies employing similar methods of data collection is justified.

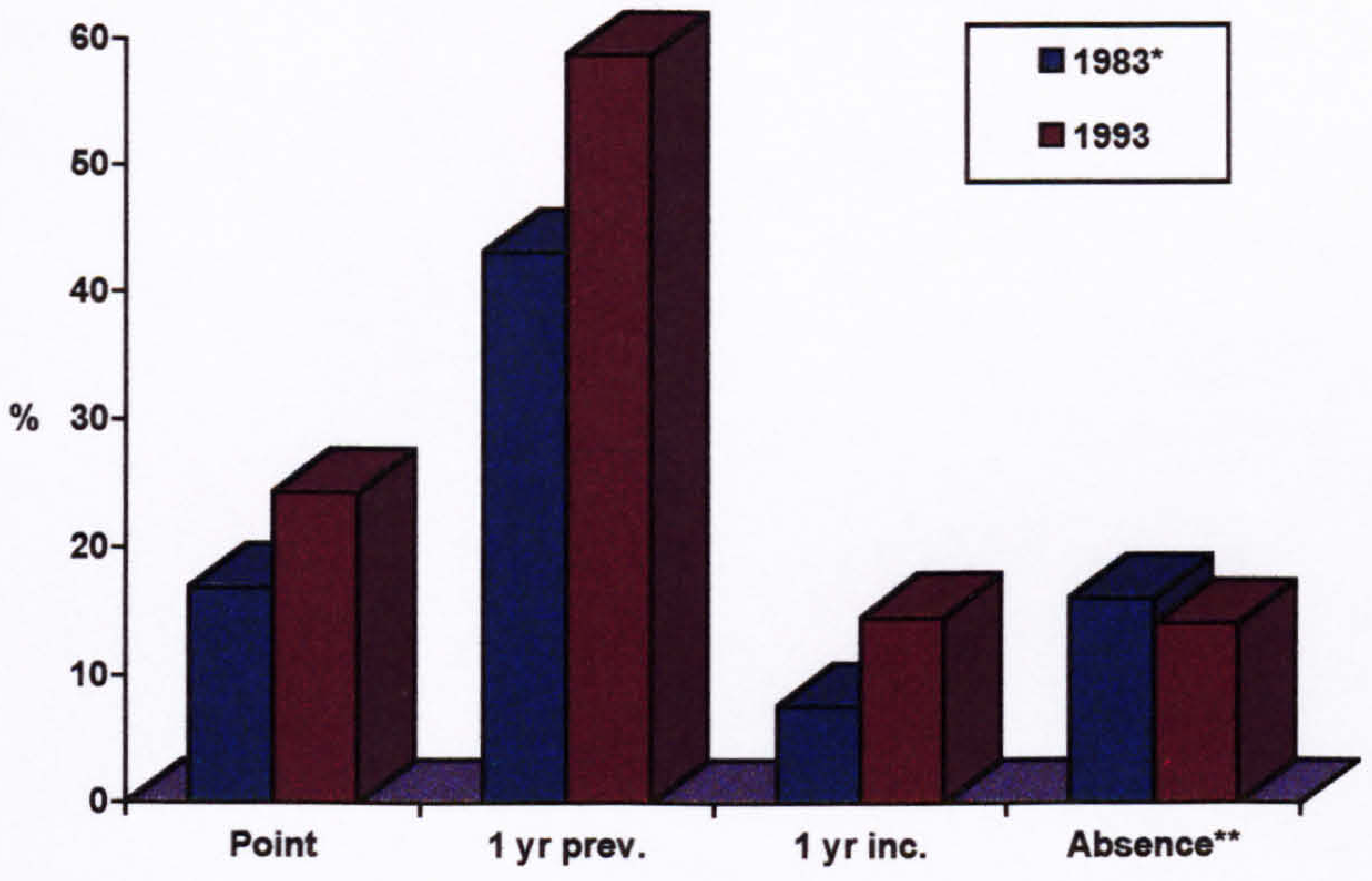


Fig. 5.3 The comparison of back pain epidemiological data for nursing personnel

* Stubbs et al. (1983)
** number of days absent due to back pain expressed as a percentage of days lost for all causes

The point and annual prevalence figures derived from the current study and that of Stubbs et al. (1983) differ by approximately 40% and the number of new cases of back pain arising during one year (annual incidence) has almost doubled. Examination of the sickness absence figures from these studies failed to indicate an entirely concomitant increase in the consequences of the condition. Stubbs et al. (1983) reported that 9.5% of nurses sampled took sick leave for back pain, compared to 9.1% in the present study. When the number of days of sickness absence due to back pain was expressed as a percentage of total days lost for all causes, the present study indicated a value of 14.2% compared to a figure of 16.2% (Stubbs et al., 1983). It may be inferred from these comparisons that the number of nurses reporting to have taken sick leave due to back pain has remained constant but that the proportion of sick leave being taken for back pain as opposed to for all causes has decreased by 14%. It would appear therefore, that there has been an increase in the number of nurses reporting to have experienced symptoms of back pain over the ten year period although the condition has not resulted in an equivalent increase in number of nurses taking sickness absence. It may also be deduced that nurses who took sick leave for back pain were absent from work for a slightly shorter length of time than previously reported by Stubbs et al.(1983). In the latter study, questionnaires were posted to nurses who were taking sick leave and personnel on annual leave. It was not feasible to do this in the current study, although it was anticipated that the time period between questionnaire distribution and collection was great enough to include the majority of personnel within these categories. It is difficult to quantify the consequences of this methodological difference and therefore, the sickness absence data should be interpreted with caution.

Walsh et al. (1992) found only small geographical differences in the prevalence of back pain in Britain. It is unlikely that differences in the epidemiology of back pain between the Merseyside sample and the nurses in South East England (Stubbs et al., 1983) could be attributable to geographical variation.

From the discussion above, it appears that three main issues have arisen as a result of the questionnaire surveys. Firstly, there has been almost a 40% increase in the prevalence of back pain in nursing personnel over a ten year period. Secondly, the annual incidence of back pain was observed to be greater in the nurse respondents in the current study compared to non-nursing members of the general population and the figures reported by Stubbs et al. (1983) for nursing personnel. The third point for consideration is the fact that number of nurses taking sick leave for back pain has not altered concomitantly over the ten year period. Each of these points will be discussed further and a number of explanations offered.

i) Increased prevalence of back pain. It is not possible to account directly for the apparent increase in the prevalence of back pain symptoms in nursing personnel over a ten year period. The results of the present study have only been compared with the data collected by Stubbs et al. (1983). It is therefore difficult to predict whether the increase has occurred gradually over the entire period of time or whether the figures represent an acute (2-3 years) increase in the prevalence rate. The latter may be a reasonable explanation, taking into consideration that the European Directive on the manual handling of loads (1990) and the implementation of the Health and Safety Executive (Health Services Advisory Committee) guidelines on the manual handling of loads in the health services, in January 1993. Prior to this date, in preparation for the implementation of the guidelines, revised training in approved lifting techniques and heightened awareness of the new regulations were initiated within the NHS Trusts. The implications of this are possibly too numerous to list. However, it is likely that nurses who previously performed lifting tasks using preferred methods no longer approved by the English Nursing Board would require time to adapt to new techniques and the associated re-training. Back problems may have arisen as a consequence of the repeated adoption of unfamiliar postures, particularly if performed in conjunction with load bearing. The implementation of prospective studies and future cross-sectional epidemiological surveys should be endorsed and would enable the incidence and prevalence rates of back pain to be monitored more closely.

ii) Greater annual incidence of back pain in nurses. Regarding the greater annual incidence of back pain in nurses compared to members of the general population, it is possible that this figure is acutely raised due to changes in the regulations governing lifting as discussed above. The implementation of the new guidelines on the manual lifting of patients and loads may have caused a sudden increase in the number of nurses reporting to have back pain symptoms. If this is the case, the figure for the annual prevalence of back pain may also be raised. However, the condition of individuals who have recently left the profession has not been considered within the analysis of the data and may influence the results further. As stated already, prospective and future cross-sectional epidemiological studies could be implemented to monitor changes in the magnitude of the problem.

iii) Sickness absence. The sickness absence figures relating to back pain may indicate either the stoicism of nursing personnel or that the severity of the symptoms in the majority of nurses does not prevent them from performing their work. The latter is endorsed by the results of the questionnaire study. Nurses who did require time off work due to back pain were absent for a slightly shorter length of time than reported in 1983.
It should be ascertained whether epidemiological figures for the general population also demonstrated an equivalent increase over the same period of time. Raspe (1993) reported the increasing occurrence of back pain. Evidence suggests that the prevalence of back pain has increased within the last 40 years. Clarification of whether the prevalence of back pain in nursing personnel was previously greater than members of other occupational groups would assist in this. Examination of the results of earlier epidemiological studies would clarify the disparity. Frymoyer and Cats-Baril (1991) suggested that the disability resulting from symptoms has increased as opposed to an increase in the prevalence of symptoms over the past twenty-five years in members of the general population. Waddell (1987) stressed the importance of distinguishing between low back pain and the disability caused by symptoms: back pain would appear to be a universal, benign, self-limiting condition, whilst disability appears to be a recent Western epidemic not related to any demonstrable change in the physical disorder. These statements may be applicable to the general population but whether they are appropriate to specific occupational populations such as nursing personnel is uncertain.

The current study demonstrated that the prevalence of back pain was similar in the two sample groups. It has been proposed that back pain occurs irrespective of occupation, training and lifestyle (Scholey and Hair, 1989). Waddell (1987) and Frymoyer and Cats-Baril (1991) are of the opinion that back pain is ubiquitous and that the majority of individuals reporting symptoms have little or no physical impairment; many people never seek medical attention. However, studies have demonstrated that it is the perceived causes of back pain that differ among groups of workers (Biering-Sørenson, 1985; Scholey and Hair, 1989). Nurses perceived their back pain to be caused by lifting and postures adopted at work; it was not possible to determine the specific causes of symptoms amongst a non-nursing sample of the general population.

5.2 THE IDENTIFICATION OF OCCUPATIONAL TASKS PERCEIVED TO BE MOST STRESSFUL BY NURSING PERSONNEL

Aspects of this work have been presented to The Society for Back Pain Research meetings at Leeds General Infirmary, November 1994 and at The University of Aberdeen, April 1995.

5.2.1 Introduction

The results derived from the survey conducted in the previous section established that a substantial number of nurses associate the onset of back pain symptoms with manual handling/lifting tasks. These results are supported by similar findings by Stubbs (1980) and Smedley (1995). The performance of these occupational lifting activities may also indirectly influence the insidious onset of back pain symptoms, for example when task repetition is high.

Harber et al. (1987) identified the frequency and duration of various nursing activities performed during the course of a shift. Owen and Garg (1989) went further to identify particular patient-handling tasks that nurses regarded as stressful to perform although the effects of the performance of non-patient handling activities were not examined. It was the object of this study to identify specific patient handling tasks that nursing personnel perceived to be most stressful and to establish the extent of the exertion experienced. The survey also aimed to ascertain why the tasks were stressful and to identify the areas of the body where strain was felt.

5.2.2 Methods

The study was conducted by semi-structured interview to simplify the mode of response that a self-administered questionnaire would have demanded.

(i) Subjects

Sixty-seven female nurses participated in the study. The nurses interviewed were either from one NHS Trust hospital in Liverpool or nurses attending courses in a University School of Health Care. The mean age of the nurses was 25 (±6.7) years. Seventy percent of the nurses interviewed had experienced back pain at some time during their life (lifetime prevalence).

(i) Definition of "most stressful"

All the participants interviewed were given a verbal definition of the term "most stressful" related to the performance of occupational activities:

> "those tasks requiring the greatest amount of physical exertion, and which may cause feelings of pain and fatigue".

During the interview, nurses were asked to identify tasks which they perceived as the "most stressful".

(ii) Task analysis questionnaire and interview procedure

The "questionnaire" consisted of 4 sections. It was explained to each nurse on an individual basis and administered in the order detailed below. Responses to each section were recorded by the interviewer. All interviews were conducted by the same individual.

A list of 13 occupational tasks had previously been compiled (Table 5.6). The tasks were identified following discussions with nurses of various grades, nursing administrators and lecturers. The frequency of task performance and the association with stress and/or discomfort during execution of the activity were considered during the selection of the tasks. Nurses were asked to select the five tasks they considered to be the most stressful to perform and rank them in order of 1 - 5 (most - less stressful).

To determine why any of the tasks listed in Table 5.6 were considered stressful, a second list was produced. The nurses were asked "What **most** affects your ability to perform the tasks?" and were shown a list of suggestions (Table 5.7). Corresponding to the five tasks already identified, subjects selected the most appropriate reason for each task (only one reason per task).

Table 5.6 The list of occupational tasks from which the "most stressful" to perform were selected

Turning/rolling the patient in bed
Moving the patient up the bed
Placing a bedpan under the patient
Carrying the patient from bed to chair
Assisting the patient from bed to standing
Assisting the patient to stand from a chair
Moving the patient back in a chair
Assisting the patient to become seated
Supporting the walking patient
Dressing/undressing the patient
Changing traction
Transfer the patient from bed to trolley
Static postures for medical attendance

Nurses were shown a body diagram (Appendix 3) and asked to indicate on the figure where on their own body they felt most the most stress during performance of each of the five selected tasks. The specified site was coded within a pre-determined anatomical area. Perceived exertion (RPE) was rated by applying Borg's (1970) scale to measure the overall stressful nature of the task subjectively. Nurses were asked to rate the intensity of the exertion felt during performance of the ranked tasks, using the scale from 6 - 20, shown in Appendix 4.

(iv) Analysis of data

Statistical analysis of the data generated by the questionnaire was performed using SPSS (version 4.1). Frequency and descriptive analyses were sufficient to rank the factors within the questionnaire.

Table 5.7 List of responses to the question "Why are the tasks stressful?"

You suffer back pain?
Your own physique?
Equipment hinders your movement?
Confined working area?
Tasks performed incorrectly?
Task requires awkward postures/movements?
Understaffing?
The patient?

5.2.3 Results

(i) Task ranking

The task which was ranked the highest for stress was the procedure for moving a patient up the bed (mean = 3.9 ± SD 2.3). The task ranked second in terms of stress was the patient-transfer task of carrying a patient from bed to chair (mean = 4.5 ± 2.9). Static postures adopted during medical attendance activities achieved the third rank order (mean = 4.8 ± 3.5) and the task of transferring a patient from a bed to trolley was ranked fourth (mean = 5.5 ± 4.2). Turning/rolling the patient in bed was ranked number 5 (mean = 6.3 ± 3.7).

(ii) Perceived limitations to performance of the tasks

The procedure for moving a patient up the bed was considered the most stressful due to the confined working area in which nurses must perform the manoeuvre. Physique was the factor most affecting the nurses' ability to perform the procedure to carry a patient from bed to chair. It was also apparent that the stress associated with static work postures was initiated by the adoption of awkward positions. The task of transferring a patient from bed to trolley was considered stressful due to the equipment hindering the movement of the nurses as they performed the transfer. Posture was also perceived to be the factor most often associated with the stress of the fifth ranked task of turning/rolling the patient in bed.

(iii) Site most associated with stress

With regards to the area of the body where most stress was felt during performance of each of the five ranked tasks, Table 5.8 lists the responses.

(iv) Rating of perceived exertion

The rating of perceived exertion subjectively quantified the 'overall' stressful nature of the task; therefore this rating was therefore not just applicable to the site where nurses reported feeling the most stress.

Table 5.8 The anatomical sites where most stress was perceived to occur during the performance of the ranked tasks

Rank	Task	Anatomical site
1.	Move patient up the bed	neck, shoulders, upper back
2.	Carry patient from bed to chair	multiple sites of upper body
3.	Static postures	lower back and buttocks
4.	Transfer patient from bed to trolley	lower back and buttocks
5.	Turning/rolling patient	lower back and buttocks

The values corresponded to the rank order of stressfulness (1-5) in as much that the greatest RPE values were associated with the high ranked tasks. The highest ranked task of moving a patient up the bed achieved a mean RPE of 14.6 (± 1.8), whilst the carrying of a patient form bed to chair was considered less stressful (mean = 13.2 ± 3.6). Static postures were rated with a mean of 12.8 (± 2.5) and the patient transfer from bed to trolley was rated with a mean of 12.7 (± 3.0). Turning/rolling a patient in bed was the least stressful of the five ranked tasks with a mean of 11.3 (± 2.5).

5.2.4 Discussion

The study identified the tasks that nursing personnel considered to be the most stressful from a list of frequently performed activities. The tasks ranked as stressful included the activities requiring the adoption of static postures and the turning/rolling of a patient. Therefore, it was not only lifting tasks that were perceived to be stressful, either to the whole body, or to the lower back.

The mean ratings of perceived exertion for the five ranked tasks corresponded to expressions of "somewhat hard" to "fairly light" in terms of stress. No individual task was given a rating of 18 or higher (between very hard and very, very hard). There are a large number of factors that could influence how stressful a nurse may perceive a task, those of significance will be discussed in this section.

Nurses are trained in the techniques of patient-handling procedures. For the task of moving a patient up the bed the "shoulder lift" is frequently used. Two nurses perform the lift, positioned either side and facing the head of the bed. The patient sits forward and the nurses place their inside knee on the bed level with the patient's buttocks so that the outside leg is still on the floor and slightly forward. The nurses place their shoulders under the patient's axillae, supporting his or her chest; the patient's arms are placed over their shoulders. The nurses hold hands high up under the patient's thighs and place their free hands on the bed. The lift is carried out by straightening the knees and transferring the weight from the inside leg to the outside leg, leading with the head. For transferring a patient from bed to chair the same principles are adopted as for the manoeuvre up the bed but the patient is positioned on the side of the bed in preparation for the transfer with the nurses facing the patient. It would appear appropriate that nurses perceived the most stress to be felt within the neck, shoulders and upper body for these procedures and the weight of the patient would have additional bearing on that strain.

Static postures adopted during medical attendance tasks may involve stooping, standing, squatting or reaching, but it is the length of time that such positions are maintained that causes the stress. These tasks may have a considerable isometric component which contributes to the perception of stress whilst performing the activity. Bending postures in forward flexion are likely to cause strain to the lower back and buttocks, as the compressive loading on the spinal discs is greatly increased in this partial flexion posture (Nachemson, 1969). Respondents to the survey of nursing personnel (Section 5.1) also indicated an association between the incidence of back pain and the activity of stooping over a patient; this activity was indicated by over 25 of respondents with an annual prevalence of back pain to be "always/often" associated with pain.

Transferring a patient manually from bed to trolley may cause discomfort that is due to the awkward nature of the task. It is difficult to keep the patient close to the body and the task requires forward flexion to reach over to receive the patient on the trolley or pass the patient over. Lifting aids do exist though, which involve sliding the patient thus reducing the bending moments that occur with manual techniques. Such devices are used for example, in hospital operating theatres where the transfer of patients on to and off the operating table occurs frequently. Turning/rolling the patient is another task where the use of sliding devices is encouraged. Draw-sheets and slings are recommended although if these are not available, nurses are instructed to move patients away from themselves and never to reach forward.

The findings of the current study do generally appear to corroborate the results of the questionnaire survey (Section 5.1) in terms of the occupational activities to which back pain is attributed. It should be re-stated that the definition of back pain within the previous survey was provided by the respondent and indicated on a body diagram. Pain in the low back was reported by over 78% of those nurses indicating an annual prevalence of back pain; this did include responses where multiple anatomical sites were reported. Tasks involving the positioning of a patient in bed were implicated as causative in the onset of symptoms of back pain. In the current study the anatomical sites where stress was reported to be felt were predominantly sites of the upper body, including the upper back; the hip/pelvic region was the location where pain was also experienced but to a lesser extent. Although this may appear to contradict the findings of the previous study, the nurses in that study who did report multiple sites of pain should be taken into consideration.

From the discussion above, some matters of importance are derived. Firstly, that many epidemiological studies of nursing personnel have focused solely on the low back in terms of symptoms and possible causes. The current study has shown that nurses may be at risk of experiencing other musculoskeletal disorders (to the shoulders/upper body) with the repeated performance of specific tasks. This finding does not belie the fact that nurses perceive the performance of particular tasks as being stressful to perform with regard to their lower back, moreover it has highlighted an issue which should be pursued in future research. Secondly, even when a definition of low back pain is provided in a questionnaire, the respondents may wish to register the existence of pain felt in other areas of the body. It may be that not until nurses are directly questioned/interviewed about the site of pain felt during the performance of specific tasks will discrepancies occur.

A possible limitation to the study was that in order to simplify the response of the nurses to the questionnaire and the analysis performed, only one answer was permitted in terms of why a task was stressful and where stress was felt on the body. There may actually have been more than one reason why a task was stressful to perform, for example, a nurse who experiences chronic back pain symptoms may aggravate the existing condition by having to adopt awkward postures. It is possible that there may have been reasons other than those listed in the questionnaire. Similarly, the pre-determined list of nursing tasks may not have incorporated all the tasks perceived as stressful by the nurses. However, none of the nurses interviewed suggested additional tasks that were considered more stressful than those listed.

The questionnaire could not account for the use of hoists by nurses for patient-transfer activities. If some nurses did use hoists regularly, it is unlikely that they would have perceived the patient-transfer tasks as being the most stressful and the tasks ranked accordingly would be biased towards those of a less "manual" nature. A notable finding of the epidemiological survey conducted in Section 5.1 was that hoists/lifting aids were either not used or not readily available for use by nursing staff. The implementation of the Manual Handling and Lifting guidelines of 1992, instituted the need for employees to avoid undertaking manual handling operations which may involve them being injured. Obviously staff training, lack of resources and time are all factors to be considered within the hospital environment when identifying the reasons why hoists are not used routinely. However, in light of the finding that nurses perceive back pain to be caused by lifting, the use of hoists should ideally become standard practise.

A cross-section of nurses with regard to position/grade was interviewed to obtain the responses of nurses with different experience in lifting. Whilst nurses undergo similar training in lifting techniques, circumstances may arise during working shifts where theoretical knowledge may not be strictly applied. Such situations may be due to understaffing or emergencies when nurses may have to lift/move patients alone or with limited help. Nurses of very different stature also encounter problems during lifting, with unequal distribution of the mass of the patient. From an ergonomic perspective, with older models of hospital beds the height cannot be easily adjusted and Gagnon et al. (1987) found the height of the bed to be an important factor in reducing back stress.

The weight of the patient to be lifted is another factor that must be considered as a contributor to the stressful nature of lifting and transferring tasks in addition to the levels of assistance offered by them. Additionally, patients resisting transfer place themselves and the nurses lifting them, under greater strain and increased risk of injury.

5.3 SUMMARY

The main findings of the work within this chapter were:

[1] The lifetime, annual and point prevalence of back pain was similar in the age and gender matched sample samples of nurses and non-nursing members of the general population. Sickness absence due to back pain as a measure of disability was comparable in the two groups.

[2] Nurses demonstrated a greater annual incidence of back pain compared to the non-nursing group and the point prevalence of pain peaked in nurses between the ages of 40-49 years.

[3] Patient handling tasks were implicated as causative by symptomatic nursing personnel both with respect to back pain and with the occurrence of stress to other areas of the body. Static postures were also perceived as stressful to perform.

[4] The perceived causes of stress whilst performing nursing activities included ergonomic aspects the working environment, the adoption of awkward postures and the nurses' own physique.

[5] There was no significant association between the prevalence of back pain and nursing speciality or grade of nurse. High proportions of nurses working in the specialities of orthopaedics, general medicine, community nursing, ICU and geriatric nursing were reported to be symptomatic.

[6] Almost 40% of nursing staff reported that assistive devices were not available for use on their current ward.

[7] Symptoms of back pain had few consequences on nurses' ability to perform occupational tasks. This demonstrates either the stoicism of nurses or that the severity of back pain did not warrant adjustments to the working schedule.

Chapter Six

Spinal Responses to Imposed Compressive Loading (*in-vivo*)

6 SPINAL RESPONSES TO IMPOSED COMPRESSIVE LOADING (*in-vivo)*

The studies within this Chapter cover investigations of the compressive loads imposed on the spine during lifting activities. Computer aided stadiometry is the measurement technique used to reflect compressive loading of the vertebral column Different lifting protocols have been employed within the separate studies including static and dynamic tasks and occupational activities. The relationship between stature loss and the prevalence of back pain symptoms amongst different sample populations is also explored.

6.1 SPINAL AND HEART-RATE RESPONSES TO ISOMETRIC AND DYNAMIC LIFTING IN NURSING PERSONNEL

This work was carried out at the Vrije Universiteit, Brussel where the author stayed for the period of investigation. The data were collected as part of a collaborative research initiative with the Department of Experimental Anatomie of the Vrije Universiteit Brussel. Aspects of this work have been presented to the Society for Back Pain Research, London meeting, March 1993.

6.1.1 Introduction

Nursing activities involve tasks and postures which induce greater loss of stature than would occur during a non-working day (Foreman and Troup, 1987). Nurses executing patient handling tasks are frequently required to perform dynamic tasks with a considerable isometric component. Non-patient handling activities also require the adoption of awkward postures and/or the lifting of loads which may place the individual under mechanical and physiological strain; the results of Chapter 5 demonstrated that both dynamic and static actions were perceived by nurses to cause back pain or stress.

The physiological demands of a task can be assessed by monitoring heart rate and oxygen consumption. Heart rate shows a linear relationship with work intensity as an increase in heart rate contributes to the cardiac output necessary to supply the oxygen demands of the active muscles. The slope of the linear relationship increases after about 120 beats min^{-1} when stroke volume is maximal and further increases in cardiac output are due to increases in heart rate. The oxygen consumption shows a linear relationship to work intensity throughout its range (Åstrand and Rodahl, 1986). Therefore heart rate response during activities reflects the work intensity. The measurement of heart rate provides an indication of the physiological strain imposed by activities with isometric and dynamic actions.

Heart rate responds differently to static and dynamic muscular action. Isometric muscle actions can limit blood flow to active muscles. A disproportionate increase in heart rate compared to oxygen consumption has been observed during activities involving static muscular loads (Garbutt et al., 1994). Dynamic work usually demands greater aerobic activation and the relationship between heart rate and oxygen consumption may be considered linear.

Hypothesis 3. Dynamic lifting tasks induce greater changes in stature and heart rate values compared to isometric lifting.

The prevalence of back pain may be indicative of discogenic aetiology. The properties of degenerative intervertebral discs differ from healthy specimens and have been discussed in Section 3.1.3. Therefore, the following hypothesis was proposed;

Hypothesis 4. Changes in stature due to isometric and dynamic lifting are greater in nurses exhibiting a lifetime prevalence of back pain compared to asymptomatic individuals.

The benefits of procedures to unload the spine and promote disc height recovery have been discussed in Section 4.2.3. Within this study the consequences of adopting the Fowler position will be examined in terms of regains in stature.

Hypothesis 5. The Fowler position induces recovery of stature following the isometric lifting activities.

The purposes of this investigation were to i) examine changes in stature and heart rate induced by isometric and dynamic lifts; ii) determine if changes in stature and heart rate values differ between those nurses reporting a lifetime prevalence of low back pain and the asymptomatic group, and iii) evaluate the effects of a procedure to unload the spine.

6.1.2 Methods

(i) Subjects

Thirty-six Belgian nurses, 11 males and 25 females were recruited to participate in the study. The female nurses were of mean age 30 (±6) years, mean height 166.5 (±5.4) cm and mean body mass 61.7 (±5.1) kg. The male nurses were of mean age 30 (±7) years, mean height 176.0 (±5.1) cm and mean body mass 74.5 (±7.9) kg. All participants were gainfully employed as nurses at the time of the study, representing a range of nursing grades and working in a number of different specialities. Fourteen nurses (10 females, 4 males) reported having suffered back pain symptoms at some time during their life (lifetime prevalence). All subjects were instructed not to engage in any physical activity on the day prior to or on the morning of the test protocol.

(ii) Equipment

Changes in stature were measured using computer-aided stadiometry (Eklund and Corlett, 1984). Isometric and dynamic lifting tasks were performed using the LiftStation™, (Isotechnologies Inc., Hillsborough, NC). The LiftStation™ consisted of a platform, a vertical column and a horizontal arm. The arm mechanism rotated around and moved up and down the main column. The arm shortened and lengthened to allow three-dimensional movements. Isometric or dynamic lifting assessments were performed with the attachment of handles or a plastic crate on the horizontal arm, respectively.

Heart rate was monitored throughout the test period using short-range radio telemetry (SportTester PE3000, Polar Electro, Oy). The telemetry system comprised a non-invasive, lightweight chest belt which transmitted signals to a receiver worn on the wrist. Heart rate was recorded at 15 s intervals; the data were downloaded onto a personal computer post-assessment using the Polar interface and software package.

(iii) Procedure

Each subject completed the test procedure on a single visit to the laboratory. Anthropometric measures of height and body mass were obtained in addition to details of a prevalence of back pain symptoms. Prior to conducting the experimental protocol, each nurse was familiarised with the stadiometer. All subjects underwent a training regimen until achieving a standard deviation for ten consecutive measurements of less than 0.55 mm. Training was completed within 40 minutes. The reference test measure of stature was performed immediately following training in the procedure for measuring stature. All subsequent measurements were expressed in millimetres relative to this value. A test session consisted of five consecutive measurements with a standard deviation of less than 0.55 mm. Values exceeding this criterion indicated that posture was not controlled during the measurement period. The methodology also took into consideration loss of height due to equilibrium of the heel pad upon weight bearing as at least two minutes had elapsed before measurements were taken.

Each subject performed five maximal isometric lifts in standard order: a leg-lift, arm-lift, push and pull at waist height and a lift/push with the load positioned directly overhead. Plate 6.1 displays the position of the latter isometric task on the LiftStation™, the position of the heart rate monitor and receiver on the wrist are also visible. Each maximum lift consisted of three identical trials of 5 s in duration. A rest period of 30 s was allowed between each trial. The operator of the computer verbally instructed each subject during the performance of the LiftStation™ activities. A second measurement of stature was obtained following the isometric test battery after which, each subject adopted the Fowler position for 20 minutes (lying supine with upper legs raised to 45°, and lower legs supported horizontally). A further test measurement of stature was performed immediately upon rising from this position.

Three lifts were performed by each subject during the dynamic lift protocol: transferring a loaded crate from floor to a height of 76 cm (primarily sagittal plane movement); transferring a loaded crate from a 76 cm table to shoulder height (three-dimensional lift), and a task carrying a load a short distance (2.5 - 3 m) from the floor to 76 cm (three-dimensional lift). The load within the crate for the latter two tasks was approximately 50% of the subject's maximum force exerted in the isometric arm-lift. The load lifted from the floor to 76 cm height was equivalent to 40% of the maximum force generated during the isometric leg-lift. The order of lifts was counter-balanced and test measurements of stature were made following each task. Each of the three dynamic tasks was performed five times at a self-selected work-rate. Subjects were instructed to lift the crate keeping it as close to the body as was comfortable and adopting the leg lift technique where appropriate.

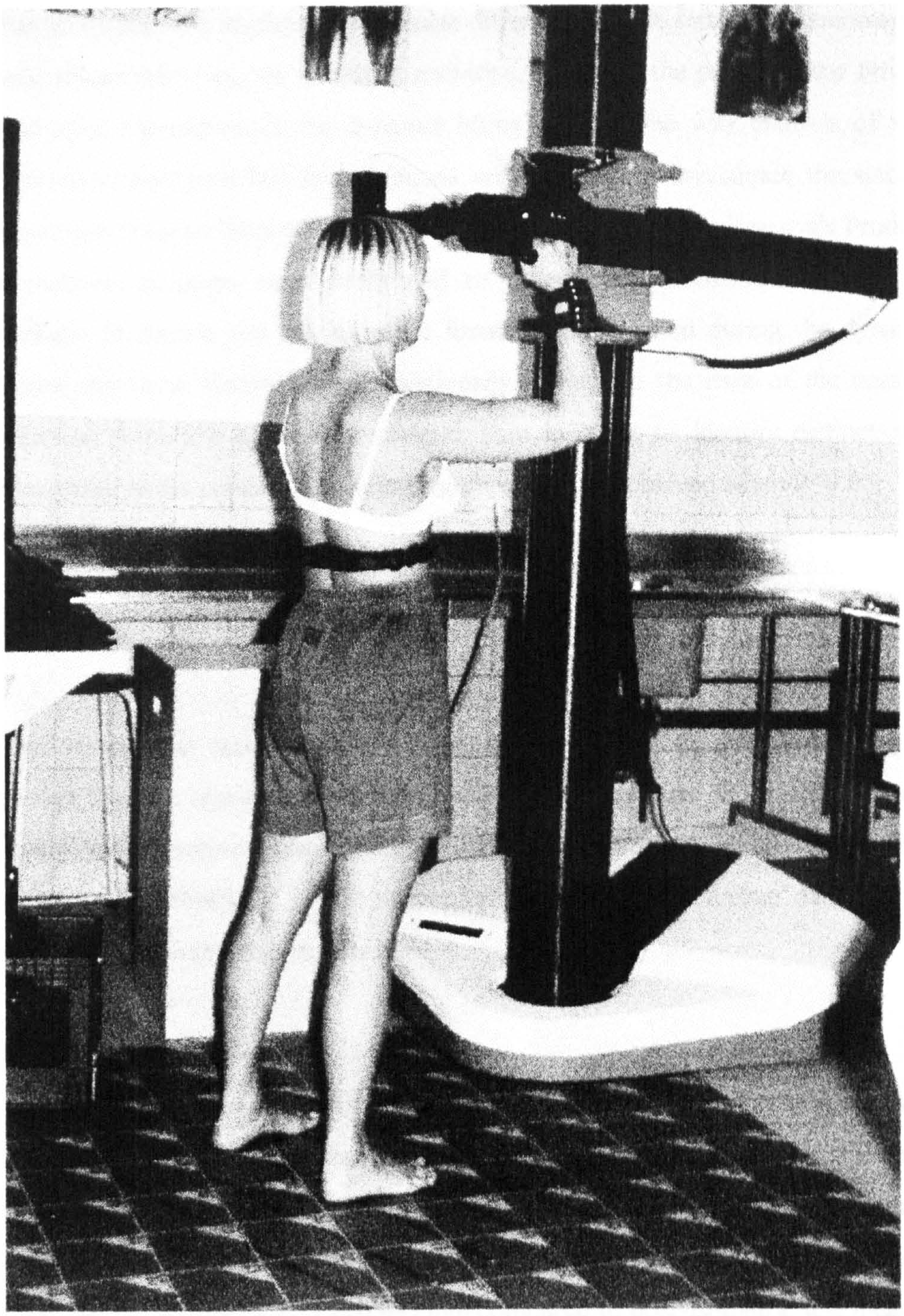


Plate 6.1 The overhead lift being performed on the LiftStation™

(iv) Analysis of data

Paired t-tests were applied to determine differences in the stature measurements and heart rate values following the isometric activities, following the period in the Fowler position and after completion of the dynamic lifting tasks. One way analysis of variance and Newman-Keuls post-hoc investigations were applied to investigate the stature loss and heart rate changes induced by each of the three dynamic lifts. Pearson's Product Moment correlation analyses were performed to determine relationships between heart rate, changes in stature and the isometric forces or loads lifted during the dynamic activity. These statistical analyses were additionally applied to the data of the nurses who had reported a lifetime prevalence of back pain in order to identify distinctions from the remainder of the sample. Statistical significance was achieved when $P<0.05$.

6.1.3 Results

The peak torque values of isometric and dynamic lifting are not cited. It has since been shown that the apparatus was consistently underestimating the torque. The validity of strength measurement data obtained from the equipment may be questioned (Zinzen et al., 1995). Nevertheless it is still appropriate to include the torque data for the purpose correlation with the stature data.

