Incidence, Prevalence and Aetiology of Chronic Exercise Induced Lower Back Pain in Runners

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The Incidence, Prevalence and Aetiology of Chronic Exercise Induced Lower Back Pain in Runners

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DECLARATION

I, Grant Lewis, hereby declare that the work on which this thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other University.

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Abstract

The aim of this study was to determine the prevalence of lower back pain (LBP) in the running population and any initiating or aggravating factors. The aetiology of low back pain in runners was also investigated. A random sample population of 225 road-runners were interviewed following the completion of six local road races. A further subgroup (n = 52) (LBP group as well as control group) of these runners was evaluated to determine if there were any biomechanical; muscle strength, flexibility and stability measures; as well as any training protocols which were more commonly associated in those runners who complained of LBP. Questionnaires were completed by 225 runners and a detailed clinical evaluation was performed to identify the incidence and aetiology of running-related lower back pain. Attention was focussed on the lumbar-pelvic muscles in terms of their flexibility, strength and coordinating ability as well as static biomechanical measures of the lower limb. LBP in runners was found to be common with an injury risk of 1.42 injuries per 1000 running hours. This running-related LBP seldom forced the athlete to stop running yet did affect running performance. It was associated with any increase in the running load. Hip flexor inflexibility on the left ($p = 0.07$); short hip adductor muscle length ($p = 0.055$), hamstring inflexibility ($p = 0.09$) and iliotibial band inflexibility ($p = 0.036$) on the right were found to be more common in the LBP group. The abdominal muscles were weaker in the LBP group when assessed in the trunk curl-up test ($p = 0.0085$) and the stabilising ability ($p = 0.032$) for this group was judged to be poor. Biomechanically, only a marginal difference was found between those with and without LBP ($p = 0.077$) with regard to the hindfoot and forefoot postures which were valgus and varus respectively for the lower back pain group. Lumbar intervertebral joints were mostly hypomobile ($p = 0.004$) in the LBP group. Adherence to a poor training regime (excessive running distances and frequencies) was associated with the LBP group. Attention to correct training patterns and adequate muscle control (strength, co-ordination and flexibility) is suggested to protect from this running-related LBP. Further research into a comparison of rehabilitation protocols is required to validate these findings.

Dedication

This study is dedicated to the glory of God who has blessed me and helped me in the completion of this thesis. It is also dedicated to my wife, Anne, family and friends who have stood by me, constant in love, support and understanding.

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Abbreviations and definitions

Running-related lower back pain (LBP): lower back ache or discomfort associated with the commencement, duration or post running exercise i.e. pain which is exacerbated by running.

LBP group = runners reporting to suffer from running-related LBP
Control group = runners without any LBP

ADL:	activities of daily living
ASIS:	anterior superior iliac spine
IAP:	intra-abdominal pressure
ITB:	ilio-tibial band
LBP:	lower back pain
P-A:	posterior-anterior
PNF:	proprioceptive neuromuscular facilitation
PSIS:	posterior superior iliac spine
ROM:	range of movement
TA:	Achilles tendon
TLF:	thoraco-lumbar fascia

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1 Chapter 1

1.1 Introduction and scope of the thesis

The popularity of running as a form of exercise and recreation has grown rapidly since the 1970s (Van Mechelen et al 1993). The reasons for this increase in popularity include health and fitness, pleasure or relaxation and competitive or personal performance (Van Mechelen et al 1993). As in all sports, runners are prone to injury, including lower back pain. Lower back pain (LBP) is also a major health problem in the general population and has physical and psychosocial consequences (Risch et al 1993), affecting 80% of the population at one time or another (Nuber et al 1995). The one-year prevalence of lower back pain in a general population of 30-60 year olds is estimated as 45% (Biering-Sorenson et al 1989). In another study, the annual incidence of lower back pain in a general urban population was 64% and the lifetime prevalence was 79% (Laslett et al 1991).

1.2 Running-related lower back pain

Many runners report discomfort in the lower back while running (Stanish 1987). Low back pain is a common overuse injury in many runners and a frequency of 5 - 10% of lower back pain has been reported in the running population (Warren and Davis 1988, Lysholm and Wiklander 1987, Walter et al 1989). Lower back pain in runners apparently requires no treatment in many cases, responding to rest or limited activity (Christie et al 1995, Nuber et al 1995). Furthermore, it has been documented that the incentives to recover are less tangible in the general population compared with the athletic population due to increased motivation, conditioning and activity levels in the latter group (Nuber et al 1995). The question arises whether lower back pain is a specific running-related injury or whether its occurrence in runners is merely a reflection of lower back pain in the general population.

Lower back pain in runners has not been well documented, in particular the aetiological factors related to the development of lower back pain in runners have not been investigated. Prevention of injuries is receiving more emphasis in the health care system. For this reason it is important to determine aetiological factors of lower back pain in runners. There is therefore a need to identify causes and the natural history of lower back pain in runners to formulate appropriate preventative and treatment programs (Nuber et al 1995).

The aim of this thesis was to

1) determine the epidemiology of lower back pain in a running population and
2) identify aetiological factors that may be related to the development of lower back pain in runners.

In chapter 2 and 3 a review of the literature concerning the incidence and risk factors of back pain, especially in runners will be presented. The investigations presented in this thesis were conducted in two parts. The first study was designed to identify the lifetime prevalence and annual incidence of lower back pain in runners and to identify aetiological factors. It consisted of an interview questionnaire completed by a randomly selected group of runners at the finish of local races. The second study included a more detailed history and clinical evaluation of a subset of runners from the population interviewed in the first part. This part was designed to identify clinically observable aetiological factors for running-related lower back pain and to describe the nature of lower back pain in runners.

These two studies will be discussed in chapters 4 and 5 of this thesis. Each chapter will consider the aim of the study, methodology employed, results obtained and a discussion of the results in relation to previous research.

Finally the conclusions of the study are discussed in chapter 6. Recommendations for further research have also been included.

2 Chapter 2

The epidemiology of running injuries

2.1 Introduction

In the last 3 decades, more people are participating in large endurance events, in particular running (Van Mechelen 1992, Walter et al 1989). This is related to an increased awareness of the potential health benefit of aerobic exercise (Warren and Davis 1988). However, about 50% to 70% of runners sustain a running-related injury per year sufficient to interrupt usual training (Warren and Davis 1988). Clinically though, a runners injury is often subtle and difficult to diagnose (Bach et al 1985).

It is difficult to compare the incidence of running injuries between studies because of the differences in definition of the injuries and the population sample profiles in different studies (Hoeberigs 1992). Studies based on a period of data not equivalent to a full year can not be translated to an annual incidence rate as running is seldom of the same intensity all year round (Van Mechelen 1992).

2.2 Epidemiology of running injuries

Running-induced injuries affect up to 45% of all runners (Brody 1995). The incidence of running-related injuries is 2 - 2.5 times less than injuries from other sports such as contact, racquet or court sports (Van Mechelen 1992). The annual incidence of injury in runners varies between 24 - 72% (37 - 56% in studies of over 500 athletes) (Van Mechelen 1992). In one study, over 48% of runners observed over a one-year period were found to experience at least one injury of which 54% were new injuries (Walter et al 1989). In a review of running injuries, it was documented that 50 - 75% of all running-related injuries were overuse in nature with a recurrence of 20 - 70% (Van Mechelen 1992). This injury frequency depended on the affected body part and the difference in study design.

The incidence of injuries is best expressed relative to exposure (1000 hours of activity). Total injury rates of 2.5 per 1000 running hours in long distance runners and 5.8 per 1000 running hours in middle distance athletes have been reported (Lysholm and Wiklander 1987). It can be hypothesised that the difference between the long distance and middle distance groups of runners may be that the latter group would be likely to run at a greater running intensity and may therefore be more predisposed to injury. In one review of running injuries the overall annual injury rate in recreational runners was documented as 2.5 - 12.1 injuries per 1000 running hours (average of 3.6 injuries per 1000 running hours) (Van Mechelen 1992).

In one study 60 athletes from two local clubs were observed over a one-year period (Lysholm and Wiklander 1987). In this group, injury was found to be a result of either intrinsic or extrinsic factors or in combination; probably both in exertional injuries. Exertional injuries were classified into two categories: primary, in which there was no identifiable intrinsic factor (40% of their sample), and secondary, in which there was an acquired or congenital disorder.

2.3 Epidemiology Of lower back pain in runners

In a number of case series it has been documented that five to twenty percent of all injuries in runners involve the lower back (El-Sayyad and Sabry 1987, Harvey and Tanner 1991, Lysholm and Wiklander 1987, Walter et al 1989). The latter two studies investigated the frequencies of back injuries in specific groups of runners. The frequency incidences of lower back pain in runners in these two groups were 13% and 11% respectively. In another review of running injuries, back injuries constituted only 3 - 11 % of all running-related injuries (Van Mechelen 1992). These studies were all case series, and no prospective or retrospective survey has been conducted to investigate the epidemiology of lower back pain in runners.

2.4 Risk factors for running-related injuries

The risk factors for running-related injuries can be classified into;

- factors related to the runner,
- factors related to running and
- factors related to the running environment (Powell et al 1986).

Most injuries to runners are thought to be due to an interplay between a biomechanical predisposition and / or a recent change in their training program (Fredericson 1996).

Overuse injuries in general have been suggested to be predisposed by poor flexibility in combination with ligament laxity and muscle weakness (Pope et al 1998). On the contrary, good flexibility in combination with a short stature and greater strength and speed are predisposing factors for acute injuries (Pope et al 1998). Running injuries are likely due to a combination of different risk factors than a single anatomical, biomechanical or environmental anomaly (Warren and Davis 1988). There is controversy in the literature with regard to the possible risk factors for running-related injuries. The epidemiology of running injuries including risk factors for running injuries was investigated in the late 1980's. In Table I nine studies investigating risk factors related to running injuries are summarised. The results of these studies were recently reviewed. In this review risk factors were divided into three groups: factors significantly related with running injuries, factors not significantly related with running injuries, and factors poorly related with running injuries (Van Mechelen 1992) (Table 2).

Table 1 Factors relating to running injuries in selected studies

Reference	Significant Factors	Non-significant factors	Number of subjects in study	Duration of study	Type of study
Jacobs and Berson 1986	* Excessive running distance * Increased running frequency * Higher training speeds * Stretching * Other sports	* Age * Gender * Running surface * Time of day of run * Hill running * Running duration * running sprints or intervals	451	24 months	Retrospective
Blair et al 1987	* BMI (low correlation) * Excessive running distance	* Age * Running experience * Time of day of run * Frequency of stretching	438	12 months	Retrospective
Lysholm and Wiklander 1987	* Excessive running distance * Sudden change of training routines * Malalignments	* Gender	60	12 months	Prospective
Marti et al 1988	* BMI * Running experience * Previous injury * Excessive running distance * Running frequency * Competitive runners	* Participation in other sports * Running shoe type * Running surface	4723	12 months	Retrospective
Warren and Davis 1988	Combination of problems rather than specific abnormalities	* Knee ROM * Subtalar supination * Age * Gender * BMI * Running experience * Running surface * Average running distance * Description of workouts * Shoe type * Competitive race times * Other sporting activities * Previous athletic injuries * Stretching routines * Anthropometric analysis * Malalignments	134	12 months	Retrospective
Bovens et al 1989	* Excessive running distance * Running surface		73	18 – 20 months	Prospective
Kaplan et al 1989	* Excessive running distance	* Age * BMI * Running experience * Training speed	1423	12 months	Retrospective

Reference	Significant Factors	Non-significant factors	Number of subjects in study	Duration of study	Type of study
Macera et al 1989	* Running experience * Previous injury * Excessive running distance * Increased running frequency * Running surface (women)	* Age * BMI * Hill running * Time of day of run * Running surface (men) * Stretching	583	12 months	Prospective
Walter et al 1989	* Competitive runners * Excessive running distance * Previous injury * Increased running frequency * Running whole year round * Warm up (marginal)	* Usual training pace * Racing / training experience * Running surface * Frequency of racing * Hill running * Cool-down practices * Other sporting activities * Use of hard training days * Time of day spent sitting or standing or driving * Malalignments * Anthropometric variables * Gender * Age * BMI	1680	12 months	Prospective

Table 2 Factors related with running injuries: a summary of the results from the literature (Van Mechelen 1992)

Factors significantly related with running injuries	Fators not significantly related with running injuries	Factors related with running injuries that are not clear, or are contradicting or based on scantly information
• Previous injury • Lack of running experience • Running to compete • Excessive weekly running distance	• Age • Gender • Body mass index • Hill running • Running on hard surface • Participation in other sports • Time of the year • Time of the day	• Warming up • Stretching exercises • Body height • Malalignment • Restricted range of motion • Running frequency • Intensity of performance • Stability of running pattern • Shoes • In-shoe orthoses • Running on one side of the road

It seems that the major risk factor may be simply cumulative overload (Fredericson 1996). Reducing the training load may therefore prevent injury and the enormous medical and social cost of a running-related injury (Walter et al 1989).

2.5 Risk factors for lower back pain in runners

Running has been regarded as an activity that increases lumbar extension (Behrsin and Andrews 1991). The lumbar spine is particularly hyperextended with downhill running (Herring and Weinstein 1995) and in flexion with uphill running (Lindgren and Twomey 1988). Conversely, the repetitive cyclical loading of the spine in extension in downhill running and flexion with up-hill running may predispose to lower back pain (Lindgren and Twomey 1988, Herring and Weinstein 1995). Excessive flexion of the trunk and an anterior pelvic tilt (due to inflexibility of the hip flexor muscles) can cause excessive stress on the postural muscles, the lumbar fascia and lumbar vertebra (Bach et al 1985). It has been suggested that flexion / extension and torsional forces combined with compression are most damaging to the lumbar spine (Norris 1995b). During running these flexion / extension and torsional stresses may be accentuated by the increased forward lean and swing of the arms (Bach et al 1985). It is also hypothesised that there is a relationship between inflexible hamstring muscles and lower back pain in distance runners. Inflexibility in the hamstrings can develop as a result of repetitive short-range use of the hamstring muscle in fast running (Lindgren and Twomey 1988). Furthermore, inflexible hamstrings can cause lower back pain due to their ability to posteriorly tilt the pelvis thereby reducing the normal lumbar lordosis (Lindgren and Twomey 1988).

2.6 Summary

There is a need to determine causative factors for running injuries in order to plan appropriate management of the injury. Present data indicate that about half of all runners sustain an injury in one year which is severe enough to prevent normal training. The frequency of injury at different anatomical sites have been documented. The results of these case series indicate that the lower back is not a common site for running injuries. However, the lower back has generally not been investigated well and no epidemiological studies documenting running-related lower back pain have been published.

A number of studies have examined risk factors for running-related injuries in general. The risk factors that are most strongly related to running injuries are:

- excessive running distances (Jacobs and Berson 1986, Blair et al 1987, Lysholm and Wiklander 1987, Marti et al 1988, Bovens et al 1989, Kaplan et al 1989, Macera et al 1989, Walter et al 1989)
- poor running experience (Marti et al 1988, Macera et al 1989)
- running intensity (Jacobs and Berson 1986, Marti et al 1988, Walter et al 1989)
- previous injury (Marti et al 1988, Macera et al 1989, Walter et al 1989).

However, no risk factors for the development of running-related lower back pain have been studied. Current hypotheses include excessive laxity of the lumbar spine during extension (downhill running) and flexion (uphill running), excessive flexion of the trunk, anterior pelvic tilting and inflexible hamstrings all of which can alter axial loading on components of the lumbar spine.

3 Chapter 3

Epidemiology and aetiology of chronic lower back pain

3.1 Introduction

Lower back pain has a 60 - 90% lifetime prevalence and a 5% annual incidence in the general population (Nuber et al 1995). Seventy to ninety percent of lower back pain episodes recur and almost 90% resolve without any medical attention (Nuber et al 1995). In a general population of 30 - 60 year old male and females, the lifetime prevalence of lower back pain was found to be 45% (Biering-Sorenson 1989). However, the lifetime prevalence of lower back pain has been documented at being closer to 75% (Pope and Novotny 1993). A one-year prevalence of lower back pain in a general population has been found to vary between 37% (Papageorgiou et al 1995) and 64% (Laslett et al 1991).

Furthermore, sporting pursuits may predispose the back to injury because of excessive loading of the spine. Poor postural control is common (Richardson et al 1992). In this chapter the classification of lower back pain will be mentioned briefly, the biomechanics of the lumbar spine will be discussed briefly and possible factors associated with lower back pain in runners will be reviewed.

3.2 Definition / terminology and classification of lower back pain

There are many classifications of lower back pain. Acute lower back pain can be classified as pain for less than 6 months and having had no pain for the year preceding the present onset whereas chronic lower back pain can be classified as pain in a continuous or recurrent nature for more than 6 months (Christie et al 1995). Although some acute low back injuries in sport are attributed to specific incidents, chronic lower back pain often has no apparent cause and is classified as an overuse injury (Fenety and Kumar 1992).

Lower back pain injuries in athletes have also been broadly classified into three diagnostic categories; that is dysfunction of the intervertebral discs, hyper- / hyperhypomobility abnormalities and muscular strains and imbalances (Snyder-Mackler 1989).

Another classification of lower back pain is based on the anatomical structure involved, the pathology in the structure or according to onset (acute, subacute or chronic). A detailed, discussion of all the causes of lower back pain is beyond the scope of this thesis. A brief outline of the combined anatomical and pathological classification of lower back pain in athletes is depicted in Table 3 (Herring and Weinstein 1995).

Table 3 Combined anatomical and pathological classification of lower back pain in athletes

Anatomical structures	**Pathology**
Bone – vertebral body, growth plate, pedicle, lamina, transverse process, spinous process	Fractures, spondylolysis, Spondylolisthesis, infections, inflammation, metabolic disorder, neoplasia
Joint – facet joints	Fractures, degeneration, arthritis, arthrosis
Intervertebral disc	Herniation, annular tears, infection, inflammation
Muscle	Sprains, strains
Ligament	Sprains, strains
Neural structures – nerve root, dural sleeve	Nerve root compression, neuropathies
Blood vessels	Infarction
Viscera	Referred pain

It is well established that in the majority of patients complaining of lower back pain, a clear diagnosis can often not be made clinically. Under such circumstances lower back pain is generally termed mechanical or idiopathic (Christie et al 1995).

Running induced lower back pain is usually chronic in nature and probably as a result of repetitive microtrauma. However, in a runner presenting with lower back pain all the structures and the potential pathology depicted in Table 3 must be considered. As always, all attempts must be made to establish a clear diagnosis for lower back pain in runners. The present study is primarily concerned with injuries due to repetitive mechanical strain caused by running and, as such, mainly considers injuries secondary to repetitive trauma to the anatomical structures around the spine.

3.3 Biomechanics of the lumbar spine

3.3.1 Introduction

Biomechanics is a scientific discipline which includes the study of kinematics (motion) and kinetics (forces) on an anatomical structure. This chapter therefore considers both the intrinsic forces (produced by muscular tension) which move the spine as well as extrinsic forces which are applied to the spine. Furthermore, this review of the biomechanics of the spine will focus mainly on running. During running, various forces act on the basic anatomical structure of the spine which is the motion segment (Herring and Weinstein 1995). The motion segment consists of two vertebra and their articulations. The main components of the motion segment are the intervertebral disc and the two facet joints. The forces affect each component of the motion segment differently. Furthermore, the response of each component of the motion segment to these forces may affect other components in the motion segment. The forces that are imposed on the spine during running vary because running is a dynamic motion.

The lumbar spine is inherently unstable (Hodges and Richardson 1997). It is supported by three inter-relating systems. The three interrelating systems are:

- the passive support (bone, cartilage and ligamentous structures),
- active support (muscle control) and
- the neural control system (Panjabi 1992).

Sensory feedback between the active and the passive systems provides a co-ordination between all the systems. Failure in one system will result in some form of compensation in another system (Norris 1995a). The muscular and neural systems are dynamic in that their supportive roles can change and therefore adapt to the nature of the forces on the lumbar spine. Central to these stability mechanisms is the motion segment which, as previously mentioned is the functional unit in the lumbar spine.

In this review on the biomechanics of the lumbar spine the following will be discussed. A short description will be given on the need for controlled regular strain on the spine for normal growth and maintenance. The motion segment and forces affected will also be discussed. The mechanical strain on the spine imposed by running will also be reviewed. The final biomechanical principle to be reviewed in this section is lumbar-pelvic rhythm.

3.3.2 Mechanical loading of the lumbar spine for normal joint function

Although regular physical activity is important to maintain the health of the lumbar spine, excessive physical activity and chronic repetitive exertion can be detrimental (Herring and Weinstein 1995). The normal function of joints depends on repeated low stress applications to ensure proper flow of fluid and nutrients across and through joint surfaces (Twomey and Taylor 1995). All cartilaginous structures respond adversely to either disuse or conditions of sustained high stress loading (Twomey and Taylor 1995). Moderate regular loading and joint motion ensures the passage of synovial fluid over the articular cartilage. The alternate compression and relaxation of the cartilage results in expression and drawing back of fluid into the articular cartilage as the pressure changes. Thus a lack of movement or a sustained posture results in atrophy, degeneration of cartilage and sclerosis of the subchondral bone (Twomey and Taylor 1995). Back rehabilitation training methods can be employed to improve the nutrition of the intervertebral discs and joints through regular motion (Johannsen et al 1995).

Appendix I discusses the back rehabilitation to strengthen and nourish the spinal tissues currently published in the literature.

3.3.3 Mechanical strain on the motion segment

As previously mentioned, the motion segment is defined as two lumbar vertebrae with the intervening annulus-disc complex placed anteriorly, the two posterior synovial facet joints and the interspinous soft tissue elements posteriorly (Herring and Weinstein 1995). Both the disc and the facet joints are subjected to compressive forces while the disc also withstands shear and tensile forces such as with flexion / extension and rotation movements (Herring and Weinstein 1995). Pathological changes in one part of the motion segment can result in pathological changes in another part of this same segment and even in adjacent segments (Herring and Weinstein 1995). The biomechanical manifestation of early excessive loading are either hypomobility in the early phase of the pathology (phase I) or hypermobility in the latter phase of the pathology (phase II). Secondary soft tissue changes (muscle spasm and shortening of ligaments, fascia and musculo-tendinous structures) can also contribute to pain and altered mobility. The effects of forces imposed on a motion segment of the lumbar spine during running will be discussed further in the section on forces and loading (section 3.3.5).

3.3.4 Functional stability of the lumbar spine

As previously mentioned, lumbar spine stability depends on passive support (bone, cartilage, ligaments), active support (muscle) and neural control. Active support together with neural control provide four main mechanisms by which stability is provided to the lumbar spine:

i) Attachments of the internal oblique and transversus abdominis to the thoracolumbar fascia (TLF);

ii) Increased tension produced by the contraction of the paraspinal muscles which lie between the middle and posterior layers of the thoracolumbar fascia;

iii) The intra-abdominal pressure (IAP) mechanism. Abdominal muscle activity is associated with an increased intra-abdominal pressure. The muscles of the ventro-lateral abdominal wall which are the obliques and transversus muscles, the erector spinae, diaphragm and pelvic floor muscles contract to increase the intra-abdominal pressure (Cresswell, Blake and Thorstensson 1994);

iv) The stabilising role of the deep lumbar extensor muscles (Richardson et al 1990).

3.3.4.1 Internal oblique, transversus abdominis and the thoracolumbar fascia

These mechanisms can also be considered as the functional stability mechanisms of the lumbar spine. The transversus abdominis and the internal and external oblique muscle groups have been recognised as the main contributors to functional stability of the lumbar spine. Their function is believed to be enhanced by co-contraction of the multifidii, interspinales and intertransversarii muscles which provide individual segment stabilising control (Norris 1995a-e, Jull et al 1993, Richardson et al 1992, Wohlfahrt et al 1993).

It is hypothesised that the thoraco-lumbar fascia serves two roles. Firstly, the transversus abdominis, through its attachment to the lateral raphe, exerts a tensile force on the thoraco-lumbar fascia. The deep lamina are angled upwards, the superficial laminae downwards and both attach to the lateral raphe. As the transversus abdominis contracts, it increases the tension in the lateral raphe and a force is transmitted along the length of the thoracolumbar fascia and tenses it (Norris 1995c). This transmits a compressive force to the spinal column which enhances its stability and assists in the recruitment of the multifidii muscle groups.

The second role of the thoracolumbar fascia is to act as a haudraulic amplifier mechanism which exerts a greater stabilising effect on the spine. The posterior layer of the thoracolumbar fascia envelops the erector spinae and as the muscles contract, their expansion is resisted by the thoracolumbar fascia. The resultant increase in fascial tension increases the stress generated by the muscles by 30% (Hukins et al 1990). This effect is important in resisting flexion of the lumbar spine.

3.3.4.2 Paraspinal muscles

A distending force between the diaphragm / rib cage and the pelvic floor is produced by increased pressure in the mainly fluid compartments. This provides an extensor moment about the spine. The muscles required to generate this pressure are the external oblique, internal oblique and the transversus abdominis. The latter two muscle groups originate from the anterior trunk and extend to the lumbar spine via the thoracolumbar fascia (Miller and Medeiros 1987). Therefore, in order to increase the stability of the spine a co-contraction of the obliques, transversus abdominis and multifidii needs to be facilitated (Richardson et al 1990). Stress on the spine is decreased because fewer muscular forces are required for equilibrium.

3.3.4.3 The intra-abdominal pressure mechanism

The intra-abdominal pressure mechanism exerts a tensile force on the rectus sheath and reduces axial compression and shear forces which are then transmitted over a wider area. A synchronous contraction of the abdominal muscles, diaphragm and muscles of the pelvic floor is required to increase pressure in the abdominal and thoracic cavities (Norris 1995c). The co-contraction of the lower back muscles and obliques which is known as abdominal bracing, results in an increase in intra-abdominal pressure and thus stabilises the spine (Richardson et al 1992).

The spine can be considered to function as a lever which has an arch abutting on the sacrum caudally with body weight, muscular and ligamentous forces acting cranially. The intra-abdominal pressure and thoracolumbar fascia probably exert their major effects by introducing another force vector over the anterior lumbar region to retain the thrust line of the force load within the spinal vertebral bodies (Norris 1995c). The intra-abdominal pressure and thoracolumbar fascia also help to increase the stiffness of the spine and therefore resistance to flexion.

3.3.4.4 Deep lumbar muscle stabilisers

Excessive movement in a motion segment may stretch or compress, and thereby injure any of the pain-sensitive structures of the lumbar spine (disc, facet joint, periosteum, meninges, blood vessels, muscles and ligaments) (Wheeler and Hanley 1995, Norris 1995c). This may result in discomfort (D'Orazio 1993). If muscles do not act in a co-ordinating manner to support the structures, excessive movement can occur in a motion segment.

The lack of lumbar stabilisation becomes critical when the muscles of the trunk are required to control the lumbar spine and pelvis when load is applied to the limbs (Richardson et al 1992). The anti-gravity function of the trunk muscles provides a background support for limb movements and for protecting the spinal column from forces imposed through limb loading (Jull et al 1993). These muscles need to be continuously active over long periods of time at low forces. The multifidus muscle is active during full range of motion of flexion and bilateral rotation and contributes to the stability of the pelvis in extension movements of the lower limb (Richardson et al 1990). The combinations of the lumbar stabiliser muscle contractions and the nature of their work depend on positional and directional requirements of the task being performed (Jull et al 199-3). In rehabilitation, many athletes emphasise strengthening of their thoracic and upper and lower extremity musculature but do not emphasise the stabilising muscles of the spine and the pelvic girdle (Herring and Weinstein 1995).

The results of recent scientific studies have supported the role of the deep lumbar stabiliser muscles in stabilising the lumbar spine. In one study, muscular activity of the upper and lower rectus abdominis, obliques and the lumbar erector spinae was measured using needle electro-myographic probes while subjects performed abdominal hollowing and bracing manoeuvres (Richardson et al 1992). During the abdominal hollowing technique, the abdominal muscles are hollowed and the back slightly flattened as the umbilicus moves cephallically against the spine. Abdominal bracing involves a contraction of the abdominal muscles by actively flaring out laterally in the region of the waist just above the iliac crests (Richardson et al 1992). When comparing abdominal stabilisation techniques, a lower pressure reading was documented in a biocuff placed under the lumbar spine with abdominal bracing and hollowing actions when compared with conventional posterior pelvic tilting (Richardson et al 1992). These results indicate that a more neutral posture of the lumbar spine was achieved with abdominal hollowing and abdominal bracing. These techniques are therefore regarded as more suitable lumbar stabilisation patterns because with these forms of muscle contraction, the lumbar spine motion is minimal indicating that it has remained in it's neutral posture. Abdominal muscle stabilisation techniques are therefore advantageous given the deleterious effects on the lumbar spine of extremes of flexion and extension.

In another recent study, it has been established that the central nervous system controls the stabilisation of the spine by contraction of the abdominal (particularly the transversus abdominis muscle) and multifidus muscles in anticipation of reactive forces produced by limb movement irrespective of the direction of this movement (Hodges and Richardson 1997). In this study, electro-myographic testing revealed the transversus abdominis muscle to contract prior to any contraction of the prime mover during test movements of hip flexion, abduction and extension. Multifidus contractile function was inhibited in patients suffering acute, first-episode lower back pain (Hides et al 1996) while the timing of the transversus abdominis contraction with limb movement was significantly delayed in patients suffering lower back pain (Hodges et al 1996). Atrophy of the multifidus has also been correlated with lower back pain corresponding to the clinically determined level of symptoms (Hides et al 1994).