(i) Changes in stature

In total, six test measurements of stature were obtained for each subject. Mean loss of stature (± SE) following the isometric lifting tasks was 0.33 (±0.30) mm. Stature measurements obtained following the isometric activity were not significantly different from the pre-lifting measurements. Twenty minutes in the Fowler position induced a mean gain in stature of 2.57 (±0.44) mm compared to post-isometric test measurements.

Mean change in stature as a result of dynamic lifting was calculated from the differences observed following the period in the Fowler position and the final measurement on the stadiometer. The mean of the observed total shrinkage in this period was 3.03 (±0.31) mm. Cumulative stature loss was significantly greater than the shrinkage induced by the isometric activities ($P<0.01$). The differences in the stature loss as a result of each sequential dynamic lift (irrespective of condition) was not significant ($P>0.05$). Analysis of variance and post-hoc investigations revealed that the dynamic lifts induced shrinkage which differed with the lifting conditions ($F_{2,72} = 4.72$). Table 6.1 and Table 6.2 summarise the changes in stature observed throughout the test protocol and the loss of stature noted following each dynamic lifting condition respectively.

(ii) Heart rate data

Mean heart rate (±SD) during the period of isometric lifting was 107 (±20) beats min^{-1}. Mean heart rate during the period in the Fowler position was 76 (±10) beats min^{-1} and mean values during performance of the three dynamic lifts (irrespective of condition) were 120 (±20), 120 (±23) and 127 (±21) beats min^{-1} respectively. These values were significantly greater than pre-test heart rate values ($P<0.01$).

The two dynamic lifts requiring the transfer of a load from the floor to a height of 76 cm induced greater shrinkage ($P<0.05$) and heart rate increases ($P<0.01$) than the lift from shoulder height to 76 cm. Table 6.1 summarises the mean heart rate values noted during the test protocol and the mean heart rate values for the three dynamic lifting conditions are reported in Table 6.2.

No significant relationships were evident between heart rate, changes in stature, the isometric forces or loads lifted during the dynamic activity. Analysis of the data from the 14 nurses reporting a lifetime prevalence of back pain did not reveal significant distinctions from the remainder of the study sample in any experimental condition.

Table 6.1 Changes in stature (mm) and mean heart rate values (beats min^{-1}) during isometric lifting, the period of unloading and the randomised dynamic lifts

Condition	Mean (±SE) change in stature (mm)	Mean (±SD) Heart-rate (beats min^{-1})
Isometric Lifting	-0.33 (0.30)	107 (20)
Unloading	+2.57 (0.44)	76 (10)
1st Dynamic	-1.52 (0.24)	120 (20)
2nd Dynamic	-0.86 (0.32)	120 (23)
3rd Dynamic	-0.65 (0.28)	127 (21)

*A minus (-) sign indicates loss of stature, a gain in stature is indicated by +

Table 6.2 Mean loss of stature and mean heart rate values for the three dynamic lifts

Dynamic Lift	Loss of stature ±SE (mm)	Mean HR ± SD (beats min^{-1})
Shoulder to 76 cm (asymmetrical)	0.24 (0.04)	111 (20)
Floor to 76 cm (symmetrical)	1.34 (0.05)	124 (25)
Floor to 76 cm (carry)	1.45 (0.05)	128 (18)

6.1.4 Discussion

The isometric and dynamic lifting protocol employed during the investigation was not specifically designed to simulate the occupational tasks of nursing personnel or equate the degree of spinal loading or physiological stress imposed during such activities. It enables standard isometric and dynamic tasks to be performed and comparisons made between sample populations.

Changes in stature:

The cumulative stresses placed upon the intervertebral discs and vertebral end-plates by the five isometric tasks (indicated by the values for loss of stature) may be considered negligible. This may be due to the short duration and low number of repetitions of each task.

Unloading of the spine following the isometric tasks induced an increase in stature and reduction in mean heart rate values compared to the immediate post-isometric measurements. This demonstrates the benefits of adopting the Fowler position to the intervertebral discs. The magnitude of the recovery in stature following static shoulder loading has been shown to be in proportion to the shrinkage induced by the load (Tyrrell et al., 1985). Therefore the amount of stature gained during unloading procedures depends upon the activity performed prior to unloading. The duration of the unloading period may also affect observed increases in stature although the effects of unloading the spine are short lived (Boocock et al., 1988). This phenomenon is supported by the evidence that within the first hour after rising, 54% of the total diurnal loss of stature occurs (Wilby et al., 1987). In the present study the isometric lifting activity did not result in significant changes in stature compared to the baseline measurement. Consequently, the gain in stature noted following twenty minutes in the Fowler position reflects the combined unloading of, i) the compression responses to activity performed prior to experimentation; ii) the compressive loading of the isometric lifting, and iii) diurnal compression adaptations.

Intradiscal pressure is low when the Fowler position is adopted (van Dieën and Toussaint, 1993). The rapid recovery of disc height observed in the short period of time would be a result of a reduction in the compressive loading of the spine and the subsequent partial re-hydration of the intervertebral discs. The intradiscal pressure observed during sitting is greater than whilst lying supine (Nachemson et al., 1976) and as a result the intervertebral discs would not have been unloaded to the same extent if this posture had been adopted during the recovery phase.

In order to evaluate fully the dynamic lifting tasks in terms of biomechanical loading, the kinematics and kinetics of each lift would need to be compared. From the shrinkage data alone, the consequences in terms of intervertebral disc compression during lifting and/or carrying a load from the floor to a height of 76 cm have been demonstrated. Flexion of the motion segment in vitro has been shown to cause an increase in height loss and fluid expulsion (Adams and Hutton, 1983). It was proposed that upon flexion of the motion segment, the posterior annulus became stretched and more permeable. Inferences may be cautiously applied to the present study where loss of stature was more pronounced following the dynamic lifts. These tasks necessitated greater forward bending/flexion of the spine as the actions involved a combination of flexion and compression. In addition, the influence of the musculature and ligaments may also play a role in the compressive loading of the spinal structures. The lift from 76 cm to shoulder height engages the muscles of the upper back, upper arm and shoulders primarily. Tasks requiring the lifting of a load to and from the floor involve greater activation of the quadriceps muscles, the hamstrings, gastrocnemius and the erector spinae in addition to demanding greater spinal flexion. The greater shrinkage resulting from these dynamic lifts implies that the compressive loads were also markedly elevated compared to the asymmetrical lift to shoulder height. Investigations incorporating biomechanical modelling, stature measurement and electromyographic (EMG) activity are required to examine the relationship between the forces applied during dynamic lifting, the co-ordination of the muscles used and the consequences in terms of spinal shrinkage.

Heart rate responses:

Christensen (1953) classified occupational work load in terms of physiological responses. The classification system is still a relevant means of indicating the severity of physical work. Work loads categorised as "light" were equivalent to heart rate values during the work of between 60-100 beats min^{-1}; heart rate values between 100-125 beats min^{-1} were deemed to constitute moderate work loads.

The mean heart rate values were significantly greater during the isometric tasks than pre-test values. This indicates the stress upon the circulatory system and the physical exertion experienced by the participants during the activity. The severity of the work load during the isometric tasks may be classified as "moderate" (Christensen, 1953). However, it has been shown that isometric tasks induce a disproportionate increase in heart rate values compared to VO_2. The interpretation of these observed values for isometric lifting is that the work load was low in metabolic demands.

Heart rate data also confirm the stressful nature of the dynamic lifting activity with mean values for the two lifts from the floor being significantly greater than from 76 cm to shoulder height. The mean HR values during these two dynamic tasks were marginally greater than those demonstrated during the first circuit of a weight training routine which included nine separate exercises (n=10, Garbutt et al., 1994). It may be assumed that HR values for actions requiring combined arm and leg activity are greater than during predominantly arm dependent actions only.

The mean heart rate values for the symmetrical dynamic lifting task from the floor may be interpreted as being of moderate work load. The heavy work load classification of the carry task confirms that this task induced the greatest physiological strain. The spinal shrinkage data also corroborate this observation; the greatest compressive loads were imposed on the spine during the carry task from floor to 76 cm.

Shrinkage responses in nurses with and without low back pain identified by life time prevalence, did not reveal differences in response to spinal loading. Whilst it is known from *in vitro* studies that degenerated intervertebral discs show greater creep response to loading than healthy discs (Keller et al., 1987), it is also clear that degeneration is not the cause of all low back pain. Subjects with low back pain may not show greater shrinkage response to compressive loading than their asymptomatic colleagues because the intervertebral disc is not involved in the pathology. Also, asymptomatic individuals may have disc degeneration without the presence of painful symptoms. Because of the simple life time prevalence criteria used to identify low back pain, these factors may have masked any differences between the groups because in this study sufferers. Results from this study support the observations of Garbutt et al. (1990) who found no differences in shrinkage, between subjects with and without low back pain, following both running and repetitive lifting. Such findings highlight the complex nature of the relationship between spinal shrinkage, disc degeneration and chronic low back pain. Clearly, life time prevalence of low back pain is not a sufficiently robust indicator of severe or chronic low back pain and does not separate discogenic from non-discogenic aetiologies. Comparison of individuals with disc degeneration or pain of discogenic origin and normal controls, may enable *in vivo* comparison of the consequences of compressive loading in terms of spinal shrinkage.

The measurement of spinal compression in relation to the duration of loading, the forces applied and the properties of the motion segment is considered relevant in the quest for information regarding the aetiology of low back pain (van Dieën and Toussaint 1993). The measurement of spinal shrinkage provides a non-invasive method of assessing the deformation/height loss as a result of compressive forces such as those experienced during heavy lifting. Consequently the methodology may help in the identification of tasks that impose high compressive loads on the intervertebral discs.

The horizontal distance the load was carried did not significantly affect the loss of stature or heart rate compared to the vertical lift from floor to 76 cm. The horizontal distance was approximately 2.5 - 3.0 m depending upon the route taken by the subject and the lifting technique adopted. Studies to determine the effects of carrying loads greater distances and an increased frequency, would have ergonomic implications in occupations requiring load transfers.

Subjects were verbally encouraged to adopt a "safe" lifting posture to reduce the compressive force on the lower back during the dynamic lifting protocol. Consequently, lifting styles varied between individuals although the nurses lifted in a way which was comfortable. A small number of subjects had great difficulty in lifting the loads whilst adopting a leg-lift posture. These subjects had demonstrated extreme exertion during the isometric protocol and the loads calculated for the dynamic phase exceeded their capability to lift comfortably and safely. This would shift the biomechanical stresses on the body from the back to the legs (Leskinen et al., 1983).

To summarise the main findings of this section, both stature loss and work load were greatest following the dynamic activity of carrying a load a short distance from the floor to a height of 76 cm. The two dynamic lifts to transfer a load from the floor to a height of 76 cm induced greater stature loss ($P<0.05$) and heart rate increases ($P<0.01$) than the lift from shoulder height. The mean heart rate during the performance of the isometric tasks was significantly greater ($P<0.01$) than pre-test values. Recovery of stature was observed following a period of 20 min in the Fowler position.

It does appear that there is an association between work load, physiological strain as reflected in the from heart rate data and the magnitude of stature loss following dynamic lifting activity. These tasks involved greater flexion of the trunk and activation of larger muscle groups than the asymmetrical transfer. The results have implications for the physiological stress and spinal loading induced by occupational tasks. The distinction between symptomatic and asymptomatic individuals should also be based upon a more detailed selection criterion in order to examine sample differences in the measured parameters of future studies.

6.2 THE EFFECTS OF REPETITIVE LIFTING ON FEMALE NURSES WITH AND WITHOUT LOW BACK PAIN

This work was presented at the Annual Conference of the Ergonomics Society and has been published in Contemporary Ergonomics 1994 (edited by S. Robertson) pp 106-112. London: Taylor & Francis, a copy of which is presented in Appendix .

6.2.1 Introduction

The previous Section demonstrated that dynamic lifting tasks imposed greater loads on the vertebral column and greater physiological stress than isometric activities. Dynamic activities form a greater proportion of the manoeuvres performed during nursing shifts compared to tasks requiring the adoption of static postures. (Harber et al., 1987). Therefore, a further study of lifting was designed to evaluate the changes in stature induced specifically by an occupational lifting task, among nursing personnel.

Degenerative intervertebral discs exhibit increased elasticity (Hutson, 1993). Such a phenomenon is due to changes in the proteoglycan content of the nucleus pulposus and annulus fibrosus; the water-binding capacity of the disc becomes reduced. The decrease in stiffness of the intervertebral discs associated with degeneration effects the magnitude of stature loss following compressive loading. It may be postulated that if degenerative discs were subjected to a period of compressive loading, greater height loss would be observed in these individuals compared to healthy subjects. The symptomatic nurses involved in the experimental work of the previous Section indicated a lifetime prevalence of back pain (back pain at some time during their life); lifetime prevalence of back pain was demonstrated to be a poor indicator of chronic low back pain. Therefore, a more rigorous selection criterion was enforced to recruit nurses with chronic back pain symptoms for the current study. It was hypothesised that:

Hypothesis 6. Loss of disc height following the repetitive lifting activity is greater in nurses experiencing chronic low back pain compared to healthy individuals.

A linear relationship between height loss and intervertebral disc area has been reported (Althoff et al., 1992) and discussed in Chapter 3. The height decrease of the intervertebral discs at a given load should be inversely proportional to the disc cross-sectional area. However, the relationship between estimated lumbar disc area, changes in stature and the prevalence of low back pain has not been established. The following hypothesis was proposed:

Hypothesis 7. Estimated lumbar disc area exhibits a linear relationship with loss of disc height such that greater shrinkage occurs in smaller discs.

The aims of the study were to i) investigate changes in stature caused by repetition of a lifting task simulating patient-transfers routinely performed by nursing staff and to determine if such changes in stature differed between nurses with back pain symptoms and asymptomatic nurses, and ii) examine the influence of lumbar disc area estimated from anthropometric measures, on shrinkage in the two groups of nurses.

6.2.2 Methods

(i) Subjects

All participants in the study were female Registered Nurses. They were assigned to one of two test groups matched for age, height and weight. Eight nurses had no previous history of back pain (mean age 28.9 ± 3.8 years, height 162.1 ± 4.3 cm, body mass 58.5 ± 4.7 kg) whilst the symptomatic group comprised seven nurses who suffered chronic (>12 months) back pain (mean age 27.9 ± 3.6 years, height 160.0 ± 4.4 cm, body mass 61.8 ± 6.2 kg).

Individuals in the back pain group experienced symptoms at least once a month with the pain occurring between the mid-back and buttocks. Nurses were excluded if they had been given a clinical diagnosis by a general practitioner or other doctor concerning their back pain, or if they were taking prescribed medication to alleviate pain. All subjects were asked to recall the number of years they had been employed as nursing personnel and the back pain group stated the age of onset of their back pain.

Ethical approval from Liverpool John Moores University had been obtained with regard to the recruitment of symptomatic subjects.

(ii) Equipment

Stature was measured using computer-aided stadiometry as described in Section 3.1.4. The stadiometer was inclined at an angle of 13° to aid subject relaxation and maintenance of posture. Subjects were considered trained and capable of reproducing stature measurements on the stadiometer if ten consecutive measurements were obtained with a standard deviation equal to or less than 0.5 mm. Five consecutive measurements of stature were required for the actual test measures (pre- and post-lifting); similarly the standard deviation of 0.5 mm or less was the criterion employed for reproducibility.

(iii) Anthropometric measures

Diameters (cm) of the wrist, elbow, ankle and knee were obtained using condyle callipers on the right side of the body, the protruding epicondyle and malleolus indicating the points of measurement. The elbow and knee diameters were measured with the joint flexed (90°). Body height and body weight were also recorded.

(iv) Procedure

Subjects were required to visit the laboratory on two occasions during non-working days and between 09.00-12.00 hours. The length of time between each session could not be standardised due to the differing work schedules of the nurses. Familiarisation with the procedure to measure stature was undertaken during the first visit with training completed within 20-50 min. Rehearsal of the lifting technique to be performed during the test protocol and the collection of anthropometric data were also undertaken during this first session. The test protocol employed during the second visit required all subjects to adopt the Fowler position to unload the spine for a period of 20 min immediately prior to the first measurement of stature. Following this, a lifting task was performed simulating the gait-belt transfer of a patient from bed to chair and vice versa. The entire two-way transfer was performed at a rate of 4 lifts min–1 for a duration of 20 min. One repetition of the lifting task involved transferring a square box with side handles, from standard bed height (65.5 cm) to chair seat height of 45.5 cm and return to bed height; the mass of the box was 10 kg. The "chair" was positioned in front of the "bed" such that the nurse was required to pivot through 90° in order to place the load at chair height; the movement was reversed to return the box to the starting position on the bed. A second measurement of stature was taken immediately upon cessation of the lifting task.

(v) Analysis of data

Cross-sectional area (cm^2) of the L3-4 disc was estimated using the anthropometric measures and an empirical regression formula as described by Colombini et al. (1989).
A t-test was applied to compare the estimated disc area of the two groups of nurses. Changes in stature following the lifting task were calculated and a t-test was used to examine whether there was a difference in the stature alterations recorded for the two groups of nurses. Pearson's Product Moment correlation analyses were then applied to determine if a linear relationships existed between the estimated lumbar disc area and changes in stature.

6.2.3 Results

Mean loss of stature for all subjects following the lifting task was 3.88 (SE=0.26) mm. Although the mean value was 24% greater in the group with back pain, the difference did not reach statistical significance (P=0.12). Mean loss of stature and mean values for the estimation of lumbar disc area for the two groups of nurses are displayed in Table 6.3.

A linear relation was found between lumbar disc area and spinal shrinkage for all subjects ($r=0.71$) but lumbar disc area was not different between the back pain and asymptomatic subjects ($P>0.05$). The length of employment for all participating nurses averaged 9 years and the back pain group had experienced symptoms for between 18 months and 5 years.

Table 6.3 Mean estimations (±SE) of lumbar disc area (L3-4) and mean loss of stature in nurses with and without low back pain

Group	Loss of stature (mm)	Lumbar disc area (cm^2)
Back pain (n=7)	4.32 ±0.39	15.51 ±0.20
Non-back pain (n=8)	3.49 ±0.31	15.37 ±0.32

6.2.4 Discussion

The difficulties associated with the identification of individuals with or without back problems of discogenic origin in the absence of radiological evidence were highlighted in Section 6.1. It can not been assumed that the nurses comprising the back pain group in this study suffered discogenic abnormalities. However, consideration must be given in this discussion to the consequences of disc degeneration on the properties of the motion segment. In terms of stature loss, this second lifting study only indicated a trend, such that the individuals with chronic low back pain exhibited 24% greater loss of stature than asymptomatic nurses. It was stated in Chapter 3 that a decrease in the stiffness of the intervertebral disc has been observed with disc degeneration. In conjunction with this there appears to be an increase in hysteresis (Stevens et al., 1982). In practical terms, there is the potential for greater loss of stature to occur in degenerative discs, but hysteresis delays this process. Therefore compressive loading activities of short duration may result in similar loss of stature in people suffering discogenic abnormalities and healthy individuals.

The loss of stature was proportional to the estimated cross-sectional area of the lumbar discs (L3-4) such that for the 10 kg load, a linear relationship was observed between disc area and loss of stature: the smaller the cross-sectional area of the disc, the less the observed change in stature. When corrected for body height the correlation was no longer apparent, therefore the relationship between estimated lumbar disc area and loss of stature is an effect of body size. Althoff et al. (1992) stated that rate of height loss was inversely proportional to the estimated cross-sectional area of the lumbar discs at a given load. However, the variation in lumbar disc area of the age, height and weight-matched female nurses participating in the present study was slight (range 13.64 to 16.60 cm^2) in comparison to that of the male and female sample population studied by Althoff et al. (1992) (age range 20 to 60 years), where lumbar disc area values ranged from approximately 18.0 to 29.0 cm^2. Therefore, the assumption of Althoff et al. (1992) that fluid exchange and viscoelastic deformation is larger in small discs compared with large discs cannot be applied to the results obtained in this study due to the small inter-subject variation. Further investigations to determine the response of larger lumbar discs to compressive loading would clarify the observed disparity between the studies.

Pain is a subjective sensation and even without pathological abnormality symptoms vary significantly. The nurses in the back pain group reported symptoms ranging from chronic, dull aching with insidious onset, to recurring acute low back pain caused by lifting activities or the adoption of awkward postures for significant periods of time. The properties of the intervertebral discs and mechanisms inducing changes in stature did not appear to respond differently in individuals with chronic, non-specific back pain compared to asymptomatic nurses during the lifting task. Acute loss of disc height observed under such experimental conditions as those performed in the present study may therefore not be applied as a diagnostic tool although Hindle et al. (1987) noted that the diurnal stature variation of patients suffering from the condition ankylosing spondylitis was reduced compared to that of healthy individuals.

The lifting task performed during the experimental protocol was designed to simulate patient-transfers routinely undertaken by nursing staff although the rate and duration of lifting may not be characteristic of a typical working shift. The loss of stature induced by the lifting indicated that such occupational tasks induce compressive loading of the intervertebral discs. During the lifting protocol the load was positioned in front of the body, thus bending moments and shear forces were created in addition to spinal compression. Loss of disc height is indicative of compressive loading of the spine; however, it was not possible to determine the individual effects of different forces on the nucleus pulposus and annulus fibrosus during the lifting activity. Flexion of the vertebral column was minimised by the nurses keeping the load close to the trunk and occurred predominantly when the load was initially grasped and when placed on the bed/chair. A more detailed analysis of the response of the intervertebral discs, vertebrae and associated muscles, ligaments and tendons to dynamic and static loading may be obtained by *in vitro* experimentation or computer simulation with finite element modelling.

Adams et al. (1987) hypothesised that in the early morning, forward flexion movements may subject the lumbar ligaments and discs to damaging bending stresses. The load lifted on the morning of the experimental protocol was 10 kg. This is within the Health and Safety Executive's (1992) guidelines for lifting.

The duties of nursing personnel vary on a daily basis according to the level and type of patient care they are required to give. Patients may differ enormously in body size, dependence and willingness to co-operate, therefore the load lifted during the test protocol would not reflect the load transferred in the majority of actual patient-handling tasks. The forces experienced by individuals during strenuous tasks involving the transfer of a heavy, immobile patient would be in excess of those of the simulated task despite the movement normally being performed by at least two nurses and possibly with the aid of a hoist. The loss of stature induced by the relatively light load transferred during the task simulation indicates that nursing work induces spinal compression. This has implications for the time of day lifts are performed (there exists a diurnal variation in stature), the regulations governing the maximum load that may be lifted, task repetition and the postures adopted during lifting activities.

Changes in stature reflect changes in disc height along the entire length of the vertebral column. Modifications to the stadiometer to enable the measurement of changes in the height of specific regions of the spine, for example the lumbar region, would result in greater ergonomic application of the methodology to assess working environments and occupational activities in terms of health and safety.

It was observed in the previous chapter that nurses attribute back pain symptoms to patient-handling and lifting activities; the symptoms reported by nursing personnel are clearly idiopathic. The prevalence of back pain did not influence the loss of stature induced by an occupational lifting task in the current study and the following points offer possible explanations for this:

i) The measurement of stature loss along the entire length of the vertebral column was not sensitive enough to detect differences between symptomatic nurses and asymptomatic controls.
ii) Pathological abnormality did not exist in the symptomatic individuals.
iii) Given that back pain symptoms occur in individuals without pathology, intervertebral disc degeneration may be present amongst the control subjects.

The prevalence of idiopathic back pain is widespread throughout society and may be related to the condition of the trunk musculature. It may be appropriate to consider a preventive approach and to investigate the efficacy of physical training of the trunk musculature as a means to reduce the incidence of back problems.

6.3 SUMMARY

The main findings within this chapter were:

[1] Dynamic lifting tasks from the floor induced greater physiological strain and loss of stature than both isometric lifting tasks and dynamic lifts from shoulder height.

[2] Loss of stature and the estimated cross-sectional area of intervertebral discs were not associated with the existence of chronic back pain symptoms or the reporting of a lifetime prevalence of back pain.

[3] Loss of stature was linearly related to estimated lumbar disc area such that loss of stature was smaller in individuals with smaller cross-sectional areas. This is accounted for by differences in body size.

[4] A preventive as opposed to a diagnostic approach to the widespread problem of idiopathic back pain may be appropriate to consider.

Chapter Seven

Functional Assessment of the Trunk Musculature and the Effectiveness of Physical Training on Manual Handling Capability

7 FUNCTIONAL ASSESSMENT OF THE TRUNK MUSCULATURE AND THE EFFECTIVENESS OF PHYSICAL TRAINING ON MANUAL HANDLING CAPABILITIES

It was suggested in Chapter 6.2 that preventive measures may be adopted in an attempt to reduce the incidence of back pain. Reduced strength capabilities have been demonstrated among back pain populations and a relationship appears to exist between trunk muscle strength and the prevalence of back pain symptoms. Training programmes may be implemented to investigate the efficacy of physical exercise in ameliorating trunk strength. This in turn may have implications for reductions in the incidence of back pain.

The purpose of the current Chapter is to investigate the effects of a physical training programme on trunk muscle strength and manual handling skills. Physical training may result in greater strength capabilities and an increased ability to perform repetitive actions. The possible consequences of training include a reduced risk of experiencing back pain and/or injury.

The repeatability of an isokinetic dynamometer used in the assessment of trunk muscle strength will also be established in a preliminary investigation. This equipment has an application within the study investigating the effects of a physical training programme on trunk muscle strength and manual handling skills, therefore it is important that the dynamometer provides measurements which are repeatable over a period of time.

7.1 THE REPEATABILITY OF THE ASSESSMENT OF TRUNK MUSCLE STRENGTH USING THE LIDO ISOKINETIC DYNAMOMETER

7.1.1 Introduction

The assessment of trunk muscle function is feasible with the use of isokinetic equipment (Delitto et al., 1991; Perrin, 1993). It is important that if isokinetic dynamometry is to be used to assess trunk muscle strength either in isolation or pre-post intervention, the repeatability of the equipment is established. This confirms that single measurements of trunk strength may be used reliably and that the equipment is sensitive to detect changes induced by external influence. The current study was performed to examine the repeatability of isokinetic dynamometry in the assessment of trunk muscle strength. The results of the study have implications for the use of the dynamometer to assess trunk muscle strength during the muscle strength training study (Chapter 7.2) and provides an opportunity to explore the data obtained from asymptomatic individuals.

7.1.2 Method

(i) Subjects

Thirty one volunteers (18 males, 13 females) gave informed consent to participate in the study. The mean age of the female sample was 24 (±4) years, mean body mass 63.1 (±8.7) kg and mean body height 163.4 (±7.5) cm. The mean age of the male subjects was 30 (±7) years, mean body mass 81.6 (±13.7) kg and mean body height 176.7 (±7.5) cm. The criteria for admission to the study included being asymptomatic of any low back symptoms for the duration of the study. In addition, no individual had experienced a major episode of back pain (requiring analgesics or medical consultation) in the previous 6 months.

(ii) Procedure

A test-retest design was applied, each subject being assessed twice. Trunk muscle strength was assessed on an isokinetic dynamometer (Lido Active, Loredon, Davis, CA) with subjects in the standing position (Plate 7.1). The axis of the dynamometer was aligned with the iliac crest; subjects were stabilised across the chest, waist and shoulders. The range of motion was established for each individual and gravity compensation procedures performed. Prior to testing, warm-up exercises to familiarise subjects with the equipment were performed; these consisted of two-three submaximal flexion-extension efforts, leading up to maximal exertion at each angular velocity. All subjects then completed four maximal reciprocal trunk flexion-extension exercises at three different velocities: 1.05, 1.57 and 2.09 rad.s^{-1}, throughout maximal range of motion. A minute of recovery was provided between testing at each angular velocity. All subjects were re-tested between 4 and 7 days following the initial test. Peak torque, average peak torque and the angle at which peak torque occurred (flexion and extension) were recorded at each angular velocity measured during the two test sessions.

(iii) Analysis of data

Analysis of the data was performed using SPSS (Windows, version 6.0.). The normality of the data was examined using the Shapiro-Wilks test and the Levene test checked the homogeneity of variance. Repeated measures, two-way analysis of variance sought differences between the angle at which peak torque occurred at the three angular velocities during flexion and extension (retest data only). In addition, where the homogeneity of individual variables was significant, the Kruskal Wallis non-parametric test was performed to ensure that the correct levels of significance were reported. Wilcoxon or paired t-tests identified significant differences between the test-retest values of peak torque and average peak torque (for example, average peak torque difference between Test 1 and Test 2). Differences between average peak torque and peak torque values at each angular velocity were examined using independent t-tests or the Mann-Whitney test. These test were performed in preference to two way repeated measures analyses of variance where the homogeneity of the variances of particular parameters was contraindicated.

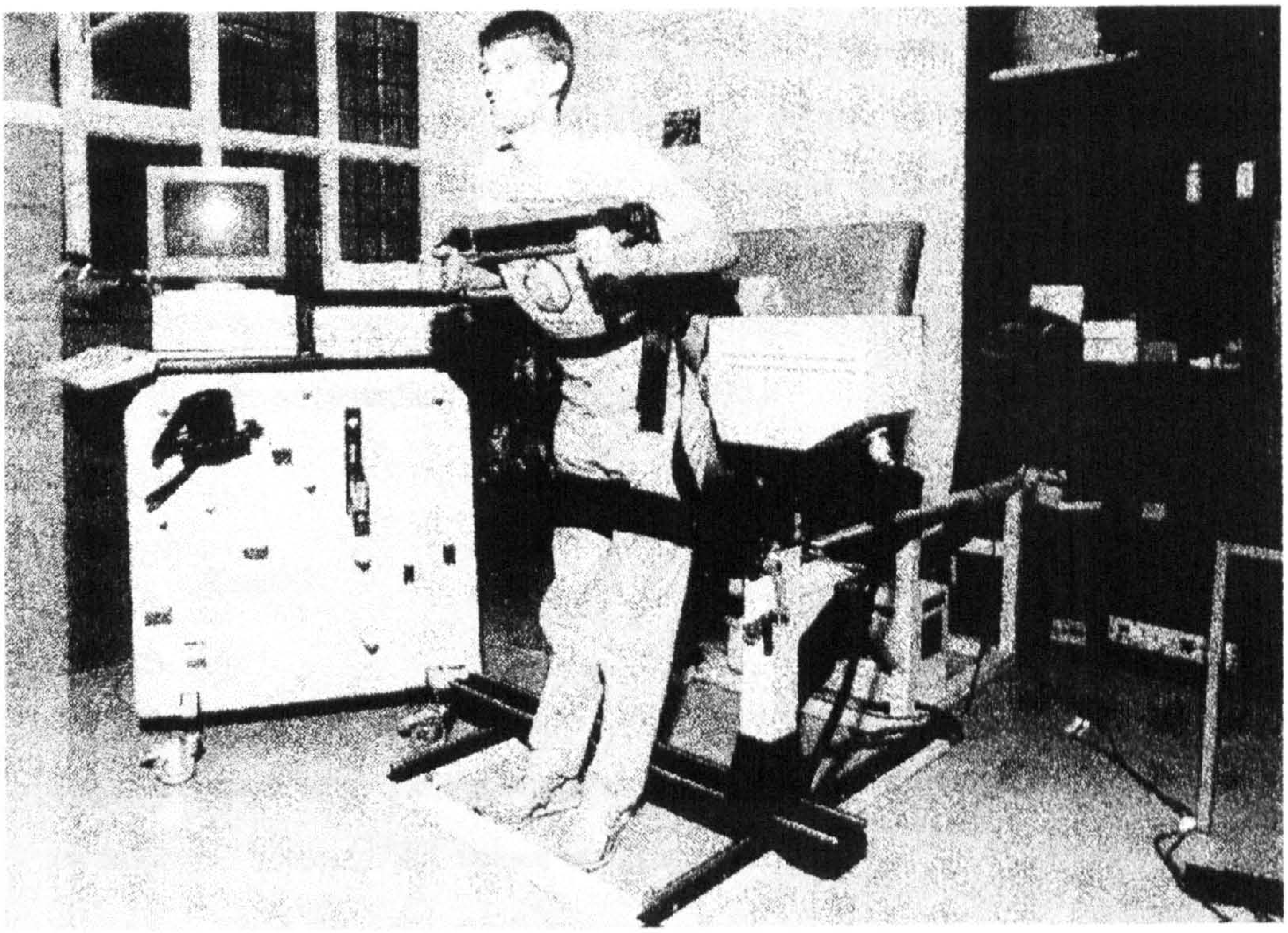


Plate 7.1 The Lido isokinetic dynamometer

The test-retest repeatability of the isokinetic dynamometer was evaluated using several statistical methods. The influence of angular velocity on peak torque was examined using one-way analysis of variance. The 95% agreement limits were calculated for peak torque at each angular velocity (mean difference between test and retest ± the standard deviation of differences between test and retest scores multiplied by 1.96)(Altman, 1991). Similarly, the coefficient of variation (CV) was calculated from the standard deviation of differences between test and retest divided by the overall mean score of the test and retest multiplied by one hundred. For comparison purposes only, Pearson correlation coefficients and intraclass correlation coefficients were calculated from the test-retest data. The applicability of these statistical methods in relation to the heterogeneity of the sample has been described by Atkinson (1995).

7.1.3 Results

Figures 7.1 (a) and (b) and 7.2 (a) and (b) display peak torque and average peak torque values (respectively) for the test and retest, at each angular velocity for the whole group of subjects. Mean (±SD) values are presented.

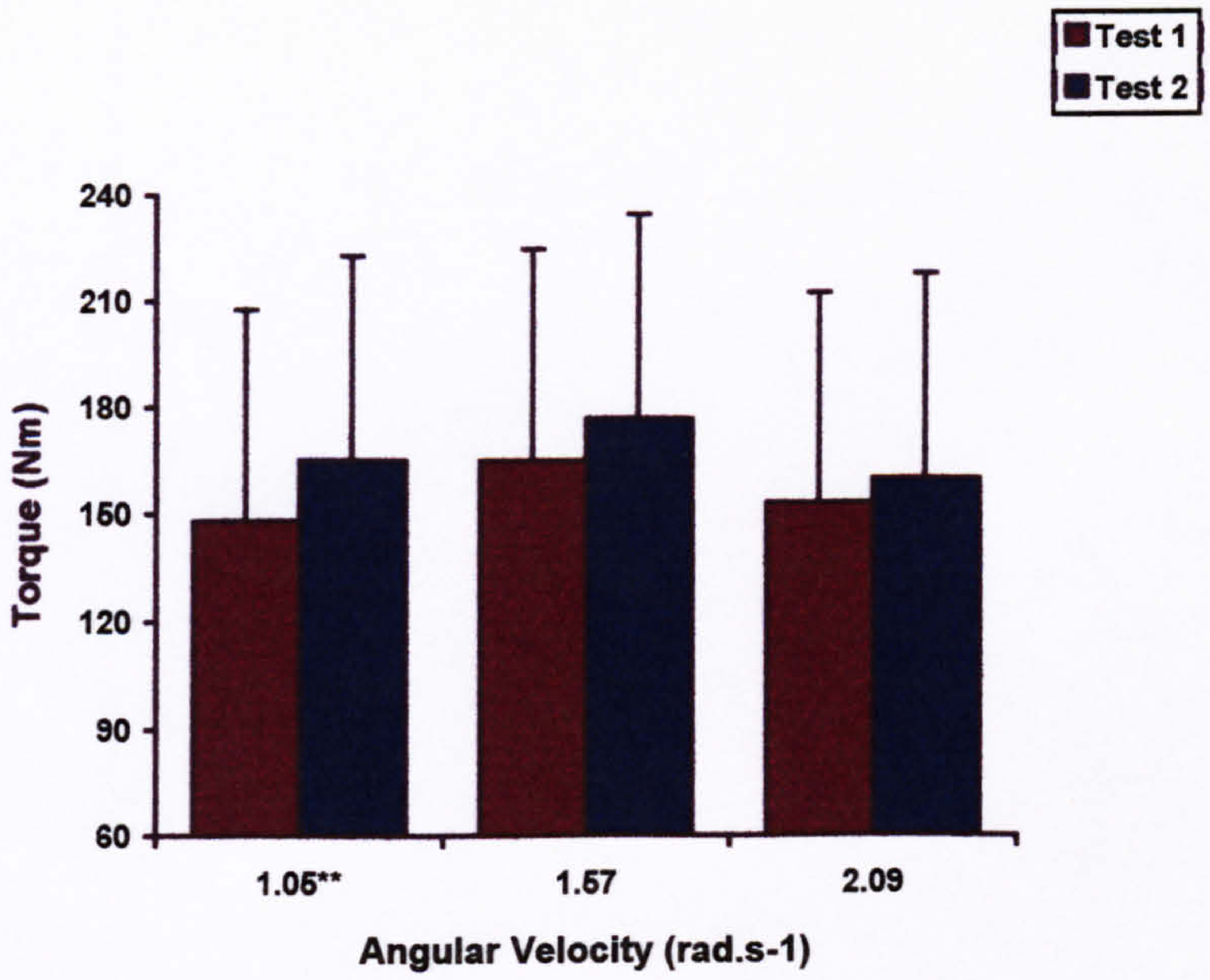
The peak torque values produced in extension and flexion at 1.05 rad.s^{-1} were significantly greater at the retest (Wilcoxon test, $P<0.01$ and t-test, $P<0.05$ respectively). Differences between average peak torque and peak torque values were not significant for any angular velocity, either in flexion or extension ($P>0.05$). Values of peak torque were not affected by changes in angular velocity ($P>0.05$). At each of the three angular velocities, peak torque values for flexion were significantly greater than extension peak torque values ($P<0.01$). However, when peak torque was expressed as a percentage of body weight significant differences were evident only during flexion at 1.05 and 2.09 rad.s^{-1}. The coefficients of variation, the 95% agreement limits and Pearson correlation coefficients for flexion and extension are displayed in Table 7.1. Intraclass correlation coefficients were all highly significant ($R>0.9992$) between the test and retest for each angular velocity.

Table 7.1 Mean differences between test-retest, the 95% agreement limits (Nm) and coefficients of variation (CV) for test-retest trunk assessment. A positive mean difference indicates that strength was higher in the retest than in the first test

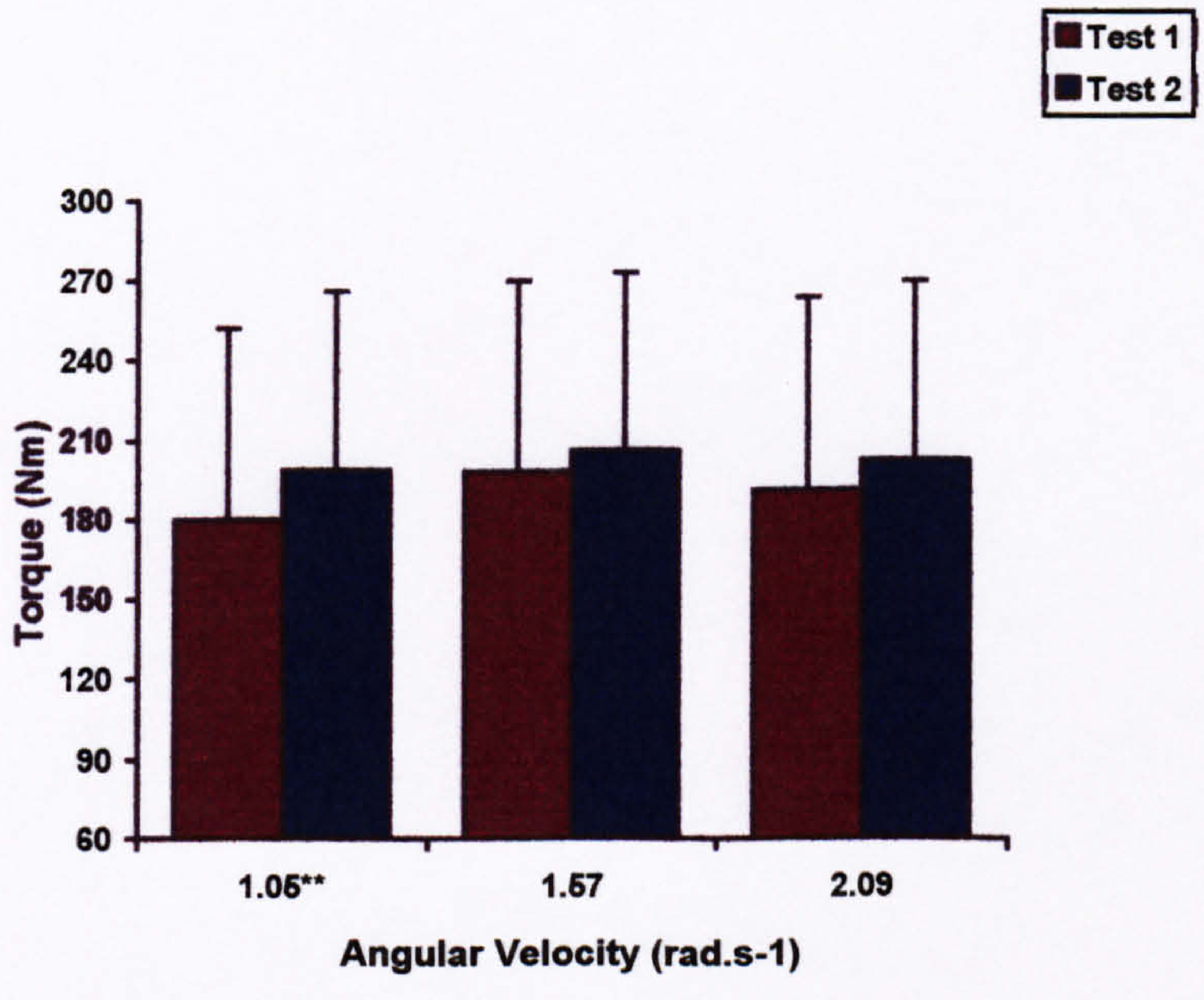
	Extension $1.05 rad.s^{-1}$	 $1.57 rad.s^{-1}$	 $2.09 rad.s^{-1}$	Flexion $1.05 rad.s^{-1}$	 $1.57 rad.s^{-1}$	 $2.09 rad.s^{-1}$
Mean (SD) difference	+18 (36) P<0.05	+12 (45) P>0.05	+6 (47) P>0.05	+19 (48) P<0.05	+8 (53) P>0.05	+11 (50) P>0.05
95% Limits	-52 to 88	-76 to100	-86 to 99	-75 to 114	-94 to 112	-86 to 108
CV (%)	23	26	30	25	26	25
Pearson Correlation	r=0.82 P<0.01	r=0.70 P<0.01	r=0.65 P<0.01	r=0.78 P<0.01	r=0.70 P<0.01	r=0.76 P<0.01

The angle at which peak torque occurred for all subjects during flexion and extension is displayed in Figure 7.3. Neither during flexion or extension did the angle vary significantly between each angular velocity (P>0.05). The angle at which peak torque occurred during extension was significantly (P<0.01) greater than during flexion at each angular velocity.

Values of peak torque expressed as a percentage of body weight illustrate gender differences within the data (Figure 7.4). Values of flexion and extension were significantly greater (P<0.01) for males. In females, flexion values were not significantly different from peak torque values of extension (P>0.05).

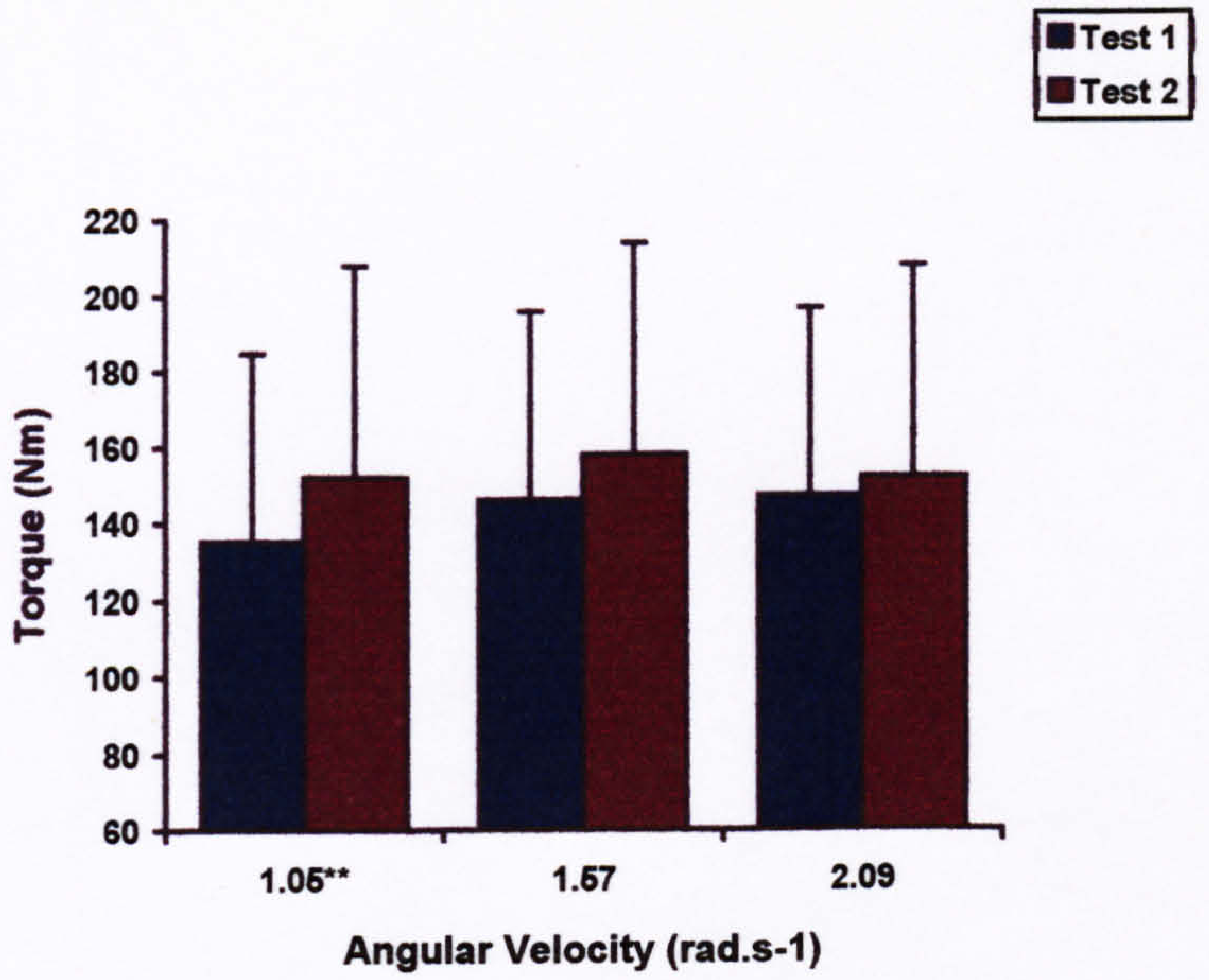


(a)

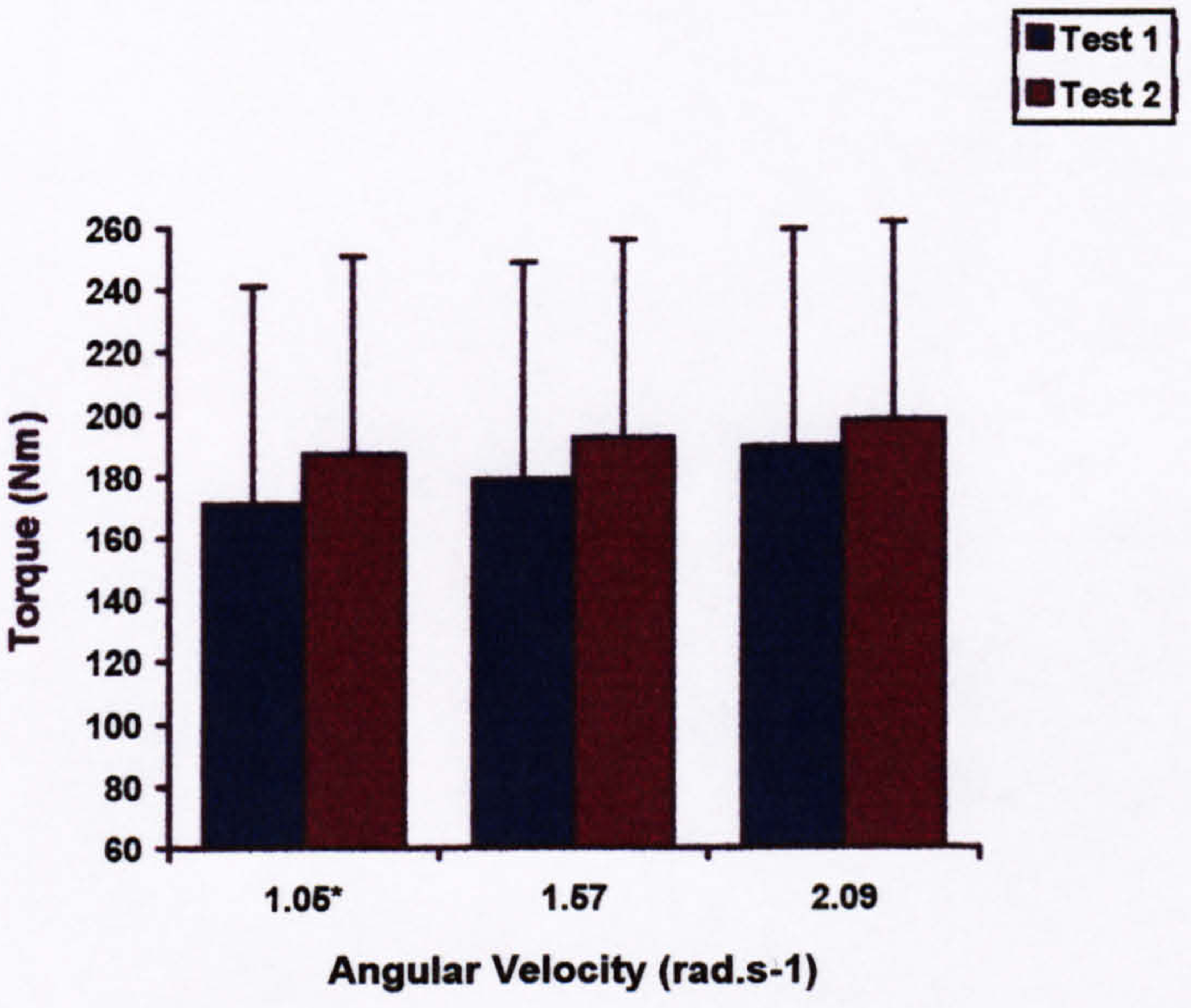


(b)

Figure. 7.1 Peak torque values (+SD) for (a) extension and (b) flexion at each angular velocity (**P<0.01, test-retest differences)



(a)



(b)

Figure. 7.2 Average peak torque (+SD) for (a) extension and (b) flexion at each angular velocity (*P<0.05, **P<0.01, test-retest differences)

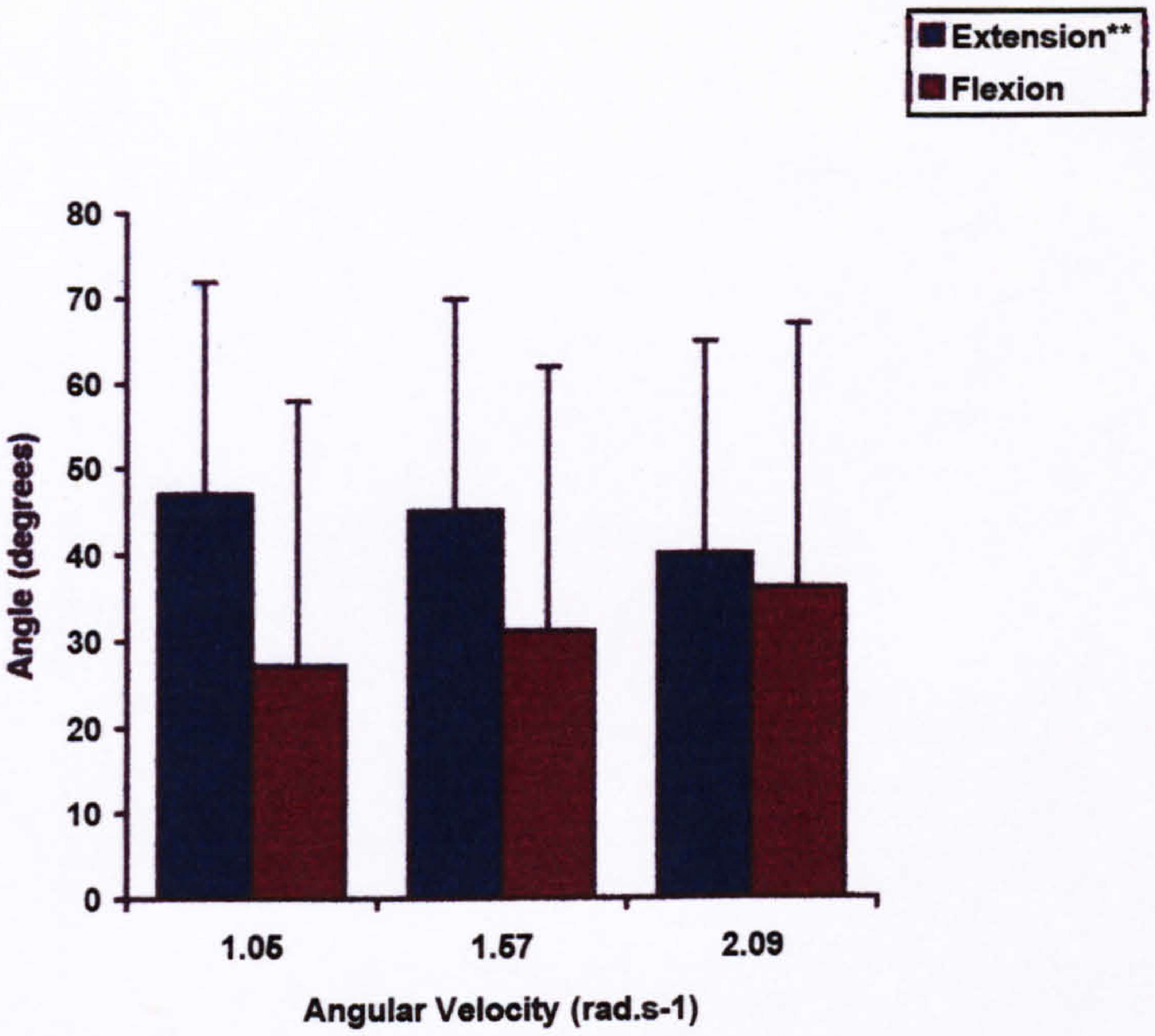


Figure. 7.3 The angle (+SD) at which peak torque occurred for all subjects (n=31) during flexion and extension (**P<0.01)

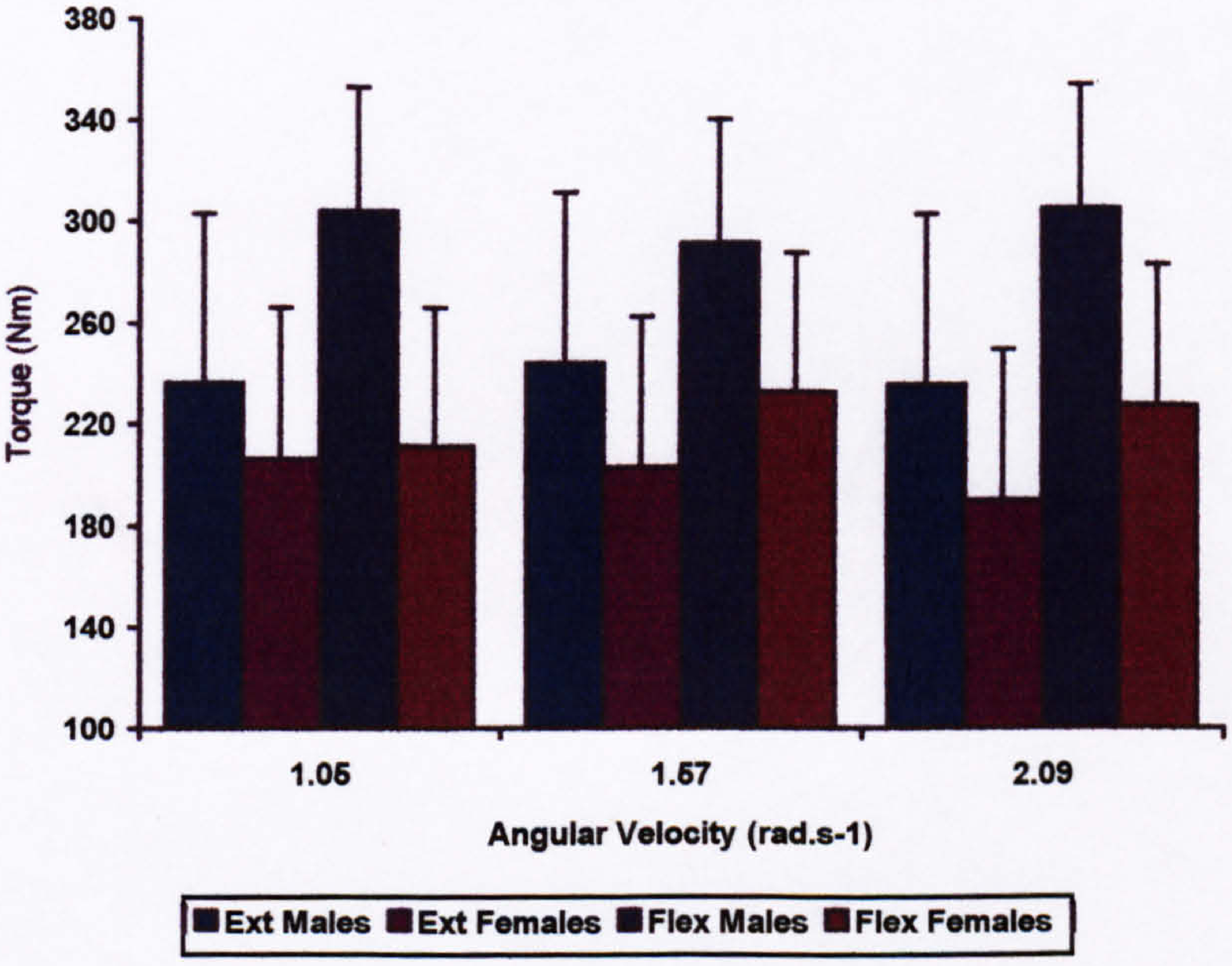


Figure. 7.4 Peak torque (Nm) (+SD) expressed as a percentage of body weight for males and females during trunk flexion (flex) and extension (ext) at each angular velocity

7.1.4 Discussion

It is more appropriate to divide this section into discussions of i) the repeatability of the isokinetic dynamometer, and ii) examination of the flexion/extension values obtained from the measurement apparatus.

7.1.4.1 The repeatability of the isokinetic dynamometer

It is apparent that there was a familiarisation/learning effect associated with extension and flexion at 1.05 rad.s^{-1}. Whether this phenomenon was due to familiarisation with that particular angular velocity or the fact that this was the first test to be performed on each occasion can not be established. Future studies, adopting counter-balanced research design would identify the cause of this significant difference. Particular importance may be placed upon this issue as it appears almost standard practise to perform sequential isokinetic strength tests starting at the slower velocities (Smith et al., 1985; Grabiner et al., 1990). For individuals unaccustomed to generating peak torque at a slow velocity, the combination of this factor in addition to having to perform an unfamiliar action, may have contributed to the disparity between the results of the test and retest. The reciprocal flexion-extension movement bears little resemblance to any habitually performed action. Therefore the use of familiarisation procedures should be endorsed to ensure that all individuals are accustomed to the action being performed and the speed at which tests are carried out.

To assist in the interpretation of the agreement limits reported in Table 9.1, it may be stated that for a new sample of subjects, the test-retest difference of 95% of the population would be expected to lie within these limits. Therefore if a change in a subsequent measurement of extension at 2.09 rad.s^{-1} exceeds 93 Nm, it may be concluded that the change is beyond that which would occur due to error from test to retest and is more likely to be due to the subject either becoming stronger or weaker. The magnitude of the 95% agreement limits (range approximately 45% to 59% of the mean test-retest peak torque) suggests a lack of agreement between the test and retest at all three angular velocities. In addition, the coefficients of variation derived from the data may be considered unacceptably high (>10%) for both flexion and extension, demonstrating poor repeatability between the test and retest. However, this test assumes that test-retest variability is greatest with the strongest subjects. The 95% agreement limits do not make this assumption and therefore provide a more appropriate method of assessing repeatability in a heterogeneous sample. Traditionally, the analysis of test-retest data has incorporated hypothesis testing, the use of intraclass correlation coefficients or Pearson correlation coefficients. Within the current study the intraclass correlation coefficients were all significant and Pearson correlation coefficients for test-retest were highly significant for each angular velocity, indicating erroneously, good levels of repeatability. The latter test is a measure of relationship as opposed to an assessment of agreement and the heterogeneity of the sample will also influence the results. Therefore, these statistical techniques are insensitive to systematic changes in subjects across trials such as that which would occur with a learning effect.

The variability of the data has been established as relatively large and most likely reflects contributions by variables related to either or both the dynamometer and the heterogeneity of the subjects. Large variability is inherent in human performance measured upon heterogeneous groups such as the sample in the current study (males, females; various ages). Although the individuals used in this study were healthy and asymptomatic, there were no controls placed upon selection other than the absence of back disorders. The level of physical fitness, related to the activities in which the subjects did or did not regularly participate may have influenced their ability to generate isokinetic flexion and extension torque.

As mentioned above, the dynamometer may have contributed to the variability of the data. Grabiner et al. (1990) included the possibility of different inter- and intra-subject motor strategies in the novel performance of reciprocal trunk exercises. The test position and the stabilisation of the body within the dynamometer may also have provided sources of variability, for example, the contribution of knee and/or hip extensor torques to extension peak torque during assessment in the standing position. These points will be discussed further in Section 7.1.4.2.

Repeatability studies applying statistical techniques such as those in the current study are few in number. Therefore, although the 95% agreement limits indicate that variation is inherent in repeated measurements, until the data collected from other isokinetic devices are analysed in a similar way, the relationship between the data for agreement derived from the Lido dynamometer and the repeatability data calculated for other devices can not be established. The repeatability data of other isokinetic dynamometers may be even more variable than that of the Lido system. In this situation, the data derived from these devices should only be applied taking into consideration the variability of the results. For example, it would be recommended that diagnostic decisions should not be based upon a single assessment of trunk muscle function. In addition the data collected from individuals categorised as back pain symptomatic may actually exhibit greater variability than asymptomatic individuals (Perrin, 1993).

The continued application of the Lido dynamometer for the assessment of trunk muscle strength is endorsed although caution is advocated in the interpretation of data collected. It would appear that measurements collected at the faster angular velocities are less sensitive to the effects of repeated testing. Although this may have been the result of the experimental design, subjective preference of measurement at the angular velocity of 2.09 rad.s^{-1} was indicated.

7.1.4.2 The assessment of trunk muscle strength

The purpose of this section is to explore further the data obtained using the isokinetic dynamometer and to identify characteristics particular to the assessment of trunk muscle strength. The peak torque data from the retest (second) measurement will be discussed as this partially compensates for the familiarisation effect observed in the measurement of peak torque. In addition, absolute values of "peak torque" have been examined in preference to those of "average peak torque" despite there being a non-significant difference between these torque values within the data collected. Peak torque is the parameter most frequently reported in the literature and therefore enables comparisons to be made where necessary.

Peak torque values for flexion at each angular velocity were significantly greater than extension peak torque ($P<0.01$). These results contradict those reported by Smith et al., (1985) where trunk extensor strength was greater than trunk flexor strength throughout a range of angular velocities (0.52, 1.05, 1.57, and 2.09 rad.s^{-1}). Thompson et al. (1985) and Davies & Gould (1982) observed that at the relatively slower velocities of 0.52 and 1.05 rad.s^{-1}, peak torque values of the extensors exceeded that of the flexors. At 1.57 rad.s^{-1} balanced muscle activity of the antagonistic groups was observed and only at 2.09 rad.s^{-1} did flexion torques exceed extension torques. Smith et al. (1985) attributed the greater strength of the trunk extensors compared to the flexors due to the larger cross-sectional area of the trunk extensors (muscle pairs of the erector spinae). However, the flexor peak torque in the current study could have been accentuated by the influence of the iliopsoas, which can approximately double the strength of the trunk flexors. This is especially likely when assessing trunk muscle strength in the standing position when stabilisation of the hip is difficult to achieve fully. The introduction of gravity compensation procedures such as those incorporated within the testing procedure in the current study could also partially account for inconsistencies noted between the different studies cited above. The effect of gravity on trunk assessment may be considerable as the trunk constitutes more than 50% of the total mass of the body.

Referring again to Fig. 7.3, it may be seen that as the angular velocity increased during flexion and extension, the angle at which peak torque occurred (extension and flexion) also increased, but not significantly. As the angular velocity increased during trunk extension, there was a trend for the peak torque to occur earlier in the range of motion. Similarly, during trunk flexion, the peak torque occurred later in the range of motion as angular velocity increased (Figure 7.5). This finding was contrary to the results reported by Thompson et al. (1985) but the trend appears to be similar to that observed by Davies and Gould (1982). As the angular velocity increases, greater momentum is required to attain peak torque and this would account for the adaptations of the peak torque angle to angular velocity. The significant differences between the angle at which peak torque occurred in flexion and the equivalent angle in extension were independent of the angular velocity. These differences also appear to be consistent with the data of Davies and

Gould (1982) who examined a wider range of angular velocities: 0.52 rad.s^{-1} through to 2.09 rad.s^{-1}.

Force-velocity relationships exist when assessing the muscles of the lower extremities such that net moment (Nm) and angular velocity may be described as being inversely related (Cabri, 1991). Values of peak torque in the current study were not affected by changes in angular velocity; this could be a consequence of the relatively narrow range of angular velocities examined. A similar phenomenon has been observed in studies of populations with low back pain and attributed to a number of factors (Perrin, 1993). In particular, the faster angular velocities for the reciprocal trunk assessment such as 2.09 rad.s^{-1} are associated with a reduction in the compressive forces at the intervertebral joints. Additionally, less forceful muscular contractions are allied with more rapid movements. It should also be stated that within the current study, the combined consequences of the experimental design and familiarisation with the performance of the movement may have masked any effect of test velocity. The range of angular velocities in the current study may be considered narrow

The aims of the current study were to examine the repeatability of isokinetic dynamometry in the assessment of trunk muscle strength and to explore the data obtained from asymptomatic individuals. To summarise the main findings in fulfilment of these aims, the repeatability of the Lido isokinetic dynamometer was established. Although variability between test and retest was apparent, particularly at the slowest angular velocity, the magnitude of this variation in comparison to other isokinetic devices could not be established. The assessment of trunk muscle strength may be endorsed at the faster angular velocities and within asymptomatic populations.

The assessment procedure compensated for the effects of gravity and in combination with the effects of test position, may explain the greater trunk flexor values obtained compared to trunk extensors. Peak torque was observed to be independent of angular velocity which again justifies the use of the faster angular velocity during the assessment of trunk muscle strength in the training study implemented in Chapter 7.2.

7.2 THE EFFECTS OF A TEN WEEK PHYSICAL TRAINING PROGRAMME ON TRUNK MUSCLE STRENGTH AND MANUAL HANDLING SKILLS

Aspects of this work have been published in Contemporary Ergonomics 1995 (edited by S. Robertson) pp 397-402. London: Taylor & Francis, a copy of which is presented in Appendix 7.

7.2.1 Introduction

Exposure to repetitive lifting has been associated with a high prevalence of back pain and injury (Frymoyer et al., 1983). In addition, inadequate strength of the trunk musculature has been identified as a risk factor in the incidence of low back pain (Smidt et al., 1983). If trunk muscle strength is inadequate and stabilisation of the ligaments insufficient, injury or loss of optimal function may result.

Numerous studies have been performed to investigate muscular strength in relation to the incidence of low back pain (Elnaggar et al., 1991; Pope et al., 1985). However, the efficacy of training programmes aimed at increasing the lifting capability of individuals has important implications for the prevention of low back pain. In order to reduce the stress placed on the back during manual handling activities, it is advisable to reduce the load lifted and/or the number of repetitions of the lift, or to increase the lifting capacity of the worker. The latter recommendation was the subject of this study which aimed to determine the effects of physical training on trunk muscle strength and lifting capability.

Adaptations to physical training may be evaluated using the measures to assess manual handling, lifting performance and trunk muscle function; these were discussed in Chapter 3. It was hypothesised that:

Hypothesis 8. A 10-week physical training programme results in improved performance of isometric and isokinetic muscle assessment of the trunk, and psychophysical tests of manual handling skills.

7.2.2 Method

(i) *Subjects*

Twenty-three female undergraduate students volunteered to participate in the physical training programme. All subjects had responded to a letter advertising the study and were inexperienced in manual handling. During the course of the study, seven individuals withdrew from the training programme for various reasons (time commitment, study) although no subject was could not complete the training due to injury. A further fourteen females comprised a control group and performed physical assessments on four occasions at identical time intervals to the participants on the training programme. All subjects gave informed consent to participate in the training programme, physical testing sessions and the training programme if appropriate. The physical characteristics of the fifteen females completing the training programme and members of the control group are displayed in Table 7.2.

Table 7.2 Physical characteristics (Mean ±SD) of the control group and training programme participants at the start of the ten week testing period

Measure	Training (n=15)	Control (n=14)
Age (years)	20.6 (1.84)	20.4(2.98)
Height (cm)	165.6 (6.30)	165.4 (4.26)
Body Mass (kg)	65.4 (5.73)	63.2 (8.12)
Body fat (%)	27.9 (3.26)	27.5 (3.91)

(ii) Physical assessments

Physical assessments were performed before the start of training, during weeks 4 and 7, and at the end of training (week 10). Each assessment consisted of eight test parameters, details of the test procedures are given below:

[1] *One repetition maximum lift (1-RM)*

Subjects performed a "one repetition maximum" vertical lift. A square box with handles was lifted from 87 cm to 30 cm and returned to the starting position. The weight of the box was selected by the subject from a number of visually identical lead-filled bags, weighing between 0.25-2.5 kg. The weight of the box, unknown to the lifter was recorded.

[2] *Maximum acceptable weight of lift (MAWL)*

This was identified using the box and weights utilised for the 1-RM. Subjects were asked to select the load they perceived as a comfortable weight to lift at a rate of 6 lifts per minute for 10 min without becoming out of breath or fatigued. Subjects then performed only three vertical lifts, each time returning the box to the starting position at a height of 87 cm. The weight of the box, unknown to the lifter was recorded.

[3] *Maximal isometric lifting strength (MILS) of leg lifting strength*

Vertical isometric lifting strength in a leg-lifting technique was assessed on an isometric lift dynamometer as described in Section 3.3.1 and displayed in Plate 7.2. Subjects adopted a squat lifting posture (leg lift), grasping the horizontal bar handles either side of the knees; handles were positioned at the level of the upper border of the patellae when the knees were straight. Subjects were instructed to exert a maximum force, lifting the bar vertically. Three maximum lifts were performed, each over a three second period. The peak from the three trials was recorded.