Therefore, to minimize loading of the motion segment of the spine, specific muscular contractions are required prior to the performance of any task. The transversus abdominis and multifidii muscles have been recognised as being primarily responsible for this function of stabilising the functional unit (motion segment) of the spine.

It has also been shown that muscle contraction speed influences the function and activity of the muscles that stabilise and support the articular structures of the lumbar spine (Wohlfahrt et al 1993). A higher static capacity of the abdominal muscles was found in subjects with a greater ability to perform trunk curl-up exercises. A weaker stabilising function was apparent in subjects who performed these exercises at a rapid rate (Wohlfahrt et al 1993). The capacity of the abdominal muscles to perform a dynamic function carries over to their stabilising function but only if a high volume of contraction repetitions is performed (Wohlfahrt et al 1993). Rapid movements primarily recruit the moving muscles without comparable activity in the muscles required for stability (characterised by an increase in the activity of the rectus abdominis but not of the oblique muscles). This may explain why low impact exercises that are performed slowly were found to be the treatment of choice in the management of lower back pain disorders (Timm 1994).

Muscle function therefore seems specific to the manner in which it is trained. It follows, that for the trunk muscle to provide optimal stability to the lumbar spine, these muscles need to be trained using slow contractions with many repetitions.

3.3.5 Mechanical loading on the lumbar spine during running

Mechanical loading of the lumbar spine during running will now be discussed. Firstly, the transmission of forces through the lumbar spine will be reviewed and secondly the compensatory mechanisms to reduce these forces on the lumbar spine will be discussed.

3.3.5.1 Force transmission through the lumbar spine during running

A repetitive reaction force of 2000N is generated at heelstrike during running (Carrigg and Hillemeyer 1992). The impact following the airborne state is absorbed on one leg only and as such greater loads are imposed on the supporting limb (Bach et al 1985). It has been calculated that for a runner of 70 kg with a stride length of 1.5m, as much as 60 tonnes per km of force is transmitted to the body while running (Van Mechelen 1992).

The repetitive compressive force during running acts on the vertebral body in all directions. The intervertebral disc is compressed by the axial loading force (Carrigg and Hillemeyer 1992). This compresses blood into the sub-chondral post-capillary venous network which then reduces the bone volume and dissipates energy (Norris 1995b). However, this shock-absorbing property is reduced as blood slowly returns during the release of this axial compression. Dynamic loading (as in running) results in a greater degree of discal height shrinkage compared with static loading (Carrigg and Hillemeyer 1992).

In a study of 18 - 25 year-olds, a reduction in vertebral column height and lateral flexion after a 7-mile run was documented (Carrigg and Hillemeyer 1992). A 3.25-cm height loss has been associated with a 6 km easy run (Leatt et al 1986). No significant differences were evident between young (20-27) and older (50-57) year-old group of runners with respect to vertebral column height reduction after a 9 km run (Ahrens 1994). However, within the groups, significant decreases of vertebral column height and range of motion were evident. The loading imposed through running therefore actually compresses the lumbar spine segments limiting full range of motion in any runner of all age groups.

Disc compression reduces shock absorption and elasticity of the disc material and may make the vertebral column more vulnerable to injury (Carrigg and Hillemeyer 1992). The axial force during running may also injure the facet joints which are compressed. Bony sclerosis may occur causing alteration of normal motion in that motion segment. However, no studies have investigated this.

When the spine is being strained (e.g. in response to an applied flexor moment), the abdominal and thoracic cavities are actively pressurised (Grew 1980). The intra-abdominal pressure response is reduced in a flexed posture compared to an upright posture (Grew 1980). A poor posture during running such as excessive lumbar flexion can result in detrimental loads on the lumbar spine (Cappozzo 1983) because of a reduced intra-abdominal pressure protection ability.

3.3.5.2 Compensatory mechanisms to reduce mechanical loads on the lumbar spine during running

It has previously been stated that increased intra-abdominal pressure can reduce mechanical loads (axial, compressive, torsional and flexion-extension) on the spine (Cresswell, Blake and Thorstensson 1994). In runners, an increase in intra-abdominal pressure has been documented just prior to heel-strike (Cresswell, Blake and Thorstensson 1994). This may be a neural strategy designed to prepare the trunk for loadbearing. This mechanism is dependent on co-ordination of muscle contraction (Cresswell, Blake and Thorstensson 1994). In another study changes in intraabdominal pressure were observed during lifting manoeuvres. Intra-abdominal pressure was found to increase with increased load on the lumbar spine and this may help protect the lumbar spine when subjected to the increased forces involved during running (Cresswell, Blake and Thorstensson 1994). A further compensation strategy employed by the body to attenuate forces imposed during running is to increase the range through which the muscles of the lower extremity are active. There is an increase in the range through which the muscles of the lower extremity are active in order to aid in the absorption of stress from the increased load of running compared with walking (Bach et al 1985).

The importance of proprioceptive training to achieve co-ordination and balance in the lumbar spine has been suggested (Norris 1995a). Neuro-muscular retraining (co-ordination and muscle balancing training) can result in an increased tension of the muscles to improve an athlete's ability to attenuate forces converging onto the lower back (DeRosa and Porterfield 1992). It may therefore be important to teach specific patterns of movement to reduce strain on the lumbar spine.

It can be hypothesised that during running the lumbar spine would need to have optimal function of stabilisation mechanisms such as: muscle function (stability, strength, endurance, balance, fatigue-resistance and flexibility), normal joint movement and optimum neural control of the dynamic stabilisers.

3.3.6 Lumbar -pelvic rhythm

There is a normal lumbar-pelvic rhythm when one pelvic tilt position synchronously changes to another. Normally, hip flexion must be greater than lumbar flexion and hip flexion should occur first during activities of daily living (ADL) (Norris 1995b). Pelvic tilting affects the lumbar spine and is controlled by intrinsic factors and extrinsic factors. Intrinsic factors are the shape of the sacrum, intervertebral discs and lumbar vertebrae, inclination of the sacral end plate, the length of the ilio-lumbar ligament and obliquity of the pelvis. Extrinsic factors are muscle attachments to the pelvis and lumbar spine and affect lumbar-pelvic rhythm by contraction (active) and or inflexibility (passive). These muscles include abdominal muscles, hip flexors, erector spinae, gluteal muscles and hamstring muscles (Siff 1991).

It is hypothesised that pelvic tilting maintains the neutral lumbar curvature by placing the least stress on the lumbar spine as the tilt changes during excessive flexion or extension. There are three degrees of freedom of pelvic rotation. These are anterior-posterior tilting and superior and inferior lateral tilting which occur with normal walking and running; and rotation about a vertical axis (Siff 1991). During standing the degree of pelvic tilt is related to the degree of the lumbar lordosis (Walker et al 1987). One of the potential extrinsic factors that affects the pelvic tilt is the abdominal muscle function. Abdominal muscle contraction can tilt the pelvis posteriorly, thereby decreasing the depth of the lumbar lordosis. Excessive lumbar extension can place mechanical strain on the spine and an abdominal muscle contraction would reduce the extensor curve in the spine by flexing it gently.

In one study a poor correlation between abdominal muscle function (eccentric contraction of leg-lowering), pelvic tilt and the lumbar lordosis was documented

(Walker et al 1987). In this study minimal electromyographic activity in the abdominal muscles was demonstrated during neutral standing. These authors postulated that the relationship between abdominal muscle function and pelvic tilting appears to be related to muscle length and not muscle strength (Walker et al 1987). An increase in abdominal muscle length and inflexibility of the hip flexors is believed to result in an anterior pelvic tilt (Norris 1995b). Therefore other factors and other muscles are considered to affect this relationship too. These factors have not been specified (Walker et al 1987).

It has also been hypothesised that the relationship between inflexible hamstring muscles and lower back pain in distance runners may be as a result of repetitive shortrange use of the muscle in fast running (Lindgren and Twomey 1988). Inflexible hamstrings will rotate the ischial tuberosities and the pelvis posteriorly thereby reducing the normal lordosis of the lumbar spine causing spinal dysfimction (Lindgren and Twomey 1988). During normal gait the pelvis needs to tilt anteriorly to maintain hip extensor power. It is possible to speculate that the need to tilt the pelvis anteriorly is likely to be exaggerated during running and may increase the stress on the lumbar spine. The finding that gluteal activation and pelvic stability are reduced in lower back pain sufferers may support this hypothesis (Bullock-Saxton et al 1993).

The majority of the literature presented in this section are hypotheses of the risks for lower back pain as a result of imbalances between the muscles acting around the pelvis and lumbar spine. These imbalances affect the motion segment leading to injury of the spinal tissues. For the purpose of this study, the exact nature of the imbalance (either resulting in an anterior or posterior pelvic tilt) is not considered important. Rather, the study acknowledges their presence and makes the assumption that the consequences of such imbalances is an increased force transmission and therefore strain on to the lumbar spine is considered critical.

3.4 Predisposing factors to lower back pain in runners

3.4.1 Introduction

Factors predisposing to injury in runners were discussed in Section 2.5. All these factors may have a role in the development of lower back pain in runners. Risk factors for running injuries can be 1) related to the running environment and would include equipment (shoes), terrain and weather conditions; 2) related to running and would involve training practices and; 3) related to the runner and would include the runner's age, gender, somatotype and functional factors.

The following section will review the possible functional factors which may predispose a runner to developing lower back pain. In particular, the role of the lumbar spine stabilising mechanisms, including the role of muscular function in protecting the runner from developing lower back pain will be discussed.

3.4.2 Functional factors that may predispose to running-related lower back pain

A number of functional factors may predispose to the development of running-related lower back pain. These include poor muscular stability, muscle imbalance, decreased muscle strength, muscle fatigue, musculotendinous inflexibility, abnormalities of motion segment stability, decreased range of motion and others. These factors and their potential role in the development of lower back pain in runners will now be reviewed.

3.4.2.1 Poor muscular stability

The dynamic stability of a joint refers to the ability of muscles around a joint to control its whole range of movement. It has been postulated that in the lumbar area, a lack of dynamic stability can lead to an increased stress being placed on the spinal tissues, consequently structures such as ligaments and musculotendinous junctions become either inflexible or more flexible (D'Orazio 1993). This can lead to a restriction or an excessive motion of spinal joints. Trunk muscle activity is vital for lumbar spine stability because of the inherent unstable structure of the spine (Hodges and Richardson 1997). A lack of localised muscle support may lead to recurrences of lower back pain (Hides et al 1996).

It is hypothesised that weakness of the pelvic stabiliser muscles (internal obliques and hip abductors) and lumbar stabiliser muscles (transversus abdominis and multifidii) can result in poor lumbar-pelvic stabilisation. This will cause excessive motion in the lumbar spine which may increase shear forces, compressive forces and tensile forces to the spinal structures (Norris 1995a). Excessive movement of the lumbar spine may also be a reflection of the inability of the stabilising muscles to co-ordinate an appropriate muscular force which is necessary to support the spine under load (Jull et al 1993). This may be one of the possible processes involved in the development of lower back pain. Furthermore, the lateral abdominal stability synergists may not be optimally recruited even in asymptomatic individuals (Jull et al 1993).

It is suggested that stability mechanisms protect the lumbar spine from injury when subjected to loading (Wohlfahrt et al 1993). There are no scientific studies to support this hypothesis as a cause for lower back pain in runners. However, the role of poor muscular stability has been investigated in patients with lower back pain. In one study, muscular control has been found to be poor in the lumbar region in subjects with chronic lower back pain compared to those with no pain (Soderberg and Barr 1983). Inadequate endurance of the erector spinae muscles has been hypothesised to be a contributing factor to idiopathic lower back pain (Moffroid et al 1993, Jorgensen and Nicolaisen 1987).

A high isometric endurance of the back muscles (extensors) has been shown to protect the lumbar spine from lower back pain (Biering-Sorenson et al 1989). This active protection of the lumbar spine is important in the prevention of lower back strain during exercise (Richardson et al 1992).

The need to stabilise the lumbar spine to reduce physical stress on the motion segment has been discussed. Scientific evidence suggests that the functioning of the stabilising muscles (transversus abdominis and multifidus) is poorer in those suffering from lower back pain (Jull et al 1993, Hides et al 1996). Muscular endurance, which refers to the ability of a muscle to maintain a contraction and therefore maintain a specific posture (thereby enhancing stability) has also been shown to be poorer in those with lower back pain when compared with subjects without lower back pain (Soderberg and Barr 1983, Moffroid et al 1993, Jorgensen and Nicolaisen 1987).

3.4.2.2 Muscle imbalance

Muscle imbalances occur when muscles are constantly shortened or lengthened with respect to each other. A shortened muscle group shows a lowered contraction irritability threshold (that is it is more easily excited to contract) because the muscle is pre-tensioned and accordingly a contraction is easily induced. This means that the muscle is recruited first (Norris 1995d). The sequence of muscle contractions or firing pattern, is therefore affected. The repetition of certain movement patterns can lead to patterns of overactivity in some muscles and a relative underactivity in others (Richardson et al 1992). Some muscles are therefore overused while others seldom contract. An example of muscle imbalance as a possible cause of lower back pain in runners is the cross-pelvic syndrome which has been suggested by Janda (Christie et al 1995). In this syndrome inflexible hip flexors may inhibit the hip extensors and this results in an excessive anterior pelvic tilt. This causes elongation of the abdominal muscles by virtue of the excessive anterior pelvic tilt and then predisposes them to underactivity and subsequent weakness (Sahrmann 1992).

A second example of a possible muscle imbalance has been proposed by Norris (1995d). An imbalance between inflexible hip adductors and overactive tensor fascia lata and quadratus lumborum muscles can cause reciprocal inhibition of the gluteus medius and minimus muscles. This imbalance may lead to poor pelvic stability. The hip abduction movement pattern during running would therefore be altered as it would be controlled by the tensor fascia lata and quadratus lumborum muscles rather than by the gluteal muscles (Norris 1995d). This imbalance (due to shortening of the hip adductors) results in delayed contraction of the gluteal muscles while the shortened tensor fascia lata is activated too soon and the abduction movement occurs with a compensatory flexion and external rotation movement (Norris 1995d). These movements may cause pelvic rotation or tilting disturbing the lumbar-pelvic relationship during running.

Finally, postural imbalances such as excessive flexion or extension of the spine can result in an increased stress placed on the musculo-skeletal system and may cause pain (Jull et al 1993). Ideally a runner should therefore avoid slumping into a flexed posture (Brody 1995) or running with a hyperextended posture.

The three abnormalities of muscle balance (Christie et al 1995, Norris 1995d, Jull et al 1993) that have been described have not been investigated in scientific studies. Accordingly there are no data to support these hypotheses as factors related to lower back pain in runners.

3.4.2.3 Decreased muscle strength

It has been postulated that decreased trunk muscle strength is an aetiological factor in lower back pain (Rissanen et al 1995). Patients with lower back pain have frequently been found to have weaker static and dynamic trunk flexor and extensor muscle contractions compared to those without lower back pain (Van der Valk et al 1995, Moffroid et al 1993, Liemohn et al 1983, Smidt et al 1983, Klein et al 1991).

In one case control study, static and dynamic measures of trunk flexor and extensor strength and endurance were performed in patients with lower back pain and a control group (Smidt et al 1983). The peak abdominal muscle and lumbar extensor muscle strengths in the control group was found to be 48 - 82% stronger compared with those suffering from lower back pain (Smidt et al 1983). However, in a clinical trial study, static trunk extensor strengths in a group of rowers failed to correctly identify subjects with and without lower back pain (Klein et al 1991).

The role of isometric and isokinetic muscle strength testing of extensor muscle strengths in patients with lower back pain is controversial. There is considerable variation in methods, procedures, equipment, contraction types (isometric, concentric, eccentric) and velocity of contraction used in studies where trunk muscle strength was evaluated. Results have therefore varied, and there is a lack of consistency in the differences in trunk muscle strength of healthy subjects and those with lower back pain (Shirado et al 1995).

In one case control study, 50 patients with lower back pain were compared with 50 control subjects with respect to flexor and extensor peak torques / body weight and flexor / extensor peak torque ratio during concentric and eccentric contractions; and eccentric / concentric peak torque ratios in the trunk flexors and extensors (Shirado et al 1995). The results showed that the extensor muscles were weaker in those complaining of lower back pain: the extensors in the male subgroup showed a peak torque to body weight ratio at 30 degrees / second of approximately 3 : 1 compared to that of those with chronic lower back pain of 2 : 1. For eccentric contractions in this same group under these same conditions the ratio was approximately 4.5 : 1 in the control group as compared to 4 : 1 in the pain group. This was not statistically different. In the female subjects, both concentric and eccentric contractions were statistically different. The ratios for the concentric test being approximately 2.2 : 1 in the control group and 1.2 : 1 in the lower back pain group. For the eccentric test, the ratio for the control group was approximately 3.5 : 1 compared to 2.5 : 1 for the lower back pain group.

There was also an imbalance between concentric and eccentric strengths of both the flexors and extensors in the lower back pain group. When testing the male subgroup at 30 degrees / second, these ratios were 1.4 : 1 for the control group compared to 1.8 : 1 for the lower back pain group in testing of the flexors while in the extensor group this ratio was 1.5 : 1 in the control group and 2.1 : 1 in the those with lower back pain. The female ratios followed a similar pattern. In a previous study by these same authors comparing absolute muscle strength between control and lower back pain subjects, it was found that flexor and extensor muscle strength were likely to be less in the chronic lower back pain group, although this was not confirmed statistically (Shirado et al 1995).

The difference in strength between the trunk flexors or extensors in lower back pain have also been investigated in a recent study (Shirado et al 1995). Back extensor muscles were found to be weaker in subjects with lower back pain compared with controls. Maximal muscle torque was found to be greater in the back muscles (extensors) compared to the abdominal muscles (flexors) in control subjects (Hasue et al 1980). Assessment of the maximal muscle torque for the male subgroup in their third decade for isometric contractions of the abdominal muscles was 124.6 ± 25.4 foot / pounds compared to 154.5 ± 18.8 foot / pounds in the back extensor muscle groups.

In abdominal strength training, most notably resisted trunk rotation has been shown to increase intra-abdominal pressure (Cresswell, Blake and Thorstensson 1994). In one clinical trial (15 subjects), 10 weeks of specific abdominal training (resisted trunk rotations) increased the intra-abdominal pressure by 12%. The rate of this intra-abdominal pressure development was improved during functional activities by increasing the strength of the trunk rotators. A rise in intra-abdominal pressure has been suggested to protect the spine as it provides an additional extensor moment to the spine during flexion loading of the spine (Norris 1995c).

In summary, it appears that decreased trunk muscle strength (both flexors and extensors) is associated with lower back pain (Smidt et al 1983, Shirado et al 1995). Furthermore, trunk muscle strength training can increase intra-abdominal pressure which may be protective against the development of lower back pain because of it's stabilising role (Cresswell, Blake and Thorstensson 1994). However, trunk muscle weakness has not been investigated as a specific cause of lower back pain in runners.

3.4.2.4 Muscle fatigue

Normal movement of the spine depends on passive mobility and active stability. Muscle contractions are responsible for this active stability and muscles can be divided into postural muscles and phasic muscles dependent on the muscles' reaction to physical stress and injury (Jull and Janda 1987):

- Postural muscles are proportionally stronger than their phasic counterparts. They tend to become inflexible and are therefore likely to develop painful trigger points and their irritability threshold is accordingly lowered (Norris 1995d). There may be reciprocal inhibition of the muscle's antagonist due to this overactivity.

- Phasic muscles are antagonistic to the postural muscles and show a tendency to weaken and lengthen with inactivity and following injury.

Muscles are also classified as being either stabilisers or movers (Norris 1995d). The stabilisers are characterised by their ability to be fatigue resistant. They are capable of sustaining a contraction for a long period of time at a low intensity of contraction. These muscles are therefore appropriate to stabilise the body segments. The movers are the primarily responsible for movement of the body segments. These muscles are capable of powerful contractions, yet fatigue rapidly. They are therefore not designed to stabilise the body but rather move the various body segments.

The function of the muscular system around the spine is to provide support and control of joints during movement and this involves a coordinated interaction between many muscles. In the lumbar spine, the abdominal muscles and back extensor muscles support the spine acting as "guy wires" (Nuber et al 1995). The different muscle groups that comprise the back musculature contract in an alternate fashion thereby sustaining the necessary force to limit the development of fatigue (D'Orazio 1993). The back extensor muscles are highly specialised and are composed of a large number of type I fibres, with a large cross sectional area, to provide high levels of force that can be sustained over long periods to maintain posture and provide movement (D'Orazio 1993). The deeper muscles are shorter, often spanning over only one joint. These are more suited to ensuring stability at specific motion segments.

Back muscles overlap each other and share common insertions into the thoracolumbar fascia. The deep muscles (multifidii) and the anterior-lateral abdominal stability synergists (transversus abdominis and internal oblique) work together to maintain optimal stability of the lumbar spine (Hodges and Richardson 1996). It is by strengthening the transversus abdominis muscle (the deepest of the abdominal muscles) that the function of the deeper back muscles is facilitated (Hodges and Richardson 1996). It has been postulated that any impairment in the synchronous contractions of these muscles may result in injury because there would be reduced support and therefore increased mechanical stress to the motion segments.

The development of muscle fatigue could therefore compromise the function of the back stabiliser muscles (D'Orazio 1993). If the muscles can no longer maintain the tension demanded by the task, injury to the muscles or other structures may result (Risch et al 1993). However, more research needs to be conducted to substantiate these theories.

It has been suggested that the obliques and transversus abdominis muscles are not always optimally recruited and the development of fatigue may decrease their stabilising role (Jull et al 1993). It appears that the abdominals (trunk flexor muscles) of patients who complained of lower back pain are usually more susceptible to fatigue (Smidt et al 1983). Trunk muscles are more easily fatigued by sustained contractions than repeated contractions with the abdominals being affected more than the extensors (Hasue et al 1980).

As muscle contraction is responsible for active stability of the lumbar spine, muscle fatigue would result in an inability of the muscles to provide support to the lumbar spine (Hodges and Richardson 1996, Risch et al 1993). Furthermore, even though muscle firing is arranged to function in a synchronous manner to prevent fatigue, their improper use (by the phasic and not the postural muscle types) may result in fatigue

(Jull et al 1993). Finally, it has been shown that the muscles of subjects with lower back pain are prone to fatigue while those without lower back pain have a greater resistance to the development of fatigue (Smidt et al 1983, Hasue et al 1980).

3.4.2.5 Muselotendinous inflexibility

In general, musculotendinous inflexibility is poorly related to injury predisposition in all injuries (Brunet et al 1990, Van Mechelen 1993). Stretching exercises have not been related to the prevention of running injuries in general (Van Mechelen 1993). However, this study did not investigate the relationship between musculotendinous inflexibility in specific muscle groups and injuries.

In one study in runners, decreased flexibility of the flexor muscles was related to injuries in runners (Bach et al 1985). The development of low back pain has also been suggested to be related to inflexibility of the hamstrings muscles (Warren and Davis 1988).

It has also been suggested, based on clinical observations that a lack of trunk extensibility can induce low back pain during jogging (Slocum and James 1983) and that long distance runners develop inflexibility of the external rotators of the hips and the back extensor muscle groups (D'Orazio 1993). However, these hypotheses have not been investigated in well conducted studies.

3.4.2.6 Abnormalities of motion segment stability

Every joint has a normal stiffness (resistance to movement) (Maitland 1991). Alterations in this stiffness would render the joint either hypermobile if there was an excessive laxity in the joint, or hypomobile if the joint were less flexible than normal. In the spine, changes in the normal stiffness of the spinal structures would affect the function of the motion segment. It has been suggested that localised segmental instability or abnormal coupled motions are associated with an increased frequency of recurrent lower back pain (Burton and Tillotson 1989). Furthermore, it has also been suggested that ligamentous or capsular stiffness of the joints are associated with the development of lower back pain (Mellin 1990). In a single study, intervertebral instability, defined as excessive range of physiological and translatory motions, was found to be the cause of pain. It may therefore be important to identify hypomobile or hypermobile segments in patients with lower back pain (Behrsin and Andrews 1991).

3.4.2.7 Decreased range of motion

Range of motion tests are performed to determined whether the length of muscles and the compliance of soft tissues are adequate to permit normal function (Ada and Herbert 1988). Lower back pain was reported to affect spinal range of motion (Williams et al 1993). Range of motion measures of the lumbar spine can therefore be used as a measure of spinal function. However, Klein et al (1991) observed no significant difference between normal healthy people and lower back pain patients with respect to joint ROM. In another study reviewing possible risk factors for lower back pain, no such relationships were noted either (Pope 1989).

3.4.2.8 Other possible functional factors predisposing to lower back pain in runners

A number of other functional factors may also predispose to the development of lower back pain in runners. In a review article, hypermobility at the SIJ as a result of overstretching of the lower back and an altered mobility of the trunk and hip joint were suggested as possible contributing factors to the development of lower back pain (Liemohn et al 1988). In another study, decreased internal rotation of the hip joint was found to be more prevalent in those suffering from lower back pain than in a group of healthy subjects (Ellison et al 1990).

3.5 Summary

Low back pain accounts for about 5 - 10% of all injuries. There are no studies that have identified specific aetiological factors associated with lower back pain in runners. Identifying specific aetiological factors for lower back pain in runners is fundamental to plan an efficient management program for runners suffering from lower back pain.

This literature review considered 1) the biomechanics of the lumbar spine, in particular important biomechanical considerations related to running, and 2) evidence that specific factors are related to lower back pain in runners.

Mechanical loading is important for normal joint function. The four main mechanisms by which stability is provided to the lumbar spine are by; 1) attachments of the internal oblique and transversus abdominis to the thoracolumbar fascia (TLF), 2) increased tension produced by the contraction of the paraspinal muscles which lie between the middle and posterior layers of the thoracolumbar fascia, 3) the intraabdominal pressure (IAP) mechanism. Abdominal muscle activity is associated with an increased IAP. The muscles of the ventro-lateral abdominal wall which are the obliques and transversus muscles, the erector spinae, diaphragm and pelvic floor muscles contract to increase the IAP, and 4) the stabilising role of the deep lumbar extensor muscles. Compensation mechanisms to relieve mechanical loading on the lumbar spine involve a co-ordination between the active and neural stabilising mechanisms. Improved neural control over muscle action results in an improved muscle strength, endurance and control. An increase in the intra-abdominal pressure and an increase in tension of the thoracolumbar fascia have been shown to occur with increased loading of the spine.

Specific postulated predisposing factors to the development of lower back pain in runners are related to a disturbance in the functioning of the compensation strategies mentioned above (poor stability, muscle imbalances, weakness, fatigue) as well as to any increase in the load or nature of this load imposed on the spine while running.

Further possible predisposing factors to the development of lower back pain in runners include poor musculotendinous flexibility, altered (increased or decreased) motion segment control or injury to the sacroiliac joint.

However, none of these factors have been investigated in well conducted studies in a group of runners. This thesis will describe a study designed to document the association between some of these factors and lower back pain in runners.

4 Chapter 4

The epidemiology of lower back pain in distance runners.

4.1 Introduction

Although lower back pain is common in the general population, the incidence of lower back pain from sports participation has been poorly reported. There are no studies investigating the incidence and lifetime prevalence of lower back pain in runners. In a review of running injuries in general, lower back pain had a frequency of only 10% (Van Mechelen 1992). Furthermore, in clinical practice, running is sometimes regarded as a contraindication for a patient suffering from lower back pain and yet there is little evidence that lower back injuries occur in runners. It is the view of the author that any production of pain (even that which does not cause cessation of activity) would affect performance. In this study all forms of back pain induced by running are therefore included.

Only the frequency of lower back pain has been investigated in previous case series studies. Furthermore, the injury of lower back pain was only documented if it prevented running altogether. Running-related lower back pain has therefore had a very low frequency of 11 - 13% in these studies (Lysholm and Wiklander 1987, Walter et al 1989). There have been no attempts to identify any risk factors specifically for the development of lower back pain in runners or to describe the nature of running-related lower back pain. During this study, the exact nature of this lower back pain in runners was investigated as were the effects of loading (training practices) and the runners' attempts to treat or prevent it's recurrence.

The most significant risk factors for running-related injuries have included: excessive running distances, poor running experience, previous injuries and running to compete (Van Mechelen 1992). These risk factors have however, not been related to the occurrence of lower back injuries.

This present study is a descriptive study of a random sample of active middle to long distance runners. It was cross-sectional as lower back pain and its aetiology was described relative to the runner's response and experience of the problem at the time of the interview. This gave the examiner an opportunity to view all factors relating to lower back pain in running at a glance.

4.2 Aims of the study

The first aim of this study was to determine the annual incidence and lifetime prevalence of lower back pain in runners. A second small aim was to identify running-related factors associated with lower back pain in runners in terms of training and demographic variables.

4.3 Methodology

4.3.1 Subjects

Subjects for the study were runners who were randomly selected by approaching them at the finish of local club road races during the track season. The selection of races included two 10km, two 15km and two half -marathon (21 km) races. A total of 225 runners agreed to take part in the study. All the runners completed a baseline questionnaire (Appendix 2) under the supervision of the principal investigator.

This part of the study was divided into two parts. The first part was a descriptive study to determine the incidence and prevalence of lower back pain in runners as well as the nature of training regimes of this population of runners. A small second part was comparative in terms of demographic and training variables between those who complained of lower back pain and those without lower back pain (control group) that is a pain and non-pain group. These two groups were obtained from the full sample (n = 225) of runners interviewed, the lower back pain group comprising all runners who reported that they had a running-related lower back pain and the control group included all runners without lower back pain. A small sample from the full sample was excluded from this comparison, as these were runners who had a history of lower back pain not related to running. A more detailed comparison between the "pain" and "non-pain" groups of runners is investigated in the following chapter (chapter 5).

4.3.2 Questionnaire

This questionnaire (Appendix 2) was designed to determine the nature and characteristics of running-related lower back pain in a sample of road-runners. The lifetime prevalence (in answer to a question of ever having had a running-related lower back pain) and annual incidence (in answer to a question of running-related lower back pain in the previous 12 months) in running-related lower back pain was determined.

The following information was obtained from the questionnaire:

- subject demographics (age, height, weight, sex, occupation),
- a detailed history of any lower back pain (mechanism of origin, aggravating and relieving factors and associated symptoms),
- running history (running discipline, level of competition, years of running),
- training practices (running distance, frequency and intensity),
- the use of stretching, warming-up and cooling-down routines,
- shoe and orthotic wear, and
- other general running-related injuries and injury history.

Information with respect to age was sought, as various back pathologies have been associated with specific age groups. Body profiles of height and weight have also been hypothesised to be related with certain back pathologies. As posture and daily activities may have an effect on the development of lower back pain, occupations were classified into 4 groups: sedentary, standing, driving and manual work (Appendix 3). This selection process was aided by the respondent indicating that more than 50% of their day was spent driving, sitting, standing or manually working.

The nature of the lower back pain, that is its effect on the runner during a run, was also recorded to describe it, as were any aggravating or relieving factors. The treatment approaches of lower back pain in runners was also determined. An attempt was made to determine the role of various treatment modalities sought to relieve the lower back pain. This was done for two reasons. Firstly, to determine if physiotherapy treatment has a role to play in the management of running-related lower back pain; and secondly to determine which modalities were most effective in the treatment of this type of lower back pain. Specifically, previous exercise employed by the runner to alleviate their lower back pain was considered as was its effect of relief of this lower back pain.

Knowledge of diagnoses given was also obtained and any associated problems (lameness, numbness, pins and needles, loss of sensation, decreased muscle power or loss of sensation) associated with the lower back pain were investigated. These questions also helped describe the entity of lower back pain in runners.

For the purpose of this study lower back pain was defined as pain in the lumbar region, induced by running either during the run or within 2 hours after the run. All this information allowed for this entity of running-related lower back pain to be described.

Running-related variables were also considered. Running discipline was defined as a running specialty of track, cross-country and/or road-running. This selection and that of "level of competition" was determined subjectively by the runner but confirmed by an arbitrarily analysis of their best times for 10km, 15km and 21 km, road races.

Classification according to level of competition in male runners was as follows:

- A national runner was defined as the ability of a runner to average a racing pace of faster than 3 minutes 10 seconds per km,
- a provincial runner was defined as the ability of a runner to average a racing pace of faster than 3 minutes 30 seconds per kilometer,
- a club athlete was defined as the ability of a runner to average a racing pace of under 5 minutes per kilometer,
- a social runner was defined as the ability of a runner to average a racing pace of over 5 minutes per km as race pace.

A similar classification was made for female runners as follows:

- A national runner was defined as the ability of a runner to average a racing pace of faster than 3 minutes 40 seconds per km,
- a provincial runner was defined as the ability of a runner to average a racing pace of faster than 4 minutes per kilometer,
- a club athlete was defined as the ability of a runner to average a racing pace of under 5 minutes 30 seconds per kilometer,
- a social runner was defined as the ability of a runner to average a racing pace of over 5 minutes 30 seconds per km as race pace.

Training routines were also determined by obtaining information on the duration (hours, days, distance) and intensity of runs so that the effect of running load on lower back pain in runners could be determined.

Stretching, warm-up and cool-down routines were also investigated by obtaining information on the frequency of their use during training or racing. Further information was obtained regarding the nature of the stretching regime. Although flexibility has been poorly related to the incidence of injury in runners, inflexibility of some muscle groups has been hypothesised to predispose to back pain. Furthermore, the role of warm-up and cool-down routines, although poorly associated with injury, are commonly recommended and as such it is worth assessing their association (if any) with running-related lower back pain.

The type of shoe worn as well as the need and duration of any orthotic use was also determined. The reason for including these questions was to determine if the type of foot-wear worn had any relevance on the occurrence of lower back pain in runners as shoe type has previously been suggested as being implicated in running-related injuries (Warren and Davis 1988).

Other running-related injuries were also recorded.

The questionnaire also sought contact addresses and telephone numbers so that runners could be recruited for the second phase of the study which is described in Chapter 5.

The incidence of running-related lower back pain was calculated as the number of lower back pain complaints per 1000 running hours. This was determined by considering the total number of hours run per week by the whole group and the number of respondents complaining of lower back pain in one year. The number of lower back pain complaints per 1000 running hours was then calculated for this group.

4.3.2.1 Reliability and validity

Answers from prior completion of the questionnaire by five non-partaking subjects on three occasions showed no variance between answers.

The nature of each question was deemed valid by comparing the questions of previous studies' (Lysholm and Wiklander 1987; Warren and Davis 1988; Walter et al 1989) whose focus was to identify the epidemiology and aetiology of sports injuries.

4.4 Statistical Analysis

All statistical procedures were conducted at the medical research council using the SAS system. Descriptive statistics were used for the baseline characteristics of the study. A non- parametric analysis was done due to the skewness of the data. In all cases, $p \leq 0.05$ was taken as being statistically significant while $0.05 \leq p \leq 0.10$ was taken as being marginally different. Where categorical variables were compared, the Chi - Square test was used. The Fischer's Exact test (2 - Tail) was used where expected cell frequencies were less than 5. For the continuous variables, the Wilcoxon 2 - Sample test was used. Data were compared between subjects with and without running-induced related lower back pain.

4.5 Results

4.5.1 Subject Demographics

Two hundred and twenty-five subjects (males = 179, females = 46) were individually interviewed after six road races. However, some subjects failed to complete every question. For this reason the true population sample is given where necessary in brackets in the caption under each graph. Tables 4 and 5 summarise the demographic variables of the population sample (BMI = body mass index).

Table 4: Demographic variables of the male respondents (n=179)

Variable	Mean ± SD	Range
Age (years)	36.3 ± 9.5	16.0 – 65.0
Weight (kg)	72.5 ± 10.6	47.0 – 112.0
Height (m)	1.8 ± 1.8	1.5 – 2.0
BMI ($Kg.m^{-2}$)	23.4 ± 2.6	17.3 – 30.9

Table 5: Demographic variables for female respondents (n =46)

Variable	Mean ± SD	Range
Age (years)	36.8 ± 9.3	20.0– 54.0
Weight (kg)	58.7 ± 7.8	48.0 – 82.0
Height (m)	1.7 ± 0.9	1.5 – 2.0
BMI ($Kg.m^{-2}$)	21.3 ± 2.9	15.3 – 32.0

The occupations of the subjects were divided into four groups. Figure 1 summarises the study population by occupational category and gender.

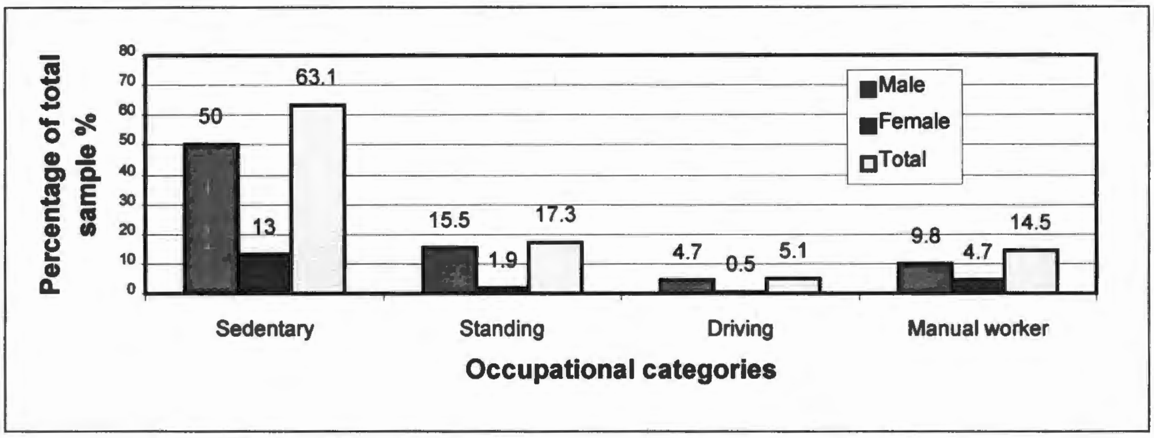

Figure 1: Occupational categories of the sample (n = 214)

There were no significant differences between the "pain" and "non-pain" groups with respect to occupation. For this reason no distinction was made between "pain groups" with respect to the construction of Figure 1. Appendix 3 outlines the various occupations listed in each of the four categories.

4.5.2 Prevalence of lower back pain in runners

The lifetime prevalence of lower back pain in this group of runners was 47% (n=105). Eighty-two percent of which was in the preceding year. This is equivalent to 1.42 episodes of lower back pain per 1000 running hours. The percentage annual incidence of lower back pain was 38.4%. Eighty percent (four-fifths) of those complaining of back pain were male. This gender ratio may be skewed as the number of male respondents far outweighed that of the female sample. Forty-one percent of the total sample (n=225) had suffered a previous back injury, with acute trauma accounting for 21.9% of all back pain, the remainder having a gradual or insidious onset. At the time ofthe interview, 51 % of all runners with a past history of lower back pain still suffered from lower back pain. The severity of lower back pain in the runners is depicted in Figure 2.

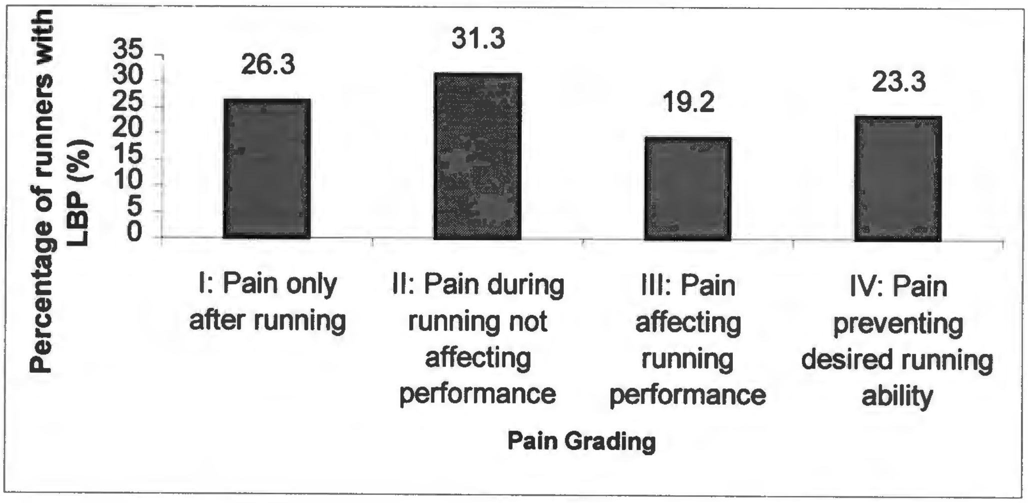

Figure 2: Severity of pain (grading I-IV) in the runners with lower back pain (n =99)

The frequency of aggravating or relieving factors for the runners with lower back pain are depicted in Table 6.

Table 6: Frequencies of reported aggravating and relieving factors in the runners with lower back pain (n=105)

Aggravating factors	% of total	Relieving factors	% of total
Longer runs	29	Bending forwards	32.
Uphill running	28	Stretching	31
Prolonged standing	24	Taking it easy	21
Downhill running	23	Lying on back	21
When tired / unfit	22	Bending backwards	11
Prolonged sitting	21	Lying on stomach	7
Increased running speed	13	Walking	6
End of run	11	Sitting	5
Beginning of run	6	Standing	4
Racing	5		

Lower back pain was most commonly aggravated by longer runs (29%), uphill running (28%), prolonged standing (24%), prolonged sitting (21%) or downhill running (23%), and being tired and unfit (22%). Bending forwards (32%), stretching (31%) and "taking it easy" (21 %) all gave relief of running-related lower back pain and bending backward (11%) also appeared to ease the back pain. Twenty-one percent found resting supine to relieve their back pain.

Of the runners complaining of lower back pain, 64.7% sought medical attention from different medical professionals. Most runners consulted a physiotherapist (56%) or a doctor (34%). Fewer consulted a chiropractor (25%) or an orthopaedic surgeon (22%) while a third of the population (33%) sought help from other professionals including orthotists, body stress release practitioners, first-aid attendants, biokineticians and acupuncturists. The subjective rating of the effectiveness of different physiotherapy treatment modalities for lower back pain conditions is depicted in Table 7.

Table 7: Subjective rates of effectiveness of the various treatment techniques and modalities sought (% of injured runners, n=105)

Treatment intervention	Effective (%)	Moderately effective (%)	Not effective (%)
Posture correction (n=10)	50	40	10
Muscle stretches (n=28)	46	50	4
Exercise (n=28)	43	43	14
Massage (n=28)	32	64	4
Mobilisation (n=7)	29	43	29
Manipulation (n=18)	17	67	17
Neural stretching (n=7)	14	86	0
Ultrasound (n=15)	7	73	20
Electrical stimulation (n=8)	0	75	25
Laser (n=6)	0	50	50

Hands-on manual therapy (massage, mobilisation and manipulation), postural modification, stretching and exercise regimes were perceived to be the most effective forms of treatment of running-related lower back pain in runners.

Only 50% of runners complaining of lower back pain were aware of the specific diagnoses of their lower back pain. These diagnoses could be categorised into 5 subgroups as follows:

- muscular damage (strain, spasm, trigger points) (38%)
- degenerated disc (21%)
- facet joint (10%)
- bony pathology (stress fractures, spondylosis, spondylolisthesis) (9%).

The cause of this running-related lower back pain was unknown by the medical professional in 22% of cases and was termed a mechanical back pain.

Of those complaining of lower back pain, 35.2% also reported the occurrence of one or more other symptoms. Figure 3 shows a breakdown of these associated symptoms expressing their frequency of occurrence relative to this population of 35.2%.

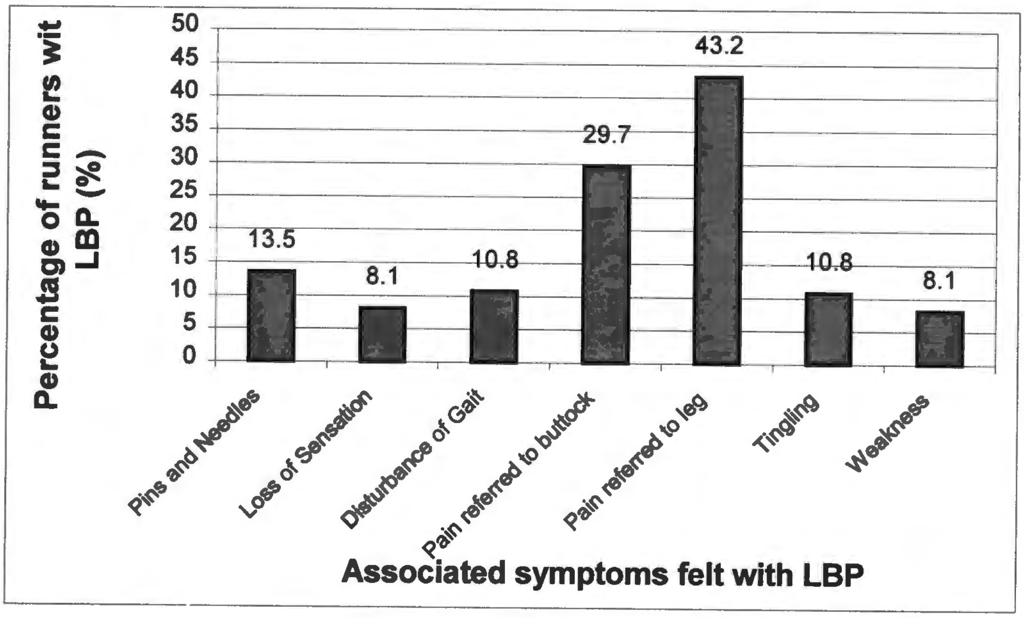

Figure 3: Associated symptoms reported by athletes with lower back pain expressed as a percentage of runners with lower back pain (n = 37)

Fifty-six percent of runners with lower back pain had participated in previous exercise(s) for their lower back pain. Again, frequently more than one type of exercise was employed. The frequency and types of exercises are depicted in (Figure 4).

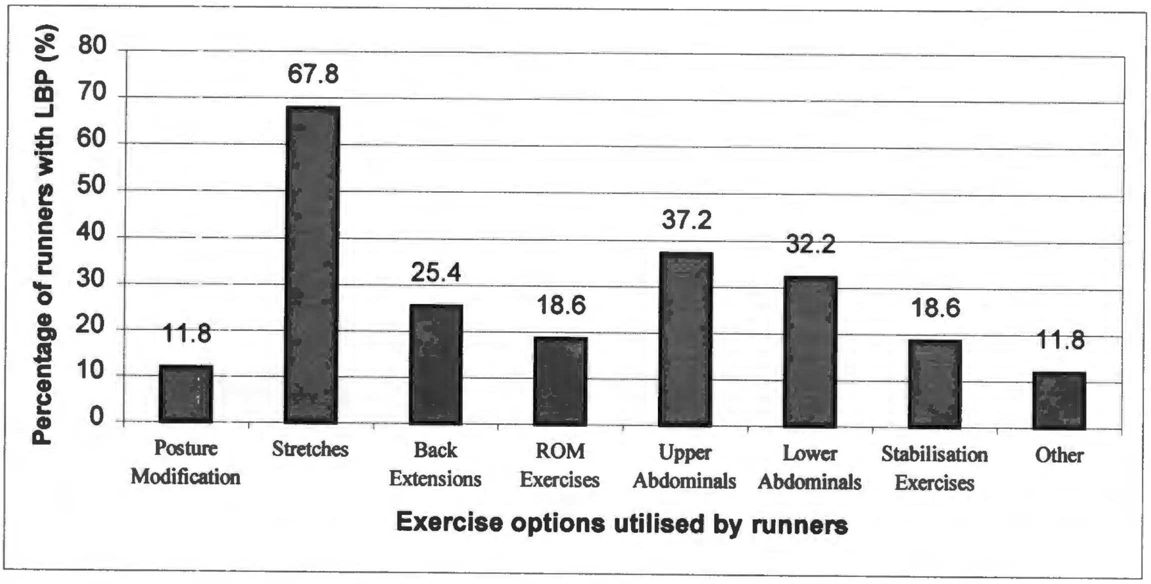

Figure 4: Exercise options utilised by runners with lower back pain to relieve 9 their discomfort expressed as a percentage of the pain group (n = 59)

4.5.3 Training

The running-related variables in the runners are reported for the male (Table 8) and female (Table 9) respondents.

Table 8: Running-related variables of the male respondents (n = 179)

Variable	Mean ± SD	Range
No. of years running (years)	8.8 ± 8.0	1.0 – 45.0
Hours run per week (hours)	5.2 ± 2.5	0 – 16.0
Days run per week (days)	4.7 ± 1.5	0 – 7.0
Distance run per week (km)	56.3 ± 25.0	10.0 – 160.0
Running intensity (minutes per km)	4.6 ± 0.6	3.3 – 6.50
Best time for 5 km (minutes)	19 ± 2.7	14.5 – 27.0
Best time for 10 km (minutes)	39.7 ± 5.9	29.9 – 59.0
Best time for 21 km (min)	78.6 ± 27.8	70.0 – 122.0
Races run per month (races)	2.8 ± 1.3	0 – 7.0

Table 9: Running-related variables of the female respondents (n =46)

Variable	Mean ± SD	Range
No. of years running (years)	7.6 ± 5.3	1.0 – 26.0
Hours run per week (hours)	5.2 ± 2.1	2.0 – 11.0
Days run per week (days)	4.8 ± 1.4	2.0 – 7.0
Distance run per week (km)	52.5 ± 25.7	15.0– 120.0
Running intensity (minutes per km)	5.1 ± 0.5	4.1 – 6.5
Best time for 5 km (minutes)	21.4 ± 2.8	17.8 – 28.0
Best time for 10 km (minutes)	46.0 ± 6.9	36.7 – 62.0
Best time for 21 km (minutes)	84.0 ± 32.9	98.0 – 127.0
Races run per month (races)	2.5 ± 1.2	1.0 – 5.0

Runners were selected from all running ages (16 - 65, mean = 36 years) and participated in most running disciplines (track, cross-country and road-running) (Figure 5). The average number of years of running was 8.5 years for the whole sample and 8.8 and 7.6 for the males and females respectively. Males had a respective range of running of 1.0 - 45.0 while females had been running for between 1.0- 26.0 years. The sample averaged 18 training sessions per month, each session lasting just over one hour.

The level of running disciplines among the runners is depicted in Figure 5 and the level of competition among the runners is depicted in Figure 6.

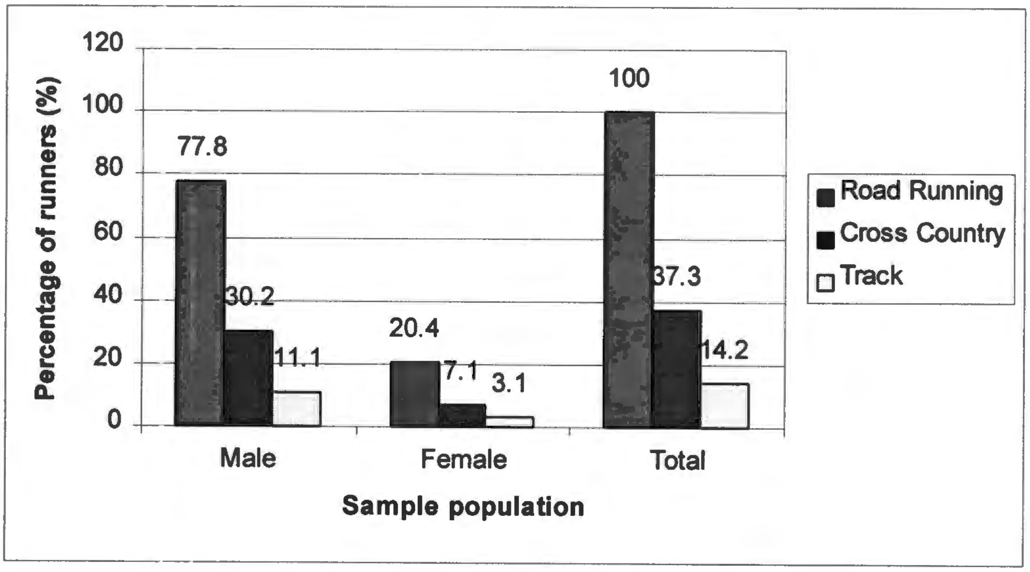

Figure 5: Distribution of running discipline according to gender (n=225)

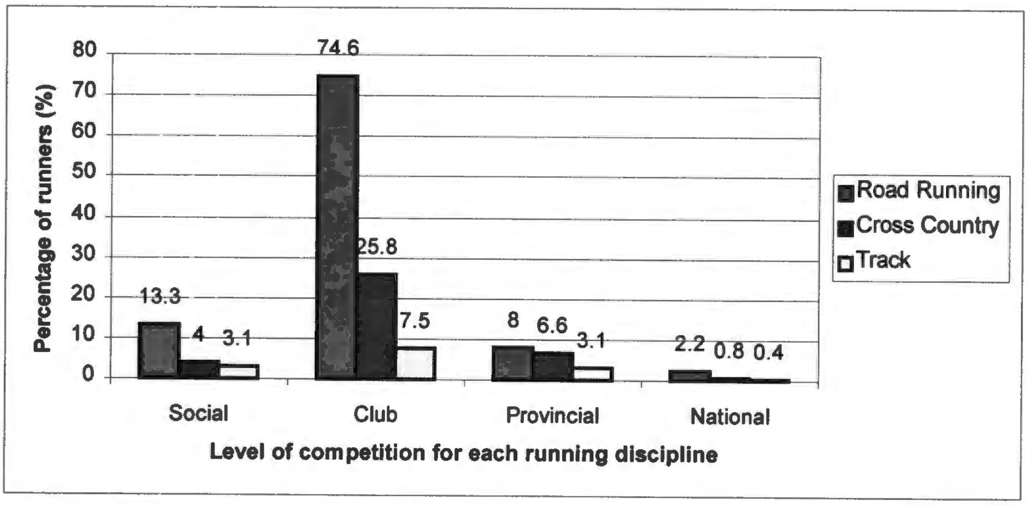

Figure 6: Level of competition by running discipline for the population sample (n=225)

The sample population consisted mostly of club road-runners, 50% of which competed in other running disciplines as well. All runners participated in road-running, compared with 37.3% (n = 84) for cross-country and 14.2% (n = 32) for track. Most runners competed at club level (75%).

Twenty-four percent (n = 42) of the runners claimed to wear an orthotic, 70% of these for more than 2 years. With regard to shoes, 60% wore neutrally aligned shoes while 25% and 15% used anti-pronation and soft / flexible shoes respectively. The most common brands of shoes worn were Asics (33%), Nike (29%), Adidas (16%) and Saucony (12.5%). There were no significant differences between the "pain" and "non-pain" groups regarding shoe type of the use of an orthotic.

Half of those suffering from low back pain related to running reported the occurrence of at least one other injury during the preceding year. These injuries were grouped as upper limb injuries (left: 7%, right: 6%) and lower limb injuries (left: 48% and right: 59%).

The following data displays the results from the second part of this study; that which compared those with and without lower back pain. Table 10 shows the comparison of all the demographic and training variables questioned in the first phase.

Table 10: Comparison of the lower back pain and control groups for demographic and training variables sought from the first questionnaire.

	"Pain" (LBP) group (n = 105)	"Non-pain" (Control) group (n = 120)
Variable	**Mean ± SD**	**Mean**
Age (years)	35.8 ± 8.6	38.4 ± 9.3
Weight (kg)	73.1 ± 9.5	68.1 ± 10.5
Height (cm)	174.5 ± 11.9	174.3 ± 8.1
BMI ($Kg.m^{-2}$)	24.2 ± 3.6 *	22.4 ± 2.4
Years of running (years)	6.6 ± 5.1	6.3 ± 5.3
Days run per week (days)	4.4 ± 1.5	4.8 ± 1.5
Distance run per week (km)	56.9 ± 26.9	58 ± 28.6
Hours run per week (hrs)	5.3 ± 2.4	5.7 ± 3.5
Average running speed (minutes per km)	4.9 ± 0.75	4.6 ± 0.43
5 km best time (min)	19.3 ± 3.1	18.8 ± 2.4
10km best time (min)	42.4 ± 6.9	42 ± 6.7
21 km best time (min)	86.6 ± 27.9	84.2 ± 20.9
Races per month	3.2 ± 1.4	3 ± 1.3

* = $p < 0.05$ LBP versus control group

There was a tendency ($p = 0.055$) for the "pain" group to have an increased body mass compared with the "non-pain" group. The BMI (kg/M^{-2}) scores were significantly lower in the "non-pain" group compared with the "pain" group ($p = 0.042$). Comparison of the other demographic variables showed no significant differences of age, gender, and height between groups.

There were no significant differences between the "pain" and "non-pain" groups of runners with respect to number of years of running; days, distance and hours run per week; running intensity and best times for 5, 10 and 21 km (Table 10). There were also no differences with respect to running discipline or level of competition (Figures 5 and 6), or the number of races run per month (Table 10).

4.5.4 Stretch, warm-up and cool-down routines

Most athletes claimed to stretch (90% of the sample) and those who stretched reported the use of long sustained holds. Fifty percent of runners held the stretch for 20 - 60 seconds (Figure 7). Figure 8 gives a breakdown of the body areas that were being stretched.