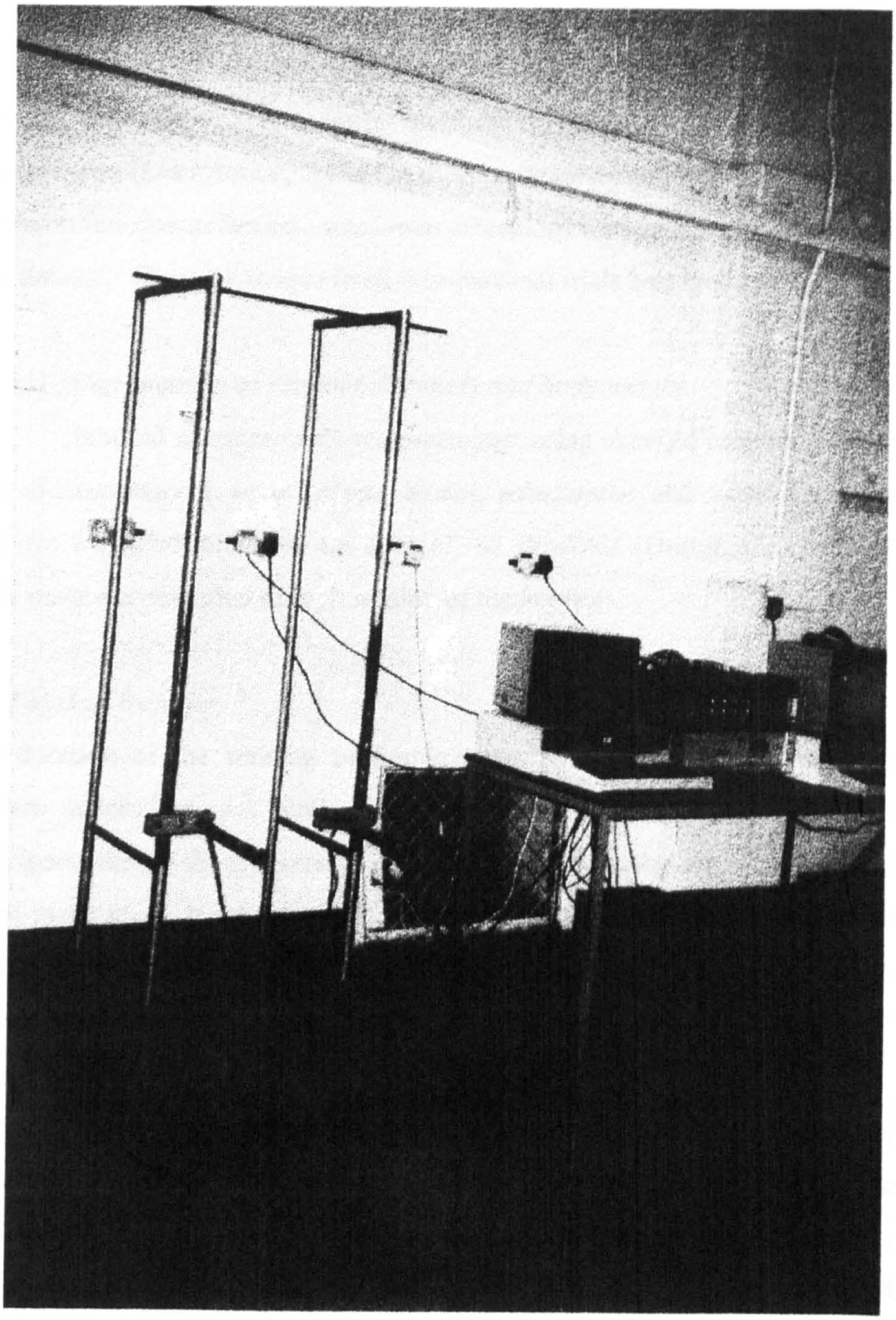


Plate 7.2 The isometric lift dynamometer

[4] *Isokinetic strength of the trunk flexors and extensors*

This was assessed from standing and at a velocity of 2.09 rad. s^{-1}. This angular velocity was selected as the results of the previous section demonstrated that peak torque was independent of angular velocity; it offered the least resistance against which to perform the test. Tests were performed on a computer-controlled isokinetic dynamometer (Lido Active, Davis CA). Three submaximal movements through the range of motion (maximum flexion - maximum extension) were performed to familiarise subjects with the test. The peak torque from four maximal trials was recorded.

[5] *Measurement of skinfold thickness and body weight*

Skinfold measurements were obtained using skinfold calipers (Harpenden). The sites of measurement were: triceps, biceps, subscapular and supra-iliac. Percentage of body fat was predicted from the sum of the skinfolds (Durnin and Womersley 1974)). Body mass was recorded at each session of testing (kg).

(iii) Physical training

The duration of the training programme was 10 weeks. Three supervised training sessions undertaken each week. Exercises were additionally performed at home by all participants during the weekends to maintain mobility in this intervening period (stretches of the trunk, groin, hip, hamstrings). These exercises were routinely performed during the course of a training session and as such were familiar to all subjects; they did not require the use of additional equipment.

Two of the weekly supervised sessions involved progressive resistance exercises performed on circuit-weight training equipment and activities involving exercise against body weight. A circuit training session constituted the third supervised class. At the start of each exercise class a standard whole body warm-up regimen was performed and stretching exercises concluded each session.

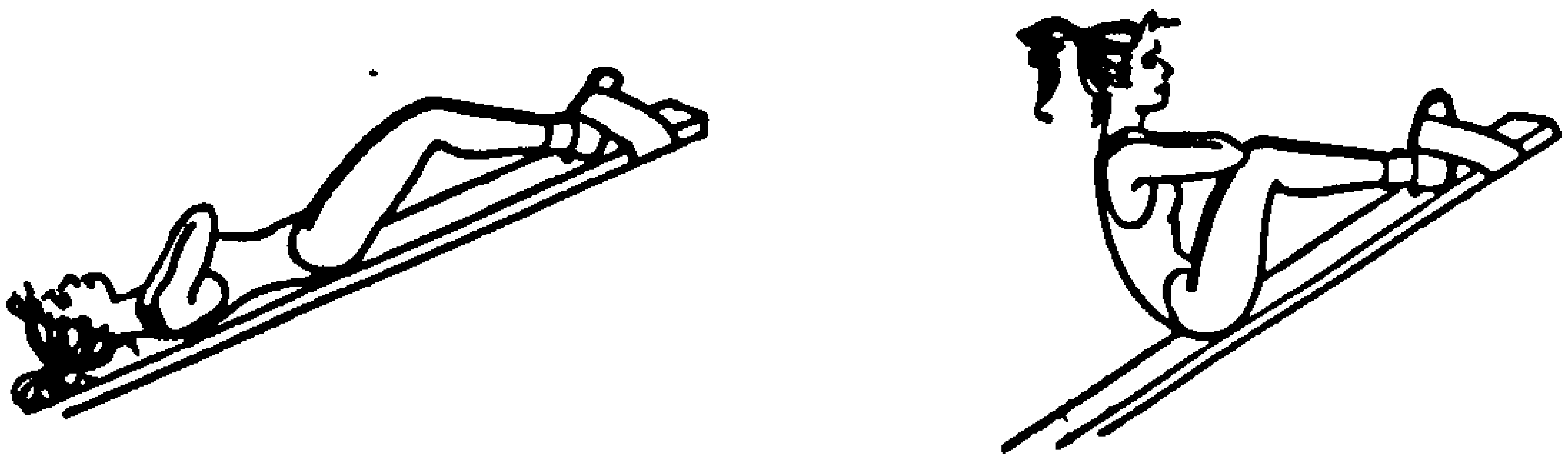
The progressive resistance exercises were based upon the subject's one repetition maximum for each exercise (the maximum weight at which the exercise could be performed once only, 1-RM). The 1-RM was re-evaluated during weeks 3,5 and 8 and subsequent exercise intensities were based upon the revised 1-RM.

Three circuits comprising ten exercises were performed during each weight training session. The only exception to this being the first class where subjects were familiarised with use of the equipment and instructed on the correct exercise technique, therefore only two circuits were performed. Figure 7.6 illustrates the exercises performed during the weight training sessions. The intensity of the workload increased from first to third circuit (between 50-80% of the 1-RM) within a training session. The 1-RM was evaluated at 3 week intervals (following five weight training sessions). The training schedule was repeated within the 3 week periods but subjects could actually be working at a greater intensity if the 1-RM for any particular exercise had increased. Details of the intensity of the exercises and the number of repetitions performed during each session in a 3 week cycle are displayed in Table 7.3.

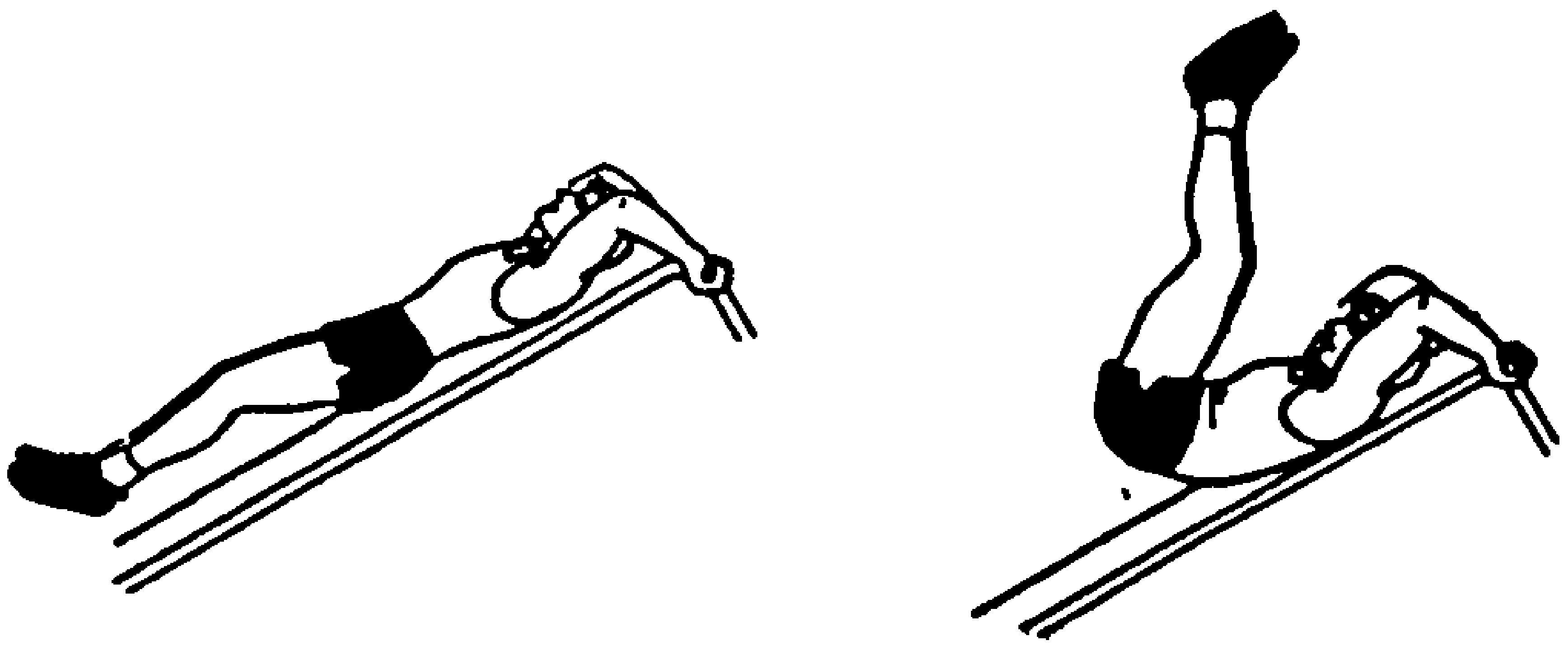
Table 7.3 Intensity (% 1-RM) of weight training sessions and number of repetitions of each exercise following the evaluation of 1-RM at 3 week intervals

Session	Intensity of circuits	Number of repetitions	Session	Intensity of circuits	Number of repetitions
1	1 x 50 1 x 60 1 x 70	10 10 8	4	1 x 60 1 x 70 1 x 80	10 10 8
2	1 x 60 1 x 70 1 x 70	10 10 8	5	1 x 60 1 x 70 1 x 80	10 10 10
3	1 x 60 1 x 70 1 x 80	10 10 8	Evaluation of 1-RM followed by repeat of session 1 exercise intensities.		

1. Inclined sit-up
(rectus abdominis)

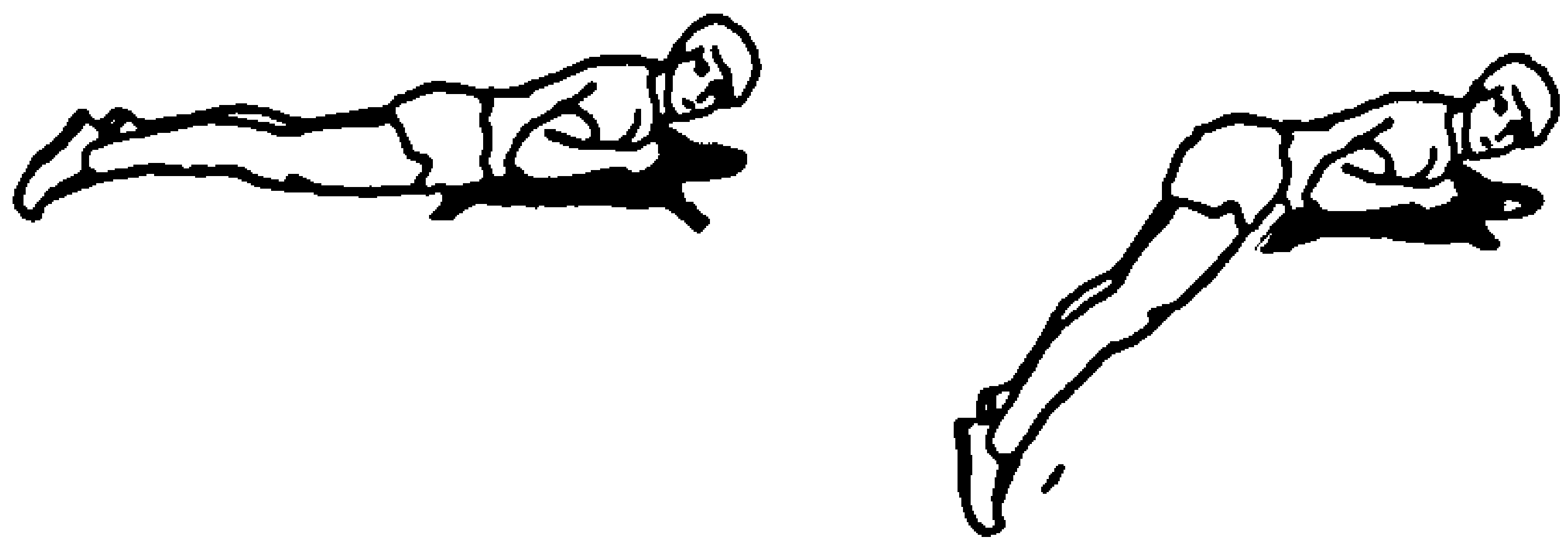


2. Inclined board leg raise
(lower abdominals)



3. Lower back extension
(erector spinae)

4. Swimmers' kick
(gluteus maximus, biceps femoris,
semimembranosis, semitendinosis also:
adductors longus, brevis, minimus).



5. Leg extension
(quadriceps)

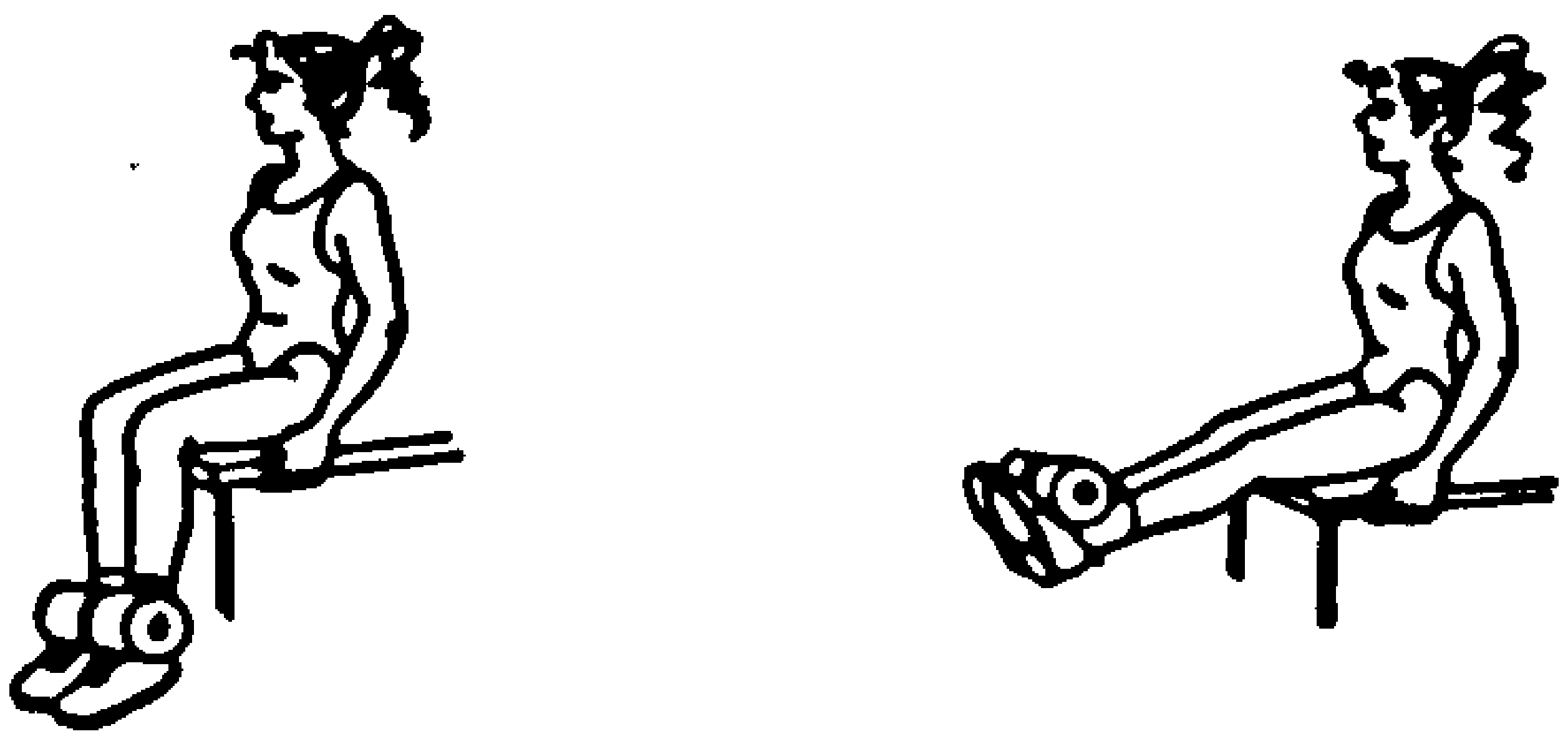
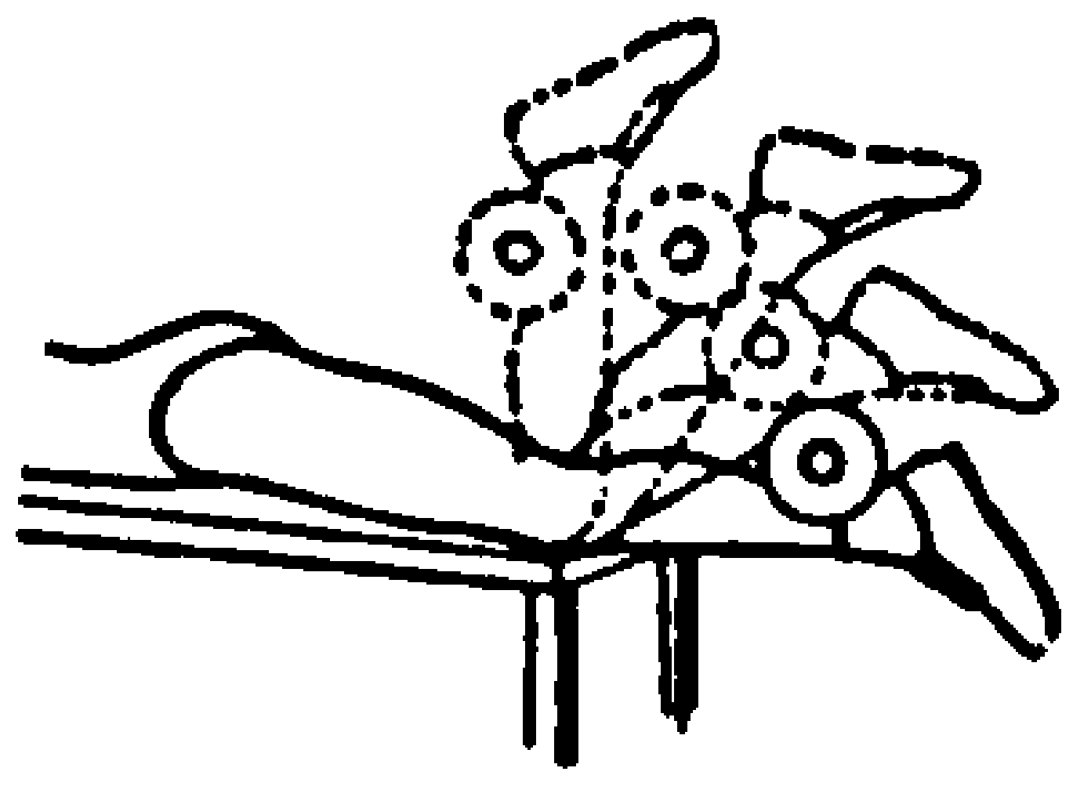
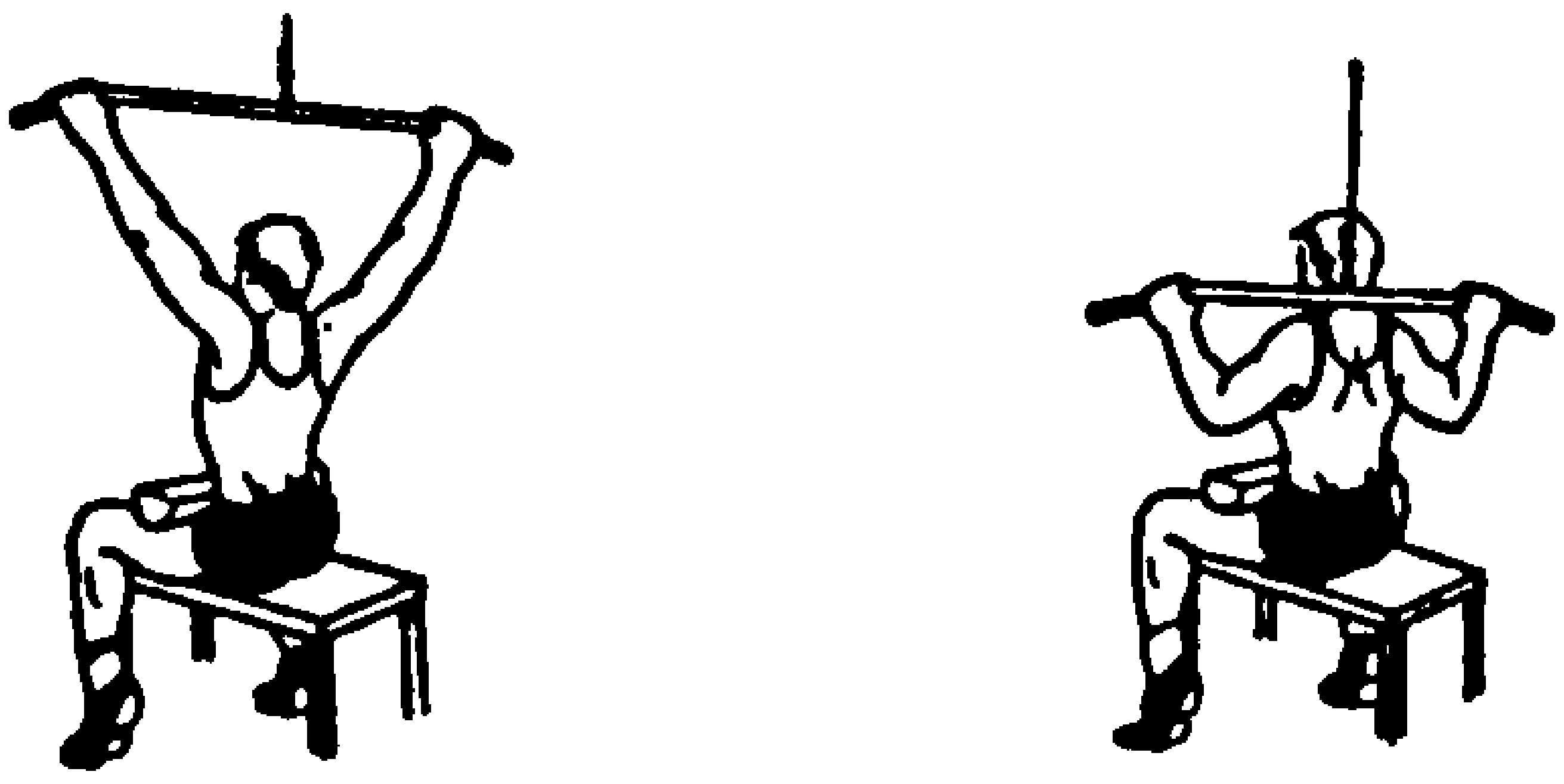


Figure. 7.5 Weight training exercises performed during the twice-weekly exercise sessions

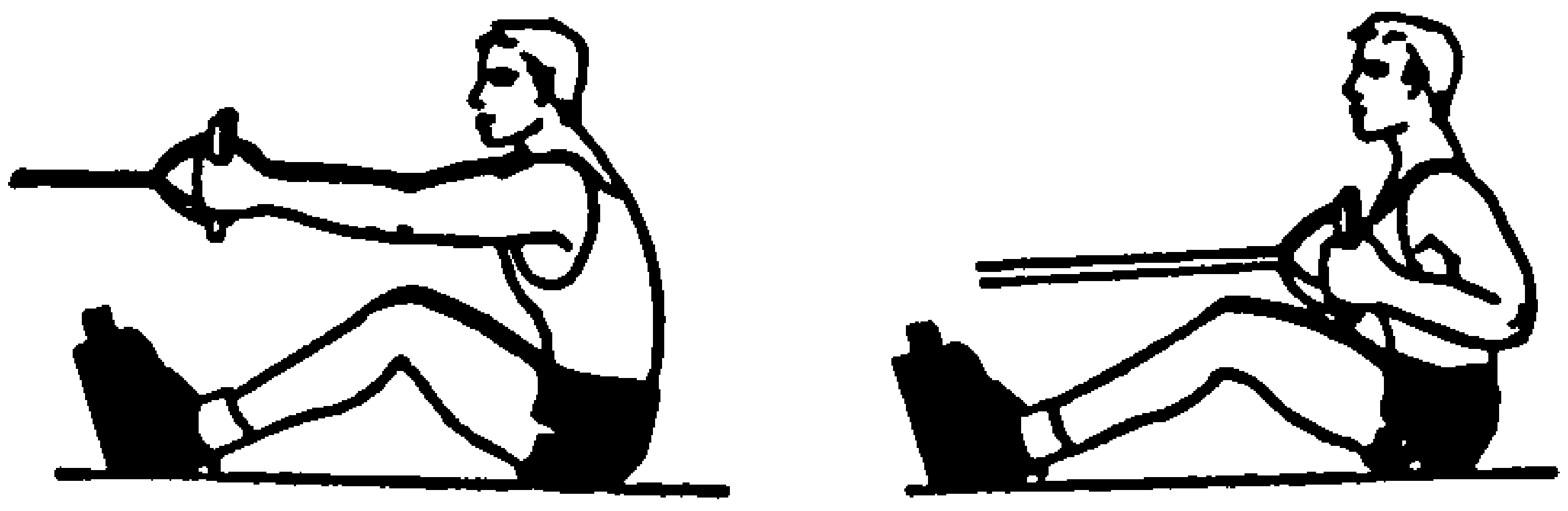
6. Leg curl
(biceps femoris)



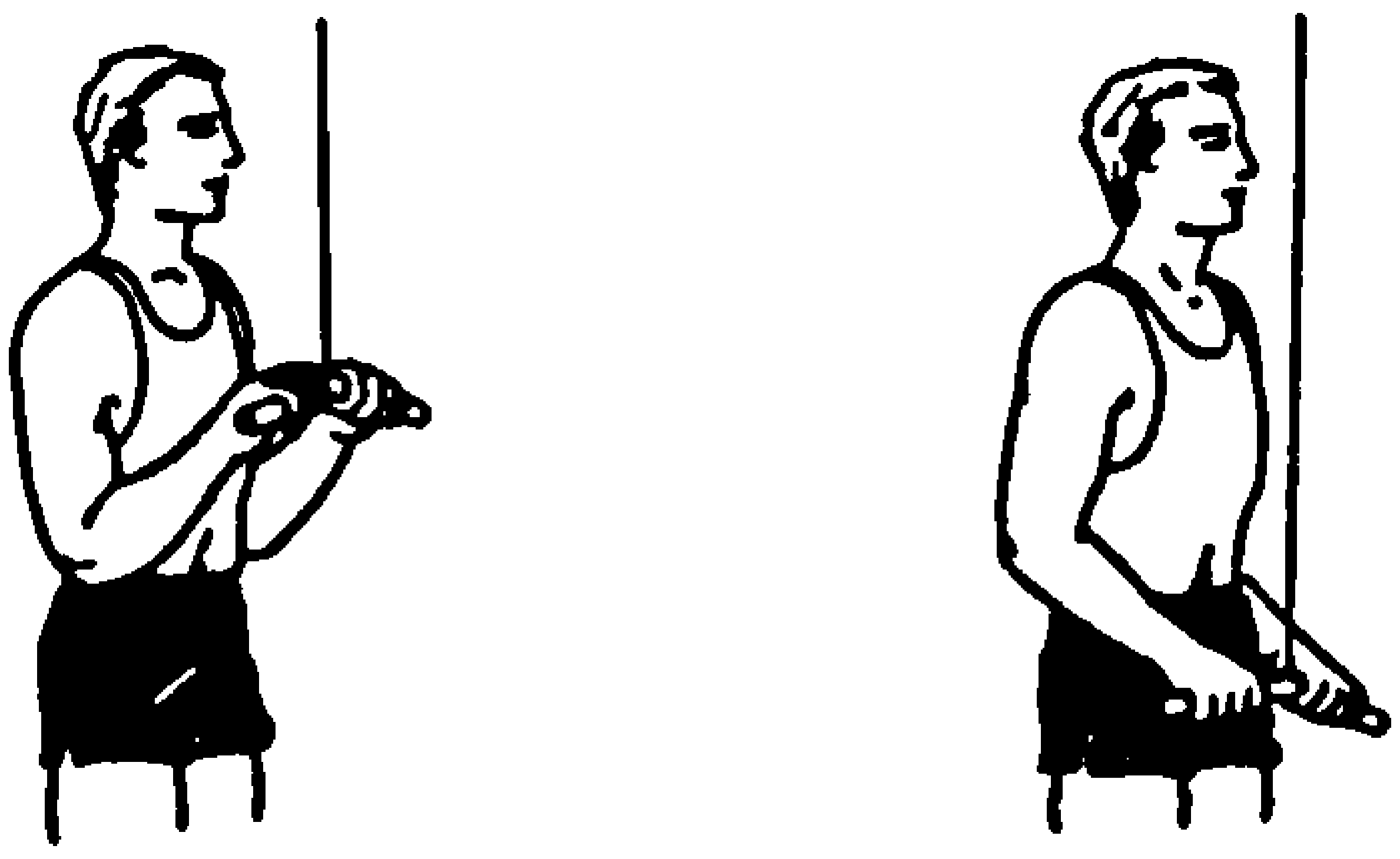
7. "Lat machine" pull down
(latissimus dorsi, terres major)



8. Seated pulley-row
(lower trapezius, teres major,
rhomboids, infrasspinatus, deltoids).



9. Triceps pushdown
(3 heads of the triceps)



10. Bench press
(pectoralis major & minor, front of
deltoid, triceps, coracobrachialis,
serratus)

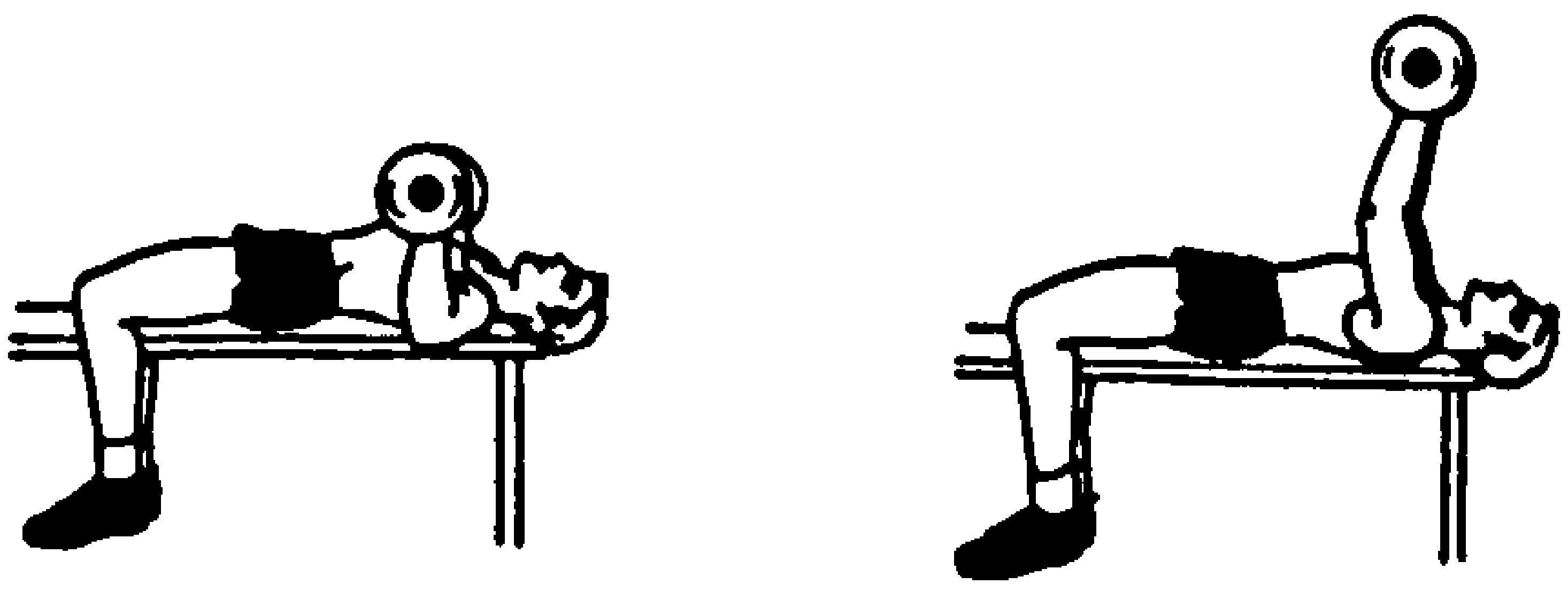


Figure. 7.5 (continued) Weight training exercises performed during the twice-weekly exercise sessions

The circuit training session performed each week comprised seven activity stations; these activities are listed in Table 7.4. Within a single circuit, pairs of subjects exercised at the seven activity stations, performing as many complete exercises within a 30 s period as was possible; one individual of the pair preceding the other so that each subject exercised for 30 s then rested whilst her partner exercised or vice-versa. All subjects immediately rotated to the next exercise station when both members of the pair has completed a particular activity until all exercises had been performed by each pair. A 4 min rest period was allowed between each circuit. Three circuits were performed, preceded by a warm-up regimen and concluded with stretching exercises.