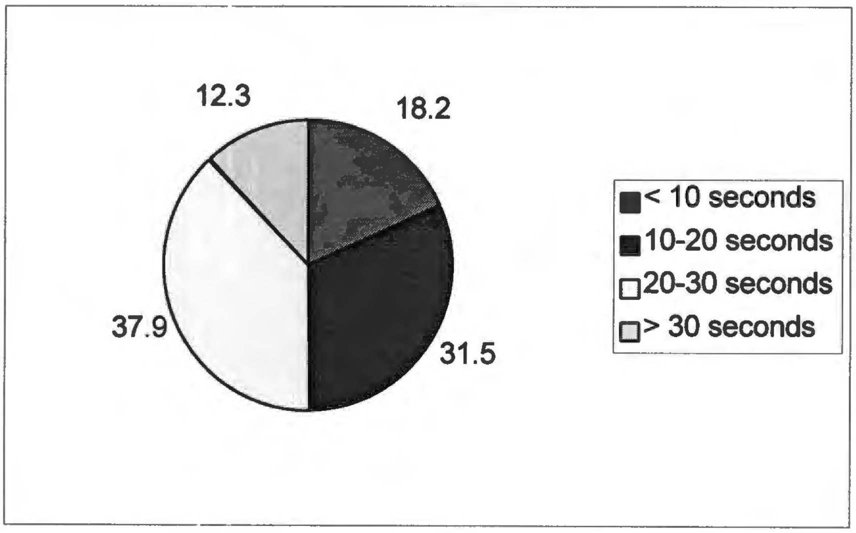

Figure 7: The duration of stretching time expressed as a percentage of the runners. (n = 203)

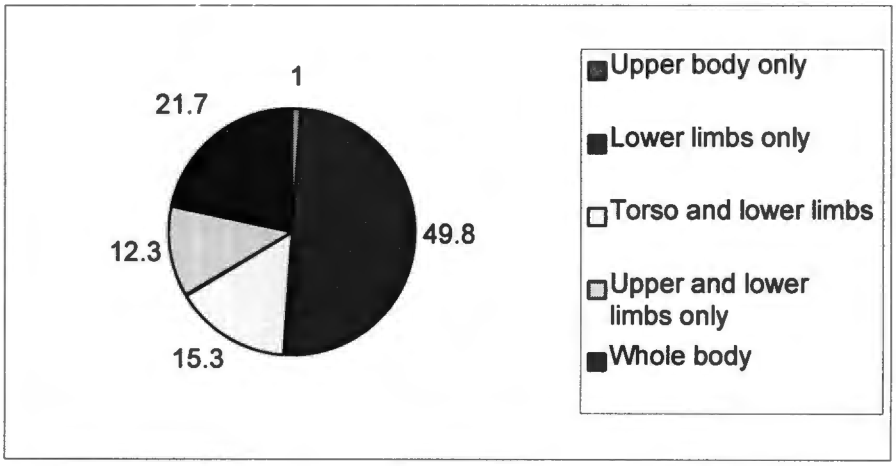

Figure 8: Anatomical areas stretched expressed as a percentage of the runners. (n = 203)

The control group stretched prior to training (p= 0.028) and racing (p = 0.003) significantly more than the "pain" (lower back pain) group. An analysis showed that there were no statistical differences between the "pain" and "non-pain" groups with respect to warm-up and cool-down routines. Therefore these data were combined for the whole group and are displayed in Figures 9 - 11.

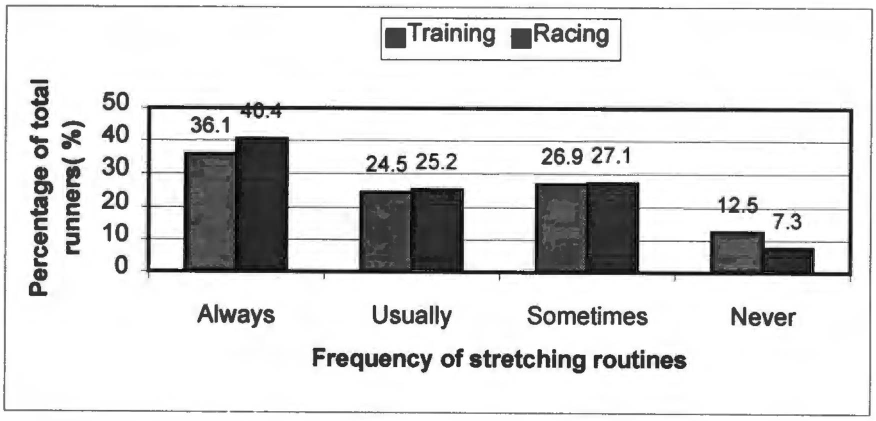

Figure 9: Stretching prior to running expressed as a percentage of the runners

(n =218)

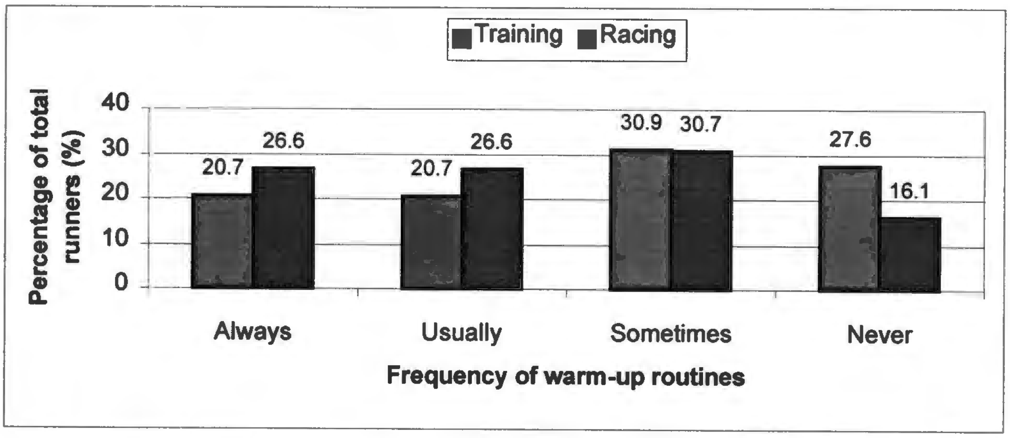

Figure 10: Warming-up prior to run as a percentage of runners (n = 218)

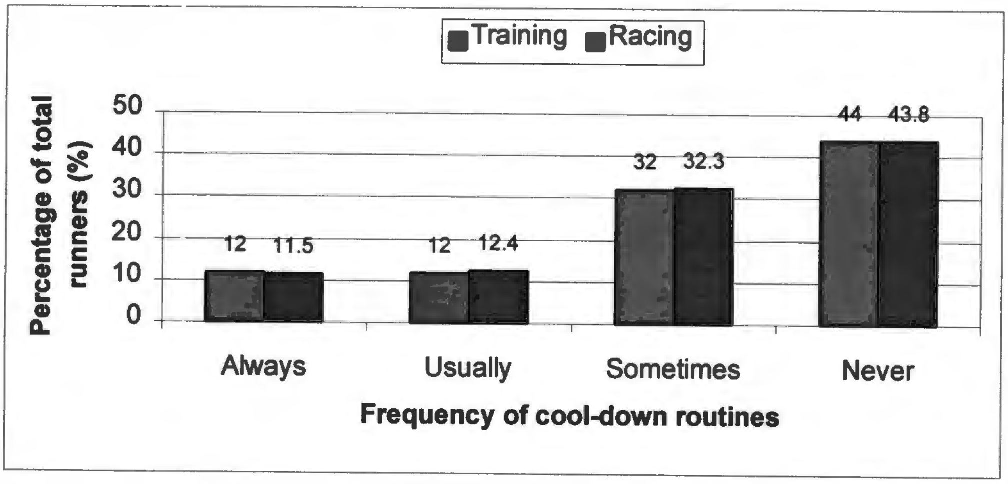

Figure 11: Cool-down after a run as a percentage of runners (n = 217)

4.6 Discussion

The aim of the study was to determine the epidemiology and potential factors associated with lower back pain in a sample of active middle-distance runners. The recruitment of subjects took place randomly after the completion of local club road-races during the track season but out of cross-country season. Therefore there was a tendency for runners to represent the road-running discipline. Most of the subjects had sedentary occupations and participated in running at a recreational or mildly competitive level. This was reflected by analysis of their training regimes: running about one hour per day, on average five days per week.

4.6.1 Epidemiology of lower back pain as a running injury

In the study described in this thesis the annual incidence and lifetime prevalence of lower back pain in runners competing in races was determined. This is the first study to document the annual incidence and lifetime prevalence of lower back pain in runners. The annual incidence of lower back pain in runners was 38.4% and the lifetime prevalence was 47.0%. This incidence appears to be high considering that there are studies documenting that runners have an annual incidence of all injury of 48% (Walter et al 1989). In a case series lumbar spine pain accounted for only 5 - 8% of all injuries in runners (Harvey and Tanner 1991). Furthermore, in two other studies the annual incidence of lower back pain in runners was 11% - 13% (Walter et al 1989, Lysholm and Wiklander 1987), which is lower than the annual incidence in the present study.

There are two possible explanations for the discrepancies between the present study and previous studies with regard to the incidence of lower back pain in runners. Firstly, study designs differed particularly with respect to the diagnostic criteria that were used to identify lower back pain (Walter et al 1989, Lysholm and Wiklander 1987). In the studies by Walter et al (1989) and Lysholm and Wiklander (1987), only lower back pain severe enough to prevent training or competition for more than one week or lower back pain for which medical treatment was sought were documented.

The present study included all lower back pain disorders on a subclinical level and those disorders not significantly affecting training. This may have increased the incidence. The primary focus of this study was to determine if running would induce back pain and how common this back pain was in the running population. Although this would have increased the sample size of runners with running-related lower back pain, the format of approaching runners would have excluded any runner whose back pain was severe enough to prevent running. Therefore, discrepancies in the definition of lower back pain is the most likely explanation for the differences in annual incidence of lower back pain observed between the studies.

Secondly, there may be an actual increase in the annual incidence in this subgroup of runners because of the nature of the running surfaces (in the geographical area of Cape Town which is characterised by hilly, off road or mountain running). It is also interesting to note that running-related lower back pain was judged to be aggravated by hilly runs - often the very nature of most runners training routes in Cape Town.

The incidence of injuries in running can also be expressed more accurately as the number of injuries per 1000 hours of running. The incidence of running-related lower back pain in this study was found to be 1.42 back injuries per 1000 running hours. There are no published data to compare this incidence rate of lower back pain in runners to other groups. Overall injury rates of 2.5 injuries per 1000 running hours for long distance runners and 5.8 per 1000 running hours for middle-distance runners have been recorded (Lysholm and Wiklander 1987). In a review of running injuries as a whole, annual total injury rates equating to 2.5 - 12.1 (average 3.6) injuries per 1000 running hours were established (Van Mechelen 1992). However, no special mention was made with regard to lower back pain as a subgroup of these frequencies.

The lifetime prevalence of lower back pain for runners in this study (47%) compares favourably with the lifetime prevalence for lower back pain in the general population. A number of studies have reported a lifetime prevalence varying between 45% - 75% for lower back pain in the general population (Biering-Sorenson et al 1989, Pope and Novotny 1993). The annual incidence of lower back pain in this present study

(38.4%) is also comparable with data showing annual incidences of lower back injuries in the general population. The annual incidence for lower back pain in the general population varies between 37% - 64% (Papageorgiou et al 1995, Laslett 1991).

Hoeberigs (1992) noted the difficulty in comparing varying incidence rates for all injuries (24% - 65%) between studies because of differences in study design and methodology. Studies where data were not collected over a full year do not represent annual incidence rates as running is seldom of the same intensity all year round (Van Mechelen 1992).

In summary, this study determined an annual incidence of 38.4% and a lifetime prevalence of 47% of running-related lower back pain. These frequencies are far larger than have previously been documented in studies concerning running-related injuries, yet compare favourably with incidences of lower back pain in the general population. The annual incidence expressed in terms of exposure per 1000 running hours was also found to be high in this study. The most probable reason for these differences is the criteria used in the classification of a runner as having lower back pain.

4.6.2 Clinical characteristics of lower back pain in runners

Fifty eight percent of runners reported that their pain did not affect their running performance (Grade I – II pain). The remainder of the sample (42%) felt that their running-related lower back pain affected their running ability or prevented them from achieving their full running potential (Grade III – IV pain). A limitation of this study is that runners were approached at the end of races, thereby eliminating runners whose lower back pain was severe enough to prevent them from running. Furthermore 41% of the runners had a previous history of an insidious onset of lower back pain. This finding of a previous history of an insidious onset of lower back pain was similar to that documented in another study where it has been shown that 60% of lower back pain sufferers had an insidious onset of symptoms (Christie et al 1995).

Specific clinical characteristics of the lower back pain in runners are; 1) that it is associated with referral of pain to the buttocks (30% of runners), 2) there is referral of pain into the leg (43% of runners) and, 3) there is altered sensory perception into the legs (32% of runners).

The factors most commonly associated with the onset of the initial presentation of back pain were uphill and downhill running, longer runs and "being tired and unfit". Lower back pain in runners was frequently (13%) associated with an increase in running speed, yet was poorly associated with racing (7%). These latter variables were not similar to risk factors of all injuries that were documented in studies on running-related injuries (Walter et al 1989). In this latter study, injury was only associated with excessive running distance and frequency and the occurrence of a previous injury. In addition, these authors found an increased competitiveness to be associated with injury while racing was not related to the occurrence of lower back pain in this present study.

Prolonged sitting and standing were also aggravating factors associated with lower back pain in this study. Lying supine, "taking it easy", bending forwards and stretching had the greatest beneficial effects for pain relief. The fact that rest or relative rest relieved the lower back pain may suggest that this lower back pain could be a result of tissue stress overload. Finally, no trends in subject somatotype, age or occupation were associated in the "pain" group.

4.6.3 Subject management of lower back pain

The severity of any disorder can be determined by the measures the patient takes to avoid it or manage its recovery. In this study, most runners complaining of chronic lower back pain (65%) sought medical attention by consulting with a physiotherapist, general practitioner, chiropractor or orthopaedic surgeon. This is considerably more than the reported thirty-nine percent of another study sample of a group of non-runners who sought medical care for an acute episode of lower back pain (Carey et al 1996). It is also higher than the forty-four percent of runners who sought professional care for running-related injuries in general (Van Mechelen 1992). Another study has shown that mechanical lower back pain has been found to be the fifth most common reason for visiting a physician (Borenstein 1996). The fact that most runners sought medical attention for their lower back pain suggests that it was severe enough to have a major impact on their running performance. Alternately, they may have just been more educated regarding the value of early treatment intervention. Furthermore, the number of runners seeking medical attention in this study is greater than in previously mentioned studies and probably relates to the desire of the runner to return to their full running potential as quickly as possible.

Runners in this study reported that hands-on manual treatment and rehabilitation exercise regimes provided the best relief of lower back pain. Other effective means of therapy reported by runners were posture correction and stretching. General treatment techniques such as these were effective despite the lack of diagnosis for many of the complaints of backache. This is in contradiction to another study in which these techniques failed to show any positive effects (Martin et al 1986).

Almost all of those athletes seeking medical treatment were noted to utilise some form of rehabilitative exercise program. The abdominal muscles were mostly targeted, less attention given to the back extensors and even less to posture modification, mobility exercises and stability exercises. This is in contrast to their reporting the positive effects of posture modification and rehabilitation exercise. Stretches were the most commonly used exercise. Reasons for this could be that stretching exercises are quick and easy to perform while posture correction and stability training takes practice and time and may therefore be ignored.

4.6.4 Diagnosis of lower back pain

In this questionnaire, runners were asked what the diagnosis of their lower back pain was. It is well established that patients suffering from lower back pain often receive many different diagnoses, including ruptured disc, trigger points, ligament sprain, muscle tear, "bone out of place" / malaligmnent, pinched nerve and sacroiliac torsion

(DeRosa and Porterfield 1992). Diagnoses in this study corresponded with these above mentioned diagnoses and included: muscular damage, degenerated discs or disorders of the facet joints.

4.6.5 Training habits

Flexibility, warm-up and cool-down routines have been identified as important factors in decreasing injury risk (Van Mechelen 1993, Brunet et al 1990). Most runners "took measures to protect themselves from injury" by stretching and doing a warm-up, especially during training. However, in this component of the study the details of these exercises such as duration, frequency and type were not assessed. These factors will be discussed in more detail in chapter 5.

Ninety percent of all the runners claimed to stretch regularly and concentrated mainly on flexibility of the lower limbs. Previous studies have documented a large (more than 50%) portion of their sample of runners to perform stretches (Walter et al 1989). A large proportion (70%) of the runners in the present study reported to maintain their stretches for 10 - 30 seconds. Furthermore the group of runners who did not suffer from any lower back pain were found to stretch prior to training ($p = 0.028$) and racing ($p = 0.003$) significantly more than the group of runners who reported suffering from lower back pain while running.

It appears that stretching, being a simple and easy exercise to do anywhere, anytime; was frequently used. These stretching exercises were performed in a manner in which the stretch was maintained long enough for muscle relaxation to occur (Norris 1995d). A significant finding in this study was that runners without lower back pain stretched more frequently than those with lower back pain. A lack of regular stretching exercises was therefore more commonly found in runners suffering from lower back pain and may therefore be associated with lower back pain in runners.

Eighty percent of the runners reported warming-up prior to racing and training and only 45% cooled down after the run. In one study it was documented that 88% of runners stretch, 93% of runners perform a warm-up and 64% of runners cool-down (Van Mechelen 1992). The value of warm-up, cool-down and stretching to prevent running injuries in general has not been well established. It has been shown that an intervention of warm-up and cool-down and stretching was not effective in preventing running injuries in general (Brunet et al 1990, Van Mechelen et al 1993). In these two studies a large number of subjects who complied to strict criteria of selection and maintained detailed notes of their training habits were monitored. The value of adding warm-up and stretching exercises to prevent injuries may therefore be questionable. Although a lack of stretching and warm-up exercises have not been shown to clearly be a risk factor for injuries in general, there may be a need for runners to continue doing these exercises as these runners clearly stated that stretching exercises did relieve their lower back pain.

A comparison between those suffering from running-related lower back pain and those without pain in terms of both training and demographic variables found no significant differences between these two groups. These variables, as well as a more in-depth investigation into training habits is compared in the following chapter (Chapter 5).

4.6.6 Summary

In this study the annual incidence of running-related lower back pain of 38.4% and lifetime prevalence of 47% is much higher than has previously been suggested in the literature. These figures are more comparable with the incidence and lifetime prevalence of back pain in the general population rather than from specific sports participation. However, the diagnostic criteria used for lower back pain in this study differed and probably accounts for the differences in incidence rates.

The running-related lower back pain that runners complained of was associated with some pain referral into the legs or a mild alteration of sensation. The lower back pain was probably as a result of training overload. In many cases runners sought treatment for their pain, mostly to a physiotherapist where manual therapy and exercise regimes were regarded by runners as effective in providing pain relief. On analysis of possible factors associated with lower back pain, only a lack of performing regular flexibility exercises was significantly associated with the "pain" group. Overall, it therefore appears that controlled training regimes practiced in moderation and the adherence to a regular flexibility program could protect a runner from the onset of running-related lower back pain.

5 Chapter 5

Aetiological factors associated with lower back pain in distance runners

5.1 Introduction

A case control study was conducted in a group of runners suffering from back pain by comparing them to a pain-free group of runners. Both runners and controls were recruited from the sample population that was interviewed as part I of this research thesis (Chapter 4). Comparisons were made between the groups with respect to:

i) training routines

ii) flexibility, warm-up and cool-down routines

iii) measures of spinal ROM, lumbar-pelvic-femoral muscle flexibility, biomechanical anomalies, lumbar segmental stiffness and abdominal muscle function.

The above comparisons were made based on previously documented risk factors associated with running injuries. Excessive running distances have been significantly associated with running injuries (Walter et al 1989). Other aspects of training have also been suggested to contribute to injury. These include hill running, running on hard surfaces and running frequency and intensity (Walter et al 1989, Lysholm and wiklander 1987, Blair et al 1987, Macera et al 1989). The role of flexibility, warming-up and cooling-down exercises have been poorly related to injury predisposition, yet are frequently recommended in clinical practice to prevent or aid recovery from injury. In view of the use of these exercises clinically, their association with lower back pain will be investigated.

The role of physiotherapy in the treatment of lower back pain would be to: restore full range of motion to the spinal joints, full flexibility to the lumbar-pelvic muscles, correct any biomechanical anomalies and improve muscle control and function, particularly of the abdominal and back muscles. Chapter 3 of this thesis discussed the aetiology of poor muscle control and subsequent lack of stability of the lumbar spine. Previous hypotheses relating to lower back pain have included:

- segmental stiffness of the motion segments of the lumbar spine (Burton and Tillotson 1989)
- compression, a result of the axial loading induced by running which has been found to reduce range of motion of the spine itself (Carrigg and Hillemeyer 1992)
- dysfunction of the active stability mechanisms of the lumbar spine thereby diminishing control of the motion segments (Hodges and Richardson 1997)
- poor lumbar-pelvic rhythm, a result of an imbalance between inflexible and weak muscles about the pelvic area (Norris 1995d).

The following study has been designed to investigate if any of these hypotheses are associated with running-related lower back pain.

5.2 Aim of the study

The aims of this study were to describe the nature of running-related lower back pain and to identify aetiological factors associated with lower back pain in runners using a case-control study design.

5.3 Methodology

5.3.1 Subject selection

Subjects for this study were selected from those runners (n = 105) who indicated that they suffered from a running-related lower back pain from the study described in Chapter 4. The initial selection process took the form of selecting every fifth runner. However, there was a large non-response at the testing times. For this reason, the full quota of subjects was not achieved. The selection process was therefore affected and accordingly this approach of selection was altered to include other runners selected randomly.

Two groups of subjects were selected from runners recruited in the first part of the investigation. The lower back pain group was randomly selected as mentioned above from the runners who reported running-related lower back pain. Runners, who reported that their lower back pain was related to a previous acute traumatic episode and was only aggravated by running, were excluded. A control group was selected from runners who had never complained of lower back pain. The subjects in the two groups were matched according to age, height, weight and gender. Table 11 summarises the subject characteristics in the low back pain and control groups.

There were no significant differences between the lower back pain group (n = 29) and the control (n = 23) group with respect to age and height although there was a tendency for the low back pain group to be slightly heavier (p = 0.054). There was a significantly higher BMI in the low back pain group compared with the control group (p = 0.042). However, when comparing the two groups using the BMI categories of under 20 = underweight; 20 - 25 = normal; and over 25 being overweight, no apparent differences were evident.

Table 11: Subject characteristics in the low back pain and control groups

Variable	Means / %	
	Lower back pain group (n = 29)	Control group (n = 23)
Male	58.5%	41.4%
Female	45.5%	54.5%
Age (years)	35.8	38.4
Height (m)	1.74	1.74
Weight (kg)	73.1	68.1
BMI ($Kg.m^{-2}$)	24.18	22.36

All runners were recruited by telephone and informed consent was obtained. The two groups were well matched for age, height, weight and gender. The final number of subjects in the lower back pain group was 29 subjects and in the control group was 23 subjects.

5.3.2 Experimental procedure

All subjects in the lower back pain group and the control group were assessed in the laboratory. Each subject completed a medical history and training questionnaire. Thereafter, a clinical assessment was performed on each subject.

5.3.2.1 Medical history and training questionnaire

5.3.2.1.1 Repeatability of the questionnaire

This questionnaire was tested in a pilot study for repeatability and was considered repeatable as the same responses were given by five athletes who completed the questionnaire twice.

The nature of each question was deemed valid by comparing the questions of previous studies' (Lysholm and Wiklander 1987; Warren and Davis 1988; Walter et al 1989) whose focus was to identify the epidemiology and aetiology of sports injuries. Discussion with runners in terms of the characteristics of their running-related lower back pain and the common questions asked of a back patient in clinical practice also guided the questionnaire.

5.3.2.1.2 Content of the questionnaire

All runners in the lower back pain and control groups completed the questionnaire which was designed to determine the exact nature of running-related lower back pain and to identify which training factors could be associated with this lower back pain (Appendix 4). Some of the questions in this questionnaire were repeats of those in the survey questionnaire. This was done to double-check the accuracy of the subjects' responses. Most of the remaining questions were designed to gain an in-depth analysis of their training and activity patterns. The final part to the questionnaire involved establishing the exact nature of this lower back pain.

The following information was obtained:

- Structure of the runner's training program
- description of training sessions (hill sessions / interval training / long runs), the weekly frequencies of runs and daily running distance as well as recent changes in training distance
- type of training surface
- participation in other athletic activities
- typical environmental conditions during running (terrain / climate)
- stretching routine frequency and body areas stretched as well as the nature of the stretches performed
- frequency of warm-up and cool-down routines during training sessions and at races
- rest periods during the year
- the affect of the lower back pain on their running performance
- the association between some training factors and the commencement of their lower back pain
- the site of their pain
- to describe the pattern their pain usually follows during their run.

Subjects were also asked to rate the intensity of lower back pain during running on a numerical pain rating scale (10 being the most pain ever experienced; 0 being no pain at all).

5.3.2.2 Clinical assessment

Following the completion of the questionnaire, each subject underwent a full clinical assessment (Appendix 5) which was performed with the subject suitably dressed in shorts and a loose-fitting T-shirt to allow the examiner to pull up to view the spine.

The assessment was performed by the same examiner (a physiotherapist), a trained assistant and the same equipment was used. The examiner was blinded (had no knowledge of the "pain" status of the runner) to the group from which the subject came (lower back pain or control group). The clinical assessment was designed to assess the following functional parameters that may be related to the development of lower back pain in runners:

- flexibility tests
- lower limb biomechanics
- passive intervertebral movements
- abdominal muscle strength
- lumbar spine muscle stability tests.

5.3.2.2.1 Pilot testing of the clinical assessments

Prior to the testing of the subjects, a pilot study (appendix 6) to assess the reliability of the testing methods was performed on nineteen non-partaking subjects. These tests were performed on two separate occasions by the same examiner for each subject and the examiner was blinded to the results of previous assessments. The details of this pilot study can be found in appendix 6 and the results are displayed in Appendix 7.

Gajdosik and Bohannon (1987) advocate short time intervals between tests (a test, re-test design) to most accurately evaluate reliability. However, reliability studies conducted over longer time intervals help establish the stability of the measurement. For keep reasons, a 3-4 day time period separated the performance of the two reliability tests.

The results of these tests show good intra-tester reliability (that is for the same examiner doing the same test on different occasions). No inter-tester reliability testing (that is for different examiners doing the same test on different occasions) was performed as the same examiner performed all the tests.

The reliability of joint range of motion measurements would be increased by standardizing the force applied by the physiotherapist (Ada and Herbert 1988). An effort was made by the examiner to deliver the same force during the application of each test. Ada and Herbert (1988) comment that the main reason for the poor inter-tester (and intra-tester) reliability is possibly due to a failure to standardize the force at which a joint range of motion measurement is taken. However, they do support that the use of gravity be used as it is a consistent force i.e. use the weight of the body segment. This is exactly what was done for all the measures of flexibilty and biomechanics tested in the study. Certain tests performed were subjectively rated and therefore could be deemed unreliable as measurement tools, although they may be clinically useful. The tests which fall into this category include the PPIVM and PAVIM tests to assess spinal stiffness and some of the abdominal stability tests involving visual detection of changes in abdominal muscle function while using the biocuff. The results of these tests have still been included, given the good reliability results from the pilot study yet should be interpreted with caution and are discussed appropriately as such.

5.3.2.2.2 Flexibility assessment

a) Spinal flexion: (for reliability measurements refer to appendices 6 and 7)

Patients with lower back pain frequently have a reduction in spinal range of motion (Smidt et al 1983). The modified-modified Schober technique has been suggested as a reliable method for measuring spinal flexion (Williams et al 1993). The method, originally described by Schober, made use of a tape measure held directly over the spine and a mark made 10 cm proximal to the lumbar-sacral junction. The difference between this length in neutral standing and full spinal flexion was recorded and gave an indication of spinal flexion (Williams et al 1993). The actual length of spinal flexion (in cm) was taken to be the difference between the initial length between the skin markings and that measured in full flexion. There is little increase in length in the measurements of spinal movement during flexion between markers above the first lumbar vertebra and thus it can be assumed that the upper lumbar and thoracic levels contribute least to spinal flexion (Williams et al 1993).

For the purpose of this study spinal flexion was determined using a modification of the Schober technique (Williams et al 1993). The following procedure was followed:

- The distance between the spinous processes of the second sacral vertebra (S2) to the first lumbar vertebra (L1) and to the first thoracic vertebra (T1) were measured in mm. using a rigid tape measure.
- S2 was chosen as it was easy to palpate between the posterior superior iliac spines (PSIS's) of the pelvis.
- L1 was identified by palpating and counting the spinous processes cranially from S2.
- The L1 spinous process is difficult to palpate, and the skin stretches and moves superiorly to the marked spinous processes during movement (Williams et al 1993). During the performance of this test, every effort was made to ensure that L1 was correctly identified by repeating the procedure identifying the lumbar vertebra after flexion.

- The distance between the first thoracic vertebra and S2 was measured. The spinous process of the seventh cervical vertebra was located by fully flexing the neck. T1 was then identified by palpating the next spinous process caudally from C7.
- Measurements were done with a rigid tape measure and compared between standing upright in the neutral position and full active flexion using the S2 spinous process as the reference point.

b) Flexibility tests of the hip and pelvic musculature: (for reliability measurements refer to appendices 6 and 7)

Measurements of the flexibility of the hip and pelvic muscle were taken bilaterally with a goniometer or tape measure. The type of flexibility tests were chosen on the basis that they are used during assessment in clinical practice.

I. Thomas test

The Thomas test was used to assess flexibility of the hip and pelvic muscles. The subject stood with his/her back against the long end of a standard examination couch. The subject then half-sat on the bed with the ischial tuberosities touching the side of the bed. The subject then rolled backwards until the spine was flat against the bed while grasping both legs at the knees, and pulled them to the chest. This position was then maintained while one leg was dropped over the side of the bed. The resting position of this lower leg determined the inflexibility. In this position hip flexor, rectus femoris, iliotibial band and hip rotator muscle flexibility was measured (in degrees) relative to this resting position.

Initially both legs were flexed to tilt the pelvis backwards and thereby eliminating the lordosis in the lumbar spine. The tested leg was straightened and supported by the examiner. At the same time the subject grasped the contralateral knee firmly to the chest, to maintain the pelvic position and avoid an anterior pelvic tilt. The pelvis remained flat and symmetrical.

i) **Hip flexor inflexibility** was evident if the knee of the lower leg rested above the level of the hip in the horizontal plane. The degree of this inflexibility was measured with a standard goniometer (in degrees), the stationary arm lying parallel to the long axis of the trunk in line with the greater trochanter while the moving arm was placed along the lateral midline of the femur (on a line between the greater trochanter and the lateral femoral condyle) towards the lateral epicondyle. One centimeter anterior and superior to the greater trochanter was taken as the axis of this measurement (Joint Motion 1988).

ii) **Rectus femoris** inflexibility was measured as a reduction in knee flexion from a normal value of 90 degrees. The stationary arm of the measuring goniometer was placed parallel to the lateral midline of the femur on a line from the lateral epicondyle to the greater trochanter. The moving arm was parallel to the lateral midline of the fibula (on a line between the fibula head to the lateral malleolus) towards the lateral malleolus. The lateral joint line of the knee was taken as the axis of rotation of movement (Joint Motion 1988).

iii) **Iliotibial band (ITB) inflexibility** was measured as the leg rested in an abducted position and was assessed using a goniometer. A goniometer was placed over a mid-point between the anterior superior iliac spine (ASIS) and the pubic symphysis. The stationary arm was placed in a position parallel with the long axis of the trunk and the moving arm was parallel with the femur directed to the midpoint of the superior patella pole (Joint Motion 1988).

iv) Inflexibility of the **medial or lateral hip rotators** was measured as the lower leg deviated from the vertical. This rotation was measured using a goniometer that was placed over the knee and the mid-patella was taken as the axis of rotation. The stationary arm was vertical, perpendicular to the supporting table and the moving arm was placed along the tibia to a point midway between the malleoli (Joint Motion 1988).

II. Hamstring muscle inflexibility:

The hamstring muscle length was measured using the straight leg raise test with the subject supine on the examination couch. The contra-lateral leg remained extended and flat on the supporting table. Flexion of the hip with the knee in extension was performed passively to ensure that no abduction, adduction or rotation of the hip occurred. The end of range of movement was taken as the point when the pelvis began to tilt posteriorly. This movement was palpated by the examiner observing and feeling for movement of the anterior superior iliac spine (Norris 1995d, Bach et al 1985). Hamstring flexibility was measured with a standard goniometer (in degrees). The stationary arm was placed parallel to the long axis of the trunk in, line with the greater trochanter while the moving arm was placed along the lateral midline of the femur, pointed towards the lateral epicondyle. One centimeter anterior and superior to the greater trochanter was taken as the axis of this measurement (Joint Motion 1988). However, Bohannon (1984) questioned the use of the straight leg raise as a technique for measuring hamstring muscle length. He therefore advocates measuring the angle of straight leg raise in reaction to the pelvis as this gives a more valid indication of hamstring length. This is exactly what was done in this study. By palpating for any pelvic rotation, the straight leg raise was measure relative to the pelvis which was aligned in a neutral horizontal position.

III. Hip adductor muscle inflexibility:

Hip adductor muscle inflexibility was assessed in crook lying (supine with the hips and knees comfortably flexed and feet flat on the supporting bed and hip width apart.) The subject performed a posterior pelvic tilt contracting the abdominal muscles and flattening the lumbar lordosis. While the feet remained in position, the tested knee was lowered to abduct the hip while the contralateral leg remained in a crook-lying position with the hip, knee and ankle aligned. A tape measure measured the vertical distance (in cm) from the inferior aspect of the lateral patellar border to the surface of the supporting couch. The abduction measurement was performed at the moment just prior to any anterior pelvic tilt. Any pelvic movement away from the starting position was monitored by palpation of the anterior superior iliac spine.

Lower limb biomechanical measurements: (for reliability measurements refer to appendices 6 and 7)

The biomechanical methods used for this study were according to standard tests described by Gould et al (1985).

(a) Leg length discrepancy:

The subject lay supine on the examining couch such that a line through the iliac crests was perpendicular to the length of the examining couch. The hips were placed in neutral alignment with the legs touching at either the medial femoral condyles or medial malleoli. The distance (in cm) between the most prominent part of the anterior superior iliac spines and the most prominent part of the medial malleolus were measured using a rigid tape measure. The length between the most prominent part of the tibial tuberosity and the most prominent part of the medial malleolus was also measured to determine the part of the leg with the leg length discrepancy.

(b) Quadriceps angle:

The quadriceps angle (Q-angle) is defined as the angle between the lines of pull of the quadriceps muscle and the patellar tendon. The subject stood erect in a relaxed position, feet together (touching either at the inner thigh, medial femoral condyles or the medial malleoli). The following bony points were marked: 1) anterior superior iliac spines, 2) the middle of the superior pole of the patella, 3) the middle of the inferior pole of the patella, and 4) the most prominent part of the tibial tubercle. A line connecting the anterior superior iliac spines and middle of the superior patella as well as a line joining the tibial tubercle to the inferior pole of the patella were drawn. The angle (in degrees) between these two lines was measured using a standard goniometer and this was taken as the Q-angle.

(c) Valgus or varus deformity at the knee:

The valgus or varus deformity at the knee was measured by visual observation with the legs together touching either at the knees or at the ankles. Observation of the knees touching was regarded as a valgus deformity while touching of the medial malleoli was taken as varus. Measurements were taken with a set of standard dividers as the distance (in mm) between either the malleoli (valgus knees) or medial femoral condyles (varus knees). This distance was then measured using a rigid tape measure.

(d) Rearfoot valgus or varus deformity: (Normal ROM varus–valgus 18-62 degrees, with 1/3 being pronation and 2/3 being superation).

The subject stood upright on the examining table with the legs together touching either at the knees or at the ankles. A mark was made in the middle of the proximal calf muscle bulk and also at the point at which the muscle bulk inserts into the Achilles Tendon (TA). A line was then drawn connecting these two points. A line was also drawn bisecting the calcaneus from the following two points: i) the midpoint of the insertion of the TA into the calcaneus; ii) the mid-point of the base of the calcaneus. The angle (in degrees) between these two lines was then measured with a standard goniometer. Rearfoot valgus was indicated when the base of the calcaneus was lateral to the insertion of the TA and was varus when the calcaneus base was medial to the TA insertion.

(e) Forefoot varus / valgus deformity:

Forefoot varus or valgus was determined by first positioning the subtalar joint in a neutral position with the subject in the prone position on a couch. The subtalar joint has a locking motion and when pronating and supinating the foot it will swing through an arc (Gould et al 1985, Schwellnus 1990). One third of the motion is in the direction of pronation (eversion of the calcaneus) whilst two-thirds of the motion is in the direction of supination (inversion of the calcaneus). The neutral subtalar position was also determined by palpating the head of the talus. The head of the talus adducts

in pronation and abducts in supination. It therefore becomes more prominent on either side of the foot as it moves from pronation to supination.
The neutral subtalar position was obtained with the subject lying prone with the feet lying vertical. The navicular tuberosity on the medial side of the foot was located +/- 2.5 cm below and 2.5 cm distal to the middle of the tip of the medial malleolus. The index finger was lightly placed over this area slightly proximal to the tuberosity while the fourth and fifth metatarsals were grasped with the other hand, which gently pronated and supinated the foot.

During pronation, the medial side of the head of the talus protruded from behind the tuberosity of the navicular and bumped the index finger. Simultaneously, a sulcus appeared on the lateral aspect of the foot where the head of the talus had been. During supination, the medial side of the talus disappeared and the sulcus appeared behind the tuberosity of the navicular. At the same time the lateral aspect of the head of the talus became prominent on the outer aspect of the foot. At the point where the medial and lateral sides of the head of the talus neither protruded nor were sunken, congruency was achieved and the subtalar joint was in a neutral position.

The actual measurement of forefoot abnormalities took place with the foot in a neutral subtalar position. In this position, the foot was dorsiflexed and a line was sighted down bisecting the posterior surface of the calcaneus onto the forefoot (metatarsal heads). One arm of the goniometer was aligned with the metatarsal heads, while the other was placed in an imaginary line perpendicular to the line through the calcaneus. The angle (in degrees) between the two arms was the degree of abnormality in the forefoot. If the plane of the forefoot was perpendicular to the heel, there was no forefoot deviation. If inverted or everted, then there was either forefoot varus or valgus respectively.

5.3.2.2.3 Spinal intersegmental mobility: (for reliability measurements refer to appendices 6 and 7)

The passive physiological intervertebral movement and posterior-anterior intervertebral movement tests assessed movements of the spinal motion segment. A modification of the rating scale devised by Gonnella et al (1982) was used to grade the intervertebral movements. This grading scale composed of 7 grades, ranging from 0 to 6. The grading of 0 indicated an ankylosis (no movement) and 6 indicated instability (excessive movement). Due to the difficulty of distinguishing these grades, a modification of the grading scale was used (Table 12). The accessory movement grade 2 (grade 3 according to Gonnella et al 1982, Table 12) was taken as normal. This was the expected normal for the subject's age, body type and activity level and was a reference point for clinical use (Gonnella et al 1982). However, it should be noted that tests for pain are more reproductive than tests for compliance (Matyas and Bach 1985).

Table 12 Grading classification for PAIVM's and PPIVM tests

Grade 1: Slight restriction (hypomobility)	Limitation expected in range. Some resistance to movement
Grade 2: Normal	Expected range for body type. Uniform movement throughout range.
Grade 3: Slight increase (hypermobility)	Some increase expected in range. Less than normal resistance to movement

(a) Passive physiological intervertebral movements (PPIVMS):

Passive physiological intervertebral movements (PPIVMS) were performed slowly and taken to the end of range so as to assess end-feel of the movement. Tests were performed as described by Maitland (1991). Two movements were documented on the L3, 4, 5 and Sl vertebrae. These were rotation and flexion/extension.

I. Rotatary PPIVMS:

The subject lay on his/her side with hips and knees flexed to allow the lumbar spine to lie relaxed midway between flexion and extension. The examiner stood in front of the subject facing the feet and reached across the subject's upper side resting his lower ribs against the subjects' side. The examiners forearm pointed caudad along the spine while the other forearm grasped around the pelvis holding over the upper hip. The fingers were spread out behind the trochanter and the heel of the hand anterior to the trochanter, the forearm of this hand being aligned along the upper femur.

The pad of the middle finger of the caudad-facing forearm was placed facing upward in the underside of the interspinous process to feel the bony margin of the adjacent vertebra. Care was taken to ensure that the subject's top knee could slide freely forward over the knee that was underneath. The hips were then slightly raised and the thorax stabilised. Pulling with the hand over the hip rotated the pelvis. The pelvis and lumbar spine rotated forward on the uppermost side as the top knee slid forward. Displacement of the distal spinous process in relation to the proximal one was felt. The return movement of this rotation was effected using the heel of the hand and forearm.

II. Flexion / extension PPIVMS:

The starting position to measure PPIVMS was the same as described above for the rotatory PPIVMS test except i) the examiner reached behind and under the patient's flexed knees to grasp anteriorly around the lower knee; ii) when lifting the legs, they were rested against the examiner's upper thighs; and iii) the tip of the palpating middle finger was placed in the interspinous space to be tested.

By rocking the patient's knees back and forth through an arc of 30 degrees passive flexion-extension movement of the spine was produced. Over-pressure was applied at the limit of extension to assess any backward sliding of a vertebra which may indicate instability. The test movement was produced by a side to side movement of the examiners' pelvis carrying the subject's legs. Opening and closing of the interspinous process was felt with the rocking of the subject's pelvis and legs.

(b) Passive posterior - anterior intervertebral movements (PAIVMS):

The test for PAIVMS was performed with the subject prone with his/her arms hanging over the sides of the couch, the head turned comfortably to one side (Maitland 1991). The examiner stood on one side of the subject. The right hand of the examiner was placed on the subject's back so that part of the ulnar border of the hand between the pisiform and the hook of the hamate was in contact with the spinous process of the vertebra which was to be mobilized. The examiner's shoulders were positioned directly above the vertebra, the wrist was fully extended and the forearm was held mid-way between full supination and pronation. The left hand reinforced the right hand by fitting the carpus of the left hand, cupped by the approximation of the thenar and hypothenar eminences, over the radial aspect of the right carpus at the base of the right index finger. The left middle, ring and little fingers were allowed to lie between the right index finger and thumb. The left index finger and thumb lay over the back of the right hand. Stability was gained by grasping the palm of the right hand between the thenar eminence and the middle, ring and little fingers of the left hand.

The examiner gradually moved his body weight over the subject's vertebral column and a rocking movement of the upper trunk up and down in a vertical axis obtained the oscillating movement of the vertebra. Pressure was transmitted through the arms and shoulders. Lumbar vertebrae L3,4,5 and S1 were tested and graded according to the classification described in Table 12. Unfortunately, there are no published normative values for PAVIM stiffness tests available (Maher and Adams 1994).

5.3.2.2.4 Sacro-iliac joint (SIJ) provocation tests:

The sacro-iliac joint provocation tests were performed using a similar technique to that described above for the PAIVM'S. In this case the pressure was directed over the SIJ itself. A grade IV+ pressure as described by Maitland (1991) was used. The response of the subjects was graded as either positive or negative for the reproduction of the subjects running-related back pain.

5.3.2.2.5 Abdominal muscle strength assessment: (for reliability measurements refer to appendices 6 and 7)

The abdominal muscle strength assessment was performed according to the classification proposed by Kendall et al (1993).

(a) Curl-up abdominal (rectus abdominis) muscle test:

The abdominal muscle (rectus abdominis) strength was tested by instructing the subject to perform a single curl-up as high as possible without jerking forwards or allowing the feet to lift off the supporting surface. Only one repetition was performed and the degree of curl-up noted before the subject returned to the starting position. The grading of trunk muscle strength assessment using a single trunk curl (crook lying, feet flat and unsupported) was graded as follows (Kendall et al 1993):

Grade 0 = unable to raise more than head off table
Grade 1 = arms extended towards knees, until scapulae lift from the table
Grade 3 = arms straight, until lumbar spine lifts from table
Grade 4 = arms crossed over chest, until lumbar spine lifts from table
Grade 5 = hands behind neck, until lumbar spine lifts from table.

A leg-lowering test was performed to further assess the strength of the abdominal muscles.

b) Leg-lowering abdominal (rectus abdominis) muscle test:

The subject lay supine and the hips were both flexed to 90 degrees by the examiner with the knees in full extension. The pelvis was thereby tilted posteriorly and the anterior superior iliac spines were palpated to ensure no movement occurred while the legs were lowered. The exercise was ceased once the subject could no longer maintain the pelvic position during this leg-lowering action (Richardson et al 1990). The degree of hip flexion at this position was estimated visually.
Grades were categorised as follows (angle between the long axis of femur and table just prior to when the pelvis began to tilt) (Kendall et al 1993):

Grade 0 = 90-75 degrees

Grade 1 = 74-60 degrees

Grade 2 = 59-45 degrees

Grade 3 = 44-30 degrees

Grade 4 = 29-15 degrees

Grade 5 = 14-0 degrees.

5.3.2.2.6 Lumbar spine muscle stabiliser testing: (for reliability measurements refer to appendices 6 and 7)

These tests were designed to assess the isometric endurance of the back and abdominal muscles to stabilise the spine. The ability of the abdominal muscles to stabilise the trunk and lumbar-pelvic relationship was assessed by monitoring the function of the stabilising muscles including the transversus abdominis muscle.

A pressure biofeedback biocuff [Chattanooga Australia (Pty) Ltd] (increments of 2mm Hg) was used to assess the lumbar-pelvic control while performing three tests: 1) a static abdominal contraction for one-minute, 2) a single leg heel slide from 70° of hip flexion to neutral extension (performed by each leg alternately), and 3) an abduction movement of the knee (with the leg in crook lying) while the other knee remained in its starting position (Jull et al, 1993). A recent study has confirmed the use of the biocuff to simulate the use of electromyographic testing for transversus abdominis muscle contractions (Hodges et al 1996). These authors support the biocuff test to discriminate between subjects with and without lower back pain.

Prior to each test, the emptied pressure cuff was placed in a central position behind the lumbar spine from S2 - L1 with the distal margin of the cuff corresponding to the posterior superior iliac spines (Richardson et al 1992). The subject lay supine with the legs flexed with the feet flat on the plinth (crook lying). The hip joint was maintained in 70° of flexion to permit a mid-position of the spine and to eliminate the influence of the length of the lumbar-pelvic-hip muscles (especially that of the iliopsoas muscle) on movement of the lumbar spine (Jull et al 1993). The cushion was inflated to accommodate the space between the lumbar spine and the supporting surface while the device was sealed at the valve. Lumbar movement results in a positional change and the change in volume is recorded as a change in pressure (Jull et al 1993). Changes in pressure reflected uncontrolled movement of the lumbar spine and a drop in this pressure indicated an inability to maintain the isometric contraction.

The biocuff was inflated to a baseline of 40 mm Hg. The subject was then instructed to "pull the umbilicus in and up" as hard as possible and hold for a few seconds. They were instructed that this "effort" was their "maximum voluntary muscle contraction". Care was taken to ensure that there was no concomitant posterior pelvic tilting by palpating for movement at the anterior superior iliac spine. The subject was then requested to repeat the same contraction at 30% (or one third) of the maximum voluntary muscle contraction, continuing to breathe normally. Thirty seconds were allowed for the subject to familiarise himself or herself to this contraction (Wohlfahrt et al 1993).

During the testing procedure of the following two tests, the following observations were made regarding the muscular contractions:

- whether a contraction was in fact achieved or not
- this contraction was subsequently graded as being strong, fair or weak
- a loss in the contraction strength was noted

- the improvement in the subjects ability to contract the global abdominal muscles was observed
- any overcompensating of the muscle contraction was noted
- the ability of the subject to maintain a constant contraction was viewed as the ability to prevent the manometer needle swinging.

a) Isometric stability test:

The isometric stability test consisted of an isometric contraction of the abdominal muscles (particularly the transversus abdominis muscle). This type of maneuver is termed abdominal hollowing or bracing. It has been determined that this is the favoured stabilisation pattern (Richardson et al 1992).

The subject was shown the meter of the biocuff apparatus and encouraged to "hold" the needle at the new mark gained by the muscle contraction. This was done for a further 30 seconds; thereafter the subject was asked to maintain this while the meter was out of view for a further 1 - minute. A slight deviation of the needle was expected as breathing occurred and the maximum observed deflection of the needle was recorded. The larger the deflection of the manometer needle, the better the transversus abdominis muscle's ability to maintain an endurance stabilising contraction. The more the needle tended to swing indicated a poor stabilising ability of these abdominal muscles. Observations were also made visually and by palpation regarding the ability of the subject to:

- attain and maintain a good transversus abdominis contraction (the anterior-lateral abdominal wall was constantly palpated over the antero-lateral abdominal wall in line with the umbilicus for a gentle bulging of this part of the abdominal wall). A Grade of 1 was given if able to contract the transversus abdominis muscle while 0 signalled that no transversus abdominis contraction was felt. The contraction strength was also subjectively graded as 1 if strong, 2 if fair and 3 if weak.)
- recover the contraction if lost (observed if the lateral bulging of the abdominal wall was lost and then regained)

- improve the contraction with training (this was assessed subjectively by the examiner as a greater force of lateral bulging of the abdominal wall was felt during the second series of tests and objectively by a larger initial deflection of the manometer needle)
- overcompensate for a lost or failing contraction (noted by observing for pelvic tilting or loss of a constant reading on the manometer).

The gauge was also observed for the existence of small or large swings. A small swing was defined as a 2 - 6 mm Hg deviation of the needle, large swings were defined as deviations greater than 6 mm Hg while <2 mm Hg deviation was considered normal. The gauge was also observed for a steady drop of the needle as the contraction was gradually lost. Compensation strategies of pelvic tilting, breathe holding, using the obliques (internal and external) or rectus abdominis and legs were also noted visually and compared between the two groups.

The biocuff is not capable of differentiating between specific muscle contractions. Therefore the endurance or functional capacity of individual muscles was not tested. Rather, the stabilising ability of the global trunk muscles (including that of the transverses abdominis) was assessed and their strength recorded according to the increase in pressure generated while bracing without allowing for any lumbar-pelvic motion.

(b) Heel slide and hip abduction tests:

The heel slide and hip abduction tests followed the above procedure of isometric abdominal contractions. This test had the identical starting position to the isometric test, but this time the subject performed a unilateral heel slide into hip extension, then back into flexion (avoiding any hip rotation or abduction and adduction). The range of this hip flexion was therefore 70° to O° to 70° again. A plastic slipper was placed over the foot to reduce friction between the foot and the couch. Again the largest deflection (in mm Hg) during the course of the entire movement was recorded. The final test followed the same procedure as before as the subject abducted the bent leg maximally. The non-tested leg remained in 70° of hip flexion with the hip, knee and ankle neutrally aligned. The entire test was performed a second time.

Comparisons were made between the lower back pain and control groups with regard to the recorded deflections of the manometer needle. This test was designed to assess:

- the ability of the subject to recruit the stabilising muscles by observing for pure muscle contraction or the use of the aforementioned compensation strategies;
- the strength of the contraction by the degree of deflection of the manometer needle following the initial contraction; and
- the ability of the subject to maintain this contraction as swings or a change in the manometer reading would indicate a lack of endurance in maintaining the stabilising contraction.

The second and third tests were designed to assess whether the subject could maintain the above stabilising muscle contraction while load was applied to the lower limbs (Wohlfohrt et al 1993). The reason for including this was to observe if the co-ordination of abdominal muscle contraction could limit the pelvic movement caused by the leg action such as possibly experienced while running.

5.4 Statistical Analysis

All statistical procedures were performed at the Medical Research Council using the SAS system. Descriptive statistics were used to describe the characteristics of the lower back pain and the control group. Non- parametric analyses were because the data were not normally distributed.

Categorical variables were compared using the Chi - Square test or the Fischer's Exact test (2 - Tai) where expected cell frequencies were less than 5. For the continuous variables, the Wilcoxon 2 - Sample test was used.

In all cases, $p < 0.05$ was regarded as being statistically significant while $0.05 < p < 0.10$ was regarded as being marginal (showed a tendency towards a significant difference).

5.5 Results

During the presentation of data, frequencies (% of runners) have been used to express the results. As more than one factor could relate to each runner, the frequencies have been presented in their "raw" state and could therefore add up to greater than "100%".

5.5.1 Level of running participation

The level of participation in running for subjects in each of the two groups is depicted in Figure 12. (n = 29 for lower back pain group; and n = 23 for control group)

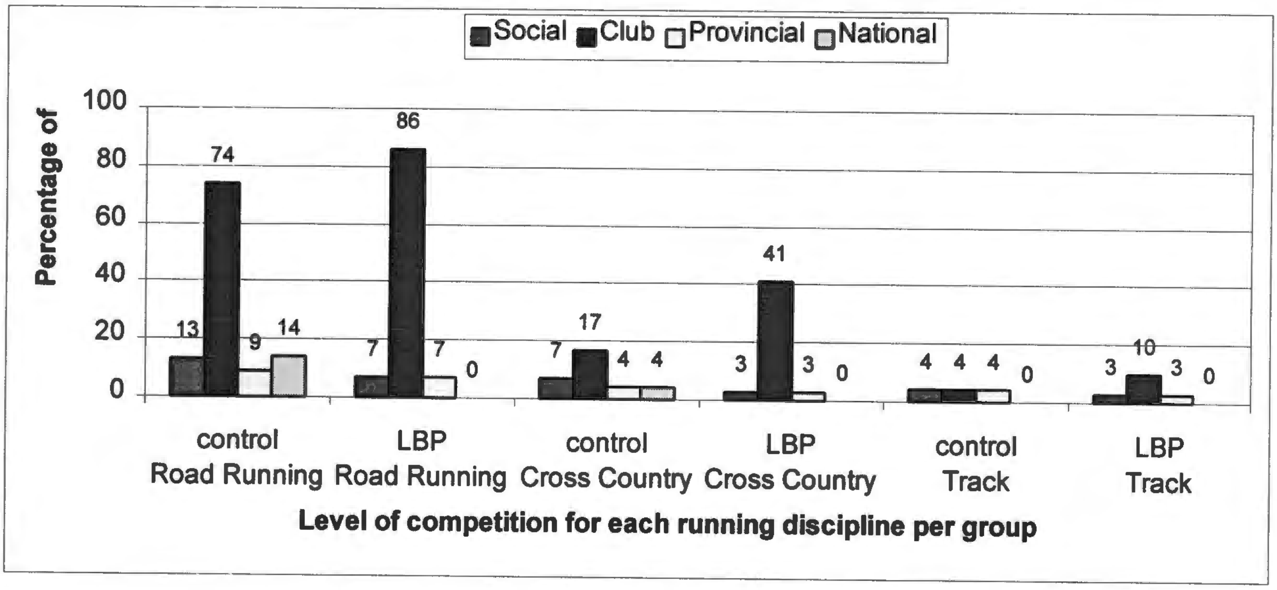

Figure 12: Level of competition by running discipline for the low back pain and control groups

5.5.2 Characteristics of low back pain in runners

Few runners with lower back pain had to stop running, or reduce the running distance due to pain. However, 35% of runners in the low back pain group had to reduce their running intensity (running speed) because of pain. A further 35% of these runners felt that their lower back pain was related to an increase in running distance, 45% to an increase in hill running and 28% with the onset of running fatigue. Twenty-one percent found that the commencement of training was aggravating their condition, while 11% associated back pain with an increase in the frequency of training, that is with an increase in the number of days running per week.

The anatomical area of the running-related lower back pain was reported, between L1 and L4 in 59% of runners and lower than L5 in 35% of runners. Seventeen percent also noted an associated pain in the left buttock. Pain was consistently described as a dull ache (45%) or discomfort (35%) while 14% felt it to be more like a burning sensation. The average rating of pain intensity on a numerical pain rating scale (1 - 10), was 5.2 ± 2.0 (mean ± SD) with a range of 2.0 - 9.0. The nature of pain in runners with low back pain was as follows:

- intermittent periods of pain throughout the run (35%)
- no pain initially, which worsened later (24%)
- pain only at the end of a run (21 %)
- no pain initially, pain felt once well into run which gradually faded (14%)
- initial pain which gradually faded (10%)
- pain only after the run (7%).

Running-related lower back pain was present in both racing and training in 59% of cases compared with racing alone (35%) and training alone (6%).

5.5.3 Training habits of runners in the lower back pain and control groups

Runners in the low back pain group more frequently adhered to a structured training program (69.6%), compared with runners in the control group (44.9%) ($p = 0.074$). No significant differences were observed between the low back pain and control groups with respect to running-related habits (Table 13). Training variables and activity habits in the low back pain and control groups are depicted in Table 14. Training variables (hill sprints, hill circuits, long runs, easy runs, time trials, fartlek or track sessions, rest days), running surfaces (grass, terrain, road, flat, undulating, hilly, sand, treadmill), weather conditions (rain, wind, heat, sunny, cloudy, drizzle, humidity, cold, dry), playing other sports, incorporating rest periods into the year, the number of times run per week and their level of competition or running discipline were not significantly different between the lower back pain and control groups (Table 14). Fifty-four percent of the entire sample participated in sporting activities other than running.

Table 13: Running-related variables of the control and lower back pain groups (mean ±SD)

Variable	Lower back pain group	Control group
No. of years running (years)	6.6 ± 5.1	6.3 ± 5.3
Hours run per week (hrs)	5.3 ± 2.4	5.7 ± 3.5
Days run per week (days)	4.4 ± 1.5	4.8 ± 1.5
Distance run per week (km)	56.9 ± 26.9	58.0 ± 28.6
Running intensity (minutes per km)	4.9 ± 0.8	4.6 ± 0.4
Best time for 5 km (min)	19.3 ± 3.1	18.8 ± 2.4
Best time for 10 km (min)	42.3 ± 6. 9	42.0 ± 6.7
Best time for 21 km (min)	86.6 ± 27.9	84.2 ± 20.9
Races run per month	3.2 ± 1.4	3.0 ± 1.3

No significant difference between groups

Table 14: Training variables and physical activity habits in the lower back pain and control groups (mean SD)

Variable	Lower back pain group (n= 29)	Control group (n= 23)
	Mean ± SD	Mean ± SD
Long runs (days per week)	1.1 ± 0.6	1.1 ± 0.5
Hilly runs (days per week)	0.8 ± 0.9	0.8 ± 0.7
Hard runs (days per week)	1.0 ± 1.0	1.2 ± 1.7
Easy runs (days per week)	3.3 ± 1.7	3.6 ± 1.4
Other sporting activities (number)	0.9 ± 1.1	0.7 ± 0.9
Length of rest period (weeks)	4.6 ± 3.2 (range 2.0 – 14.0)	5.0 ± 3.4 (range 0 – 12.0)
Times run per week (days)	4.7 ± 1.6 (range 2.0 – 9.0)	5.0 ± 1.3 (range 1.0 – 6.0)
Times stretched per week (days)	2.9 ± 2.1 (range 0 – 7.0) **	4.2 ± 2.3 (range 0 – 9.0) **

** $p < 0.05$ significant difference low back pain versus control group

There were no significant differences for the number of races run per month or the frequency of orthotics used between the two groups.