Table 7.4 The exercises comprising the circuit-training regimen

Press-ups	Sit-ups
Astride bench jump	Bench step-up
Triceps push	Shuttle run (15m)
Squat thrusts	

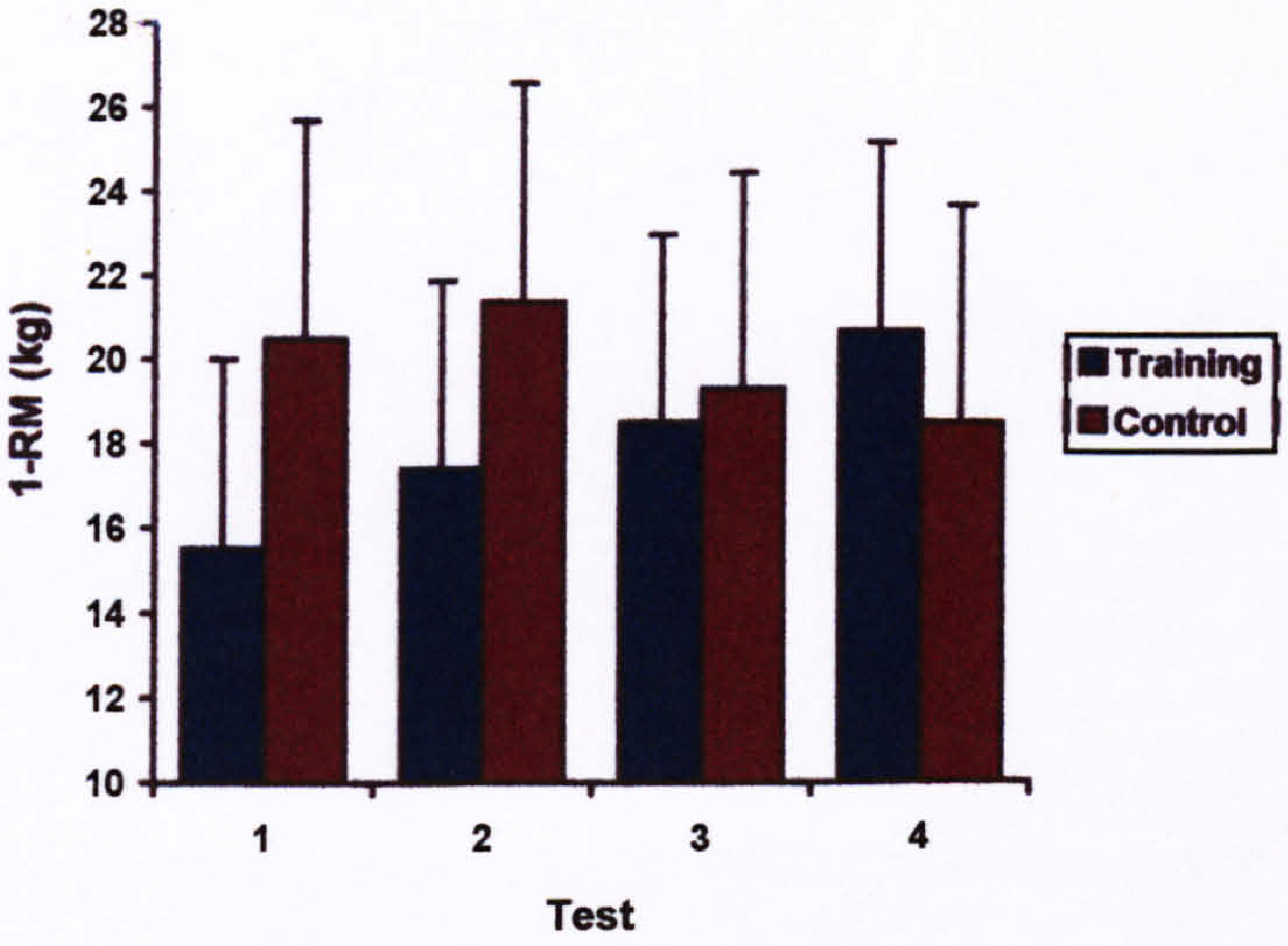
iv) Analysis of data

Statistical analyses aimed to detect any changes in back muscle strength and lifting capability as a result of the physical training. Two way analysis of variance (group x test) with repeated measures of the test factor was performed on the test parameters for the two groups during the four physical assessment sessions. In addition, Bonferroni T tests localised significant differences ($P<0.0125$) among the four test sessions for the experimental group, only where the ANOVA had revealed an overall change in the test results.

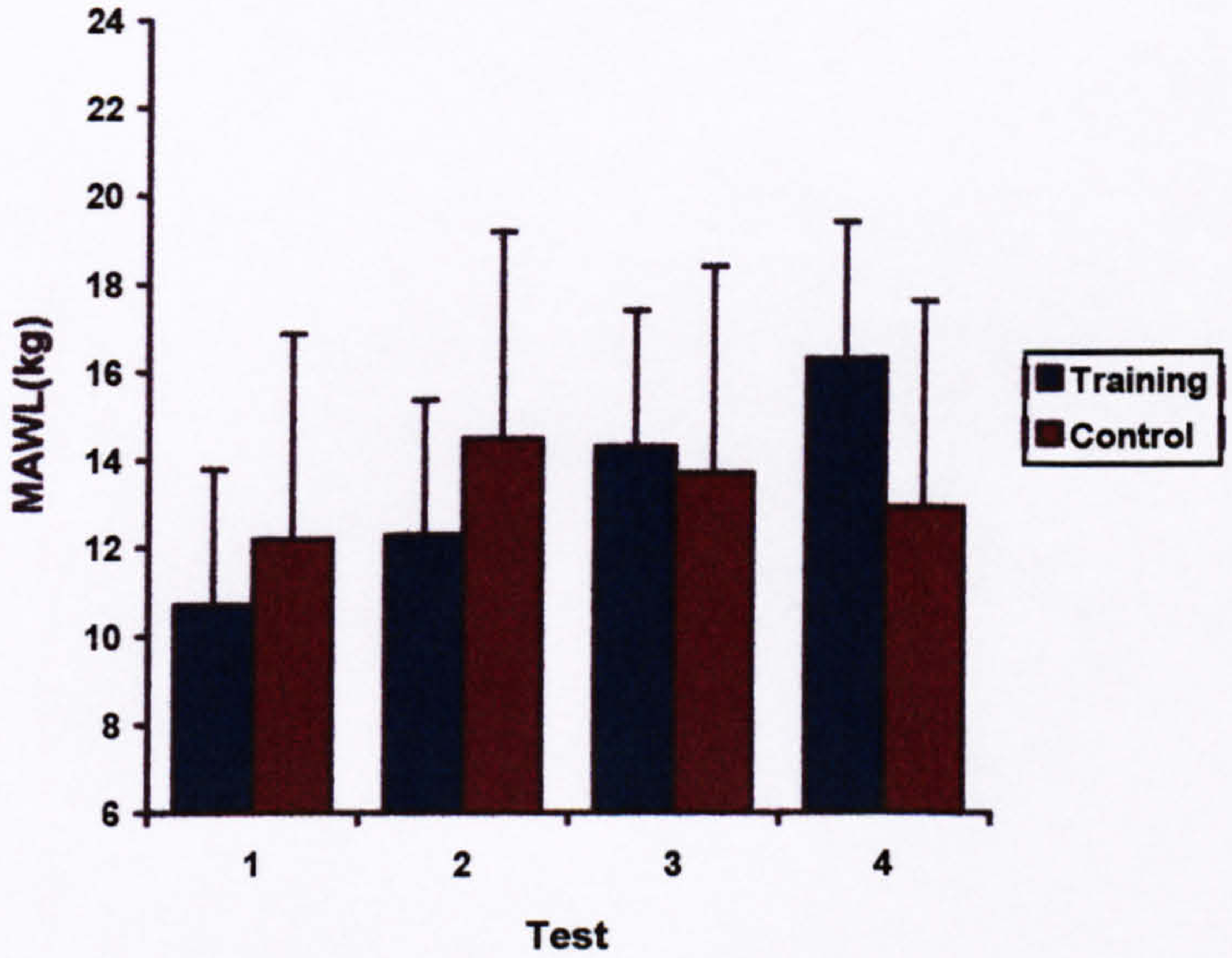
7.2.3 Results

The results of the tests performed by both groups in the four physical assessments are displayed in Table 7.5. Significant increases in the load selected by the training group for the 1-RM task were observed during the course of the physical assessments ($F_{3,81}=23.97$, $P<0.001$); increases were significant between tests 1-3, 1-4 and 2-4 ($P<0.01$). The submaximal load selected by the same group for the MAWL task also demonstrated consistent increases with significant increases observed following the second physical assessment ($P<0.01$). Graphical presentation of the 1-RM and MAWL data may be seen in Figure 8.2 (a) and (b).

Maximal isometric lifting strength increased significantly over the physical assessments (Figure 8.3) ($F_{3,81}=10.79$, $P<0.001$); the greatest improvement in performance was observed in the training group ($P<0.01$). Peak torque values for the trunk flexors increased in both groups over the four physical assessments ($F_{3,81}=2.57$, $P=0.06$). The training group demonstrated an increase in trunk flexor peak torque of 8.3% from the start to the end of training; the change in the control group was not significant. ($P>0.10$). The mean trunk extensor peak torque increased significantly in both the training and control groups over the physical assessments ($F_{3,81}=5.42$, $P<0.005$). The results of the isokinetic assessments are displayed graphically in Figure 8.4 (a) and (b). Body mass did not alter significantly during the ten week period in either group of subjects (($F_{3,81}=0.68$, $P=0.569$). In the training group the percentage of body fat was significantly reduced between tests 1-4 and 2-4 ($P<0.01$).



(a)



(b)

Figure 7.6 The (a) one-repetition maximum and (b) maximum acceptable weight of lift task for the control and training groups at each physical assessment

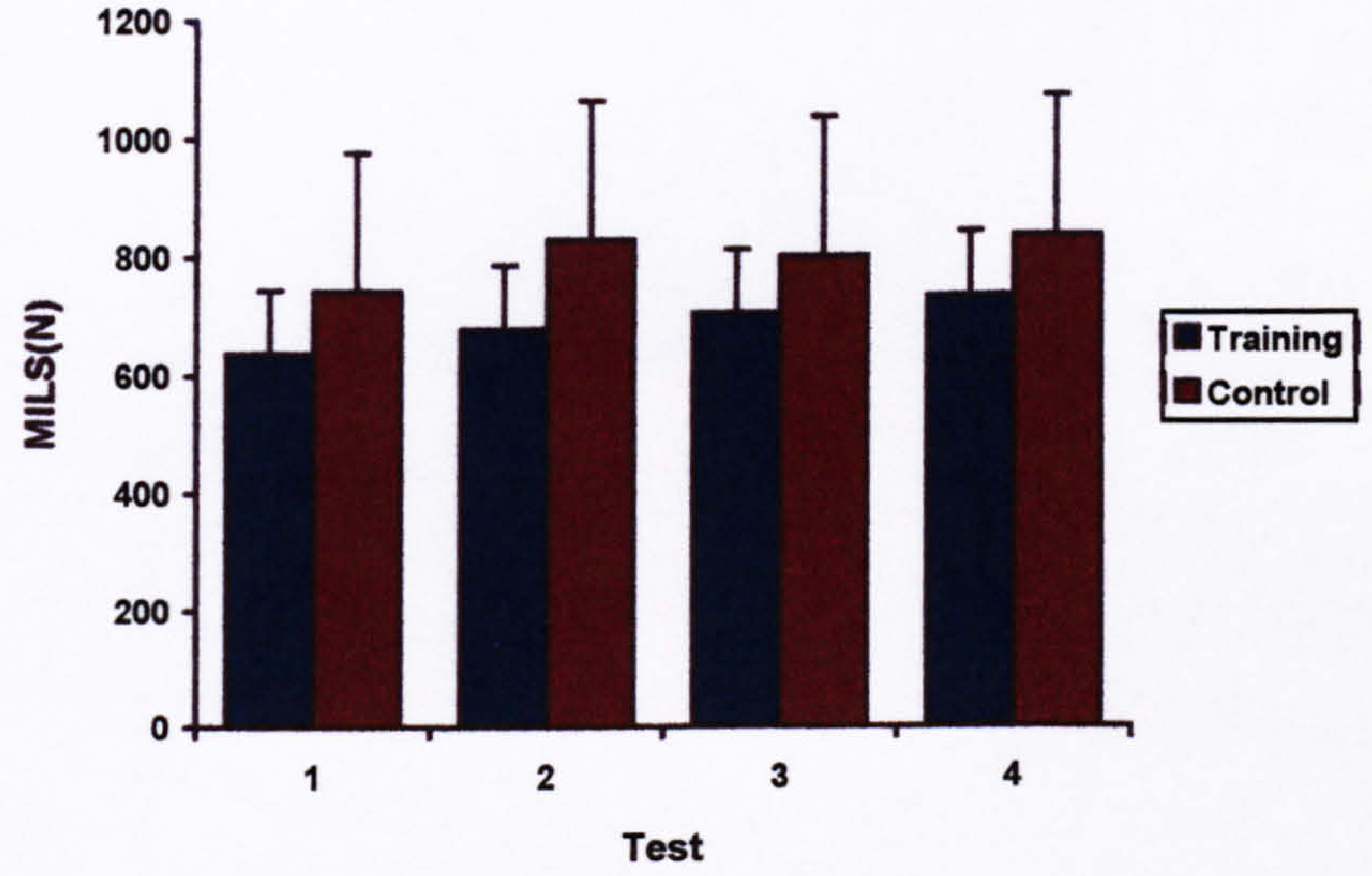
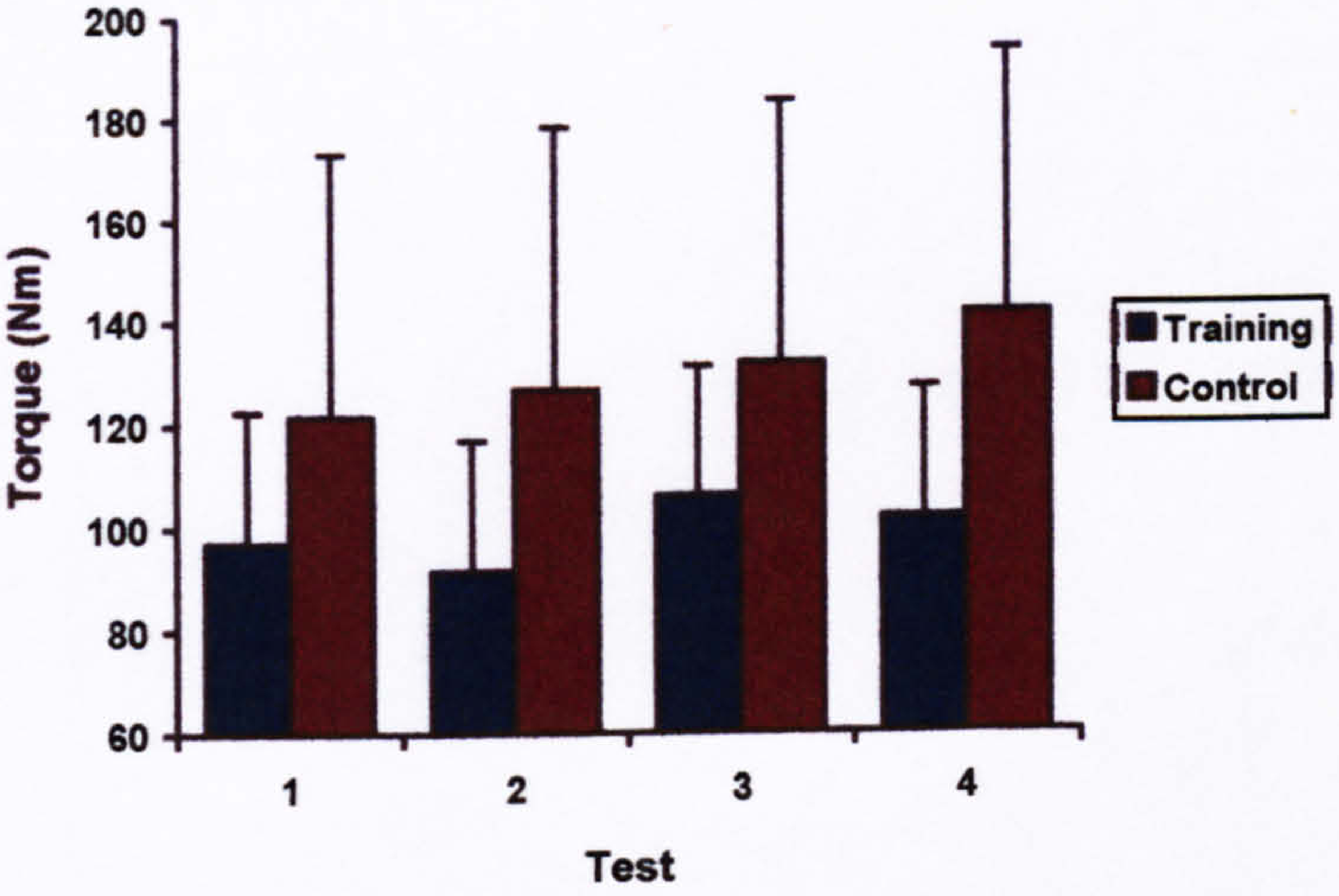
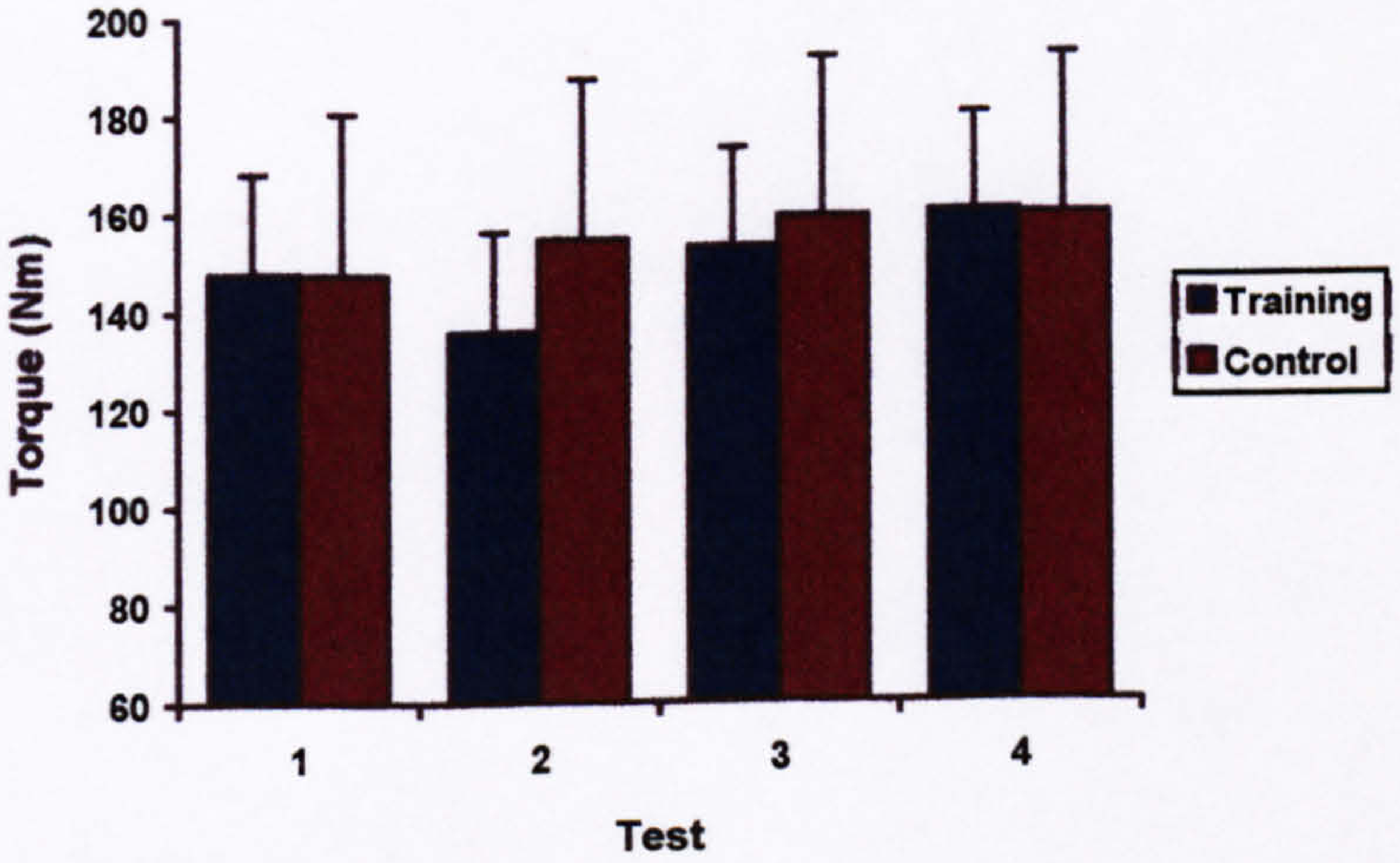


Figure 7.7 Maximal isometric lifting strength for the control and training groups at each physical assessment



(a)



(b)

Figure 7.8 Peak torque (a) extension and (b) flexion, of the control and training groups during trunk assessment at 2.09 rad. s^{-1}

7.2.4 Discussion

Training for muscular strength resulted in a significant increase in the two psychophysical measures of individual lifting capability. The increase in the maximum weight that subjects were willing to lift increased significantly after three weeks of physical training. By the end of the training programme values for the 1-RM had increased by 33.6%. In addition, the load individuals considered themselves capable of lifting once every 10 seconds for 10 min (MAWL) increased overall by an average of 52.3%. Asfour et al. (1984) also demonstrated that training significantly ($P<0.01$) increased the maximum weight lifted. Improvement in the 1-RM for lifts at three different heights was attributed to both an increase in muscular strength and an improvement in lifting technique (Asfour et al., 1984). It has been stated that progressive resistance exercises do not necessarily improve static muscular strength as much as dynamic muscular strength (Genaidy, 1992)

In the current study improvements in perceived lifting capability exceeded the magnitude of increase in muscular strength and were greater in the trained group. A factor arising in consideration of perceived lifting capability, is that increases may actually place an individual at risk of injury or muscular strain. Greater implications may be applicable when, as in the current study, improvements in perceived lifting capability exceed the magnitude of the increase in muscular strength. The perception that one is able to lift greater loads, either maximally or submaximal loads over a period of time could lead to over-exertion or mechanical injury.

The two parameters of psychophysical lifting capability did appear particularly sensitive to physical training; however, the static and dynamic measures of muscular strength appeared to be influenced partially by familiarisation with performing the tasks; this was demonstrated by the results of the control group. Maximal isometric lifting strength at knee height and peak torque for the trunk flexors and extensors increased over the four physical assessment sessions in the group who did not undertake the physical training programme. However, for MILS, the magnitude of the increase was greatest in the training group. For the isokinetic assessment of the trunk flexor and extensor muscles at 2.09 rad. s^{-1} it may be implied that variation took place under test-retest conditions. The subjects performed the physical assessments at the same time of day on each testing occasion, therefore controlling for the circadian variation in muscular strength (Atkinson, 1994). Literature relating to reliability data of isokinetic trunk assessment in the standing position is lacking and there is a need to examine sources of variation in performance of such assessments. Several implications arise relating not only to the screening of individuals for muscle function, but to the application of the methodology for pre-employment screening of individuals in occupations requiring manual handling. Present observations suggest a familiarisation effect which persists over repeated tests and the possibility that test frequency itself may have induced a training response.

Griffen et al. (1984) reported a test-retest correlation for MILS at knee height in a population of eighty females aged 29 years of less ($r=0.855$); the assessment consisted of the initial test followed by a re-rest 5-7 days later. The statistical method of applying correlation coefficients to test-retest data is subject to criticisms which do not apply to techniques such as coefficients of variation or limits of agreement. Although the training group in the present study demonstrated an increase in MILS over the ten week period, it seems that some of this improvement may be attributable to the effect of repeated testing.

The criteria for the matching of participants in the training and control groups were based upon height, body mass and age; the mean values of these parameters were similar in both groups. By referring again to Figures 7.6, 7.7, and 7.8 it may be observed that the control group mean values for the first test assessment appear to be greater than those of the training group. However, only the mean value of the parameter MAWL was actually significantly ($P<0.05$) greater in the control group at the start of the training period. Nevertheless, this highlights the importance of selecting the most appropriate criteria for the matching of sample groups. In retrospect, it may have been advantageous for all the participants of this particular study to have undergone a physical assessment prior to the start of the training programme. This would have served a dual purpose: i) to establish the standard of all individuals in the test measures and, ii) to familiarise each individual in the test procedures.

The differences in test performance observed between the two groups at the start of the ten-week test/training period may be possibly explained by differing amounts of physical activity performed by the individuals within each group. It is possible that the control group were habitually more active than members of the physical training group. The control group were instructed to continue normal activities during the course of the ten week period and not to engage in additional exercise or new manual handling activities. This group was not required to confirm their habitual activity and any violation of this request may have contributed to the changes in the test parameters observed in the control group.

This study demonstrated that a general physical training programme of 10 weeks' duration induced an increase in the lifting capability of the participants. Improvements in the maximum weight that could be lifted were apparent following three weeks' of training (equivalent to 9 exercise sessions). Improvements in MILS and dynamic peak torque of trunk extensors and flexors observed in the control group of non-training individuals, reflected an effect of repeated testing but which did not match the improvements observed in the experimental subjects; the greatest improvements in MILS were observed in the participants of the training programme. The results demonstrate the beneficial effects of physical training programmes for personnel involved in occupations demanding manual handling. The future implementation of longitudinal and intervention studies incorporating physical training to improve trunk muscle strength may have implications for attempts to reduce the incidence of back pain.

7.5 SUMMARY

[1] The repeatability of the Lido isokinetic dynamometer was established. Whilst there does appear to be variation in the data obtained between test and retest, it still remains to be ascertained whether this amount of variation is in excess of or less than that of similar isokinetic apparatus. The continued application of the Lido dynamometer for the assessment of trunk muscle strength is endorsed although limitations do apply to the interpretation of data collected.

[2] Peak torque was found to be independent of angular velocity within the range of 1.05 $rad.s^{-1}$ and 2.09 $rad.s^{-1}$.

[3] Peak torque values of flexion were significantly greater than extension values for healthy, asymptomatic males and females.

[4] Gender differences in peak torque were observed during extension and flexion at all three angular velocities, whereby values for males exceeded those of females. When peak torque was normalised for body mass, significant differences were evident only during flexion at 1.05 and 2.09 $rad.s^{-1}$.

[5] Lifting capability was significantly improved following 10 weeks of physical training. Improvements in the psychophysical tests were evident following three weeks of training. The application of physical training within future longitudinal and intervention studies is endorsed, the aim of these being to reduce the incidence of back pain.

Chapter Eight

Synthesis of Findings

8 SYNTHESIS OF FINDINGS

The purpose of this Chapter is to interpret and integrate the results obtained within this thesis. The possible applications and implications of specific findings will be discussed. The realisation of the aims of the thesis will be confirmed prior to reviewing the original hypotheses stated. Within the general discussion and conclusions which follow, the results of the array of studies will be interpreted with regard to the problem of back pain amongst the nursing profession in order to fulfil the final aim of the thesis.

8.1 REALISATION OF AIMS

Figure 8.1 provides an overview of the structure of the research. It highlights the comparative nature of aspects of the work and the investigative strategies employed amongst nursing personnel and non-nursing members of the general population.

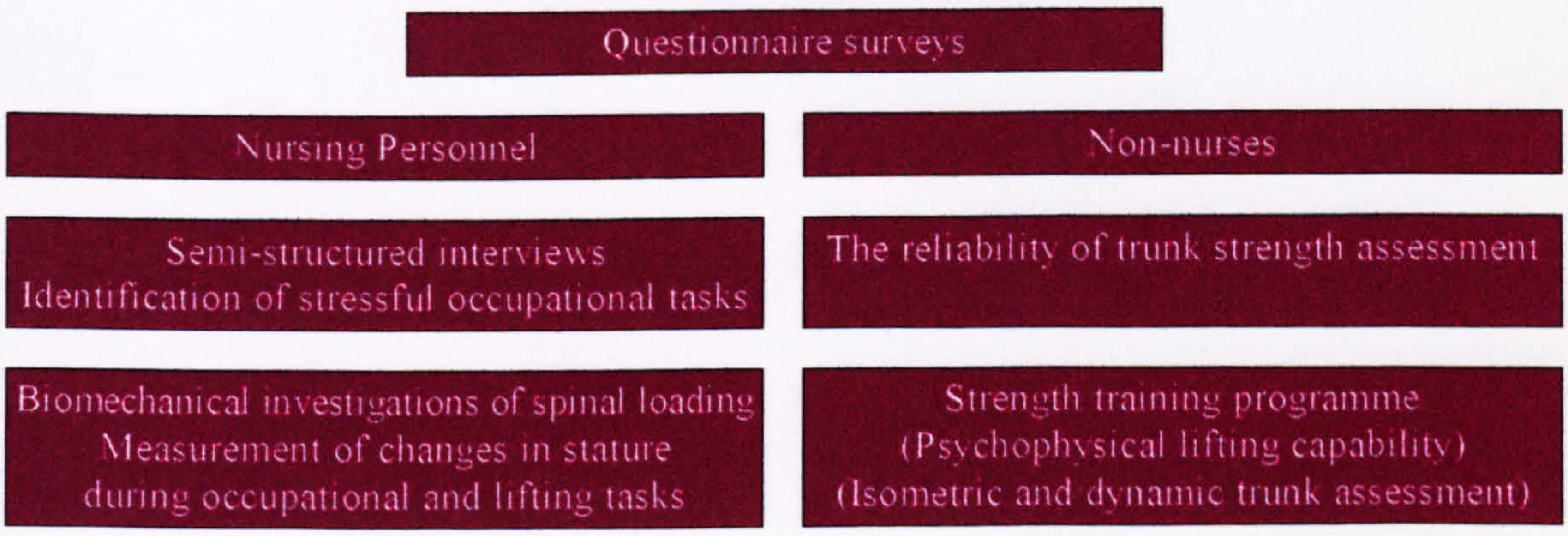


Figure 8.1 Representation of the research design structure

The multidisciplinary studies which comprise the experimental sections of the thesis have fulfilled all but one of the aims stated in Chapter 2. The epidemiological surveys established the incidence and prevalence of back pain in nursing personnel and non-nursing members of the population (aim i). The point prevalence, annual prevalence and annual incidence of back pain within the nursing sample were 24.4%, 58.8% and 14.7% respectively. The equivalent figures derived from the non-nursing respondents were 25.1%, 57.8% and 11.5%.

The spinal and physiological responses to lifting tasks were investigated utilising the technique of measuring changes in stature and by measuring heart rate (aims ii and iii). Dynamic lifting tasks, transferring a load from the floor to a height of 76 cm, induced greater loss of stature and increased heart rate values than either isometric lifting or an asymmetric lifting activity. The compressive loads imposed by the repetition of the task of transferring a patient from the bed to chair were also established. Loss of stature was not influenced by the existence of chronic back pain symptoms amongst nursing personnel.

The repeatability of apparatus used to assess trunk muscle strength was established using contemporary statistical techniques (aim iv). Functional assessment was endorsed at the faster angular velocities (1.57, 2.09 $rad.s^{-1}$). Improvements in trunk muscle strength and manual handling skills were observed following a 10-week period of physical training (aim v).

Within this Chapter, the results of the above studies will be interpreted with regard to the problem of back pain amongst the nursing profession in order to fulfil the final (vi) aim of the thesis.

8.2 REVIEW OF HYPOTHESES

A series of hypotheses were formulated throughout the thesis. It is appropriate to examine whether the results of studies have confirmed or disproved the original suppositions.

Hypothesis 1. *The prevalence of back pain is greater in nursing personnel than amongst non-nursing members of the population.*

This hypothesis was rejected. The point, annual and lifetime prevalence of back pain symptoms were similar within the two sample populations.

Hypothesis 2. *There is an increase in the prevalence of back pain in contemporary nursing personnel compared to data collected in the previous decade.*

An increase in the prevalence of back pain symptoms over a ten year period was observed following the epidemiological survey. Therefore this hypothesis was accepted. The results collected for this thesis were compared to earlier data was possible due to similarities in the methodology and sample characteristics.

Hypothesis 3. *Dynamic lifting tasks induce greater changes in stature and heart rate values compared to isometric lifting.*

This hypothesis was accepted. The mean loss of stature and following the dynamic lifting was greater than the shrinkage induced by the performance of the isometric tasks ($P<0.01$). Similarly, heart rate values were significantly greater during the dynamic activities compared to responses of the isometric task.

Hypothesis 4. *Changes in stature due to isometric and dynamic lifting are greater in nurses indicating a lifetime prevalence of back pain compared to asymptomatic individuals.*

The prevalence of back pain symptoms at some time during life did not differentiate the stature changes observed in the two groups. This hypothesis was rejected.

Hypothesis 5. *The Fowler position induces recovery of stature following the isometric lifting activities.*

The posture assumed to unload the spine of compressive loads did induce recovery of stature following the isometric lifting. This hypothesis was accepted.

Hypothesis 6. *Estimated lumbar disc area exhibits a linear relationship with loss of disc height such that greater shrinkage occurs in smaller discs.*

A linear relationship was observed between estimated cross-sectional area of the lumbar discs and the loss of stature induced by repetitive lifting. However, less stature loss was observed in discs with a smaller cross-sectional area. This observation (although a reflection of body size) is contrary to that reported by Althoff et al. (1992) and results in the rejection of this hypothesis.

Hypothesis 7. *Loss of disc height following repetitive lifting activity is greater in nurses experiencing chronic low back pain compared to healthy individuals.*

This statement represents a revisitation to the original question addressed in Hypothesis 4. Although similar to Hypothesis 4 this hypothesis is based upon different criteria for the selection of nurses participating in the study; the chronicity and severity of symptoms was greater than the lifetime prevalence of back pain reported in Chapter 6.1. However, the hypothesis was not confirmed as there was no significant difference between the loss of disc height in the symptomatic nurses and the healthy individuals.

Hypothesis 8. *A 10 week physical training programme results in improved performance of isometric and isokinetic muscle assessment of the trunk and psychophysical tests of manual handling skills.*

This hypothesis was accepted. Lifting capability was significantly improved following 10 weeks of physical training.

8.3 GENERAL DISCUSSION

The following discussion incorporates the inferences drawn from the tests of the hypotheses and attempts to integrate the main observations of the thesis. Back pain is an extremely complex problem and aspects of the multifactorial aetiology have not been considered within this thesis. It would therefore not be appropriate to develop and recommend the validation of a model associated with the prevention of back pain amongst nursing personnel (with implications for non-nurses). Consequently, the discussion forms the basis for the ensuing section which culminates in a proposition recommended for future investigation. This takes the form of a framework which recognises the need for the differentiation, and identification of the inter-relationships between factors associated with the incidence and prevalence of back pain. The schema has particular relevance amongst the nursing profession as it has been derived from the studies of the nursing population within this thesis.

The questionnaire surveys conducted amongst nurses and non-nurses provided the foundation from which further studies have progressed. The results of these surveys highlight two important points for consideration:

(i) Although there exists a prevalence of back pain symptoms amongst nursing personnel which is attributed to occupational lifting tasks, symptoms are equally as prevalent amongst non-nursing members of the general population. The perceived causes of back pain may be different in individuals working in various occupations although subjects in the non-nursing sample were not required to identify factors which they considered had precipitated pain. With regard to actual risk factors, specific manual handling tasks were associated with back pain amongst the nurses, however the causal link between the manual handling tasks and back pain was not examined since the exposure to such activities was not measured.