The frequency of a warm-up routine before racing was significantly higher in the control group (61% of the control group did a warm-up compared with 22% in the lower back pain group) ($p = 0.005$). The frequency of a warm-up prior to training was marginally larger in the control group (48% of the control group did a warm-up compared with 23% in the lower back pain group) ($p = 0.069$). There was a significantly lower frequency of stretching sessions per week in the low back pain (3 times per week) compared with the control group (4 times per week) ($p = 0.036$). Furthermore, 77% of the control group stretched while only 46% of the low back pain group stretched prior to training (significant difference, $p = 0.028$) and racing (control = 83%, lower back pain group = 41%) ($p = 0.003$). Eighty-five percent of the whole group claimed to stretch regularly with most (65%) making use of short sustained stretches while 33.3% and 2.2% stretched for a prolonged period or utilized external support respectively. No runners responded to the use of PNF (proprioceptive neuromuscular facilitation) or ballistic stretch techniques. The low back pain group appeared to stretch their groins marginally less (27% of sample) compared with the control group in which 52% of this sample population stretched the groin muscles (p = 0.07). A similar trend was noted with regard to stretching of the quadriceps muscle in that the low back pain group appeared to stretch their quadriceps marginally less (41% of sample) compared with the control group in which 65% of this sample population stretched the groin muscles (p = 0.087). There was no difference between the two groups with respect to the duration of the stretching regimes or to other body areas stretched.

The stretching habits of the low back pain and control groups for specific anatomical areas are depicted in Table 15. There was no significant difference in the frequency of stretching performed in different anatomical areas in the lower back pain and the control group.

Table 15: The frequency of subjects (expressed as a percentage) who perform stretches of different anatomical areas in the low back pain and control group

Anatomical area Stretched	Lower back pain group	Control group	Total %	p-value
Feet/toes	4	13	8	0.197
Ankle	7	22	14	0.119
Shin area	4	9	6	0.620
Calves	69	65	67	0.775
Achilles tendons	31	39	35	0.542
Quadriceps	41	65	52	0.087
Hamstrings	69	83	75	0.259
Buttocks	17	26	21	0.638
ITB	21	35	27	0.255
Groin	27	52	38	0.070
Hip	10	26	17	0.136
Lower back	34	35	35	0.982
Upper back	10	13	12	0.762
Shoulder	31	17	25	0.259
Neck	28	13	21	0.202

Participation in cool-down activities was not linked to the occurrence of running-related lower back pain. In the lower back pain group, 88% of the group did not cool-down following both racing and training runs. However, 74% of the control group failed to cool-down after training while 70% did not cool-down after races.

5.5.4 Previous running injuries

Thirty-five percent of the whole sample reported that they had at least one injury in the preceding year. A total of 56 injuries were reported. In the control group an injury frequency of 65% was documented while an injury frequency of 141% was observed in the lower back pain group indicating more than one injury per subject in this group. The most common injuries (as a percentage of total injuries that were reported) included chronic calf strains (26.7%), knee injuries (21.5%), chronic hamstring strains (16.1%) and Achilles tendinitis (9.0%). There were no significant differences in the frequency of previous injuries or the side of injury between the two groups. There was, however a tendency for the low back pain group to have an increased incidence of right (24% in the lower back pain group compared with 4% in the control group, $p = 0.064$) and left (21% in the lower back pain group compared with 4% in the control group, $p = 0.086$) of chronic calf strains. There was also a significant difference ($p = 0.028$) associated with the development of right knee pain - 21% of the lower back pain group compared with no right knee injuries in the control group.

5.5.5 Clinical assessment

There was no relationship for the level of stabilising ability of the abdominal muscles (assessed with the biocuff) and the occurrence of previous injuries or for any of the individual injuries.

5.5.5.1 Intervertebral joint flexibility assessments

5.5.5.1.1 Assessment of PAIVM Scores

The percentage of runners with low back pain and control runners classified as having normal, hypomobile and hypermobile segments in the lumbar spine are depicted in Figure 13. The majority of runners were classified as hypomobile (62%) while only 15% of all runners were classified as hypermobile.

There was a significant difference ($p = 0.0021$) between the two groups generally with respect to the proportion of hypomobile and hypermobile segments. Only 4% of the lower back pain group were assessed as having normal joint stiffness on palpation of the PAIVM tests while 39% of the control group were assessed as being normal. The remainder, as has been stated, was skewed towards having a stiffer segment (Figure 13). That is, the control had a much larger proportion of subjects rated as having normal joint stiffness in the lumbar spine. A comparison between the two groups categorised as "normal and stiff" segments was significant ($p = 0.004$, 72% of the lower back pain group were assessed to have hypomobile segments while only 57% of the control group had hypomobile segments of the lumbar spine) and was also significant ($p = 0.001$) for the comparison between groups for the category of "normal and hypermobile". In this latter classification, 24% of the lower back pain group and 4% of the control group were assessed as having hypermobile segments of the lumbar spine. Although there was no significant difference between the two groups with regards to hypo- and hypermobile motion segments, the hypomobile group was far larger (Figure 13).

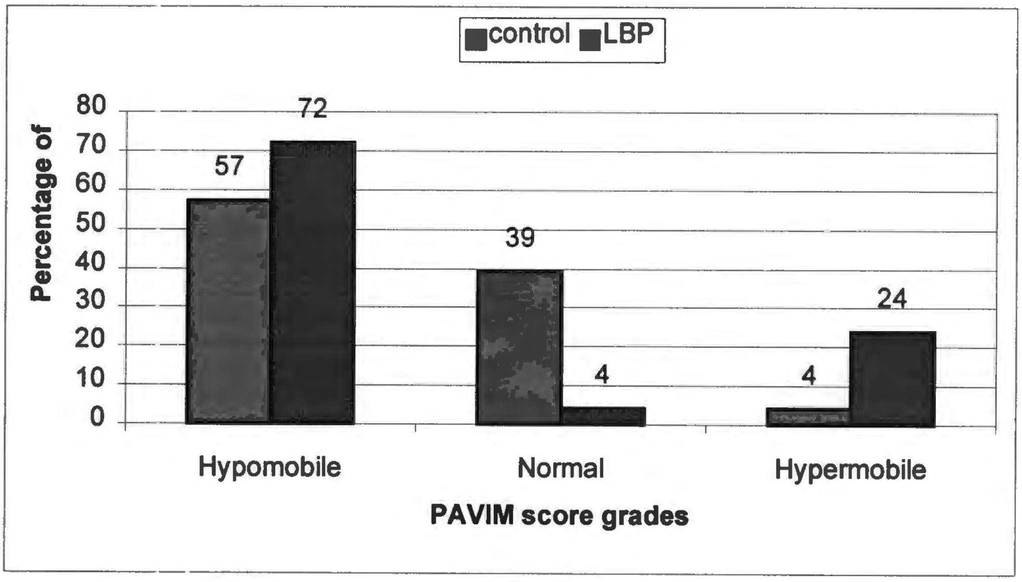

Figure 13: The frequency (% of runners) of PAIVM classification as normal, hypomobile or hypermobile in the low back pain (n = 29) and control (n = 23) groups. There was a significant difference between groups.

5.5.5.1.2 Assessment of PPIVM Scores

Those in the lower back pain group were significantly more likely to have hypo- and hypermobile segments (p = 0.0021) for both the rotation and flexion-extension movements. However, no statistical differences for the PPIVM scores of the rotation (Figures 14 to 19) and flexion-extension (Figure 20 to 22) tests were found between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L3/4 segment in response to left passive physiological intervertebral rotatory movement in the lower back pain and control group is depicted in Figure 14. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups ($p > 0.05$).

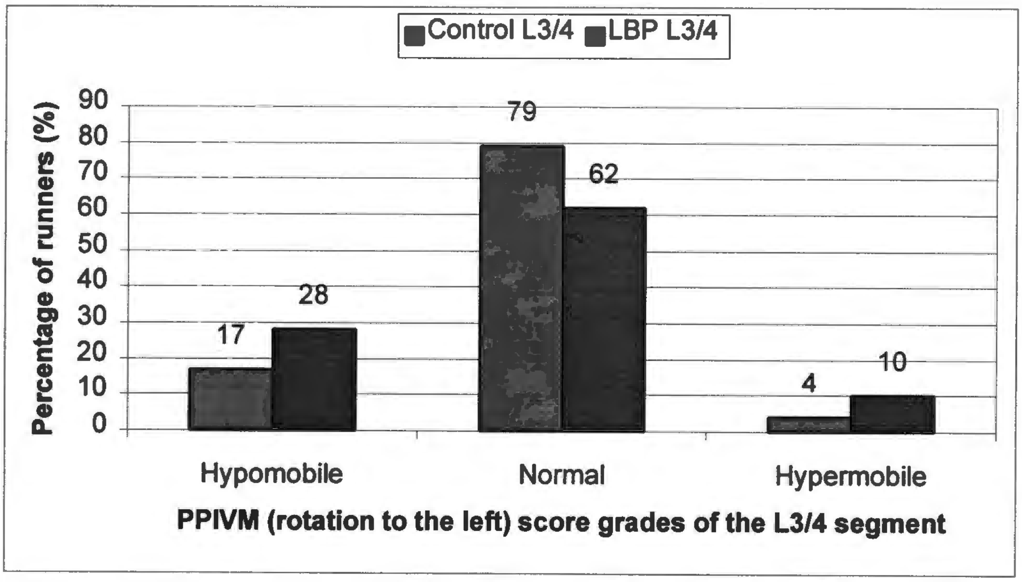

Figure 14: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L3/4 segment with PPIVM rotation to the left in the low back pain (n = 29) and control (n 23) groups. There were no significant differences between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L4/5 segment in response to left passive physiological intervertebral rotatory movement in the lower back pain and control group is depicted in Figure 15. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

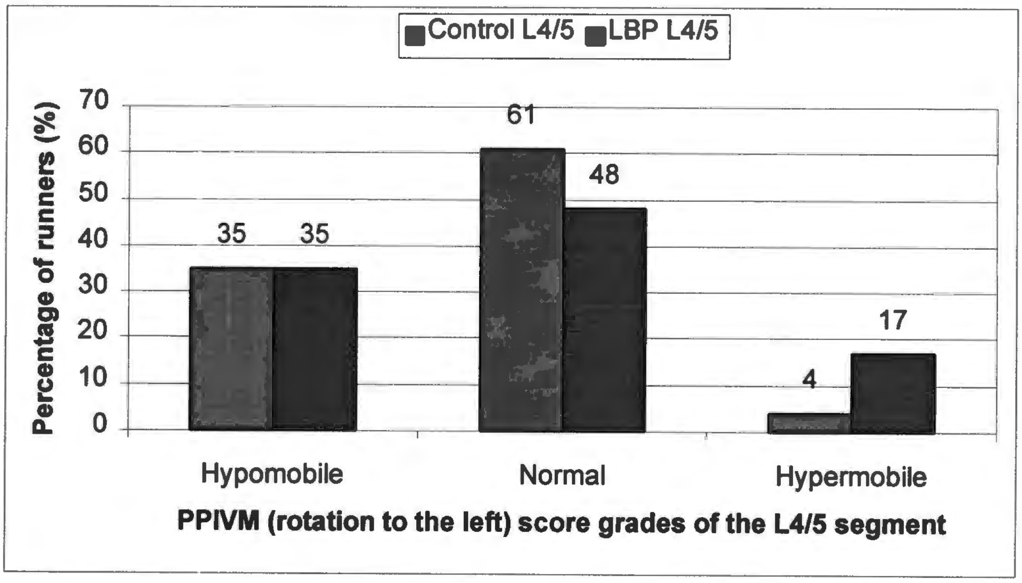

Figure 15: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L4/5 segment with PPIVM rotation to the left in the low back pain (n = 29) and control (n = 23) groups. There were no significant differences between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L5/Sl segment in response to left passive physiological intervertebral rotatory movement in the lower back pain and control group is depicted in Figure 16. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

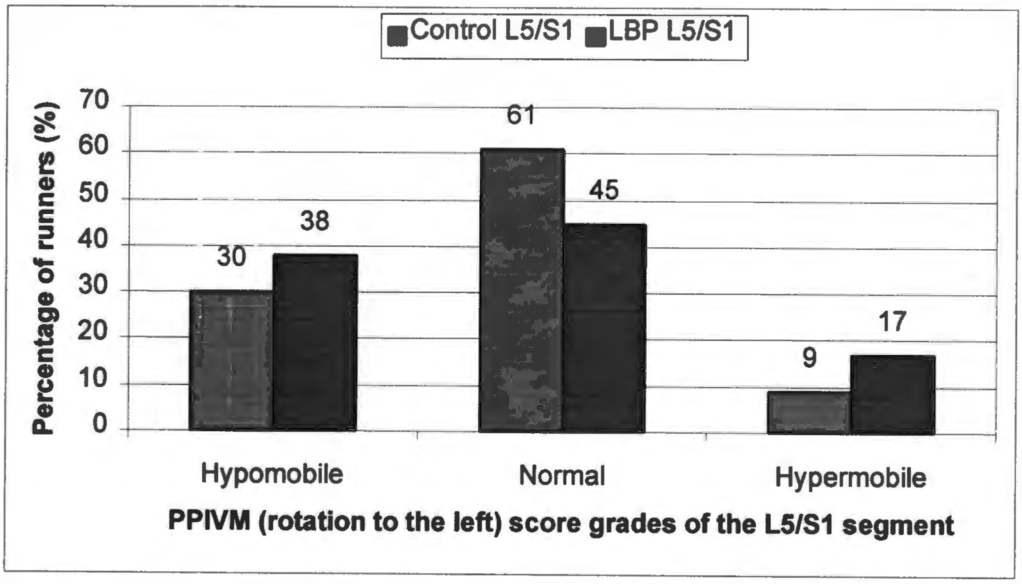

Figure 16: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L5/Sl segment with PPIVM rotation to the left in the low back pain (n = 29) and control (n = 23) groups. There were no significant differences between groups.

The frequency of runners with a normal; hypomobile or a hypermobile L3/4 segment in response to right passive physiological intervertebral rotatory movement in the lower back pain and control group is depicted in Figure 17. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

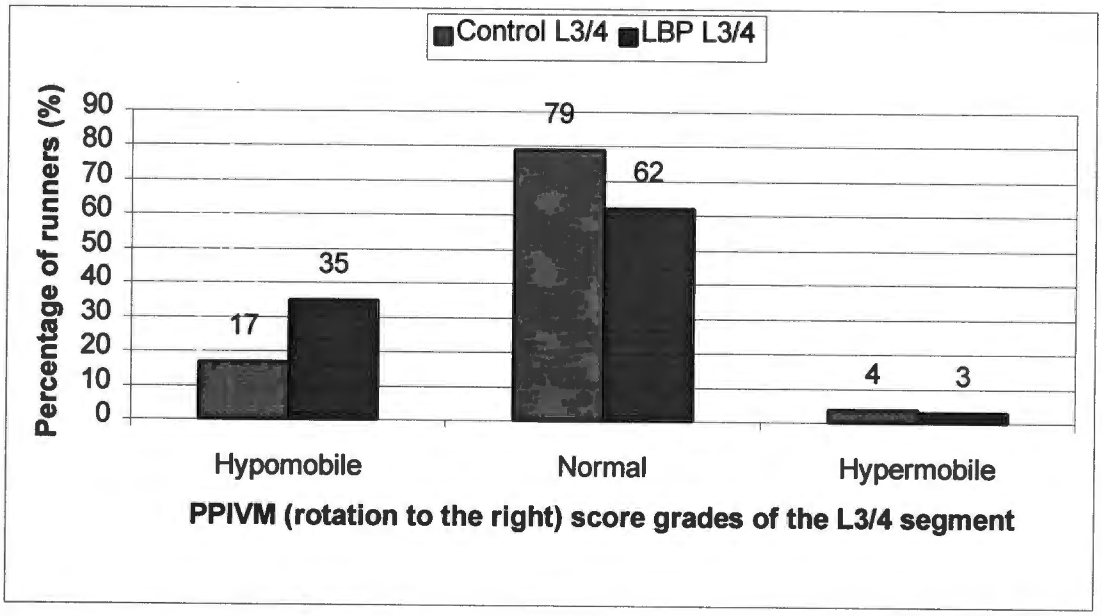

Figure 17: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L3/4 segment with PPIVM rotation to the right in the low back pain (n = 29) and control (n = 23) groups. There were no significant differences between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L4/5 segment in response to right passive physiological intervertebral rotatory movement in the lower back pain and control group is depicted in Figure 18. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

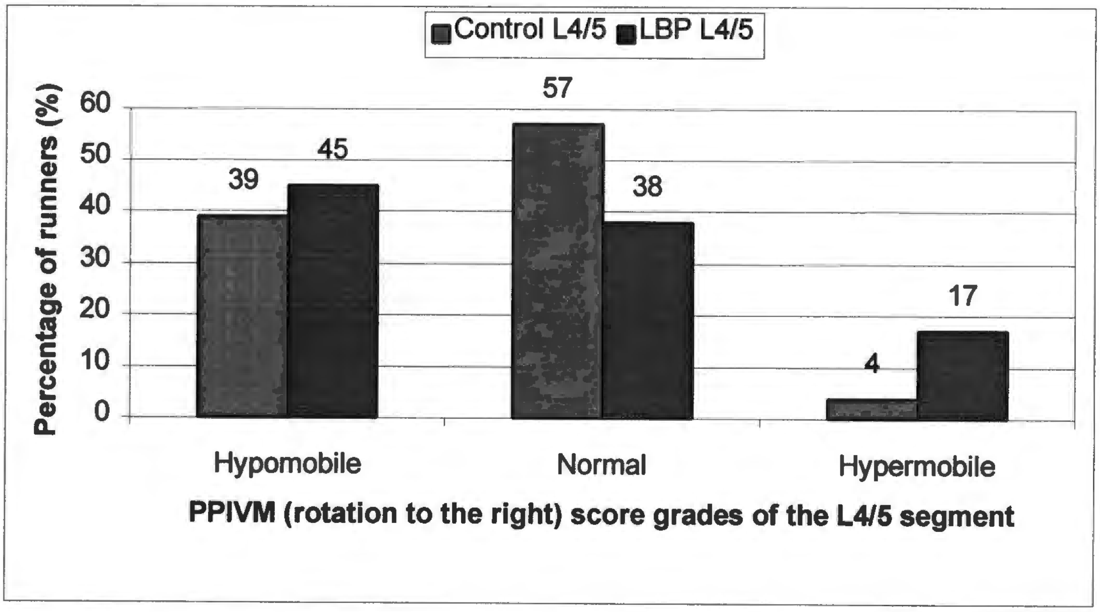

Figure 18: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L4/5 segment with PPIVM rotation to the right in the low back pain (n = 29) and control (n 23) groups. There were no significant differences between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L5/S1 segment in response to right passive physiological intervertebral rotatory movement in the lower back pain and control group is depicted in Figure 19. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

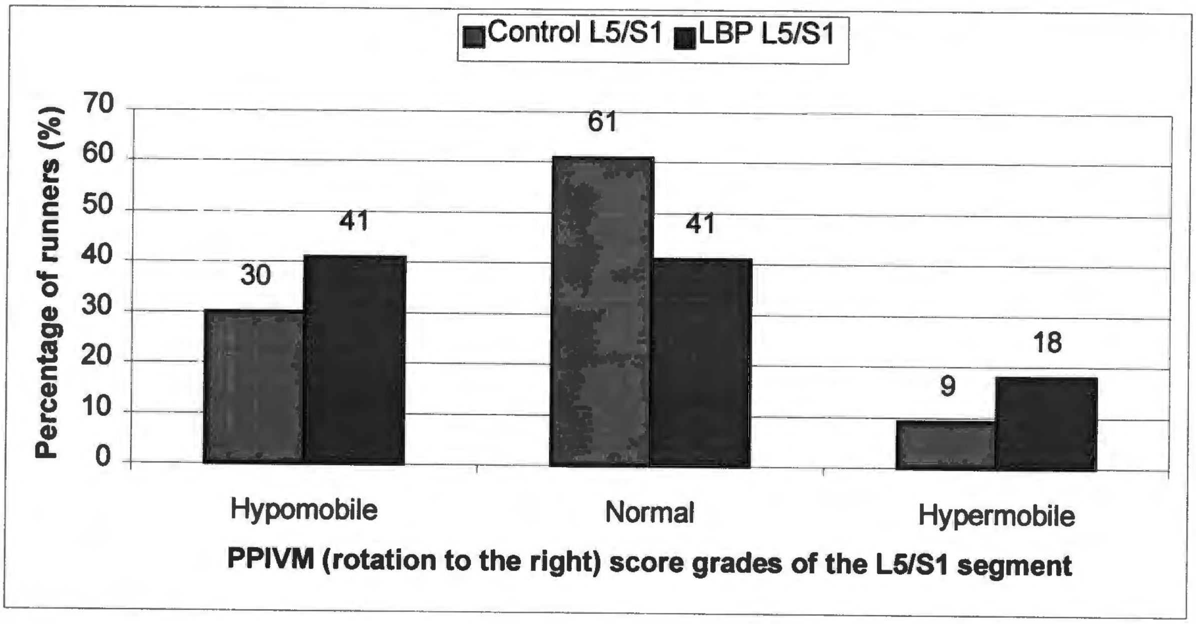

Figure 19: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L5/S1 segment with PPIVM rotation to the right in the low back pain (n = 29) and control (n = 23) groups. There were no significant differences between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L3/4 segment in response to passive physiological intervertebral flexion-extension movement in the lower back pain and control group is depicted in Figure 20. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

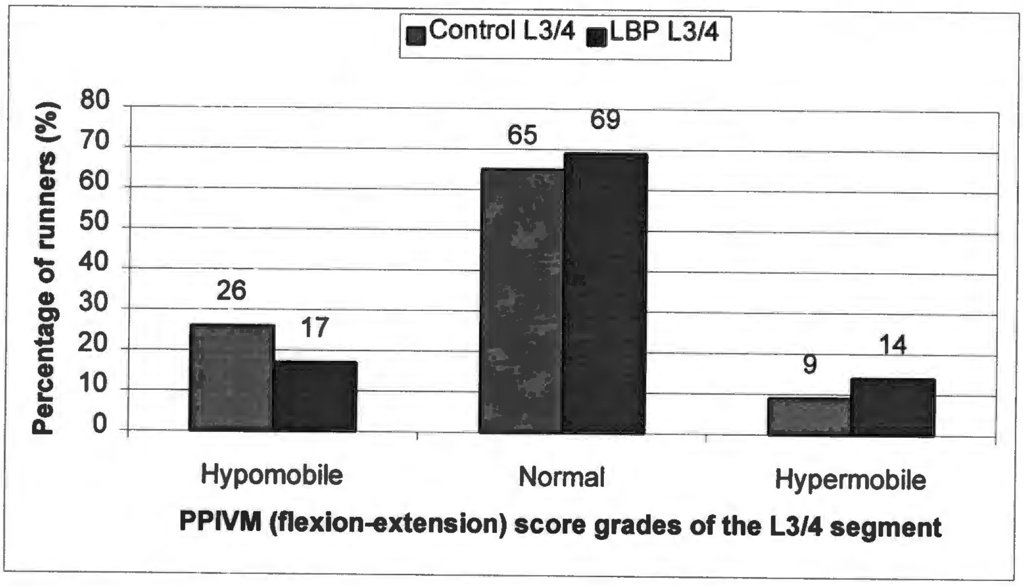

Figure 20: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L3/4 segment with PPIVM flexion-extension in the low back pain (n = 29) and control (n = 23) groups. There were no significant differences between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L4/5 segment in response to passive physiological intervertebral flexion-extension movement in the lower back pain and control group is depicted in Figure 21. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

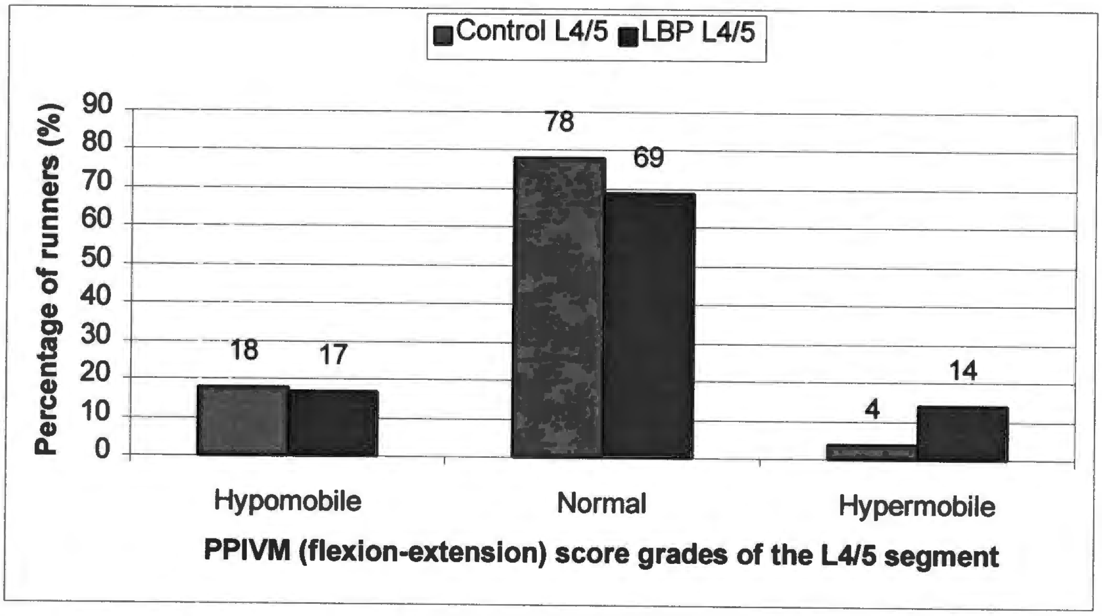

Figure 21: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L4/5 segment with PPIVM flexion-extension in the low back pain (n = 29) and control (n = 23) groups. There were no significant differences between groups.

The frequency of runners with a normal, hypomobile or a hypermobile L5/S1 segment in response to passive physiological intervertebral flexion-extension movement in the lower back pain and control group is depicted in Figure 22. There was no significant difference in the frequency of hypermobile, hypomobile or normal segments between the two groups (p> 0.05).

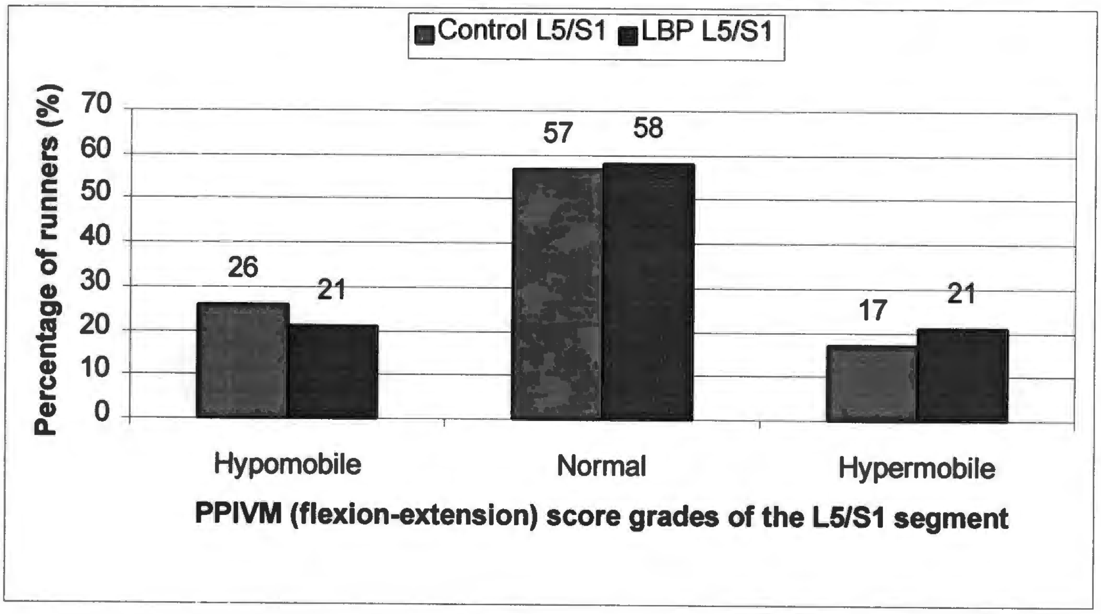

Figure 22: The frequency (% of runners) classified as runners with a normal, hypermobile or hypomobile L5/Sl segment with PPIVM flexion-extension in the low back pain (n = 29) and control (n = 23) groups. There were no significant differences between groups.

5.5.5.2 Sacrio-Iliac joint dysfunction

When testing the SIJ, 6% of the lower back pain group noted the pressure response to cause a similar pain in their back to that they experience while running. Testing of the control group revealed no positive results when pressure was applied over the SIJ.

5.5.5.3 Biomechanical assessment

Table 16: Biomechanical variables in the low back pain and control groups taken during the clinical evaluation. Values are Mean ± SD

Variable	Low back pain group (n = 29)	Control group (n = 23)	P Value
Spinal flexibility between the S2 and L1 vertebrae (cm)	6.3 ± 1.3	6.6 ± 1.7	0.533
Spinal flexibility between the S2 and T1 vertebrae (cm)	9.2 ± 1.5	9.4 ± 3.1	0.904
Q angle measurement for left knee (degrees)	14.7 ± 4.5	15.1 ± 3	0.781
Q angle measurement for right knee (degrees)	14.0 ± 4.5	14.1 ± 2.9	0.933
Valgus deformity at the knee (mm)	23.7 ± 16.9	29.3 ± 18.0	0.934
Valgus deformity of left rearfoot (degrees)	10.9 ± 3.9 *	11.2 ± 3.6 *	0.077
Valgus deformity of right rearfoot (degrees)	9.9 ± 3.9 *	9.2 ± 3.0 *	0.077
Varus deformity of left forefoot (degrees)	8.9 ± 3.0 *	7.7 ± 2.0 *	0.077
Varus deformity of right forefoot (degrees)	7.8 ± 2.4 **	6.7 ± 2.4 **	0.038
Leg length discrepancies between the ASIS and medial malleolus (cm)	0.5 ± 0.6	0.5 ± 0.7	0.825
Leg length discrepancies between the tibial tuberosity and medial malleolus (cm)	0.3 ± 0.3	0.2 ± 0.3	0.373

***indicates a marginal difference between groups (p<0.1);**

****indicates a significant difference between groups (p<0.05)**

The biomechanical variables in the low back pain and control groups are depicted in Table 16. There was a significant degree of forefoot varus on the right leg in the low back pain group compared with the control group (p = 0.038). Marginal differences between groups were observed with respect to varus and valgus deformities of the rearfoot (p = 0.077) and forefoot varus on the left (p = 0.077) (Table 16).

There were no significant differences between the lower back pain and control groups with respect to leg length discrepancy or Q-angle of the knee bilaterally, varus / valgus deformities at the knee with respect to the nature of the deformity and rearfoot or forefoot bilaterally. The measured degree of each of these biomechanical measures also had no association to the incidence of lower back pain. Spinal flexibility measures between S2 – T1 nor S2 – L1 were also not significantly different between groups.

5.5.5.4 Flexibility scores

Table 17: Measures of flexibility in the lower back pain and control groups. Values are Mean ± SD

Flexibility	Lower back pain group (n = 29)	Control group (n = 23)	P Value
Left hip flexor flexibility (degrees)	-0.7 ± 7.0 *	2.8 ± 6.6 *	0.074
Right hip flexor flexibility (degrees)	-0.2 ± 8.3	0.7 ± 6.4	0.644
Left rectus femoris flexibility (degrees)	99.5 ± 17.4	102.1 ± 15.6	0.624
Right rectus femoris flexibility (degrees)	102.8 ± 15.5	109.1 ± 11.2	0.114
Left ITB flexibility (degrees)	6.5 ± 4.3	5.1 ± 5.3	0.239
Right ITB flexibility (degrees)	9.0 ± 4.6 **	6.8 ± 4.2 **	0.036
Left medial femoral rotation (degrees)	3.5 ± 1.9 *	3.8 ± 2.7 *	0.068
Right medial femoral rotation (degrees)	4.9 ± 2.3 *	4.2 ± 1.9 *	0.053
Left hamstring flexibility (degrees)	54.2 ± 8.7	57.7 ± 10.0	0.239
Right hamstring flexibility (degrees)	56.0 ± 7.1 *	59.8 ± 8.6*	0.091
Left adductor flexibility (mm)	331.3 ± 77.1	300.8 ± 58.1	0.169
Right adductor flexibility (mm)	341.6 ± 70.3 *	304.9 ± 55.8 *	0.055

***indicates a marginal difference between groups ($p<0.1$);**

****indicates a significant difference between groups ($p<0.05$)**

The measure of the flexibility assessments in the low back pain and control groups is depicted in Table 17. The right ITB was significantly more inflexible in the low back pain group (p = 0.036). Hip flexor flexibility on the left was marginally less flexible (p = 0.074) in the low back pain group. Hamstring flexibility (on the right) was marginally less in the lower back pain group (p = 0.091), as was adductor flexibility on the right (p = 0.055), being less flexible in the low back pain group. Medial femoral rotation was marginally greater in the low back pain group on both the left (p = 0.068) and right (p = 0.053) sides.

There were no significant differences in the right hip flexor flexibility, rectus femoris flexibility bilaterally, ITB length on the left, medial or lateral femoral rotation, bilateral hamstring flexibility and bilateral adductor flexibility between the two groups.

5.5.5.5 Abdominal muscle strength grading scores

Table 18: Abdominal muscle strength grading scores in the lower back pain and control groups. Values are mean ± SD

Muscle strength variables	Lower back pain group (n = 29)	Control group (n = 23)	P Value
Functional test leg-lowering score (grading 0 – 5)	0.76 ± 0.83	1.04 ± 0.76	0.156
Functional test trunk curl-up score (grading 0 – 5)	2.14 ± 1.48**	3.26 ± 1.32**	0.0085
Able to contract the transversus abdominal muscle (expressed as frequencies)	40%	60%	
Strength of the transversus abdominal contraction (grading maximum of 3)	1.8 ± 1.0	1.3 ± 0.8	

*** = indicates a marginal difference between groups (p<0.1);**

**** = indicates a significant difference between groups (p<0.05)**

The measured variables in the abdominal muscle strength grading scores in the lower back pain and control groups are depicted in Table 18. There was significantly lower grading for the trunk curl-up test (p = 0.0085) in the lower back pain group compared with the control group (Figure 23). There was no significant difference between the two groups for the leg-lowering test (Figure 24).

On observing the differences between the two groups with regard to their mean scores, the lower back pain group had lower scores than the control group (i.e. lower back pain group had a mean score of 0.76 (SD 0.83) and 2.14 (SD 1.48) for the leg lowering and trunk curl-up scores respectively, while the control group had scores of

1.04 (SD 0.76) for leg-lowering score and 3.26 (SD 1.32) for trunk curl-up), possibly indicating weaker abdominal muscles for the pain group (Table 18).

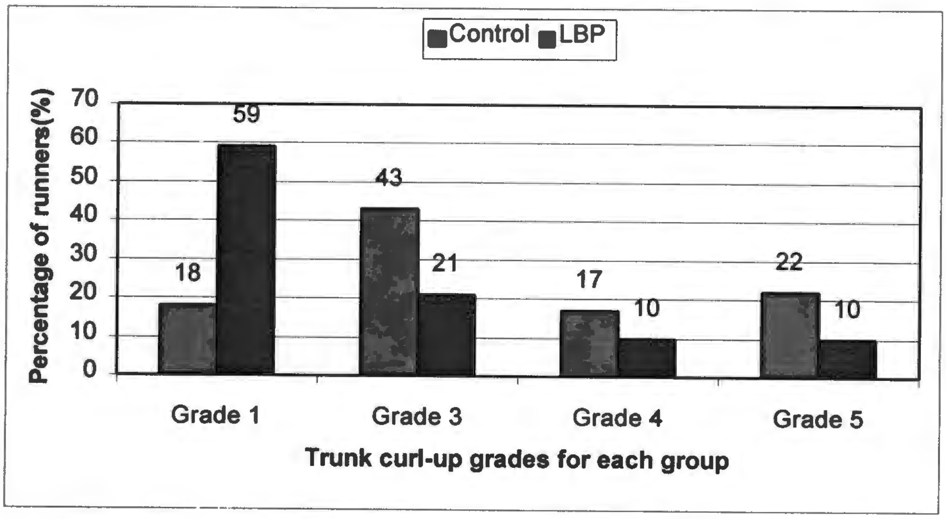

Figure 23: The frequency of trunk curl-up grades of the control (n = 23) and low back pain (n = 29) groups

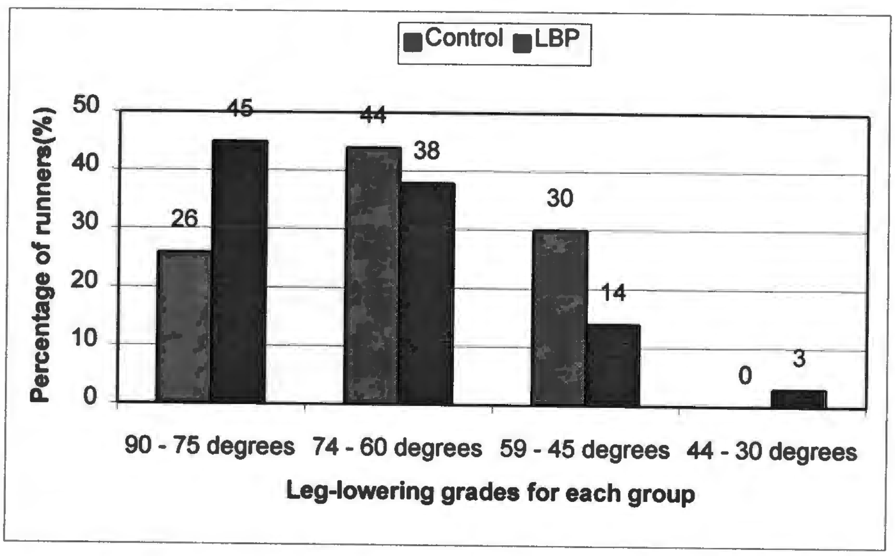

Figure 24: The frequency of leg-lowering scores of the control (n = 23) and low back pain (n = 29) groups

5.5.5.6 Lumbar Spine muscle stability tests

Table 19: Tests of lumbar spine stability using the biocuff.

Values are Mean ± SD

Stabilising ability	Low back pain group (n = 29)	Control group (n = 23)	P - value
Decrease in the manometer reading during the 1 minute isometric hold test (mm Hg)	5.9 ± 2.8	4.9 ± 1.6	0.283
Decrease in the manometer reading during the flexion / extension heel slide test on the left (mm Hg)	8.6 ± 3.6	10.0 ± 4.5	0.255
Decrease in the manometer reading during the flexion / extension heel slide test on the right (mm Hg)	7.8 ± 2.9	8.5 ± 4.9	0.999
Decrease in the manometer reading during the abduction / adduction knee drop test on the left (mm Hg)	7.8 ± 2.4 **	6.1 ± 2.2 **	0.0086
Decrease in the manometer reading during the abduction / adduction knee drop test on the right (mm Hg)	7.7 ± 2.9 *	6.3 ± 1.8 *	0.058

*** = indicates a marginal difference between groups (p<0.1);**

**** = indicates a significant difference between groups (p<0.05)**

Table 20: The frequencies (% of runners) of the lumbar spine stability tests in the low back pain (29) and control (23) groups

Variable	Low back pain	Control	p-value
Able to recruit the transversus abdominis	50	61	0.267
Good strong bracing	21	56	0.007**
Good stabilising ability	18	48	0.032**
Loss of contraction with movements of left leg	86	65	0.740
Loss of contraction with movements of right leg	86	56	0.017**
Overcompensating with obliques	90	65	0.044**
Overcompensating with rectus abdominis	69	74	0.765
Overcompensating by pelvic tilting	41	22	0.114
Overcompensating using leg	17	13	1.000
Overcompensating by breath holding	45	22	0.082*
Ability to overcompensate for failing contraction	10	4	0.621
Ability to recover lost contraction	14	22	0.486
Sudden jerks in the muscle contraction	7	9	1.000
Small swings of manometer needle	31	61	0.031**
Large swings of manometer needle	48	31	0.259
Drop in contraction with left leg movements	79	48	0.018**
Drop in contraction with right leg movements	79	52	0.038**
Ability to improve the contraction with practice	10	0	0.245

*** = indicates a marginal difference between groups (p<0.1);**

**** = indicates a significant difference between groups (p<0.05)**

The results of tests from the use of the biocuff to measure lumbar spine stability are depicted in Table 19. There was a significant difference between the groups for the left side while doing an abduction / adduction hip movement. The painful group displayed far greater instability on the left ($p = 0.0086$) with a marginal difference seen on the right ($p = 0.058$). There was a greater mean decrease in biocuff pressure in the lower back pain group (7.8 ± 2.4 mm Hg) compared with the control group (6.1 ± 2.2 mm Hg) in response to the abduction / adduction knee drop test. The ability to do the one-minute hold isometric endurance test and functional abdominal bracing with limb movement were compared. There were no significant differences in the decrease in biocuff pressures in response to a one minute isometric hold test, the heel slide test or between right and left sides. Further analysis was performed to determine if a relationship existed between poor scores for the heel slides and abduction / adduction pelvic stability tests and the occurrence of other running injuries. No such relationship was found.

A summary of the observances of the subjects' ability to use the abdominal stabilising muscles is shown in Table 20. The stabilising muscle contraction (bracing) was significantly better ($p = 0.007$) in the control group, as was the stabilising ability ($p = 0.032$) compared with the lower back pain group. The abdominal stabilising contraction was mostly lost and this was marginal with leg movements (flexion-extension / abduction-adduction) on the left ($p = 0.074$) but significant with leg movements on the right ($p = 0.017$). The obliques were most often used to assist in the stabilising process ($p = 0.044$) with breath-holding marginally useful ($p = 0.082$) in the lower back pain group. None of the other compensation strategies such as pelvic tilting, contraction of the rectus abdominis muscle and using the legs were used more frequently in the lower back pain group. There were no differences observed between the two groups in terms of their ability to recruit the global abdominal muscles.

Few runners had the strength to over-compensate the contraction or to recover the contraction once lost although sudden jerks in the muscle contraction were noted. Frequent small swings of the manometer were evident as the weak muscle struggled to maintain the contraction as the legs were moved while the bracing action was held. This was significantly apparent for the lower back pain group ($p = 0.031$). Although large swings were evident in some, their occurrence was not significantly different between groups. Those with lower back pain did have a significantly higher incidence of a steady drop in the contraction throughout the hold ($p = 0.018$ for the left side; and $p = 0.038$ for the right), very few being capable of improving their contraction with practice. This was an interesting finding as only 10% of the total tested population was able do so and all of these subjects fell into the lower back pain group.

5.6 Discussion

In this case-control study a group of runners complaining of running-related lower back pain were compared with a control group of runners having never suffered from back pain related to running. This study is the first to describe the specific clinical characteristics of running-related lower back pain. Running-related lower back pain was classically a dull or uncomfortable ache, centrally situated and of moderate intensity. Thirty-five percent of the runners suffering from lower back pain reported that they had to reduce their running intensity to alleviate the pain. There was a tendency for pain to be referred to the buttocks. Pain was usually of an intermittent nature during the run with an association between racing and the onset of lower back pain.

Running-related injuries have been associated with poor training routines (Walter et al 1989, Van Mechelen 1992). There were no significant differences between the two groups with respect to training variables except that the control group tended to adhere more to a structured training program. A poor relationship between training variables and injuries in general was also documented by some authors (Walter et al 1989) but not by others (Lysholm and Wiklander 1987). These discrepancies may be due to the differences in study design. The former study incorporated a large number of subjects reporting injury and training histories by questionnaire every 3 months for the period of one year. The latter study followed a small group of athletes every month for a year and data may have therefore been more accurate. However, due to the small sample size of the latter study and as runners in this study were not uniformly road-runners as in the former study, but were classed as either long-, middle- or short-distance runners, comparison between studies is difficult.

Lower back pain in runners was aggravated by increases in training load (hills, intensity and frequency). This finding is similar to that documented by other researchers for general risk factors of running injuries. In particular, training errors (sudden increase in mileage or change of routine) have previously been suggested as common injury-provoking factors (Lysholm and Wiklander 1987). Most injuries have been attributed to tissue overload and it has been shown that the highest incidence of injuries occurred during the months of intense training and competition (Van Mechelen et al 1993). Although low injury rates have been observed in distance runners compared with middle and short distance runners (Lysholm and Wiklander 1987), distance runners had the longest duration of symptoms, which prevented training. In this present study no relationship was found between running level and the occurrence of lower back pain.

Thirty-five percent of the lower back pain group reported that an increased running distance was related to the onset of lower back pain. An increase in hill running (45%), a more intense running intensity (35%), the onset of fatigue (28%) and commencement of training (21%) were documented as being contributing factors. An increased risk of developing running injuries in general has been associated with weekly running distances greater than 65km, higher frequencies of training and running all year round (Walter et al 1989). The result of the present study could not confirm (but did suggest) an association between an increased risk of lower back pain and training variables such as weekly distances above 65 km, increased frequency of training and running all year round (Walter et al 1989). The only significant training factor that was found to be associated with lower back pain in the present study was the running load (distance, intensity and gradient) as well as to the runners' level of fitness.

The relationship between flexibility and lower back pain was investigated in this study. Section 3.4.2.5 in chapter 3 described some of the current hypotheses regarding musculotendinous inflexibility and the onset of lower back pain. Runners with no history of lower back pain were found to stretch more frequently than the runners suffering from lower back pain. It was interesting to note that those runners with lower back pain were less likely to stretch their groin and quadriceps muscles. In one previously published study, half of the subjects indicated that poor flexibility of the hamstrings, adductors and hip flexors aggravated their back pain during running. However, in that study the sample size was small and the results therefore have to be interpreted with caution (Bach et al 1985). Runners in this present study maintained their stretches for a short hold only. Pope et al (1998) found poor flexibility of the ankle to correlate with an increased risk of injury to the ankle, foot and lower leg but this was not necessarily a casual relationship. They also found stretching to not significantly reduce the risk of injury.

Runners in the present study who reported that they consistently stretched or did not stretch seemed to be less at risk of injury (of having lower back pain) than those who reported that they stretched "sometimes". Less flexible athletes have been found to have an equal incidence of lower back pain as the more flexible ones (Lindgren and Twomey 1988). In this study there was a strong positive response for stretching as a potential protecting factor of lower back pain inferred from the discrepancy between the lower back pain and control groups in their frequencies of performing flexibility exercise routines. However in this study the stretching regimes followed by runners were not scrutinised nor evaluated in terms of their efficacy and therefore such an observation is merely speculative.

It was also observed that there were many more injuries reported amongst those runners reporting lower back pain. Although reported as being stretched most frequently, the calves, hamstrings, Achilles tendons and knees were most commonly injured. Thirty-five percent of all the runners reported the incidence of another injury within the year. This is similar to the findings in other studies documenting up to a 50% incidence of "other" injuries (Walter et al 1989). Previous research found a previous injury to be significantly related to subsequent injury (Walter et al 1989).

The clinical evaluation was the basis of the comparison between the lower back pain (those with running-related lower back pain) and control (those runners without lower back pain) groups. It was postulated that the biomechanics, muscular strength and stabilising contractions of the abdominal muscles, and flexibility of the lumbar spine, hamstrings, hip flexors and hip adductors are of major importance in the prevention of lower back pain due to their potential effect on the lumbar spine and lumbar-pelvic relationship. Norris (1995d) recommended that an assessment should include an evaluation of muscle tightness (hip flexors / adductors, hamstrings, quadriceps and ilio-tibial band), movement patterns (sit-ups, leg-lowering) and the ability of a synergist to hold a static contraction. Conversely, according to Pope (1989), posture, anthropometry and mobility measures have a limited prognostic value while muscular strength and physical fitness measures are more likely to be of value.

There was no significant difference in the measurements of lumbar spine joint stiffness between runners with lower back pain and a control group of runners for the PPIVM and PAIVM tests. However, there was a tendency for an increased frequency of hypomobility and hypermobility of the lumbar spine in the lower back pain group. The significance of segmental palpation has been suggested in a previous study as alterations in the normal stiffness could possibly be contributory to lower back pain (Burton and Tillotson 1989). However, P-A accessory mobility has been regarded to show poor inter-rater reliability and caution in the clinical decisions related to this form of evaluation has been advised (Binkley et al 1995). Furthermore there are also indications of different reliability measurements being evident between different levels tests (Maher and Adams 1994). The results of a pilot study conducted prior to the commencement of this present study reveal the tests to be highly reliable, yet the author acknowledges that these tests, although useful in the clinical setting, should be viewed with caution and interpreted for interest only. According to Matyas and Bach (1985) and Maher and Adams (1994) PAVIM tests show poorer reliability with regard to measurements of stiffness than with measurements of pain. Traditionally, information has been collected regarding stiffnress. However, it has been suggested that there may be a relationship between pain and reduced voluntary movement causing abnormal spinal joint stiffness (Maher and Adams 1994).

In the present study, the SIJ was only tender to palpation in 6% of the runners with lower back pain group. Although the SIJ has been regarded as a significant source of lower back pain (Schwarzer et al 1995) this could not be confirmed in the present study. The clinical test for the SIJ being used in the present study was in one plane only and may not have been sensitive enough to stress the joint sufficiently to indicate a dysfunction in the joint. However, Deryfuss et el (1996) performed a series of diagnostic SIJ provocation tests and found none to be worthwhile! Laslette and

Williams (1994) found the sacral thrust technique to show marginal reliability only and accordingly they advise against the use of a single test during a diagnostic SIJ physical examination test.

It has been suggested that a lack of trunk extensibility can induce back pain while jogging (Slocum and James 1968). In the present study this could not be confirmed using standard clinical tests of spinal range of movement measures. Waddell et el (1992) also found lumbar flexion to not be reduced in patients with chronic lower back pain and in those with non-specific lower back pain.

The association between lower limb biomechanics and the development of running-related injuries is frequently postulated (Van Mechelen 1992). In this study, runners with lower back pain had a significantly increased frequency of rearfoot valgus and forefoot varus. This was also associated with increased internal femoral rotation in runners with lower back pain. These biomechanical abnormalities are associated with increased subtalar joint pronation. Attempts to identify and correct lower limb biomechanics in the treatment of lower back pain in runners have to be investigated further in well conducted clinical trials.

A leg length discrepancy (LLD) of up to 1.0 cm is common in the general population (Christie et al 1995) and it has previously been suggested this may be a risk factor for the development of lower back pain in runners. However, in this present study no differences were found with regard to leg length discrepancies, knee / rearfoot / forefoot varus / valgus postures or measurements of the Q-angle at the knee. These biomechanical abnormalities have been associated with overuse injuries in previously documented studies. These biomechanical abnormalities include limb lengths, genu varus and valgus and varus or valgus anomalies of the rearfoot or forefoot (Van Mechelen 1992). In at least 40% of their sample abnormal lower limb biomechanics was one of the factors associated with running injuries in general (Lysholm and Wiklander 1987).

A lack of flexibility of the lumbar-pelvic-femoral muscle groups has been postulated among the many hypotheses regarding running injuries in general and in the aetiology of lower back pain. Pope et al (1998) noted in prospective studies that muscle strains correlated with a lack of pre-season flexibility. However no association between a lack of range of motion and injury was eveident. Waddell et al (1992) determined that the straight leg raise test was a good indictator of those suffering lower back pain. Runners with lower back pain in this present study had significantly reduced flexibility of the left hip flexors, right ilio-tibial band, right hamstrings and right adductors. This suggests that there may be an unequal force on the pelvic area which may influence the lumbar-pelvic relationship, and further demonstrates an imbalance between sides. Garrett (1987) regarded lower back pain sufferers as having shortened pelvic muscles, which reduce pelvic mobility increasing lumbar stress. The unequal forces in the pelvis (suggested by the muscle inflexibilities mentioned above) may be the reason for the findings of pain referral mostly to the left buttock. It appears from the findings mentioned above (of inflexibility of the right ilio-tibial band, right hamstrings and right adductors) that more inflexible structures on one side would cause pain on the contra-lateral side (the left buttock). Interestingly, it has been hypothesized that repetitive muscle shortening due to increased duration of muscle activity and force of contraction over accumulated miles of running, may lead to inflexibility of the hip flexors, adductors and hamstring muscle groups (Bach et al 1985).

The iliopsoas has an extensive lumbar attachment, and thereby may contribute towards compressive and lordotic forces on the lumbar spine and intervertebral discs, if the stabilisation forces of the abdominal muscles do not balance these forces (Jorgensson 1993, Bach et al 1985). The iliopsoas muscle therefore potentially influences movements in the lumbar area and may be influenced by lumbar movement. In a review on unresolved controversies in back management, Liemohn et al (1988) agreed, indicating that tightness of the hip flexors limit pelvic movement (posterior tilting and contra-lateral rotation) which places additional strain on the lumbar spine.

In one study no relationship between iliopsoas or hamstring flexibility and the incidence of lower back pain in non-runners was documented (Hellsing 1988). In another study adductor, hip flexor and hamstring flexibility was compared between runners and non-runners and the relationship between muscle tightness and lower back pain was documented. Runners were significantly less flexible than non-runners in the hamstring and adductor muscle groups (Bach et al 1985). Others have, however, documented that the hamstring and quadriceps muscle groups were less flexible in non-running lower back pain sufferers (Garrett 1987). The present study supports these latter findings. Inflexible hamstrings exert a pull on the ischial tuberosities thereby rotating the pelvis posteriorly and flattening the lumbar spine. This can cause spinal injury (Lindgren and Twomey 1988, Bach et al 1985). Furthermore, inflexibility of the hip adductors leads to the gluteal muscle groups contracting too late with a resultant poor pelvic stabilising ability (Norris 1995d). As there is a need for increased range of muscle activity to reduce the impact of the load imposed while running (Bach et al 1985), inflexibility of the pelvic-femoral muscles may cause an increase in the load to the lumbar spine. All these factors could possibly lead to the development of lower back pain.

The relationship between the incidence of lower back pain and hip joint range of motion is not clear. An association between hip rotation range of motion imbalance and the presence of lower back pain has been documented in non-runners (Ellison et al 1990). It has been shown that twenty to thirty-five percent of the general population have a 5-degree extension deficit at the hip but no significant relationship between iliopsoas muscle inflexibility and increased lumbar lordosis has been shown (Jorgensson 1993). It has been hypothesised that postural changes during running may contribute to further musculotendinous inflexibility of the hip (Bach et al 1985).

In one study a limitation of internal rotation of the hip was documented in non-runners suffering from lower back pain (Ellison et al 1990). Furthermore, long distance runners have been clinically observed to develop inflexibility of the hip external rotators (D'Orazio 1993). However, in the present study limited internal rotation of the femur was not associated with lower back pain and these results could therefore not support the hypothesis that hip internal or external rotation range of movement is associated with lower back pain. Indeed, in the present study, runners with lower back pain displayed increased internal rotation of the hip. This finding may be due to inflexibility of the hip adductor muscles. Adductor inflexibility can result in late gluteal activation with a corresponding increase in a shortened tensor fascia late contraction (Norris 1995d). This could allow femoral internal rotation as external rotation may be limited.

Strength, flexibility, posture and body mechanics have been recognised as important factors of low back function as is the importance of strong trunk muscles to prevent lower back pain (Liemohn et al 1988). It has been shown that patients with lower back pain frequently have strength deficits for both static and dynamic muscle contractions of the trunk flexors and extensors (Smidt et al 1983). It has been postulated that controlling a trunk curl-up motion without the feet anchored requires pelvic stability and trunk co-ordination skills essential for trunk training (Miller and Medeiros 1987). In the present study, runners with lower back pain were weaker than the control group for the trunk curl-up test and for the leg-lowering test. This is interesting if the answers to the first questionnaire from the first part of this thesis are analysed as the upper abdominals were trained harder than the lower abdominal muscles in runners who reported to exercise to relieve their lower back pain. Miller and Medeiros (1987) noted that lower back pain was associated with weakened lower abdominal muscles and their improper use in activities of daily living. According to Jull et al (1993) and Richardson et al (1992), these muscles are frequently found to be weak in subjects with lower back pain.

A higher static capacity of the abdominal muscles was found in those with a greater ability to do trunk curl-up exercises but there was a weaker stabilising function apparent in those who performed these exercises at a rapid rate (Wohlfahrt et al 1993). This capacity of the abdominal muscles to perform a dynamic function may carry-over to their stabilising function but only if a high volume is performed (Wohlfahrt et al 1993). Testing of dynamic abdominal exercises may possibly give an indication of the abdominal muscles' capacity to act as a stabiliser. In this way there is a direct link between the muscle function and stabilisation tests. However, Wohlfahrt et al (1993) do caution that there is not necessarily an improved isometric skill after training involving dynamic exercises.

A trunk curl-up uses both the internal and external oblique muscles and the rectus abdominis muscle. A higher rate of intra-abdominal pressure development has been shown with improved strength of the obliques (Cresswell, Blake and Thorstensson 1994). This too may direct a link between dynamic muscle activity and its stabilising function. However, rapid movements recruit primarily the mover muscles, not the stabilising muscles. For this reason the trunk-curl and leg-lowering tests were performed slowly, without sudden jerks.