(ii) The nurses' epidemiological data collected were compared to the data of Stubbs et al. (1983). An increase of approximately 40% in the prevalence of back pain symptoms by was observed; sickness absence due to back pain had not increased concomitantly. It may be assumed that a greater proportion of working nurses now experience symptoms but that the disability caused by back pain has not increased to the same extent.

Both points (i) and (ii) illustrate the problematic nature of research into back pain. The reporting of back pain symptoms is extremely subjective and the behaviour of symptomatic individuals varies from stoical to malingering. Waddell (1987) observed that the majority of the population with low back pain cope with the problem themselves without the need for medical treatment. Mild symptoms may not generate anxiety and may be relieved/managed by rest or by disregarding the existence of pain. Of course the perceived severity of symptoms will cause some individuals to seek medical attention. Expectations with regard to treatment influence the decision to seek health care advice, as do anxiety, emotional distress and stress. These latter factors are all associated with illness behaviour and the complex interaction between physical symptoms and psychosocial influences. These aspects of the evidently ubiquitous problem of back pain were not measured in the two questionnaires.

Reasons for this included the length of time it would take to complete such a comprehensive questionnaire and the subsequent fall in response rate. The distinction between those nurses/individuals in whom pain was a minor but irritating complaint and those people chronically disabled by symptoms could therefore not be made.

The reasons for the apparent increase in the prevalence of back pain symptoms amongst nursing personnel may only be suggested. There does not appear to have been an increase in the subsequent disability caused so it is possible that more minor episodes of back pain have been reported. In other words, is it now more acceptable to complain of symptoms? This leads again to the point of 'disability' and the difficulties associated the identification of individuals in whom the symptoms are more severe. The management of back pain and strategies to cope with symptoms are now recommended by clinicians in recognition of the multifactorial aetiology of back pain and the nature of symptoms in patients with the idiopathic condition.

If back pain is so widespread across different occupations such as nursing where lifting is required, and clerical jobs where seated posture is important, it could be suggested that the perceived causes of back pain by the sufferers may not actually be those wholly responsible for the onset of symptoms. Perceived causes should not be disregarded, but because nurses are made aware through training of the risks associated with poor lifting technique, this may evoke the automatic perception that lifting has caused pain.

The semi-structured interviews conducted amongst nurses did identify the specific tasks that nurses perceived to be stressful, not specifically to the low back. Musculoskeletal disorders not expressly associated with the lower back may be a problem for nursing personnel. In combination with the questionnaire surveys, the epidemiological studies appear to have identified the need for the conduct of studies of longitudinal design. These could examine the incidence of back pain and other musculoskeletal disorders amongst occupational groups in conjunction with observational analysis in order to identify whether a definite relationship between risk and exposure to particular activities exists.

The studies utilising the stadiometer to investigate the changes in stature caused by lifting activities enabled the effects of loads imposed on the spine to be quantified. However, the application of the measurement technique as a clinical tool was contraindicated to a degree as both the lifetime prevalence of pain and the 1-month prevalence of chronic symptoms did not enable distinctions to be made in terms of loss of stature. Individual differences in stature loss could be influenced by asymptomatic degenerative changes whereby the prevalence of pain is unrelated to pathology; only sophisticated scanning techniques could identify with certainty, any relationship between individual loss of stature and the presence of discogenic abnormality.

The measurement of stature changes may have a role in the identification of individuals who are at risk of experiencing back pain symptoms. The implementation of prospective studies to investigate the relationship between stature loss and the incidence of back pain is an original area of research which may demonstrate the clinical application of the measurement technique.

The implementation of training programmes to improve the lifting capability of working individuals may have positive consequences in terms of a reduction in the incidence of back pain; this may result from the improvement in the strength of the trunk musculature. The subsequent risk of sustaining injury may be reduced if an individual increases his/her capacity for work without increasing the workload. An increase in workload may have negative repercussions. Following the 10 week training programme undertaken within this thesis, the greatest changes in the test parameters were observed in the psychophysical lifting tasks. If individuals are physically trained, they may actually perceive that they are able to lift greater loads than the musculature has adapted to. Unless the load is handled more skilfully than heretofore, this may increase the risk of injury and/or the risk of experiencing symptoms of pain. Controls over load selection within occupations involving the manual handling of loads are considered important. Within the nursing profession again, the utilisation of mechanical aids would partially overcome the need for manual lifting. However, it will still require a great deal of training and ergonomic intervention before assistive devices are routinely used.

Clinicians are having to learn to treat back pain using a holistic approach, by recognising the need to consider the physical, psychological and social aspects of the illness. The same approach must be adopted by research establishments. Although the work conducted for this thesis has included multidisciplinary strategies, its value is limited because each study concentrated on a specific area (prevalence of pain, perceived caused, loss of stature and so on) and there was a degree of overlap between the inclusion of mildly symptomatic individuals and those in whom disability is a greater concern. It will require longitudinal research projects incorporating the physical, psychological and social aspects of back pain and the distinction between pain and disability, before definitive statements may be made regarding the causes of back pain.

8.4 CONCLUSIONS: THE FACTORS ASSOCIATED WITH IDIOPATHIC BACK PAIN

Figure 8.2 identifies several factors associated with the complex problem of back pain which have been derived from the epidemiological and biomechanical work within this thesis. It concentrates upon the differentiation between risk factors, the onset of pain and the consequences of pain.

It is apparent that back pain symptoms may occur in the presence or absence of abnormal intervertebral disc pathology/degeneration. Although a link between the prevalence of disc degeneration and back pain symptoms has been postulated, a relationship has not been fully established. The presence of symptoms with or without abnormal pathology will also be influenced by physical risk factors (e.g. repetitive lifting), which in turn will affect the mode of onset of pain and any subsequent disability.

The epidemiological studies conducted as part of this thesis identified occupational lifting tasks and postures as the perceived causes of back pain/injury amongst nursing personnel. The prevalence of back pain amongst the nurses was similar to the rates observed in non-nurses. This leads to the supposition that the perceived causes of pain may not be those wholly responsible (as discussed previously). This is an interesting area of research to pursue and again incorporates the other factors identified within the schema.

A problem inherent within epidemiological back pain studies is the subjective reporting of both the symptoms and mode of onset of back pain. It is difficult to differentiate between pain that occurs gradually and pain which starts suddenly following the performance of a particular activity; there is clearly some overlap within these categories. If the mode onset of pain can be distinguished, the risk factors associated with symptoms may also be identified.

The issue regarding back pain and associated disability has been discussed in depth throughout the chapters of this thesis. It is important to differentiate between these two symptomatic groups when conducting investigations relating to back pain; the influence of psychosocial variables appears to be more pronounced within the 'disability' population and these in turn have implications on the illness behaviour. The perceived risk factors and the mode of onset of pain are likely to be different between these groups.

The framework may be implemented to assist in the selection of sample populations; it may be possible to control particular factors associated with the schema (e.g. individuals experiencing idiopathic back pain but who do not suffer disability from symptoms). This has implications for the performance of intervention studies (particularly amongst nursing personnel) where the manipulation of potential risk factors is examined.

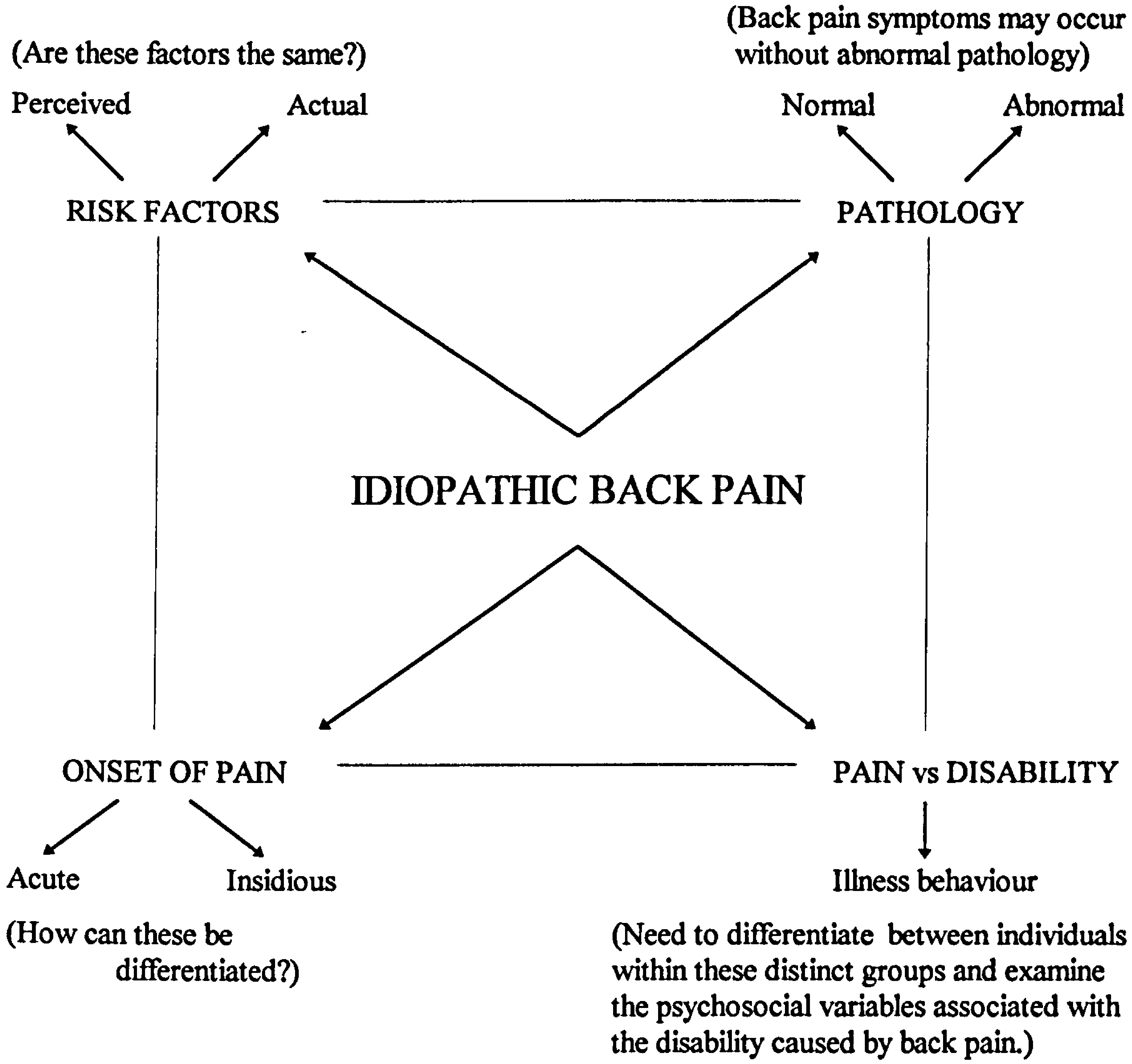


Figure 8.2 The inter-relationships and differentiation between factors associated with idiopathic back pain

Chapter Nine

Recommendations for Future Work

9 RECOMMENDATIONS FOR FUTURE WORK

The work within this thesis has helped to identify a number of areas where the potential for further work exists:

[1] There is need to investigate, by longitudinal questionnaire study, the incidence and prevalence of musculoskeletal disorders amongst nursing populations. Ideally, this would be conducted concomitantly with the performance of observational analyses to identify and quantify the exposure to potential risk factors. It would be important to identify the sample populations in terms of the consequences of existing disorders and the disability caused by them. The physical, psychological and social aspects of lifestyle and occupation would need to be considered in order for such a comprehensive study to be performed.

[2] The epidemiological work within the thesis supports the concept that back pain is ubiquitous in the population. Cross-sectional and longitudinal studies of non-nursing populations would provide data to compare the perceived and potential risk factors associated with back pain symptoms and other musculoskeletal disorders.

[3] There is now opportunity to apply the technique to measure stature in conjunction with scanning techniques (Magnetic Resonance Imaging). This would establish the clinical applications of *in-vivo* methods of the assessment of loads on the spine.

[4] It would be valuable to quantify the loss of stature within the different regions of the vertebral column. This may verify the clinical application of the measurement technique.

[5] Biomechanical modelling techniques should be used to quantify the loads imposed on the vertebral column during the performance of occupational activities. The relationship between perceived and actual risk factors associated with the prevalence and incidence of back pain may be investigated as a consequence.

[6] Further studies are needed to investigate the use of isokinetic dynamometers in the assessment of trunk muscle strength. There is a need to establish the relevance of isokinetic tests to muscle performance in occupational contexts. Studies adopting counter-balanced experimental design and familiarisation procedures for subjects would provide appropriate data on which to apply contemporary statistical techniques. These would help to establish the repeatability of the equipment and determine the validity of the tests.

[7] Longitudinal studies investigating the incidence of back pain following physical training intervention would provide detailed information regarding the relationship between of trunk muscle strength and back pain. This would verify whether trunk muscle strength is a predisposing or aetiologic factor in the incidence of back pain.

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Appendices

Appendix 1

QUESTIONNAIRE SURVEY OF NURSING PERSONNEL

This questionnaire relates to the incidence and prevalence of back pain amongst nurses.

Whether you experience/have experienced back pain or even if you have NEVER suffered symptoms, please complete this questionnaire.

Please place the completed questionnaire in the envelope provided, seal it and return it to the individual who issued the form.

Your assistance will be greatly appreciated by the research group and by members of the nursing profession nationwide.

Diana Leighton
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SECTION 1

1. Please write in today's date: eg. 22 1 93

DAY ____ MONTH ____ 1993

2. Your sex: MALE ☐ (1) FEMALE ☐ (2)

3. Age: ______ years

4. Height: ______ meters ______ cm

or ______ feet ______ inches

5. Weight: ______ kg

or ______ stones ______ pounds

6a. What nursing position do you hold now?

Pre-registration student ☐ (1)
Post -registration student ☐ (2)
Health Care Assistant ☐ (3)
Auxillary Nurse ☐ (4)
Enrolled nurse ☐ (5)
Staff nurse ☐ (6)
Ward manager/sister ☐ (7)
Clinical nurse manager ☐ (8)
Directorate nurse manager ☐ (9)
Senior nurse/Director of nursing ☐ (10)
Community nurse/Health visitor ☐ (11)
Midwife COMPLETE 6b ☐ (12)
Other PLEASE SPECIFY .... ☐ (13)

6b. Student midwife ☐ (1) Qualified Midwife ☐ (2)
Other PLEASE SPECIFY .... ☐ (3)

7. Are you currently working in a HOSPITAL/INSTITUTION ☐ (1)
or in the COMMUNITY (Health visitor, Midwife) ☐ (2)

8. Please enter the month and year in which your first started nursing:

MONTH _______ YEAR _______

9. How long in total (to nearest month) have you been nursing? (Excluding breaks in employment)

YEARS ________ MONTHS ________

10a. Were you working part-time for more than one month of the above period?
YES ☐ (1) NO ☐ (2)

10b. If "YES" for how long in total have you worked in nursing part-time?
YEARS ________ MONTHS ________

11. Did you have any breaks in nursing employment of more than 1 month in 1992?

YES ☐ (1) NO ☐ (2)

12. For how long IN TOTAL have you worked in the following fields of nursing.

INCLUDING PERIODS OF TRAINING?

	Less than 1 year	1-3 years	3+ years
General surgical	☐ (1)	☐ (2)	☐ (3)
General medical	☐ (1)	☐ (2)	☐ (3)
Paediatrics	☐ (1)	☐ (2)	☐ (3)
Geriatric/Psychogeriatrics	☐ (1)	☐ (2)	☐ (3)
Psychiatric/Mental illness	☐ (1)	☐ (2)	☐ (3)
Mental Handicap	☐ (1)	☐ (2)	☐ (3)
Maternity/Obstetrics	☐ (1)	☐ (2)	☐ (3)
Gynaecology	☐ (1)	☐ (2)	☐ (3)
ICU/Coronary Care	☐ (1)	☐ (2)	☐ (3)
Outpatients	☐ (1)	☐ (2)	☐ (3)
Accident & Emergency	☐ (1)	☐ (2)	☐ (3)
Neurology	☐ (1)	☐ (2)	☐ (3)
Orthopaedics	☐ (1)	☐ (2)	☐ (3)
Burns & Plastic Surgery	☐ (1)	☐ (2)	☐ (3)
Dermatology	☐ (1)	☐ (2)	☐ (3)
Operating Theatre	☐ (1)	☐ (2)	☐ (3)
Nursing admin./Teaching	☐ (1)	☐ (2)	☐ (3)
District nurse/Midwife	☐ (1)	☐ (2)	☐ (3)
Ear/Nose & Throat/Opthal.	☐ (1)	☐ (2)	☐ (3)
Radio./Oncology/Heam.	☐ (1)	☐ (2)	☐ (3)
Urology	☐ (1)	☐ (2)	☐ (3)
Other PLEASE SPECIFY			
	☐ (1)	☐ (2)	☐ (3)

13. What is the speciality of your present ward/department?

General surgical ☐ (1)
General medical ☐ (2)
Paediatrics ☐ (3)
Geriatrics/Psychogeriatrics ☐ (4)
Psychiatry/Mental Illness ☐ (5)
Mental Handicap ☐ (6)
Obstetrics/Maternity ☐ (7)
Gynaecology ☐ (8)
ICU/Coronary Care ☐ (9)
Radio./Oncology/Heam. ☐ (10)
Outpatients ☐ (11)
Accident & Emergency ☐ (12)
Neurology ☐ (13)
Orthopaedics ☐ (14)
Operating Theatre ☐ (15)
Nursing admin./teaching ☐ (16)
District nursing/midwifery ☐ (17)
Ear, Nose & Throat/opthal. ☐ (18)
Dermatology ☐ (19)
Burns & Plastic surgery ☐ (20)
Other PLEASE SPECIFY ....☐ (21)

14. What is the name or number of your present ward/department?

....

15. For how long have you been working on this ward/department?

YEARS _________ MONTHS _________ WEEKS ________

16. How many hours per week are you currently nursing? _______ HOURS

17a. Did you have any sick leave last year? YES ☐ (1) NO ☐ (2)

17b. How much sick leave did you have: __________ WEEKS
__________ DAYS

SECTION II

18. Do you have back pain at the moment? YES ☐ (1) NO ☐ (2)

19. Have you had any back pain within the past year (1992) including any you might have at the moment? YES ☐ (1) NO ☐ (2)

20a. Did you have any back pain BEFORE 1992? YES ☐ (1) NO ☐ (2)

20b. If YES had you started your nursing career at the time? YES ☐ (1) NO ☐ (2)

IF YOU HAVE NEVER HAD BACK PAIN, GO TO SECTION III

Otherwise, continue with question 21.

21. Did you suffer from back pain before you started nursing? YES ☐ (1) NO ☐ (2)

22. How many separate episodes of back pain have you had during the past year?

None ☐ (1) One ☐ (2) Two ☐ (3) Three ☐ (4)
Four ☐ (5) Five ☐ (6) Six ☐ (7)
More Than Six ☐ (8) Continuously ☐ (9)

23. Is or was your pain ALWAYS associated with:

Menstruation	YES	☐ (1)	NO	☐ (2)
Childbirth	YES	☐ (1)	NO	☐ (2)
Gynaecological Problems	YES	☐ (1)	NO	☐ (2)

24. At what age did you FIRST have back pain? ________ YEARS

25a. Has your back pain been clinically diagnosed? YES ☐ (1) NO ☐ (2)

25b. If YES state diagnosis ________________________________

ONLY ANSWER QUESTIONS 26 - 43 IF YOU RESPONDED "YES" TO QUESTION 19, otherwise please go to SECTION III

26a. Did you have any sick leave DUE TO BACK PAIN in 1992?

YES ☐ (1) NO ☐ (2)

26b. If YES how much sick leave due to back pain did you have?

_______ WEEKS (1) _______ DAYS (2)

27. Have you consulted any of the following regarding your back pain DURING THE PAST YEAR?

Occupational Health Doctor	YES	☐ (1)	NO	☐ (2)
Your own GP	YES	☐ (1)	NO	☐ (2)
Hospital Accident & Emergency Dept.	YES	☐ (1)	NO	☐ (2)
Osteopath	YES	☐ (1)	NO	☐ (2)
Physiotherapist	YES	☐ (1)	NO	☐ (2)
Other PLEASE SPECIFY	....			(1)

28. Please tick the box that best describes how often each of the following activities were/are associated with your back pain:

	NEVER	RARELY	SOMETIMES	OFTEN	ALWAYS
Stooping over patient	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Lift/move equipment	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Lift/move patient	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Bedmaking	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Prolonged standing	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Carrying heavy loads	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Driving	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Housework	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Sport	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Lying down	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)
Other	☐ (1)	☐ (2)	☐ (3)	☐ (4)	☐ (5)

If OTHER, please specify ____

29. Which of the following best describes the effect your back pain has had on your NURSING? (Tick ONE box only)

Has no effect	☐ (1)
Has made it SLIGHTLY more difficult (but still continue all activities)	☐ (2)
Has made it MUCH more difficult (but still continue all activities)	☐ (3)
Has made me GIVE UP some activities	☐ (4)
Other	☐ (5)

30. Which of the following best describes the effect your back pain has had on your activities OUTSIDE NURSING? (Tick ONE box only)

Has no effect	☐ (1)
Has made it SLIGHTLY more difficult (but still continue all activities)	☐ (2)
Has made it MUCH more difficult (but still continue all activities)	☐ (3)
Has made me GIVE UP some activities	☐ (4)
Other	☐ (5)

31. On the diagram opposite, please shade in the area of your MOST RECENT episode of back pain (ignore the lines)

32. Can you remember any specific incident which started your back pain or made existing pain worse? YES ☐ (1) NO ☐ (2)

IF "YES", CONTINUE WITH THE NEXT QUESTION.

Otherwise go to Section III

33. When this incident happened were you:

In nursing - ON DUTY ☐ (1)
In nursing - OFF DUTY ☐ (2)
At work in employment other than nursing ☐ (3)
Not at work but in employment other than nursing ☐ (4)
Other PLEASE SPECIFY.................................... ☐ (5)

34. On which ward/department were you working?

General surgical ☐ (1)
General medical ☐ (2)
Paediatrics ☐ (3)
Geriatrics/Psychogeriatrics ☐ (4)
Psychiatry/Mental Illness ☐ (5)
Mental Handicap ☐ (6)
Obstetrics/Maternity ☐ (7)
Gynaecology ☐ (8)
ICU/Coronary Care ☐ (9)
Radio./Oncology/Heam. ☐ (10)
Outpatients ☐ (11)
Accident & Emergency ☐ (12)
Neurology ☐ (13)
Orthopaedics ☐ (14)
Operating Theatre ☐ (15)
Nursing admin./teaching ☐ (16)
District nursing/midwifery ☐ (17)
Ear, Nose & Throat/opthal. ☐ (18)
Dermatology ☐ (19)
Burns & Plastic surgery ☐ (20)
Other PLEASE SPECIFY ....☐ (21)

35. What position did you hold?

Pre-registration student ☐ (1)
Post -registration student ☐ (2)
Health Care Assistant ☐ (3)
Auxillary Nurse ☐ (4)
Enrolled nurse ☐ (5)
Staff nurse ☐ (6)
Ward manager/sister ☐ (7)
Clinical nurse manager ☐ (8)
Directorate nurse manager ☐ (9)
Senior nurse/Director of nursing ☐ (10)
Community nurse/Health visitor ☐ (11)
Midwife COMPLETE 35b ☐ (12)
Other PLEASE SPECIFY .... ☐ (13)

35b. Student midwife ☐ (1) Qualified Midwife ☐ (2)
Other PLEASE SPECIFY .... ☐ (3)

36. Did you report this incident? YES ☐ (1) NO ☐ (2)

37. Was an accident/incident form filled in? YES ☐ (1) NO ☐ (2)

38. Did you consult any of the following as a result of the incident?

Occupational Health Doctor	YES	☐ (1)	NO	☐ (2)
Your own GP	YES	☐ (1)	NO	☐ (2)
Hospital Accident & Emergency Dept.	YES	☐ (1)	NO	☐ (2)
Osteopath	YES	☐ (1)	NO	☐ (2)
Physiotherapist	YES	☐ (1)	NO	☐ (2)
Other PLEASE SPECIFY .... (1)				

39. Which of the following best describes how this incident happened (Tick ONE box)

i) Lifting/moving a patient ☐ (1)
ii) Supporting a patient who was standing or walking ☐ (2)
iii) A slip/fall while NOT attending to a patient ☐ (3)
iv) A slip/fall while attending to a patient (other than i or ii) ☐ (4)
v) Lifting or moving equipment (specify equipment........................) ☐ (5)
vi) Other (PLEASE SPECIFY..) ☐ (6)

IF YOU TICKED i) PLEASE CONTINUE WITH QUESTION 40.

Otherwise go to SECTION III

40. Which of the following best describes the patient transfer procedure during which this incident happened? (Tick ONE box)

Repositioning a patient IN BED ☐ (1)
Lifting/moving the patient FROM A BED ☐ (2)
Lifting/moving the patient into or out of THE BATH ☐ (3)
Lifting/moving the patient onto/of THE TOILET ☐ (4)
Lifting/moving the patient from a CHAIR/WHEELCHAIR ☐ (5)
Lifting/moving the patient FROM THE FLOOR ☐ (6)
Other (PLEASE SPECIFY..) ☐ (7)

41. Were you using a hoist/lifting aid? YES ☐ (1) NO ☐ (2)

42. Were you moving/lifting/supporting the patient:

Alone ☐ (1)
With One Other Person ☐ (2)
With Two Other People ☐ (3)
With Three Or More Other People ☐ (4)

43. Please indicate the patient's condition:

WEIGHT Light (under 8 st.) ☐ (1)
Medium (8 - 12 st.) ☐ (2)
Heavy (over 12 st.) ☐ (3)

Was the patient CONSCIOUS ☐ (1)
or UNCONSCIOUS ☐ (2)

Was the patient CO-OPERATIVE ☐ (1)
or UNCO-OPERATIVE ☐ (2)

Was the patient ATTACHED (IV, ECG) ☐ (1)
or FREE ☐ (2)

SECTION III

44. On your present ward which FOUR of the following do you consider MOST limit the level of patient care you can give?

1. Your physique
2. Insufficient staff
3. Ward design
4. Insufficient mechanical hoists
5. Insufficient instruction in moving/lifting patients
6. Equipment design
7. Level of dependence of patient
8. Other (PLEASE SPECIFY....................................)

Place the FOUR most important points in order of 1 - 4 below.

1.__________ 2.__________ 3.__________ 4.__________

45. Does your present ward/department have mechanical lifts/hoists?

YES ☐ (1) NO ☐ (2) DON'T KNOW ☐ (3)
N/A ☐ (4)

46. When do you MOST OFTEN use a lift/hoist to transfer patients:

(Tick ONE box only)

Not applicable ☐ (1)
If I have to lift alone ☐ (2)
Always ☐ (3)
Only with large, heavy patients ☐ (4)
With large, heavy patients & if time allows ☐ (5)
Never ☐ (6)
Only if time allows ☐ (7)
Only with very disabled patients ☐ (8)
Only for certain transfers ☐ (9)
(SPECIFY TRANSFER..)

47. Do you have any additional comments to make regarding the topics mentioned in this questionnaire?..

....

....

....

....

Appendix 2

QUESTIONNAIRE SURVEY OF NON-NURSING PERSONNEL

This questionnaire relates to the incidence and prevalence of back pain among non-nursing members of the general population.

Whether you experience/have experienced back pain or even if you have NEVER suffered symptoms, please complete this questionnaire.

Please place the completed questionnaire in the envelope provided, seal it and return it to the individual who issued the form.

Your assistance will be greatly appreciated.

Diana Leighton
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SECTION II

8. Do you have any back pain at the moment? YES ☐ (1) NO ☐ (2)

9. Have you had any back pain within the past year (1992) including any you might have at the moment? YES ☐ (1) NO ☐ (2)

10. Did you have any back pain BEFORE 1992?
YES ☐ (1) NO ☐ (2)

IF YOU HAVE NEVER HAD BACK PAIN DO NOT ANSWER ANY MORE QUESTIONS

11. How many separate episodes of back pain have you had during the past year?
None ☐ (1) One ☐ (2) Two ☐ (3) Three ☐ (4)
Four ☐ (5) Five ☐ (6) Six ☐ (7)
More Than Six ☐ (8) Continuously ☐ (9)

12a. Did you have any sick leave DUE TO BACK PAIN in 1992?
YES ☐ (1) NO ☐ (2)

12b. If YES how much sick leave due to back pain did you have?
________ WEEKS ________ DAYS

13a. Has your back pain been clinically diagnosed?
YES ☐ (1) NO ☐ (2)

13b. If YES state diagnosis ______________________________

14. Have you consulted any of the following regarding your back pain DURING THE PAST YEAR?

Occupational Health Doctor	YES	☐ (1)	NO	☐ (2)
Your own GP	YES	☐ (1)	NO	☐ (2)
Hospital Accident & Emergency Dept.	YES	☐ (1)	NO	☐ (2)
Osteopath	YES	☐ (1)	NO	☐ (2)
Physiotherapist	YES	☐ (1)	NO	☐ (2)
Other PLEASE SPECIFY	.... (1)			

15. At what age did you FIRST have back pain? ________ YEARS

16. On the diagram opposite please shade in the area of your MOST RECENT episode of back pain (ignore the lines)

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Appendix 3

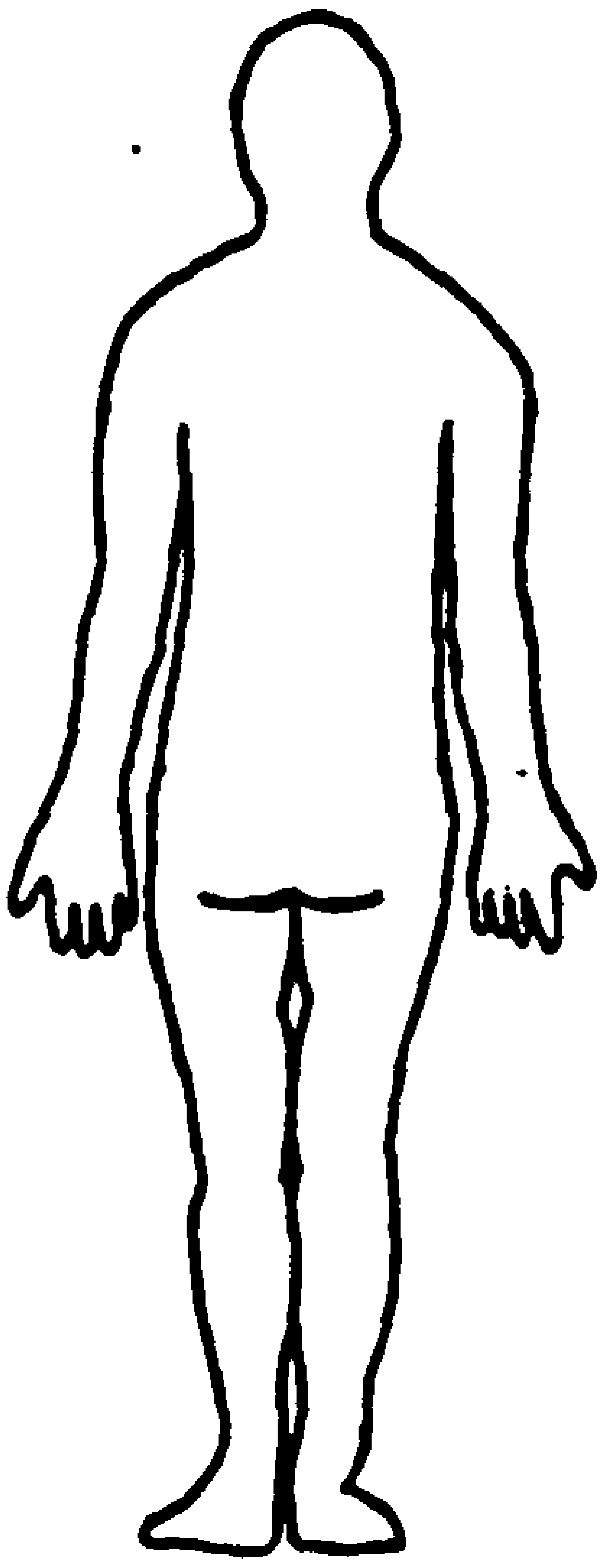
RATING OF PERCEIVED EXERTION

How stressful do you rate the task?

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Appendix 4

WHERE DO YOU FEEL THE MOST STRAIN ?



Appendix 5

Communications arising from this thesis:

Leighton, D. and Reilly, T. (1993). Back pain in nursing personnel: a review. *Proceedings of The Conference 'Ergonomics in Russia, the Independent States and Around the World: Past, Present and Future'. Vol. II* (edited by O. Brown Jnr.), pp. 102-107. St. Petersburg, Russia.

Leighton, D., Reilly, T., Garbutt, G., Zinzen, E., Van Roy, P., Caboor, D. and Clarys, J.P. (1993). Changes in stature as a result of spinal loading in nursing personnel. In *Proceedings of The Conference 'Ergonomics in Russia, the Independent States and Around the World: Past, Present and Future'. Vol. II* (edited by O. Brown Jnr.), pp. 184-189. St. Petersburg, Russia.

Leighton, D., Garbutt, G., Caboor, D., Zinzen, E., Van Roy, P., Clarys, J.P. and Reilly, T., (1993). *Changes in stature and heart-rate responses to isometric and dynamic loading of the spine in nursing personnel.* Communication to the Society for Back Pain Research, October 1993, London.

Leighton, D. and Reilly, T. (1993). Spinal shrinkage - methodology and ergonomic applications. In: *Medical Biomechanics of the Spine, Theory, Modelling and Clinical Applications.* (edited by M. Dietrich), pp 125-137, Warsaw: International Centre of Biocybernetics.

Leighton, D. and Reilly, T. (1994). *An epidemiological study of back pain in nursing personnel.* Communication to the Society for Back Pain Research, March 1994, Stoke-on-Trent, England.

Leighton, D. and Reilly, T. (1994). Effects of repetitive lifting on female nurses with and without low back pain. In *Contemporary Ergonomics 1994* (edited by S. Robertson), pp 106-111. London: Taylor & Francis.

Leighton, D. and Reilly, T. (1994). *Epidemiological aspects of back pain: the incidence and prevalence of back pain in nurses compared to the general population.* Communication at The Lumbar Spine - a basic science approach. First International Symposium of the International Society for the Study of the Lumbar Spine, August 1994, Brussels, Belgium.

Leighton, D and Reilly, T. (1994). *Changes in stature following occupational lifting and the estimation of lumbar disc area in nursing personnel.* Communication at The Lumbar Spine - a basic science approach. First International Symposium of the International Society for the Study of the Lumbar Spine, August 1994, Brussels, Belgium.

Leighton, D. and Reilly, T. (1994). *Back pain in nursing personnel: an ergonomic approach.* Communication to the Society for Back Pain Research, November 1994, Leeds, England.

Leighton, D. and Reilly, T. (1995). Trunk muscle strength and manual handling skills: the effects of training. In *Contemporary Ergonomics 1995* (edited by S. Robertson), pp 397-402. London: Taylor & Francis.

Leighton, D. and Reilly, T. (1995). Epidemiological aspects of back pain: the incidence and prevalence of back pain in nurses compared to the general population. *Occupational Medicine*, 45, 263-267.

Leighton, D. and Reilly, T. (1995). *The determination of occupational tasks perceived to be stressful by nursing personnel.* Communication to the Society for Back Pain Research, April 1995, Aberdeen.

Leighton, D. and Reilly, T. (1995). *Back Pain in Nursing Personnel.* Communication to the Medical Research Council, November 1995, Southampton.

Appendix 6

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Epidemiological aspects of back pain: the incidence and prevalence of back pain in nurses compared to the general population

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Two studies using retrospective questionnaires were conducted to obtain epidemiological information from nursing personnel (n = 1134) and among an age- and gender-matched cross-secton of the general population (n = 315). The point and annual prevalence of back pain did not differ between the two sample groups. Nurses demonstrated a greater annual incidence of back pain (14.7%, compared to 11.5% in non-nurses). The point prevalence of back pain increased with age in both sample groups. Nurses considered patient-handling tasks instrumental in the onset of back pain symptoms. Comparison of results with those obtained from a similar study published in 1983 indicated an increase of almost 40% in the prevalence of back pain symptoms in nurses, although the linearity of the rise was not ascertained. The implementation of guidelines on the manual handling of loads has led to revised training procedures and these may have influenced the epidemiological findings.

Occup Med. Vol. 45, No. 5, pp. 263–267, 1995

Epidemiological information suggests that the incidence and prevalence of back pain are high in nursing personnel compared to other occupational groups[1,2]. This has been attributed, in part, to the performance of patient-handling tasks by nurses[3]. It is apparent that the problem has severe implications on job performance and productivity and therefore on the economic prosperity of the employer. In addition, the suffering borne by the individual is of great personal cost. Within the UK, the last major retrospective epidemiological study to have been conducted among nursing personnel was published in 1983[3]. In order to be aware of changes in both the severity and consequences of the problem, more recent figures were required for nursing personnel and non-nursing members of the population.

The study was designed to collect epidemiological data regarding back pain from (i) nursing personnel and (ii) non-nursing members of the population. The prevalence and incidence of back pain were determined in both sample groups. Information regarding the possible causes of back pain in nurses and the effects of the condition on nursing and leisure activities was also ascertained.

METHODOLOGY

Two questionnaires were designed for distribution to each of the two sample groups. Back pain is often difficult to define and diagnose, and the present study used the term 'back pain' without any further definition but asked respondents to indicate the site(s) of pain and state the medical diagnosis of their condition if applicable.

The nursing personnel questionnaire

The questionnaire consisted of three sections and 47 questions in total. The three sections of the form covered (1) personal and professional data; (2) the incidence and prevalence of back pain, possible causes of symptoms/injury, and its effect on nursing and leisure activities; and (3) the use of assistive devices during patient transfers and limitations to patient care. All personnel participating in the survey were required to complete sections 1 and 3; the number of applicable questions in the second section varied depending on the prevalence of back pain symptoms.

A pilot study was conducted in December 1992 in one

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Table 1. Nursing specialities surveyed by the questionnaire

• general surgical	• general medicine
• paediatrics	• geriatrics/psychogeriatrics
• orthopaedics	• psychiatry/mental illness
• theatre	• intensive care unit
• community	• accident & emergency

NHS Trust hospital in Liverpool where 50 nurses of various grades and in a number of specialities volunteered to complete the form. Minor alterations were made to the structure of the questionnaire following this survey.

Sample. In total, 2100 questionnaires were issued to five NHS Trust hospitals and one Community (NHS) Trust in Merseyside. Nurses of all grades working in different specialities were requested to complete the form regardless of whether or not they suffered from back pain. The number of forms issued to each of the participating NHS Trusts corresponded to the number of nursing personnel within the specialities. In order to ensure that each speciality was evenly represented in the response, some hospitals were only issued with questionnaires for particular specialities. The specialities included in the survey are listed in *Table 1*.

Distribution. The questionnaire survey was conducted during January and February 1993. The mode of distribution of the forms varied according to the assistance available from the director of nursing and hospital support staff; it was not possible to standardize the distribution. In two hospitals, the director of nursing took responsibility for circulating the questionnaire to nurse managers of the appropriate specialities/directorates, where they would be subsequently issued to personnel on individual wards. The directorate nurse managers in two hospitals were willing to issue the forms to nursing personnel, and in only one hospital did the form go directly to the individual ward sister/college nurse. Distribution of the questionnaire to community nurses/midwives was arranged through the resource management coordinator to locality managers within the region and then to individual members of personnel.

Questionnaires were collected from the individual who originally circulated the form within each hospital, 3–4 weeks following distribution. Collection of the completed forms from the Community Trust resource management coordinator occurred over a slightly longer time period due to the delay in distributing and returning the forms to and from different localities. Due to the confidential nature of the questionnaire and the method of distribution, it was not possible to identify and follow-up those individuals who had not completed or returned the form.

The questionnaire issued to non-nursing personnel

This questionnaire was a shorter modified version of the form the nurses completed. It comprised two sections and 16 questions in total. Section 1 of the form covered personal and professional data whilst section 2 enquired about the prevalence and incidence of back pain. All participants were requested to complete section 1 of the form, and the number of questions responded to in the second section varied according to individual experience of back pain symptoms.

A pilot study was conducted whereby 30 volunteers in a range of occupations completed the form. It was not necessary to alter the questionnaire following the pilot study.

Sample and distribution. In order that the questionnaire be circulated to a sample representative of the non-nursing population, personnel managers of a number of established companies in Liverpool were asked to issue the questionnaire to members of staff. Six employers permitted distribution of the form to a cross-section of their employees or to individuals attending meetings/classes on their premises. It was requested that the questionnaire be distributed predominantly to females to control for gender when making comparisons between the findings of the two surveys. In total, 500 questionnaires were issued and completed forms were returned to the representative of each organization who had coordinated the distribution. These forms were collected 3–4 weeks after their initial deposit.

Analysis of data

Statistical analysis of the data generated by both questionnaires was performed using SPSS (version 4.1). The responses of male and female respondents in each sample were pooled and analysed jointly.

Categorical and numerical variables were studied using cross-tabulation and χ^2 analyses to examine the relationship between two or more variables. Pearson product moment correlation analyses (correlation coefficient = r) were applied to normally distributed numerical variables to establish the existence of a linear relationship. Responses for ranked and non-parametric variables were examined for linear relationships using Spearman's rank correlation analyses (correlation coefficient = r_s).

RESULTS

Response to questions common to both questionnaires

A response rate of 63% was obtained for the general population survey. The nurses' questionnaire was completed by 54% of the nurses sampled. The non-nursing group included sedentary workers (secretaries, receptionists) and personnel within more active occupations (fitness instructors, teachers). A small proportion of the sample was either retired, unemployed or housewives (4.5%), while 56.7% categorized their occupation as 'clerical/other' and 20% of the sample described their job as 'middle management'. The sample characteristics of both populations are shown in *Table 2*.

Epidemiology. The epidemiological data collected from both the general population and nursing personnel sam-

Table 2. Sample characteristics of the questionnaire respondents

	Nursing personnel	*General population*
Age (years)		
Mean	36	32
Range	18–64	16–61
Gender		
Female	90%	83%
Male	10%	17%
Sample size	1134	315

ples are shown in *Table 3*. The anatomical distribution of back pain in both sample groups included multiple sites of pain. Pain in the lower back was reported by 78.2% of those nurses indicating an annual prevalence of back pain: this includes responses where multiple sites were reported. The equivalent figure for non-nursing respondents was 67.6%.

Age. The age of the non-nursing respondents was significantly correlated to both the point ($r = 0.12, P < 0.05$) and annual prevalence ($r = 0.28, P < 0.01$) of back pain. For the non-nursing respondents between the ages of 42–53 years, 75% reported an annual prevalence of back pain compared with 64.9% of nurses in the same age group. The mean age at which the first episode of back pain occurred was 25 years.

The mean age of the nursing sample was 36 years (range 18–64). Age was significantly correlated with point prevalence of back pain ($r = 0.11, P < 0.01$) but there was no significant relationship between age and annual prevalence of back pain ($P > 0.05$). The first episode of back pain was reported to have occurred at a mean age of 27 years.

Absence from work. Absence from work due to back pain was reported by 11.3% of the non-nursing respondents who had experienced symptoms during the previous year. The equivalent figure from the sample of nursing personnel was 9.1%.

Response to questions specific to the nursing personnel questionnaire

Precipitating factors. For the nurse respondents reporting an annual prevalence of back pain symptoms, approximately half ($n = 361$) could recall a particular incident which started their back pain or made an existing condition worse. In two-thirds of these individuals, the incident occurred whilst lifting or moving a patient, and 47.5% of nurses in this group were repositioning a patient in bed as opposed to performing a patient-transfer task. *Table 4* lists the patient-transfer tasks implicated in the precipitation of the most recent episode of back pain.

Risk within the profession. Of the nurses working in the orthopaedic departments at the time of the study, 71% indicated that they had suffered back pain symptoms during the year prior to the survey. Nurses in general medicine, community nursing, intensive care and geriatric nursing also indicated high annual prevalence rates, with 68.6%, 62.5%, 60.9% and 60.7% of the respective staff experiencing symptoms.

Reactions to back pain. With regard to the consequences of back pain on nursing activities for those nurses indicating annual or point prevalence, 56.4% reported that back pain had made performing their work slightly more difficult but that all activities could still be continued. Only 2.5% of nurses reported that they had given up some activities. Similarly, 52.8% of nurses indicated that back pain had made activities outside nursing more difficult and 10% of respondents had been forced to give up some activities. Driving and sport were activities reported to be 'never' or 'rarely' associated with back pain by over 60% of the respondents for each activity. Occupational tasks such as stooping over a patient, lifting/moving a patient and prolonged standing were indicated by over 25% of the respondents to be 'always' or 'often' associated with back pain.

DISCUSSION

The prevalence of back pain in nursing personnel did not differ greatly from the data obtained from age- and gender-matched non-nursing members of the general population. Within the nursing sample, the number of new cases of back pain during one year was 28% greater than for the general population. Sickness absence due to back pain formed a greater percentage of the days off work for all causes in the non-nursing group. The amount of time absent from work may be an important measure for calculating the cost of the problem to a particular occupation. However, the figure for the gen-

Table 3. Back pain and sickness absence figures for nursing personnel and members of the general population

	Nursing personnel (n = 1134)	*General population (n = 315)*
Point prevalence	24.4	25.1
Annual prevalence	58.8	57.8
Lifetime prevalence	61.4	58.9
Annual incidence	14.7	11.5
Sickness absence*	14.2	35.1

* Number of days absent due to back pain expressed as a percentage of days lost for all causes

Table 4. The patient-transfer procedures implicated as causative in the precipitation of back pain by nurses who had both (i) indicated an annual prevalence of back pain and (ii) recalled a particular incident initiating pain ($n = 222$)

Task	%
Positioning a patient in bed	47.7
Moving a patient from bed	23.4
Moving a patient from a chair	13.1
Moving a patient in/out of a bath	4.5
Moving a patient on/off the toilet	4.5
Moving a patient from the floor	3.6
Other procedure	3.2

eral population reflects the demands of a range of occupations and may be the most appropriate criterion for comparing the magnitude of the back pain problem between the two sample groups[4].

The career path of nurses may involve changes in grade and experience in a number of different specialities; therefore, risk within the profession cannot be determined with ease. Analysis of the data failed to identify conclusively the nursing grades or specialities that predisposed nurses to an increased risk of experiencing episodes of back pain. Nevertheless, within the specialities of orthopaedics, general medicine, community nursing, intensive care and geriatric nursing, over 60% of the nurses reported having experienced back pain symptoms during the year prior to the survey. These results support the findings of Pheasant and Stubbs[1] who additionally stated that such areas of nursing were traditionally regarded as heavy work.

For the purposes of comparison, the incidence and prevalence of back pain in nurses detected in the present study and the figures reported by Stubbs *et al.*[3] are displayed in *Table 5*. The latter researchers employed a similar method of data collection, and the specific questions designed to elicit information enabling the calculation of figures relating to prevalence and incidence of back pain in the current study were modelled on those in the earlier questionnaire. Similarities in the characteristics of the two nursing samples exist, particularly the mean age of the nurses (36 years and 35.8 years[3]) and the proportion of male respondents (10% compared to 11.5%[3]). It is not intended that this paper be a review of the wealth of epidemiological data regarding back pain among nursing personnel; comparisons between studies have only been made where a similar questionnaire design has been applied and the sample characteristics appear homogeneous. The response rate attained for the nurses' questionnaire may be considered low and the existence of a response bias cannot be eliminated.

The point and annual prevalence figures derived from the current study and that of Stubbs *et al.*[3] differ by approximately 40%, and the number of new cases of back pain arising during one year has almost doubled. Examination of the sickness absence figures from the present study and those reported by Stubbs *et al.*[3] failed to indicate a concomitant increase in the consequences of the condition. Stubbs *et al.*[3] reported that 9.5% of the nurses sampled took sick leave for back pain, compared with 9.1% in the present study. When the number of days of sickness absence due to back pain in nurses was expressed as a percentage of total days lost for all causes, the present study indicated a value of 14.2% compared to a figure of 16.2%[3]. It may be inferred from these comparisons that the number of nurses reporting having taken sick leave due to back pain has remained constant but that the proportion of sick leave being taken for back pain as opposed to for all causes has decreased by 12%. Therefore, it appears that there has been an increase in the number of nurses reporting having experienced symptoms of back pain over the ten-year period although the condition has not resulted in an equivalent increase in the number of nurses taking sickness absence. It may also be deduced that nurses who took sick leave for back pain were absent from work for a slightly shorter length of time than previously reported by Stubbs *et al.*[3]. In the 1983 study, questionnaires were posted to nurses who were taking sick leave and personnel on annual leave. It was not feasible to do this in the current study, although it was anticipated that the time period from questionnaire distribution to collection was great enough to include the majority of personnel within these categories. It is difficult to quantify the consequences of this methodological difference, and the sickness absence data should therefore be interpreted with caution.

Table 5. Comparison of back pain epidemiological data for nursing personnel

	% of respondents reporting back pain	
	1993	*1983**
Point prevalence	24.4	17.0
Annual prevalence	58.8	43.1
Annual incidence	14.7	7.7
Sickness absence†	14.2	16.2

* Stubbs *et al.* (1983)
† Number of days absent due to back pain expressed as a percentage of days lost for all causes

From the discussion above, it appears that three main issues have arisen as a result of the questionnaire surveys. Firstly, there has been almost a 40% increase in the prevalence of back pain in nursing personnel over a ten-year period. Secondly, despite this occurrence, the number of nurses taking sick leave for back pain has not altered concomitantly. The third point for consideration is the observed greater annual incidence of back pain in nurses compared to non-nursing members of the general population. Each of these points will be discussed further and a number of explanations offered.

It is not possible to account directly for the apparent increase in the prevalence of back pain symptoms in nursing personnel over a ten-year period. The results of the present study have only been compared with the data collected by Stubbs *et al.*[3]. It is therefore difficult to predict whether the increase has occurred gradually over the entire period of time or whether the figures represent an acute increase in the prevalence rate (over two to three years). The latter may be a plausible explanation, taking into consideration the implications of the European Directive on the Manual Handling of Loads (1990) and the implementation of the Health and Safety Executive (Health Services Advisory Committee) guidelines[5] on the manual handling of loads in the health services in January 1993. Prior to this date, in preparation for the implementation of the guidelines, revised training in approved lifting techniques and heightened awareness of the new regulations were initiated within the NHS Trusts. The implications of re-training are possibly too numerous to list. However, it is likely that nurses who previously performed lifting tasks using preferred methods no longer approved by the English Nursing Board would require time to adapt to new techiques and the associated re-training. Back problems may have arisen as a consequence of the repeated adoption of unfamiliar postures, particularly if performed in conjunction with load bearing. The implementation of prospective studies and future cross-sectional epidemiological surveys should be endorsed and would enable the incidence and prevalence rates of back pain to be monitored more closely.

Regarding the greater annual incidence of back pain in nurses compared to members of the general population, this figure may have been acutely raised due to changes in the regulations governing lifting as discussed above. The implementation of the new guidelines on the manual lifting of patients and loads could have caused a sudden increase in the number of nurses reporting back pain symptoms. If this is the case, the figure for the annual prevalence of back pain may also have been raised. However, the condition of individuals who have recently left the profession has not been considered within the analysis of the data and may influence the results further. As stated already, prospective and future cross-sectional epidemiological studies could be implemented to monitor changes in the magnitude of the problem.

The sickness absence figures relating to back pain may indicate either the stoicism of nursing personnel or that the severity of the symptoms in the majority of nurses does not prevent them from performing their work. The latter is endorsed by the results of the questionnaire study. Nurses who did require time off work due to back pain were absent for a slightly shorter length of time than reported in 1983.

It should be ascertained whether epidemiological figures for the general population also demonstrated an increase equivalent to that in nursing personnel over the same period of time. Clarification of whether the prevalence of back pain in nursing personnel was previously greater than members of other occupational groups is also required. Examination of the results of earlier epidemiological studies would clarify the disparity.

Previous research has emphasized the need for mechanical hoists to be available to nurses in order to reduce the loads imposed on the spine during patient-transfer tasks[6]. However, even when aids are available, time, work space and staffing levels may dictate their practical use. Lack of training is no longer a valid reason for not using assistive devices, and their importance should be emphasized to all nursing personnel. The long-term consequences of using mechanical lifting aids have not been determined with respect to the incidence of back pain symptoms and may influence the results of future epidemiological studies.

The current study demonstrated that the prevalence of back pain was similar in the two sample groups. It has been proposed that back pain occurs irrespective of occupation, training and lifestyles[7]. Studies have demonstrated that it is the perceived causes of back pain that differ among groups of workers[7,8].

CONCLUSIONS

Nurses considered patient-handling tasks, in particular the task of repositioning a patient in bed, instrumental in the onset of back pain symptoms. The point prevalence of back pain increased with age in both sample groups.

The number of nurses reporting to have taken sick leave due to back pain and the proportion of sick leave being taken for back pain as opposed to that taken for all causes has remained relatively constant over the ten-year period.

The magnitude of the back pain problem amongst nursing personnel appears to have increased since the results of a similar study were reported in 1983. It could not be ascertained whether there has been a steady rise in the prevalence of back pain or whether the change represented an acute phenomenon. The results of the two questionnaire surveys conducted indicate that, although the prevalence of back pain among nurses and members of the general population may have been similar, a greater number of new cases of back pain was noted among the nursing personnel. The implementation of guidelines regarding the manual handling of loads has led to the revised training of nurses in the performance of patient-handling procedures. This is proposed as a possible reason for the occurrence of an acute increase in the prevalence and incidence of back pain.

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Appendix 7

CONTEMPORARY ERGONOMICS 1995

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TEXT

IN

ORIGINAL

TRUNK MUSCLE STRENGTH AND MANUAL HANDLING SKILLS: THE EFFECTS OF TRAINING

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Injuries to the back may result from repetitive lifting and manual handling, particularly if trunk muscle strength is inadequate. A regimen of physical training could increase the lifting capability of the worker and so reduce the load on the spine. This study aimed to determine the effects of physical training on trunk muscle strength and lifting capability. Fifteen females participated in a 10 week physical training programme. Two weight-training sessions comprising progressive resistance exercises and one circuit-training session were performed each week. Four physical assessments were performed during training; a control group (n=14) only completed these assessments. Psychophysical tests of lifting capability performance improved with training.

Introduction

Exposure to repetitive lifting has been associated with a high prevalence of back pain and injury (Frymoyer et al., 1983). In addition, inadequate strength of the trunk musculature has been identified as a risk factor in the incidence of low back pain (Smidt et al., 1983). If trunk muscle strength is inadequate and stabilisation of the ligaments insufficient, injury or loss of optimal function may result.

Numerous studies have been performed to investigate muscular strength in relation to the incidence of low back pain. The majority of these may be differentiated according to distinct objectives: Elnaggar et al. (1991) examined the effectiveness of physical exercise in reducing the severity of low back pain; prospective and retrospective investigations have aimed to identify predictive variables associated with the risk of experiencing back pain (Pope et al., 1985; Burton et al., 1989), and the implementation of training programmes has stimulated research investigating the relationship between muscular strength and lifting capability in manual handling operations (Asfour et al., 1984). The efficacy of training programmes applicable to personnel within various occupations is less well documented and has important implications for the prevention of low back pain.

In order to reduce the stress placed on the back during manual handling activities, it is advisable to reduce the load lifted and/or the number of repetitions of the lift, or to increase the lifting capacity of the worker. The latter recommendation was the subject of this study which aimed to determine the effects of physical training on trunk muscle strength and lifting capability.

Method

Subjects

Fifteen females participated in a physical training programme of ten weeks' duration (training group). The subjects were of mean age 20.6 (± 1.8) years, mean hei 165.6 (± 6.30) cm and mean body mass 65.4 (± 5.7) kg. A control group of females (n=14) did not participate in the training but performed physical assessments at identica time intervals to the participants in the training programme. The control group subjects were of mean age 20.4 (± 3.0) years, mean height 165.4 (± 4.3) cm and mean body mas 63.2 (± 8.1) kg.

Physical assessments

Physical assessments were performed before the start of training, during weeks 4 and 7, and at the end of training (week 10). Each assessment consisted of eight test parameters, details of the test procedures are given below.

Subjects performed a "one repetition maximum" vertical lift (1-RM). A square box with handles was lifted from 87 cm to 30 cm and returned to the starting position. The weight of the box was selected by the subject from a number of visually identical lead-filled bags, weighing between 0.25-2.5 kg. The weight of the box, unknown to the lifter, was recorded.

The maximum acceptable weight of lift (MAWL) was identified using the box and weights utilised for the 1-RM. Subjects were asked to select the load they perceived as a comfortable weight to lift at a rate of 6 lifts per minute for 10 min without becoming out of breath or fatigued. The weight of the box, unknown to the lifter, was recorded

Maximal isometric lifting strength (MILS) in a leg lifting technique was assessed on an isometric lift dynamometer as described by Birch et al.(1994). The equipment consisted of a platform in front of two 2 m vertical bars. Handles protruded perpendicular to the vertical bars, the height of which could be adjusted. Strain gauges were mounted on each bar to detect force applied vertically to the bars. Subjects adopted a squat lifting posture, grasping horizontal bar handles either side of the knees; handles were positioned at the level of the upper border of the patellae when the knees were straight. Subjects were instructed to exert a maximum force, lifting the bars vertically. Three maximum lifts were performed, each over a three second period. The peak force from the three trials was recorded.

Endurance of the leg muscle was assessed using the isometric lift dynamometer detailed above. Similarly, the leg-lift position was adopted and subjects were required to exert a vertical lifting force on the horizontal bars corresponding to between 45% and 55% of the MILS. Lifting force was displayed on a computer screen and the 45-55% limits marked. An audible signal indicated when the force exerted by the subject was not within the set limits. Subjects were instructed to maintain the lift for as long as possible. Endurance time was recorded in seconds.

Isokinetic strength of the lumbar flexors and extensors was assessed from standing and at a velocity of 2.09 rad s^{-1} (120 deg s^{-1}). Tests were performed on a computer-controlled isokinetic dynamometer (Lido Active, Davis CA). Three submaximal movements through the range of motion (maximum flexion - maximum extension) were performed to familiarise subjects with the test. The peak torque from four maximal trials was recorded.

Skinfold measurements were obtained using skinfold calipers (Harpenden). The sites of measurement were: triceps, biceps, subscapular and supra-illiac. Percentage of bodyfat was predicted from the sum of the skinfolds (Durnin and Womersley, 1974)). Body mass was recorded at each session of testing (kg).

Physical training

The duration of the training programme was 10 weeks. Three supervised training sessions were undertaken each week. In addition, exercises were performed at home during the weekends.

Two of the weekly supervised sessions involved progressive resistance exercises performed on circuit-weight training equipment and activities involving exercise against body weight. A circuit-training session constituted the third supervised class. At the start of each exercise class a standard whole body warm-up regimen was performed and stretching exercises concluded each session.

The progressive resistance exercises were based upon the subject's one repetition maximum for each exercise. The 1-RM was re-evaluated during weeks 3,5 and 8 and subsequent exercise intensities were based upon the revised 1-RM.

Three circuits comprising ten exercises were performed during each weight training session. Table 8.2 lists the exercises performed during the weight training sessions. The intensity of the workload increased from the first to third circuit (between 50-80% of 1-RM).

Table 1. The exercises comprising the weight training circuits.

*Seated pulley row	*Lateral pull-down
*Reverse grip lateral pull-down	*Hamstring curl
*Knee extension	*Bench press
Back extension	Swimmers kick
Inclined sit-up	Leg-raise (bent leg)

*exercises performed against variable resistance

Analysis of data

Statistical analysis aimed to detect any changes in back muscle strength and lifting capability as a result of the physical training. Two-way analysis of variance for repeated measures was performed on the test parameters for the two groups during the four physical assessment sessions. In addition, Bonferroni *T* Tests localised significant differences ($P<0.01$) among the four test sessions for the experimental group, only where the ANOVA had revealed an overall change in the test results.

Results

The results of the tests performed by both groups in the four physical assessments are displayed in Table 2. Significant increases in the load selected by the training group for the 1-RM task were observed during the course of the physical assessments ($F_{3,81}=23.97$, $P<0.001$); increases were significant between tests 1-2, 1-3, 1-4 and 2-4 ($P<0.01$). The submaximal load selected by the same group for the MAWL task also

Table 2. Mean values (±SD) achieved by the training and control groups during the four physical assessments

Test	Test 1		Test 2		Test 3		Test 4	
	Training	Control	Training	Control	Training	Control	Training	Control
Max. Isometric Lifting strength (N)	637 (103)	743 (204)	679 (113)	831 (232)	706 (108)	803 (232)	734 (113)	837 (276)
Endurance (s)	38 (21)	33 (19)	47 (23)	29 (13)	61 (57)	38 (21)	51 (30)	35 (17)
Max. Acceptable Lift (kg)	15.5 (4.6)	20.5 (5.2)	17.4 (4.1)	21.4 (5.5)	18.5 (4.3)	19.3 (4.5)	20.7 (5.1)	18.5 (5.6)
Submaximal lift (kg)	10.7 (2.7)	12.2 (3.7)	12.3 (3.1)	14.5 (5.2)	14.3 (3.2)	13.7 (4.9)	16.3 (3.3)	12.9 (4.8)
Extension Peak Torque (Nm)	96.9 (21.0)	121.5 (46.7)	91.5 (16.3)	126.7 (45.8)	106.0 (23.5)	132.1 (53.1)	101.8 (15.6)	142.1 (62.5)
Flexion Peak Torque (Nm)	147.7 (21.0)	147.4 (33.0)	135.7 (20.5)	154.4 (35.3)	152.8 (18.4)	159.1 (31.6)	159.9 (21.7)	159.3 (33.0)
Body Mass (kg)	65.4 (5.7)	63.2 (8.1)	64.7 (5.3)	64.4 (8.4)	64.9 (5.1)	63.7 (8.3)	65.2 (4.9)	63.3 (8.1)
Body Fat (%)	27.9 (3.3)	27.5 (3.9)	27.5 (3.2)	27.5 (4.0)	27.7 (3.3)	27.5 (3.9)	26.8 (3.4)	27.8 (4.2)

demonstrated consistent increases following the second physical assessment ($P<0.01$). Maximal isometric lifting strength increased significantly over the physical assessments ($F_{3,81}=10.79$, $P<0.001$); the greatest improvement in performance was observed in the training group ($P<0.01$). Leg strength endurance times were significantly greater in the training group compared to the control subjects ($F_{3,81}=19.13$, $P<0.001$). Peak torque values for the trunk flexors increased in both groups over the four physical assessments ($F_{3,81}=2.57$, $P=0.06$). The training group demonstrated an increase in trunk flexor peak torque of 8.3% from the start to the end of training; the change in the control group was not significant ($P>0.10$). The mean trunk extensor peak torque increased significantly in both the training and control groups over the physical assessments ($F_{3,81}=5.42$, $P<0.005$). *Body mass did not* alter significantly during the ten week period in either group of subjects ($F_{3,81}=0.68$, $P=0.569$). *In the training* group, the percentage of body fat was significantly reduced between tests 1-4 and 2-4 ($P<0.01$).

Discussion

Training for muscular strength resulted in a significant increase in the two psychophysical measures of individual lifting capability. The increase in the maximum weight that subjects were willing to lift increased significantly after three weeks of physical training. By the end of the training programme MAL had increased by 33.6%. In addition, the load individuals considered themselves capable of lifting once every 10 seconds for 10 min increased overall by an average of 52.3%. The MAL results support the findings of Asfour et al. (1984) although their test consisted of three lifts of different heights compared to the one task assessed in the current study. Asfour et al. (1984) attributed the significant improvements in the maximum amount of weight lifted to both an increase in muscular strength and an improvement in lifting technique. In the current study improvements in perceived lifting capability exceeded the magnitude of increase in muscular strength and were greater in the trained group.

The two parameters of psychophysical lifting capability did appear particularly sensitive to physical training; however, the static and dynamic measures of muscular strength appeared to be influenced partially by familiarisation with performing the tasks; this was demonstrated by the results of the control group. Maximal isometric lifting strength at knee height and peak torque for the trunk flexors and extensors increased over the four assessment sessions in the group who did not undertake the physical training programme. However, for MILS, the magnitude of the increase was greatest in the training group. For the isokinetic assessment of the trunk flexors and extensor muscles at 2.09 rad s^{-1} it may be implied that variation took place under test-retest conditions. The subjects performed the physical assessments at the same time of day on each testing occasion, therefore controlling for the circadian variation in muscular strength (Atkinson, 1994). Literature relating to reliability data of isokinetic trunk assessment in the standing position is lacking and there is a need to examine sources of variation in performance of such assessments. Several implications arise relating not only to the screening of individuals for muscle function, but to the application of the methodology for pre-employment screening of individuals in occupations requiring manual handling. Present observations suggest a familiarisation effect which persists over repeated tests and that test frequency itself induced a training response.

Griffen et al. (1984) reported a test-retest correlation for MILS at knee height in a population of eighty females aged 29 years or less ($r=0.855$); the assessment consisted of the initial test followed by a re-test 5-7 days later. The statistical method of applyi correlation coefficients to test-retest data is subject to criticisms which do not apply techniques such as coefficients of variation or limits of agreement. Although the tr group in the present study demonstrated an increase in MILS over the 10 week perio seems that some of this improvement may be attributable to the effect of repeated t

Conclusions

This study demonstrated that a physical training programme of 10 weeks' du induced an increase in the lifting capability of the participants. Improvements in the maximum weight that could be lifted were apparent following three weeks' of traini (equivalent to 9 exercise sessions). Improvements in MILS and dynamic peak torque trunk extensors and flexors were observed in the control group of non-training individuals, demonstrating an effect of repeated testing. Nevertheless, the greatest improvements in MILS were observed in the participants of the training programme. results demonstrate the beneficial effects of physical training programmes for perso involved in occupations demanding manual handling.

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Appendix 8

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EFFECTS OF REPETITIVE LIFTING ON FEMALE NURSES WITH AND WITHOUT LOW BACK PAIN

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To investigate the effects of repetitive lifting, 15 female nurses performed a lifting task simulating patient-transfers at a rate of 4 lifts min^{-1} for 20 min. Measurements of stature were obtained prior to and following lifting; lumbar disc area of L3-4 was estimated using anthropometric measures. The loss of stature induced by the lifting was 3.88 mm and did not differ ($p>0.05$) between nurses who experienced chronic back pain symptoms ($n=7$) and healthy individuals ($n=8$). Lumbar disc area did not vary significantly between the two groups. A linear relationship ($r=0.71$) was noted between loss of stature and lumbar disc area for all subjects such that discs with smaller cross-section demonstrated the least shrinkage. It may be concluded that the lifting task induced loss of stature related to compressive loading of the spine which was similar in nurses with and without low back pain.

Introduction

Back problems are particularly evident amongst healthcare professionals and nurses represent a group of such workers who accept back pain as an occupational hazard (Pheasant and Stubbs, 1992). Whilst the incidence and prevalence of back pain may be high amongst the nursing population, the severity of symptoms varies significantly. The subjective nature of pain experience and lack of pathological abnormalities in many sufferers, make treatment and prognosis difficult. Patient-handling procedures, static work postures and repetitive tasks have all been identified as activities increasing the risk of back pain and/or injury by imposing compressive loading on the spine. An association between low back pain and high compressive loads has also been demonstrated by Troup and Edwards (1985).

Changes in stature represent spinal adaptations to compressive loading and unloading such that spinal shrinkage provides an index of load on the spine (Corlett et al., 1987). The measurement of spinal adaptations to loading and unloading is a valuable ergonomic tool for evaluating the effect of activities, postures or the working environment.

Variations in stature may be attributed to the viscoelastic properties of the intervertebral discs which consist of two parts: a central area known as the nucleus pulposus and an outer ring, the annulus fibrosus. The nucleus pulposus consists of a hydrophilic gel and large proteoglycan molecules; the outer ring consists mainly of collagen fibres attached around the edge of the vertebral endplate. This forms an extremely strong network that will expand upon vertical compression but not give way. Under compressive loading conditions, the fluid of the nucleus pulposus is expelled into intra-discal spaces across the cartilage endplates and a decrease in disc height or "creep" occurs as a result. Dynamic response characteristics of the discs become altered as the stiffness of the disc increases. Reversal of this fluid extrusion process occurs when postures to unload the spine are adopted and as a consequence, increases in disc height have been observed following gravity inversion (Leatt et al., 1985) and after lying supine in the Fowler position (Boocock et al., 1988). Experiments have also demonstrated that disc height alterations due to creep and subsequent recovery occur as the fibres of the annulus fibrosus extend and contract in response to loading and unloading conditions. It is acknowledged that the mechanisms involved are not fully understood (Koeller et al., 1984).

A linear relationship between height loss and intervertebral disc area has been reported; thus for a given load the compressive stress of the disc is inversely proportional to the disc cross-sectional area (Althoff et al., 1992). It was also concluded that smaller discs, generally in women, are placed under greater stress and exhibit larger viscoelastic deformation than larger discs. Estimation of lumbar disc area by means of anthropometric measurements demonstrates a satisfactory association with radiological investigative techniques thus rendering the methodology suitable for application in biomechanical studies (Colombini et al., 1989).

The aims of the study were i) to investigate changes in stature caused by repetition of a lifting task simulating patient-transfers routinely performed by nursing staff; ii) to determine if such changes in stature differed between nurses with back pain symptoms and asymptomatic nurses; iii) to examine the influence of lumbar disc area estimated from anthropometric measures, on shrinkage in the two groups of nurses.

Method

Subjects

All participants in the study were female Registered Nurses. They were assigned to one of two test groups matched for age, height and weight. Eight nurses had no previous history of back pain (mean age 28.9 ± 3.8 years, height 162.1 ± 4.3 cm, body mass 58.5 ± 4.7 kg) whilst the symptomatic group comprised seven nurses who suffered chronic (>12 months) back pain (mean age 27.9 ± 3.6 years, height 160.0 ± 4.4 cm, body mass 61.8 ± 6.2 kg). Individuals in the back pain group experienced symptoms at least once a month with the pain occurring between the mid-back and buttocks. Nurses were excluded if they had been given a clinical diagnosis by a general practitioner or other doctor concerning their back pain, or if they were taking prescribed medication to alleviate pain. All subjects were asked to recall the number of years they had been employed as nursing personnel and the back pain group stated the age of onset of their back pain.

Equipment

Stature was measured using computer-aided stadiometry as described by Corlett et al. (1987). The stadiometer was inclined at an angle of 13° to aid subject relaxation and maintenance of posture. Subjects were considered trained and capable of reproducing stature measurements on the stadiometer if ten consecutive measurements were obtained with a standard deviation equal to or less than 0.5 mm. Five consecutive measurements of stature were required for the actual test measures (pre- and post-lifting); similarly the standard deviation of 0.5 mm or less was the criterion employed for reproducibility.

Anthropometric measures

Diameters (cm) of the wrist, elbow, ankle and knee were obtained using condyle callipers on the right side of the body, the protruding epicondyle and malleolus indicating the points of measurement. The elbow and knee diameters were measured with the joint flexed (90°). Body height and body weight were also recorded.

Procedure

Subjects were required to visit the laboratory on two occasions during non-working days and between 09.00-12.00 hours. The length of time between each session could not be standardised due to the differing work schedules of the nurses. Familiarisation with the procedure to measure stature was undertaken during the first visit with training completed within 20-50 min. Rehearsal of the lifting technique to be performed during the test protocol and the collection of anthropometric data were also undertaken during this first session. The test protocol employed during the second visit required all subjects to adopt the Fowler position to unload the spine (lying supine, legs supported at 45°) for a period of 20 min immediately prior to the first measurement of stature. Following this, a lifting task was performed simulating the gait-belt transfer of a patient from bed to chair and vice versa. The entire two-way transfer was performed at a rate of 4 lifts min−1 for a duration of 20 min. One repetition of the lifting task involved transferring a square box with side handles, from standard bed height (65.5 cm) to chair seat height of 45.5 cm and return to bed height; the mass of the box was 10 kg. The "chair" was positioned in front of the "bed" such that the nurse was required to pivot through 90° in order to place the load at chair height; the movement was reversed to return the box to the starting position on the bed. A second measurement of stature was taken immediately upon cessation of the lifting task.

Analysis of data

Cross-sectional area (cm^2) of the L3-4 disc was estimated using the anthropometric measures and an empirical regression formula as described by Colombini et al. (1989). A t-test was applied to compare the estimated disc area of the two groups of nurses. Changes in stature following the lifting task were calculated and a t-test was used to examine whether there was a difference in the stature alterations recorded for the two groups of nurses. Pearson's Product Moment correlation analyses were then applied to determine if a linear relationships existed between the estimated lumbar disc area and changes in stature.

Results

Mean loss of stature for all subjects following the lifting task was 3.88 mm (SE=0.26 mm). Although the mean value was 24% greater in the group with back pain, the difference did not reach statistical significance ($p>0.05$). Mean loss of stature and mean values for the estimation of lumbar disc area for the two groups of nurses are displayed in Table 1. A linear relation was found between lumbar disc area and spinal shrinkage for all subjects ($r=0.71$) but lumbar disc area was not different between the back pain and asymptomatic subjects ($p>0.05$). The length of employment for all participating nurses averaged 9 years and the back pain group had experienced symptoms for between 18 months and 5 years.

Table 1. Mean estimations (±SE) of lumbar disc area (L3-4) and mean changes in stature of nurses with and without low back pain.

Group	Change in stature (mm)	Lumbar disc area (cm^2)
Back pain (n=7)	4.32 ±0.39	15.51 ±0.20
Non-back pain (n=8)	3.49 ±0.31	15.37 ±0.32

Discussion

The lifting task performed during the experimental protocol was designed to simulate patient-transfers routinely undertaken by nursing staff although the rate and duration of lifting may not be characteristic of a typical working shift. The loss of stature induced by the lifting indicated that such occupational tasks induce compressive loading of the intervertebral discs. During the lifting protocol the load was positioned in front of the body, thus bending moments and shear forces were created in addition to spinal compression. Loss of disc height is indicative of compressive loading of the spine; however, it was not possible to determine the individual effects of different forces on the nucleus pulposus and annulus fibrosus during the lifting activity. A more detailed analysis of the response of the intervertebral discs, vertebrae and associated muscles, ligaments and tendons to dynamic and static loading may be obtained by *in vitro* experimentation or computer simulation with finite element modelling.

The duties of nursing personnel vary on a daily basis according to the level and type of patient care they are required to give. Patients may differ enormously in size, dependence and willingness to co-operate, therefore the load lifted during the test protocol would not reflect the load transferred in the majority of actual patient-handling tasks. The forces experienced by individuals during strenuous tasks involving the transfer of a heavy, immobile patient would be in excess of those of the simulated task despite the movement normally being performed by at least two nurses and possibly with the aid of a hoist. The loss of stature induced by the relatively light load transferred during the task simulation indicates that nursing work induces spinal compression. This has implications for the time of day lifts are performed (there exists a diurnal variation in stature), the regulations governing the maximum load that may be lifted, task repetition and the postures adopted during lifting activities.

The loss of total body height was proportional to the estimated cross-sectional area of the lumbar discs (L3-4) such that for the 10 kg load, a linear relationship was observed between disc area and loss of stature: the smaller the cross-sectional area of the disc, the less the observed change in stature. When corrected for body height the correlation was no longer apparent, therefore the relationship between estimated lumbar disc area and loss of stature is an effect of body size. Althoff et al. (1992) stated that rate of height loss was inversely proportional to the estimated cross-sectional area of the lumbar discs at a given load. However, the variation in lumbar disc area of the age, height and weight-matched female nurses participating in the present study was slight (range 13.64 to 16.60 cm²) in comparison to that of the male and female sample population studied by Althoff et al. (1992) (age range 20 to 60 years), where lumbar disc area values ranged from approximately 18.0 to 29.0 cm². Therefore, the assumption of Althoff et al. (1992) that fluid exchange and viscoelastic deformation will be larger in small discs compared with large discs cannot be applied to the results obtained in this study due to the small inter-subject variation. Further investigations to determine the response of larger lumbar discs to compressive loading would clarify the observed disparity between the studies.

Pain is a subjective sensation and even without pathological abnormality (often termed "non-specific" back pain), symptoms vary significantly. The nurses in the back pain group reported symptoms ranging from chronic, dull aching with insidious onset, to recurring acute low back pain caused by lifting activities or the adoption of awkward postures for significant periods of time. The properties of the intervertebral discs and mechanisms inducing changes in stature did not appear to respond differently in individuals with chronic, non-specific back pain compared to asymptomatic nurses during the lifting task. Acute loss of disc height observed under such experimental conditions as those performed in the present study may therefore not be applied as a diagnostic tool although Hindle et al. (1987) noted that the diurnal stature variation of patients suffering from the condition ankylosing spondylitis was reduced compared to that of healthy individuals.

Changes in stature reflect changes in disc height along the entire length of the vertebral column. Modifications to the stadiometer to enable the measurement of changes in the height of specific regions of the spine, for example the lumbar region, would result in greater ergonomic application of the methodology to assess working environments and occupational activities in terms of health and safety.

Conclusions

Repetition of routine occupational tasks resulted in loss of stature in nurses with and without chronic low back pain, although there was no difference in the magnitude of height lost by either group of nurses. A linear relationship was observed between the estimated lumbar disc area and loss of stature for all subjects which may be attributed to body size. The lumbar disc cross-sectional area of nurses reporting back pain symptoms did not differ significantly from the group of healthy individuals.

It may be concluded from the experiment performed, that a direct relationship cannot be made between the experience of chronic, non-specific back pain and i) changes in stature following lifting, ii) the estimated cross-sectional area of the lumbar discs L3-4.

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Appendix 9

POLSKA AKADEMIA NAUK
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MEDICAL BIOMECHANICS OF SPINE.
THEORY, MODELLLING AND CLINICAL APPLICATIONS

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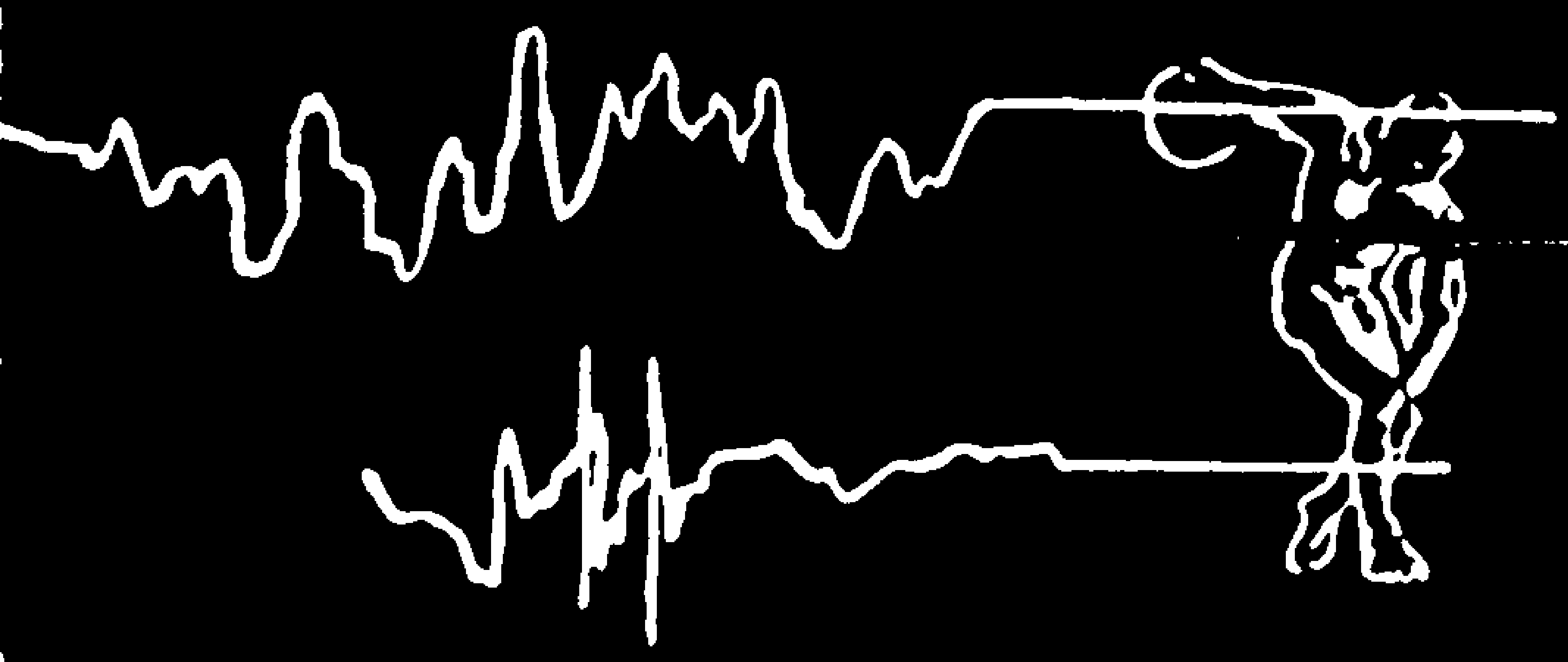

SPINAL SHRINKAGE - METHODOLOGY AND ERGONOMIC APPLICATIONS

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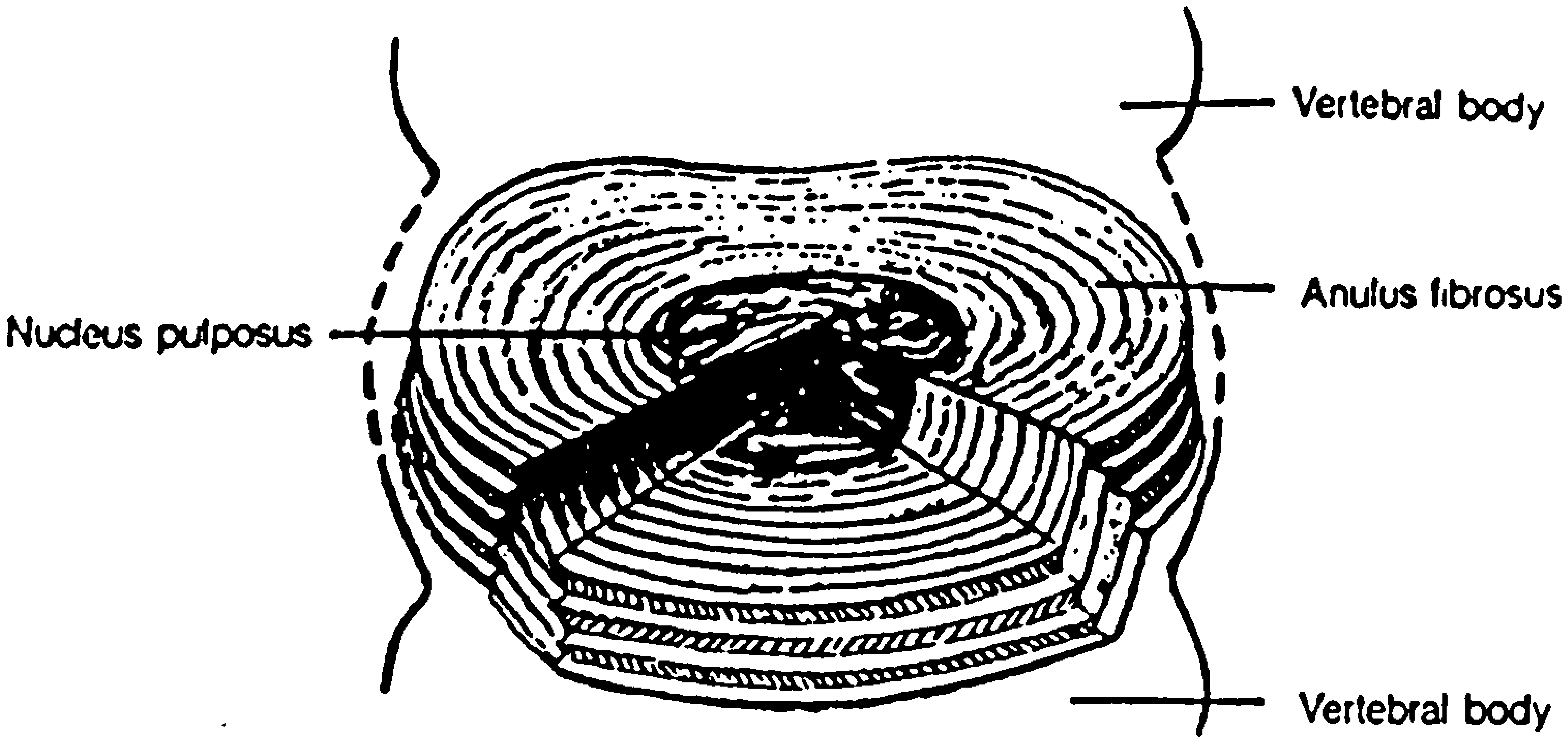
Introduction

There are ergonomic implications for the health and safety of individuals involved in static or dynamic loading activities and tasks demanding manual handling of loads. For example, a relationship between back pain and heavy work load has been established by Troup, and Edwards (1985). Consequently, there is a need to be able to quantify compressive loads on the spine in order to reduce the risk of injury. Loss of stature or spinal shrinkage provides a measure of the effect of load on the spine. Accordingly a non-invasive, reproducible and precise method of measuring stature has been developed. Changes in stature may be attributed to the properties of the intervertebral discs, the structure of which should be considered in order to comprehend the concept and the methodology.

The intervertebral discs

The intervertebral discs lying between the vertebral endplates consist of two parts: a central are known as the nucleus pulposus and an outer ring, the annulus fibrosus (Fig.1). The nucleus pulposus consists of a hydrophillic gel and large proteoglycan molecules; the outer annular ring consists mainly of collagen fibres attached around the edge of the vertebral endplate. This forms an extremely strong network that will expand upon vertical compression but not give way.

Fluid exchange and structural deformation have both been associated with changes in disc height. The fluid exchange theory proposes that pressure gradient changes occur upon compressive loading (Kramer, 1985). Compressive loads that exceed the interstitial osmotic pressure of the nucleus pulposus cause fluid to be expelled into intra-discal spaces



The nucleus pulposus is the central gelatinous part of the intervertebral disk enclosed in several layers of cartilaginous laminae. The nucleus hardens with old age.

Note: alternating obliquity of collagen fibrils

Fig.1. Schematic representation of the intervertebral disc

across the cartilage endplates and a decrease in disc height or "creep" occurs as a result. Dynamic response characteristics of the discs become altered as the stiffness of the disc increases. Reversal of this fluid extrusion process occurs upon unloading the spine, for example when lying supine. Experiments have also demonstrated that disc height alterations due to creep and subsequent recovery occur as the fibres of the annulus fibrosus extend and contract in response to loading and unloading conditions. It is acknowledged that the mechanisms involved are not fully understood (Koeller et al., 1984).

Changes in stature

There is a diurnal variation in stature amounting to approximately 1% of total body height; height is lost throughout the day and regained during the night. Rapid loss of stature occurs in the first hour of rising, accounting for as much as 50% of the total diurnal loss and under constant loading conditions, the rate of shrinkage then slows throughout the day (Reilly et al., 1984). Recovery of height occurs rapidly during the first four hours of bed-rest at night with approximately 70% of stature regained during this period. Fig.2 illustrates the height changes over a 24 hour period of eight adult males in the study conducted by Reilly et al. (1984). A similar profile has been observed in females (Wilby et al., 1987).

Body height changes may be attributed predominantly to the properties of the intervertebral discs, although compression of the lower extremities accounts for very small body height decreases. Furthermore, compression of the soft tissue structures beneath the calcaneus in the foot can account for approximately 4 mm of shrinkage upon weight-bearing. Although the may occur within a short period of time (approximately 2 min according to Foreman and Linge, 1989), it has important implications for the method of measurement of stature.

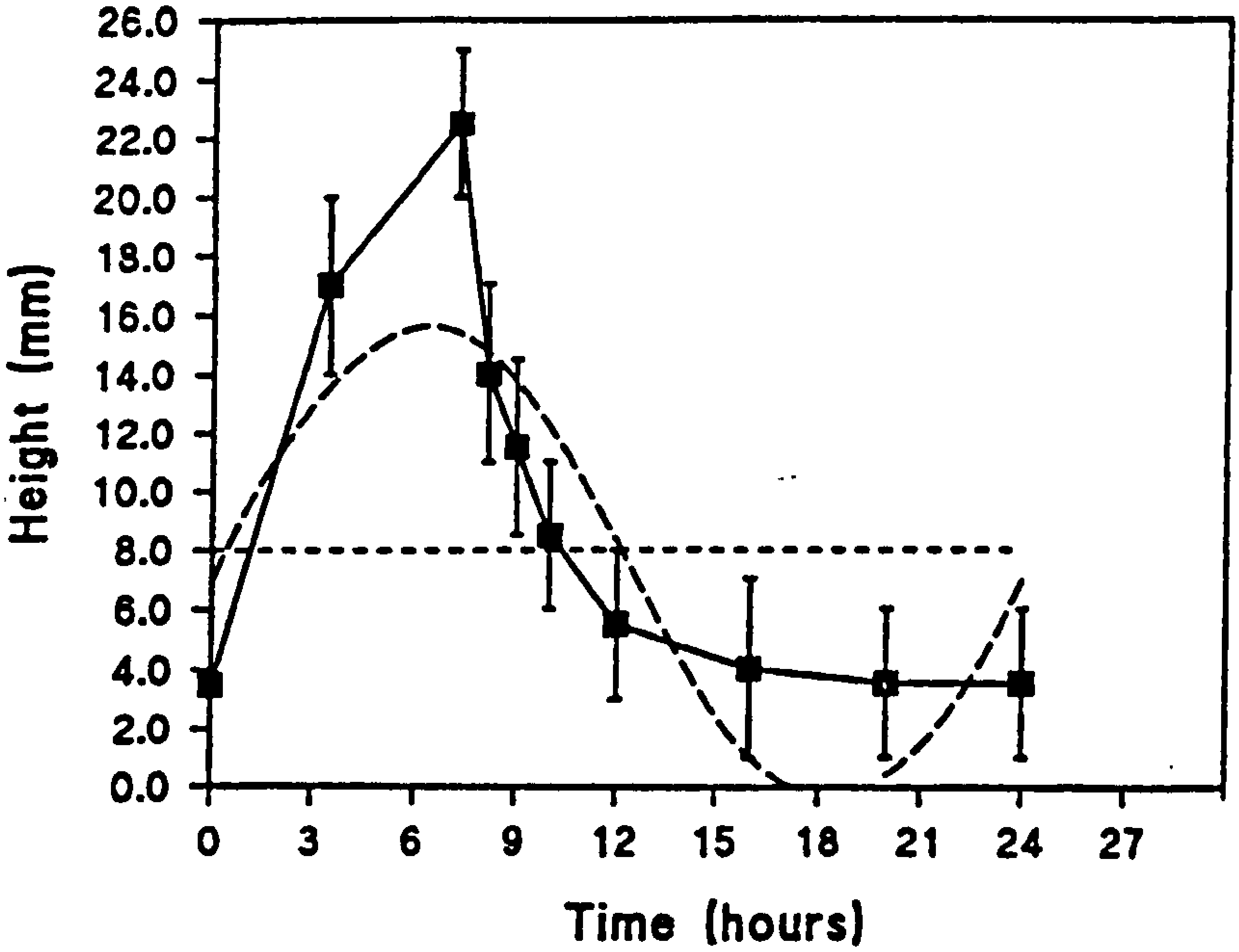


Fig.2, Changes in stature of eight healthy male adults over a 24 hour period. The unbroken line represents the mean values and 95% confidence limits. The dashed curve represents the cosinor curve fitted to the data and the midnight baseline is set at 3.5 mm (Reilly et al., 1984)

The state of hydration and degeneration of the intervertebral discs are responsible for age-related differences in the circadian variation and response of the intervertebral discs to loading conditions. The intervertebral discs of a young, healthy individual who demonstrates a daily loss in stature of generally 1% of total body height, may bind approximately 90% water. With an increase in age this value can decrease to about 65% water and coincides with a reduced circadian variation of 0.5% of total body height in elderly people (> 70 years, Fitzgerald, 1972).

Methodology - the measurement of stature

Changes in stature vary between individuals and may be induced by a loading situation, the duration of loading and the time of day. In order to assess the effect of these conditions, equipment capable of measuring stature very precisely and accurately is required. Body height measurements made routinely in medical clinics may only be accurate to within 1 or 2 centimeters and demonstrate poor repeatability. However, equipment has been developed to detect very small changes in stature that may be accurate to within 1 mm. Individuals must be able to maintain posture during the reference measurement and subsequent measures in order for comparative experimental studies to be conducted successfully.

The stadiometer

The measuring device constructed for experimental work in Liverpool is a modified model of the stadiometer used by Eklund and Corlett (1984) and is displayed in Fig.3. The stadiometer consists of a central pillar set at right angles to a base plate and is inclined backwards by 13 degrees from the vertical to assist both subject relaxation and maintenance of posture in the measurement position. Weighing scales are inset into the base plate in order for weight distribution to be standardized during measurements and a heel rest controls the position of the feet. Attached to the central pillar are six adjustable fittings with microswitches. These are positioned to contact the prominent points and curves of the spine as listed below:

1. Sacral base-plate

2. Lumbar switch
3. Two thoracic switches (left and right, between the scapula and vertebral column)
4. Cervical spine (C5-C6)
5. Occipital switch

Pressure placed through both feet onto the weighing scales equivalent to 40% of body weight triggers and additional switch. Head angle in the sagittal plane is controlled by means of spectacles worn by the subjects which contain an infra-red emitter; an adjustable switch display box and infra-red receiver are positioned directly in front of the subject. The measuring head is a 15 cm plastic disc, with a travel of 50 mm, connected to a Mercer dial gauge with a precision of 0.01 mm. The voltage from two strain gauges on the upper surface of the head disc is transferred via an amplifier unit to a micro-computer where vertical displacements are displayed graphically. All the microswitches are linked to lights within the switch display box which when illuminated allows feedback of the desired posture to the object. An audible signal is emitted when all the microswitches are triggered, indicating the posture should be controlled and that measurements will be taken over a five second period. The mean of these measurements is displayed.

Training and the measurement procedure

Training in the technique to measure stature is necessary in order to obtain accurate sequential and/or interval measurements. The microswitches used for postural control on the stadiometer may be adjusted to accommodate each individual and weight is recorded for even distribution through the feet during height measurements. The subject stands erect with hands clasped gently in front of the body below the waist and once the head disc is lowered the angle of the head can be controlled by wearing the infra-red emitting glasses. At this stage the subject should be in a relaxed posture with all control switches illuminated except the weight-control. Immediately prior to measurement, subjects are instructed to exhale and relax, and to activate the weight-control switch until the signal is heard. This position is held for five seconds.

Subjects are considered "trained" at maintaining posture when ten consecutive measurements have a standard deviation of 0.5 mm or less. Test

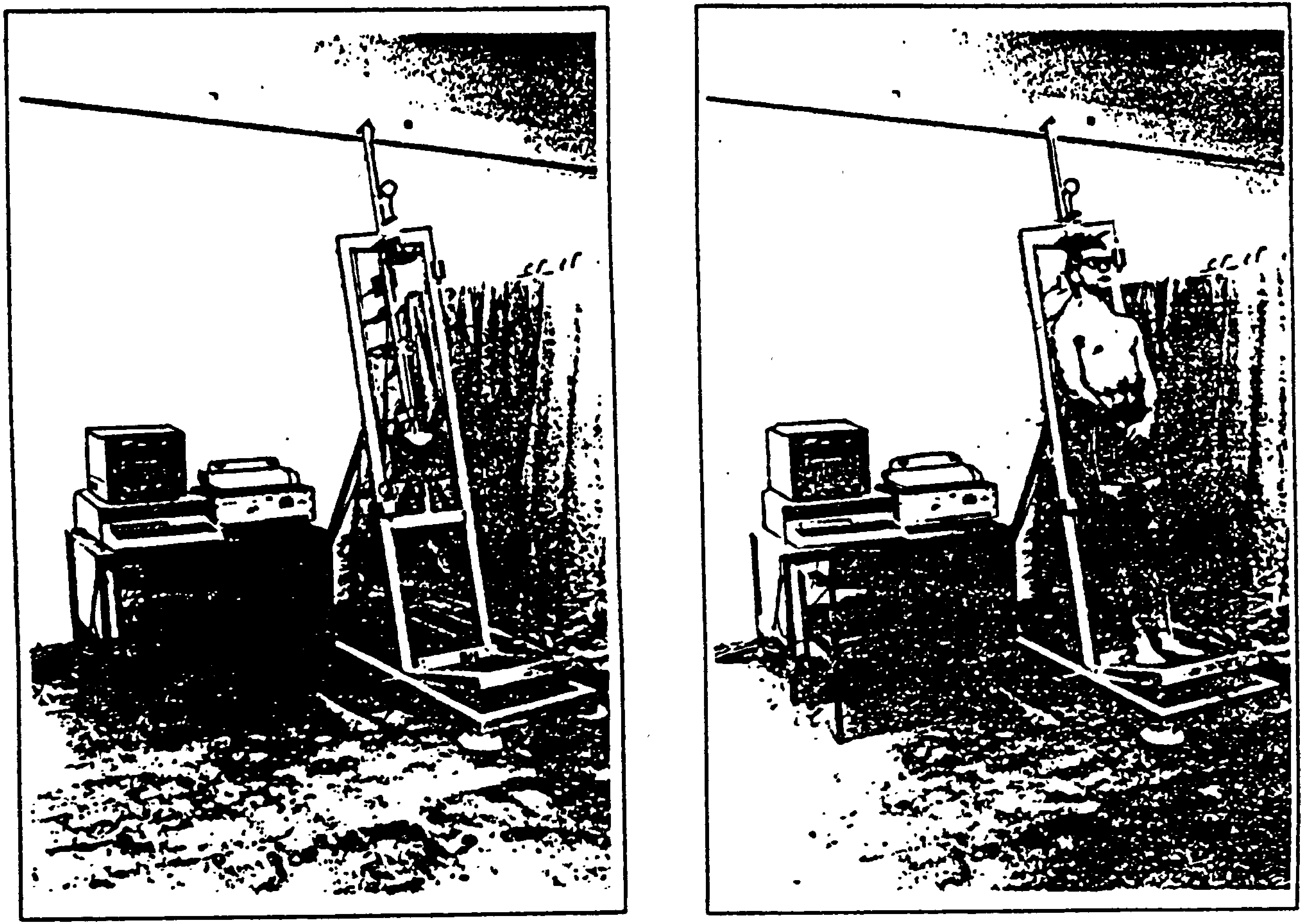


Fig.3. The precision stadiometer

conditions require five measures of stature to be recorded, again with a standard deviation of 0.5 mm or less. The experimenter can view the sequential stature measurements and has the option to eliminate a measure, for example if the subject has altered his or her posture unduly or not maintained posture for five seconds.

Shrinkage and spinal loading

In controlled circumstances, it is now well established that changes in body height can be used as a measure of the load on the spine. The rate of stature loss can be monitored as a result of external weight loading and results have indicated that the amount of shrinkage is related to the magnitude of load (Tyrrell et al., 1985). Studies conducted under experimental conditions need to consider the diurnal variation in stature and protocols should be standardized accordingly. Eklund (1986) found a linear relationship between shoulder load (0 to 25 kg) and stature changes following static shoulder loading of 45 min duration; the resulting shrinkage is listed in Table 1.

TABLE 1. Shoulder loading and spinal shrinkage (Eklund, 1986)

LOAD (kg)	STATURE LOSS (mm)
0	1.8
10	2.5
20	3.4
25	4.2

The regression equation derived from this linear relationship was:

$$y = - 0.093 x - 1.68 \text{ (SD} = 0.17 \text{ mm)}$$

where:

y - stature change (mm)

x - shoulder load (kg)

It has been demonstrated that dynamic loading exercises induced greater shrinkage when compared to static loading tasks and that the greater the load, the greater the loss of stature incurred. Tyrrell et al. (1985) investigated the loss of stature following static shoulder loading for a 20 min period with 10 kg and 40 kg barbells, and following repetitive lifting (12 lifts $\min^{-1}$ for 20 min) of the same loads. Repetitive lifting led to greater shrinkage in the 8 male subjects; the resulting loss of stature for each condition is displayed in Table 2.

TABLE 2. Spinal shrinkage following static and dynamic loading activities (Tyrrell et al., 1985)

LOAD (kg)	LOSS OF STATURE (mm) Static	Dynamic
10	5.14	6.90
40	11.22	14.49

Changes in stature have also been used to identify procedures that promote disc height recovery and as such unload the spine. Leatt et al. (1985) observed that 30 min gravity inversion at 50° (with respect to the horizontal) induced greater gains in stature than inversion at 70 and 90 degrees, increases in stature being 5.57 mm, 4.39 mm and 4.57 mm respectively. It was also noted no greater advantage was incurred by adopting the unloading posture for a 30 min period compared to 20 min. The implications of unloading procedures apply particularly to repetitive lifting in manual handling occupations where regular rest periods should be encouraged. The Fowler position (lying supine, legs raised with knees bent at an angle of 45°) is another procedure for unloading the spine and is often adopted by subjects prior to participation in experimental protocols for purposes of standardizing procedures. Recovery of disc height in the Fowler position is not as rapid compared with the effects of gravity inversion although for reasons of practicality it is a more appropriate posture to adopt.

Ergonomic applications

Measurement of spinal shrinkage as an investigative tool in the field of ergonomics enables assessment of the loads imposed on the spine during different activities and has implications for the working environment, task procedures and equipment design related to the health and safety of individuals. Studies have been conducted to assess the response of the intervertebral discs to both occupational activities and physical exercise with reference to the incidence of back pain or physical discomfort.

The workload imposed during nursing activities was studied by Foreman and Troup (1987). Stature measurements were made during two different working shifts: early (07:45-16:30 h), late (11:30-20:30) and on a day off. Less stature was lost by the twelve nurses when they worked on a late shift compared to an early shift (9.8 mm and 10.2 mm respectively) but this difference was not significant. Total height loss during the non-working day was less than the shrinkage noted following each shift for the majority of the nurses studied. The frequency and duration of postures and activities were also noted during the working shifts and shrinkage was found to be inversely related to periods when the spine was off-loaded. The duration of lean/stoop and lifting was found to be directly related to loss of stature during the early shift. Thus it has been established the nursing duties involve tasks and postures the induce greater shrinkage than would be observed during the course of a non-nursing day.

Specific nursing tasks may be simulated under experimental conditions and the spinal loading following repetition of such tasks noted. The high incidence of back pain amongst nursing personnel has in part, been attributed to the proportion of patient-handling tasks undertaken and the stooping postures adopted for significant periods of time. A study currently being conducted in Liverpool is concerned with investigating the effects of lifting on spinal shrinkage in female nurses with and without low-back pain. Preliminary findings suggest that there is no significant difference in the loss of stature between nurses suffering mild, chronic back pain symptoms and nurses without back pain following repetition of a patient-handling task. The task simulates the transfer of a patient from bed height to chair height, then return to bed height and is executed at a rate of 4 lifts min^{-1} for a period of 20 min. Mean loss of stature induced by the lifting task was 4 mm but did not differ between the two groups of nurses. Collaborative work with the Vrije Universiteit Brussel also failed to distinguish nurses reporting a lifetime prevalence of back pain from non-sufferers in terms of stature loss (Leighton et al., 1993). The study involving thirty-six female nurses did demonstrate that dynamic lifting tasks from the floor induced significantly greater shrinkage than repetitions of a lift from shoulder height to 76 cm and endorsed the use of the Fowler position as a procedure to unload the spine (mean gain in stature of 2.57 mm following 20 minutes in the position).

Stature changes of individuals participating in different forms of physical exercise have been investigated, for example weight-training and running. It was demonstrated that the loss of stature induced by running depended upon the duration of the run (Leatt et al., 1986) and that the diurnal variation in stature influenced the amount of shrinkage following weight training exercises (Wilby et al., 1987). Experienced runners completing a distance of 6 km on a treadmill at a speed of 12.2 km h^{-1} lost 2.35 mm in height and running for an additional 19 km at 14.6 km h^{-1} caused a further loss of 7.79 mm.

In many situations it is difficult to apply the results of studies conducted under controlled, laboratory conditions to events occurring under normal circumstances as the time of day and actual exercise/task performed must be considered. Nevertheless, changes in stature provide an indication of spinal loading and from an ergonomic perspective, enable activities that may be potentially hazardous to be assessed.

Spinal shrinkage and biomechanical modelling

The estimation of the compressive forces acting on the spine during activities is another investigative tool that complements the measurement of changes in stature.

Biomechanical modelling provides a mathematical, non-invasive, indirect means by which the forces acting on the human body may be estimated and has been applied as an investigative tool to compare calculated lumbar compressive forces and resultant changes in stature. However, studies of the effects of specific plyometric exercises (drop jumping or repetitive bounding drills entailing stretch-shortening cycles of muscle activity) failed to demonstrate a consistent between spinal shrinkage and lumbar compression force using a five-link segment, two-dimensional, symmetrical model (Boocock 1992). Future work to be undertaken in Liverpool aims to develop a three-dimensional, dynamic model using kinematic, anthropometric and force platform data to estimate the compressive loads imposed on the spine during manual-handling tasks. In addition to the acquisition of kinematic and kinetic data, modifications to the stadiometer will enable changes in disc height in specific regions of the vertebral column to be identified and as such may provide insight into the biomechanics of the spine in terms of back pain symptoms.

Conclusions

The assumption in spinal shrinkage measurement is that loads applied to the intervertebral discs cause creep, resulting in changes in body height. The determination of stature using computer-aided stadiometry provides precise and reproducible measures that enable changes in disc height to be recorded to within 1 mm.

Body height decreases of approximately 1% of total height occur during the day. This may be expressed as around 8% compression of the intervertebral discs by assuming that one-third of the vertebral column is comprised of discs and that vertebral column length is about 35 percent of body height (Eklund, 1986).

The physical properties of the intervertebral discs may be associated with the incidence of back pain, particularly in relation to disc building, the tension in the fibres of the annulus fibrosus and increased stiffness of the disc under loading situations. Therefore, in addition to providing an indication of spinal load, changes in stature may provide information as to the risk of experiencing back pain.

The methodology for measuring changes in stature has been widely used to evaluate spinal loads arising from different activities, postures or working environment and has the advantage of assessing such effects *in vivo*. However, significant individual and age differences have been demonstrated and so it is important to use subjects as their own controls during comparative experimental studies. The diurnal variation in stature and loading prior to experimentation are also important factors to consider. Postures to unload the spine have been studied and have implications for the design of work-rest schedules and the nature of the activity performed (static or dynamic loading).

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