It has been postulated that excessive lumbar spine movement may indicate an inability of the stabilising muscles to co-ordinate a force necessary to support the spine (Jull et al 1993). These muscles (including the transversus abdominis) may not always be optimally recruited or may fatigue. A loss of this active stabilising ability may possibly contribute to lower back pain (Jull et al 1993). The results of the present study would indicate that the contraction of the global abdominal muscles and the stabilising ability was poorer in runners with lower back pain. Control of the contraction of these muscle groups appeared to be more easily lost when testing on the right hand side. However, it is important to note that the nature of these specific tests and the following tests discussed in the next 4 paragraphs were via observation from the trained examiner and could therefore show inter-tester variation. These results therefore need to be viewed with caution.

The transversus abdominis and internal oblique muscles are the only two abdominal muscles which are attached from the anterior trunk to the lumbar spine via thoraco-lumbar fascia. They are the only abdominal muscles, which can actively support the lumbar spine in response to a rise in intra-abdominal pressure (Miller and Medeiros 1987). It has been shown that the intra-abdominal pressure increases just prior to contacting the ground on foot strike. There may be a neural strategy designed to prepare the trunk for load-bearing and hence the need to improve co-ordination of muscle synchronisation (Cresswell, Blake and Thorstensson 1994).

Testing under submaximal rather than maximal loading may be the key issue in identifying patients with lower back pain as it is more functional (Jull et al 1993). Thus testing in the present study was performed at a subjective intensity of 30% of the maximal muscle contraction. Isometric strengthening of the abdominals has been found to relieve disc pressure, straighten the lordosis, reduce strain on the facet joints and stabilise the individual segments (Hansen et al 1993). Therefore, an isometric contraction of the abdominal muscles may be the true functional contraction mode for the abdominals and these muscles were therefore tested appropriately in this contractile state.

Those with strong abdominal muscles are likely to have strong back muscles too (Hasue et al 1980). Also, a high isometric endurance of the back muscles has been found to protect the lumbar spine (Biering-Sorenson et al 1989). This may also have been the case in this present study, though this was not tested, the back muscles themselves then being the protecting factor. This abdominal-back extensor relationship may be in part due to the second mechanism of the thoraco-lumbar fascia that is the haudraulic amplifier mechanism.

The internal and external oblique muscles are significant in enhancing a stabilising function in the lumbar area. Accordingly, these muscles most commonly assist the transversus abdominis in stabilising the lumbar-pelvic area (Richardson et al 1992). In the present study subjects in both the lower back pain and control groups frequently used the oblique abdominal muscles to assist the transversus abdominis muscle contraction. The co-ordination in attaining a stabilising contraction and holding it were found to be very poor in the present study as when the necessary muscles were recruited, they were unable to sustain contraction and gradually (for most) lost the "hold".

Johannsen et al (1995) stresses the importance of co-ordination exercises as being as valuable as endurance training. Analysis of the pelvic stabilisation was evidence of this as all tested subjects had great difficulty in coordinating the abdominal muscle contractions in the pelvic stability tests, although the abdominals appeared strong in the functional tests. Functional use of this lumbar-pelvic stabilisation failed to show any comparable differences between groups except for the abduction / adduction leg movement test in the present study. This latter test showed the lower back pain group to display poorer control of the abdominal stabilising muscles during an abduction / adduction movement of the hips. It is unclear as to the association between inflexibility of the right adductors, and left iliopsoas and poor stability on the left and right sides respectively concerning the abduction / adduction test movement.

A postulated imbalance may exist between inflexible hip adductors, tensor fascia lata and quadratus lumborum which inhibit gluteus medius and minimus with a resultant poor pelvic stability and altered pattern of hip abduction. An imbalance due to inflexibility of the hip adductors leads to the gluteals contracting too late while the shortened tensor fascia lata is activated too soon and the abduction movement occurs with a trick flexion and internal rotation movement (Norris 1995d). It has already been pointed out that increased hip internal rotation was more prevalent in the lower back pain group as was tightness of the adductors especially on the right. It may be that tight adductors, by inhibiting the gluteals, allow the tensor fascia lata muscle to be more active with a resultant internal rotation of the femur. Also, as the runners in this present study were found to have weakness of the abdominal muscles and tightness of the adductors, this may be the reason for the positive findings of poor pelvic control during the abduction / adduction leg test.

It is surprising that no other significant differences were found between groups for the one-minute isometric hold and leg heel slide tests as poor lumbar-pelvic stability has been very positively associated with lower back pain in subjects (Jull et al 1993) and its improvement with the alleviation of tissue stress on the lumbar spine (Richardson et al 1992).

The above tests of limb movements with the abdominal bracing are primarily co-ordination tests in nature. The importance of a neural strategy has already been noted. Of interest is the finding of most initial strength gains in any exercise program being as a result of neuro-muscular facilitation (Carpenter et al 1991, Rissanen et al 1995). It may then be assumed that facilitation of this bracing co-ordination may be a necessary foundation upon which to build further strength training.

5.6.1 Summary

In this case-control study a group of runners complaining of running-related lower back pain were compared with a control group of runners having never suffered from back pain related to running. Running-related lower back pain was classically a dull or uncomfortable ache, centrally situated and of moderate intensity.

Training patterns appeared to be associated with the development of lower back pain in runners who did not follow a structured training program and where training loads were excessive with poor usage of flexibility regimes. Clinically, hip flexor, ITB, hamstring and adductor inflexibility, a tendency for forefoot varus and hindfoot valgus, decreased abdominal muscle strength as well as a poorer contraction of the global stability muscles were associated with runners complaining of lower back pain. Further research is recommended to determine a cause-effect relationship between these factors and the onset of lower back pain in runners.

6 Chapter 6

6.1 Summary

Running-related lower back pain is a common complaint in local club athletes and has an annual incidence of 38.4% and a lifetime prevalence of 47%. This finding may have been a reflection of lower back pain in the general population. The finding of 1.42 back injuries per 1000 running hours is high given that other studies have documented general injury rates of 2.5 - 5.8 per 1000 running hours (Lysholm and Wiklander 1987) for all running injuries. The onset of lower back pain in runners could possibly be related to inflexibility of the lumbar-pelvic-femoral muscles and training errors such as excessive running distances.

Lower back pain in runners was described as a dull ache, centrally situated in the lower back with occasional referral into the leg, especially on the left. It is commonly associated with running overload or a reduced ability of the tissues to accept stress, and can be relieved if this stress is reduced. This is similar in the general population who suffer intermittent backache where the lower back pain is probably also related to tissue overload. D'Orazio (1993) claims lower back pain to be relatively benign and self-limiting in the athletic population. Christie et al (1995) consider this condition to require no treatment. This study showed it is a common problem which affected performance of the athlete and hence is a condition which needs more consideration.

The main findings of the study were that the runners with lower back pain:

- were not following a structured training program
- had a reduced frequency of stretching during a week
- had a reduced frequency of warm-up routines for training or racing
- had a lack of normal joint stiffness (mobility) of the lumbar spine (this finding, due to the nature of the testing protocol, should be viewed with caution)
- were inflexible in the ilio-tibial band, hamstring and hip flexor muscle groups
- had poor abdominal muscle strength

- had poor abdominal muscle stability (this finding, due to the nature of the testing protocol, should be viewed with caution).

From this present study, it appears that risk factors for lower back pain in runners include some abnormal biomechanics (increased subtalar joint pronation), stiff segments of the lumbar spine and weakness of the lumbar-pelvic supporting muscles. This latter aetiological factor may simply imply that there is a neuro-muscular weakness here, which needs rehearsing to restore. There was also a tendency for tighter lumbar-pelvic-femoral muscles on the right hand side. It must be pointed out though that it is not clear whether the weakness of the abdominal muscles and inflexibility of the lumbar pelvic-femoral muscles predisposes a runner to lower back pain or whether this weakness and inflexibility is as a result of previous or present episodes of lower back pain.

Running-related lower back pain was found to follow a similar course to lower back pain seen in other sporting codes (Appendix 7). Generally, aetiological factors most closely related to the occurrence of injury have been linked to previous injury, a lack of experience, competitiveness and increased weekly distances and increased training load. However, no relationships between lower back pain and factors such as lack of a warm-up, infrequent stretching, height, malalignments, muscle imbalances, restriction of range of movement, running frequency, level of performance, stability of running pattern, shoes and orthotics and the camber of the road have been documented. Age, gender, BMI, running hills, running on hard surfaces, time of the day or year of running and participation in other sports were not significantly associated with lower back pain in runners.

The process of finding aetiological factors relating to injury is in observing those at risk. Treatment should focus on complete rehabilitation with early recognition of symptoms of overuse and on the provision of training guidelines (Van Mechelen 1992). A different and more in-depth approach is needed when treating an athlete with lower back pain as the pain symptoms frequently arise only when there is functional overloading while pain is absent during normal activities of daily living

(Van Mechelen 1992). Many of the tests used in the present study were simple, yet clinically easy to reproduce. They can therefore easily be incorporated into a clinical evaluation to assess "who" is at risk. This becomes important as many of the clinical tests are statically performed and may not stress the lumbar spine to the same extent as during dynamic functional activities.

The significance of this study was in describing a running-related injury and its mechanism of irritation so as to treat and prevent it appropriately. Furthermore, by doing so, lower back pain in non-runners and athletes, involved in repetitive jarring actions causing lower back pain, may also benefit. The study also allows a base from which to resume a second phase identifying clinically observable traits and in the construction of specific rehabilitation programs designed to resist any of the found aetiological factors. In this way, an appropriate exercise formation may by developed to treat and prevent pain from sports participation.

Finally, from a physiotherapy perspective, 10 - 50% of patients with lower back pain seek physiotherapy treatment but the effectiveness of this intervention is unclear (Van der Valk et al 1995). In this regard, the findings of this study may be helpful in evaluating the true effectiveness of physiotherapeutic intervention if such a second phase study were to be conducted as a specific dysfunction is addressed.

Further research is necessary in quantifying and standardising testing methods for identification of injury risk factors.

7 Chapter 7

7.1 Limitations of the study

This study was carefully planned and executed according to strict guidelines and formats. However, the following limitations of a study should be considered.

1. The questionnaires for phase I were completed after races when the runners were tired. There may have been recall bias and information was not fully completed on every form by each runner. The accuracy of response could also be limited due to poor interpretation by the runner of his / her symptoms.
2. There is a recognised error when performing clinical assessments. Although clinical assessments are commonly used, not all of these have been validated sufficiently and also have not always been assessed for their repeatability. As far as possible all clinical tests used in this study were subject to pilot testing and repeatability was evaluated.
3. Phase I of the study was retrospective in nature and documented running injury history in the preceding year. Other studies on running injuries have been conducted in a prospective (Lysholm and Wiklander 1987, Walter et al 1989) or cross-sectional (Warren and Davis 1988) manner.
4. The population consisted mainly of male subjects and only 20% of the sample were female. The findings may therefore not be extrapolated to women runners.
5. The differences between expected and tested outcomes in the abdominal stability tests could be a result of error in measurements of these pelvic stability readings. Further to this, the biocuff is a crude method of muscular function analysis, as readings off the manometer scale could be subjective especially if the needle is swinging.
6. Sample size for phase II was small and that is why the findings can not be generalised.
7. The clinically performed tests for the lumbar segmental palpation and lumbar stability tests were conducted in such a manner that there may have been a strong

subjective element in the examiners testing method. These tests may therefore show poor inter-tester reliability and therefore should be viewed with caution.

8 Chapter 8

8.1 Conclusion

Lower back pain is a common running-related injury. Lower back pain in runners is at least as common as lower back pain in the general population and running can aggravate underlying lower back pain. The results of this study improve the understanding of the possible mechanisms involved in the aetiology of lower back pain in runners and serve as a guide to treatment and further management. It appears that the aetiology of lower back pain in runners is as in other running injuries and is likely to be a combination of anatomical, biomechanical or environmental anomalies that can give rise to lower back pain. Several of these minor irregularities in combination probably result in injury (Warren and Davis, 1988).

The results of this study show that lower back pain in runners was aggravated by any action promoting an increase in tissue stress and strain, both statically and dynamically. Specific attention to the flexibility of the lumbar-pelvic-femoral muscles and stability and endurance of the lumbar and pelvic stabilisers could possibly protect from the development of lower back pain in running. Correction of a dysfunction of these factors would possibly restore normal movement between the lumbar vertebra thereby restoring normal joint stiffness and enhance function.

Further research into a comparison of a training regime encompassing the above principles of the present study with a more traditional back strengthening program would need to be conducted.

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Appendix 1

Lower Back Pain Rehabilitation

There is no specific exercise protocol that has been shown to be superior to other forms of training (Hansen et al 1993). Different results are possibly attributed to the different causes of lower back pain (Hansen et al 1993). Johannsen et al (1995) agreed noting that different training models are effective for the treatment of chronic lower back pain although no consensus has been found with regard to protocols employed. Wheeler and Hanley (1995) comment that the natural history of lower back pain includes recovery regardless of the treatment. D'Orazio (1993) noted that 80% of lower back pain patients get better no matter what treatment is given. Alternatively, Frost et al (1995) found a positive role for fitness programs in the management of moderately disabled patients with chronic lower back pain.

Martin et al (1986) failed to show the positive effects of physiotherapy exercises for the lower back pain patient they purported these exercises to have. Physiotherapy utilises manual therapy techniques viz. postural adjustments, ergonomic advice, exercise, mobilisation and manipulation, massage and traction for the treatment of musculo-skeletal pain and dysfunction problems (Twomey and Taylor 1995). Hansen et al (1993) observed the importance of the use of flexibility exercises for the lumbar and pelvic areas, exercises for co-ordination and slow progressive exercise of isometric back and abdominal muscle contractions. Hansen et al (1993) determined that an intensive dynamic back muscle exercise program was better for those with sedentary / light jobs versus conventional physiotherapy of isometric exercises for the trunk and legs. They found the converse also to be true with respect to those with tough physical occupations.

Wohlfahrt et al (1993) observed the differences in the back rehabilitation programs that utilised extension, flexion, aerobic, anaerobic, strength, endurance and fitness exercises. Many rehabilitation programs have focussed on strengthening the abdominal and back musculature (Buchinghain et al, Garrett 1987, Hansen et al 1993, Risch et al 1993, Sullivan in Richardson et al 1990). However, these strength exercises are frequently employed without first paying attention towards ensuring correct motor sequencing and control and as such the endurance and functional capacities of the muscles are ignored. Twomey and Taylor (1995) referred to the importance of exercise and mobility in the treatment of lower back pain over rest. This is because the musculo-skeletal system requires the loading and stress of exercise to maintain its function and strength. Risch et al (1993) mention the importance of muscle reconditioning in light of the fact that muscle atrophies with deconditioning.

Delitto et al (1993) comment on the importance of a prior classification of the patient's condition followed by a matched specifically designed conservative program to attain an effective outcome. They demonstrated a very positive and beneficial effect of an extension mobilisation regime included in the rehabilitation program. Erhard et al (1994) stressed the importance of manipulation as an adjunct to a continuing exercise program in acute back pain as it increases the ROM, reduces pain thereby allowing patient participation in an exercise program. Again they emphasise the importance of accurate patient screening and classification prior to the commencement of treatment.

Strength, flexibility, posture and body mechanics are recognised as important factors of low back function (Liemohn et al 1988) and hence the importance of strong trunk muscles to prevent lower back pain. Exercise programs should be geared towards pain reduction and functional improvement. A comprehensive program for the management of lower back pain in athletes should include stretching, flexibility and strengthening exercises for the lumbar spine, hamstrings, hip flexors / adductors and trunk as well as aerobic (cardiovascular) training, motor skills, co-ordination and functional exercises; and posture and ergonomic advice (Lindgren and Twomey 1988, Rissanen et al 1995, Frost and Moffett 1992, Herman et al 1994, D'Orazio, 1993, Foster and Fulton 1991, Norris 1995a-e).

Frost and Moffett (1992) were uncertain with respect to exercise therapy being superior to other forms of conservative treatment. This is because of the individual variation of pathology. They regarded muscle strength, aerobic and anaerobic power, endurance and neuro-muscular control as important aspects of training. Foster and Fulton (1991) found lumbar extension exercises that stabilise the pelvis, provide a means for progressively increasing the resistance and allow the exerciser to move through a full range of lumbar movement, to offer the greatest benefit. Risch et al (1993) also found a positive effect for isolated lumbar extensor muscle exercise in terms of isometric strength, pain reduction and dysfunction. Graves et al (1990) found isometric exercises to be an effective alternative for developing lumbar muscular strength. However, Wohlfahrt et al (1993) observed that training involving dynamic exercise skills do not necessarily result in an improved isometric skill.

Carpenter et al (1991) observed that many studies suggest that improving muscle strength and endurance will aid in the prevention and treatment of lower back pain and as such most programs concentrate on spinal strength and mobility routines. In this regard, Carpenter et al (1991) suggests that because many of these programs do not include progressive resistance training, they are limited in their ability to improve strength. They further go on to comment that there is also poor stabilisation and localisation of the lumbar muscles in the performance of these exercises. Trunk curl-up exercises are dependent on the dynamic strength of the abdominal muscles, yet functionally, it is more important for the abdominal muscles to be able to co-contract isometrically promoting stability of the lumbar-pelvic region in the upright posture (Wohlfahrt et al 1993). Miller and Medeiros (1987) observed that previous studies tended to concentrate on the prime movers of the rectus abdominis and external obliques rather than the stabilising muscles.

Numerous studies have looked at concentric, eccentric and isometric muscle contraction modes while eccentric contractions play the largest role in ADL especially when running and walking are performed to decelerate the body (Shirado et al 1995). The trunk extensors, which are thought to serve a postural role exhibit a high proportion of fatigue resistant fibres and fatigue more with stationary activity

(Moffroid et al 1993). One therefore needs to improve their endurance via postural exercises.
Manniche and Jordann (1995) emphasised the importance of dosage (number of repetitions and resistance) and duration (number of sessions) while Carpenter et al (1991) found training once a week / fortnight to be as effective as training 2-3 times a week in increasing lumbar isometric extension torque. This is important in the designing of exercise programs as poor trunk muscle function has been cited as a risk factor for lower back pain in up to 80% of all lower back pain cases. (Research has not yet established a definite relationship between muscle strength of the spine and lower back pain) (Carpenter et al 1991).

The lower extremity muscles, most notably the iliopsoas, quadriceps, hamstrings and calves could influence trunk muscle strength (Shirado et al 1995). Garrett (1987) regarded lower back pain sufferers as having shortened pelvic muscles, which reduce pelvic mobility, increasing lumbar stress. Because of the extensive lumbar attachment (to the spine, pelvis and femur) of the iliopsoas muscle, it is potentially hazardous in creating compressive and lordotic forces on the lumbar spine and intervertebral discs if not balanced by the stabilisation forces of the abdominal muscles. It thus has the most potential to influence and be influenced by movements here; and being a postural muscle, it will tend to shorten (Jorgensson 1993). Liemohn et al (1988) agrees stating that tightness of the hip flexors limit pelvic movement which places additional strain on the lumbar spine. However, they note this statement to conflict with other studies with respect to the relationship between the incidence of lower back pain and hip joint ROM. Jorgensson (1993) on the other hand noted that the compression and anterior shear forces postulated to be caused by iliopsoas muscle dysfunction have not been shown experimentally.

Jorgensson (1993) advocated the strengthening of weak muscles (rectus abdominis, the obliques, gluteals and hamstrings), to stretch the tight structures and improve overall body awareness. Norris (1995d) notes the need to maintain the flexibility of the iliopsoas, rectus femoris, adductors, hip rotators, hamstrings and piriformis.

Jull et al (1993) comment on the importance of rehabilitation of the trunk muscles in the management of back pain and the prevention of recurrence especially if trained to stabilise the back in a neutral position. To correct movement dysfunctions, Richardson et al (1992) stress the need to utilize techniques to induce specific lumbar and pelvic co-ordination and stabilisation independent of trunk and limb movements. Wohlfahrt et al (1993) considered promotion of this stabilising role to be a prime consideration when designing an exercise program to improve strength and endurance of the abdominal muscle group.

Johannsen et al (1995) and Richardson et al (1990) comment that optimal muscle function depends upon the co-ordination of movement and not only on muscle strength, endurance and flexibility. Norris (1995c) considered the speed of the reaction to a force potentially displacing the lumbar spine to be most critical. However, only strengthening exercises are mostly given (Richardson et al 1990). Muscles work in synergistic groups so not all the muscular activity is used to produce torque (Richardson et al 1990). Rather, muscle activity is required in mechanisms designed to stabilise and strengthen the spine. Co-ordination exercises help to improve performance and prevent injuries (Johannsen et al 1995) as when unfamiliar and complicated movements are performed, they are done so clumsily and with difficulty (Johannsen et al 1995).

With respect to exercise prescription, Richardson et al (1990) stress the importance of exercises which enhance the stability of the vertebral colunm. Stability is the ability of a muscle group to control the whole range of motion of a joint. Stabilisation exercises maintain a neutral pain free position between the lumbar spine and pelvis via the abdominals and spinal extensors co-contracting thereby protecting the lumbar spine from excessive movement. Once synchronisation of this movement is learned, it is applied to the ADL of the individual (Norris 1995e). According to Norris (1995a-e) an active lumbar stabilisation program proceeds through 4 stages.

1. Muscle re-education - the stability synergists, the obliques, transversus abdominis and multifidii are facilitated.

2. Static stabilisation - the abdomen is braced in different postures and maintained in its mid-range using low load sustained isometric contractions short of fatigue.
3. Dynamic stabilisation - correct pelvic tilting is restored and exercises are performed in a pain free range with increased local isotonic, eccentric and proprioceptive training.
4. Functional ADL activities in which proprioceptive training is geared at maintaining lumbar-pelvic alignment in an optimal position.

This enhances the active and neural control systems. Restoration of function is the focus, not isolated muscular fitness and the final goal is to make contraction an automatic process.

The continuation of a home exercise regime following a beneficial back rehabilitation group was associated with further improvements in function, strength and pain relief Callaghan (1994) and should therefore be encouraged.

Summary

Lower back pain sufferers have a reduced ability to protect themselves but can be trained to improve their protective response by means of an appropriate rehabilitation program (Magnusson et al 1996). Treatment usually follows an evolutionary process of passive to active patient participation. The role of exercise has been found to both limit pain and restore function (Wheeler and Hanley 1995) and lumbar stabilisation exercises have been found to be effective in the treatment of lumbar disc herniation (Wheeler and Hanley 1995). The current trend appears to be in favour of early movement, exercise and education with a major focus on increasing the patients' active involvement and self-responsibility. Rehabilitation therefore involves strengthening the weak muscles, stretching the inflexible muscles and finally converting conscious control of corrected movement patterns into an unconscious level. Lower back pain cannot be fully treated prior to normalising function i.e. correcting faulty motor sequence. The general regime being to prevent back pain by strengthening the trunk muscles, enhancing the "muscular corset". However, evidence for the effectiveness of such measures are conflicting (Ernst 1992). Thus the overall approach is to evaluate the dysfunction, correlate it with clinical symptoms and treat the dysfunction by promoting normal mobility, strength and co-ordination.

Appendix 2

Lower Back Pain in Runners: Questionnaire 1

Demographic data

Subject No.____________(office use only)

Telephone No.____________(H)   Address__________________

____________(W)   __________________

____________(Cell)   __________________

____

1) Date____________

2) Name____

1) Age____________

2) Occupation__________________________

Please indicate into which category

your job classified you. More than 50%

Standing
Sitting
Driving
Manual Work

5) Weight________kg

6) Height________cm

Training / Racing History

Please place a cross on the appropriate block(s) i.e.

X

7) Indicate in which discipline of running you partake; and at which level you compete?

Discipline	Level			
Road Running	Social	Club	Provincial	National
Cross Country	Social	Club	Provincial	National
Track	Social	Club	Provincial	National

8) How many years have you been running for ? __________ years

9) How many days a week do you train ? __________ days / week

10) How far do you run in an average week?__________km / week

11) How many hours a week do you run for ?__________hours / week

12) What is your average "intensity" (pace) of running over the week?

_________minutes / km

13) What is your best time for the following distances (if relevant) ?

Distance	Time
3000m (track)	
5000m (track)	
5 km	
10 km	
21.1 km	
42.2 km	
X-C placing	
Other	

14) Do you stretch prior to a run / race?

Training	Racing
Always	Always
Usually	Usually
Sometimes	Sometimes
Never	Never

15) For how long do you sustain "hold" each stretch?

under 10 seconds	20 - 30 seconds
10 - 20 seconds	30 - 60 seconds
other (specify)	

16) Please indicate which muscles / areas of your body you stretch?

arms	thigh (front) - quadriceps
upper back	thigh (back) - hamstrings
lower back	calves
groin	inner thigh - adductors
buttocks (gluteals)	ITB
other (specify)	

17) Do you warm-up prior to a run / race?

Training	Racing
Always	Always
Usually	Usually
Sometimes	Sometimes
Never	Never

18) Do you cool-down after a run / race?

Training	Racing
Always	Always
Usually	Usually
Sometimes	Sometimes
Never	Never

19) How frequently do you compete? (Express as races per month)

__________races / month

20) Do you wear an orthotic?

Y	N

21) If "Yes", for how long? __________years

22) What shoes do you run in?

	Addidas	New Balance	Nike	Saucony	Hi tech	Reebok	Brookes	Other
soft								
neutral								
anti-pronation								
other								

Running-related Lower Back Pain

23) Have you ever experienced any lower back pain in all the years that you have been running (during or shortly afterwards)?

Y	N

If "No", thank you for your time and effort in filling out this questionnaire.

If "Yes", please complete the remainder of the questionnaire.

24) Have you experienced any lower back pain in this last year (1996) of running?

Y	N

25) Please grade your running-related Lower Back Pain?

- Pain only after running (1)

- Pain during running which does not affect your running (2)

- Pain affecting your running performance (3)

- Pain (at times) preventing desired running ability (4)

1
2
3
4

26) Do any of the following ever aggravate your running-related back pain?

uphill running	end of run
increased running speed	racing
longer runs	downhill running
beginning of run	prolonged sitting
prolonged standing	when tired / unfit
Other (specify)	

27) Do any of the following relieve your running-related back pain?

bending forwards	stretching
bending backwards	sitting
lying on your back	standing
lying on your stomach	walking
taking it easy	

28) Have you ever injured you back in a sudden / acute injury?

Y	N

29) If "yes", please give details:

____

____

____

30) Have you ever consulted a medical professional with regard to your lower back pain?

Y	N

31) If "Yes", by whom?

First Aid Attendant	Physiotherapist	Chiropractor
Medical Doctor	Orthopaedic Surgeon	Body stress release
Orthotist	Biokinetician	Acupuncture
Other (specify)		

32) Was a diagnosis made?

Y	N

33) If "Yes", please indicate in the appropriate block.

degenerated disc	stress fracture
facet joint injury	spondylolysis (arthritis)
muscle spasm	spondylolisthesis
muscle trigger points	ligament sprain
muscular strain	unknown
other (specify)	

34) Have you been injured previously in the past 12 months?

Y	N

35) If "Yes", where?

	Left	**Right**		**Left**	**Right**		**Left**	**Right**
Neck			Wrist			Knee		
Upper Back			Hand			Ankle		
Shoulder			Fingers			Foot		
Elbow			Hip			Lower Back		
Other (specify)								

36) Does it still bother you?

Y	N

37) Do you experience any other symptoms?

Y	N

38) If "Yes" please indicate where appropriate:

pins and needles	loss of sensation
disturbances of gait	referred pain to buttock
tingling sensation	referred pain to leg
other (specify)	
weakness	

39) Have you tried any exercises previously?

Y	N

40) If "Yes", what exercise?

posture modification	stretches
back extensions	range of motion exercises
upper abdominals	lower abdominals
stabilising exercises	activity modification
other (specify)	

41) What treatment (if any) have you had for your running-related lower back pain?

Treatment	not effective	partially effective	very effective
muscle stretching			
massage			
exercise			
manipulation			
mobilisation			
neural stretching			
posture correction			
electrical stimulation			
ultrasound			
laser			
other			

42) Would you be willing to undergo further testing and an exercise protocol?

Y	N

Thank you for filling out this form.

Appendix 3

Occupational Categorisation

SEDENTRY	STANDING	DRIVING	MANUAL WORKER
ACCOUNTANT X3	ASSEMBLY FOREMAN	ASSISSTANT GREEN KEEPER	BOILER MAKER
ACTUARY	CHEF	COURIER	CARPENTER
ADMIN MANAGER X2	CUSTOMS OFFICIAL	DRIVER X2	ELECTRICIAN
ANALYST	ESTATE AGENT	FORKLIFT DRIVER	FARM MANAGER
ARCHITECT	HEALTH INSPECTOR	OPERATOR X2	FIREMAN
BANK MANAGER	HOTEL GUEST LIASON	POLICEMAN X4	FITTER & TURNER X2
BANK OFFICIAL	JOURNALIST	RADIATION PROTECTION	HOUSEWIFE X 4
BREWER	LECTURER X2	REPRESENTATIVE X3	MOTOR MECHANIC
BUSINESSMAN	OPERATOR X2	SALES REP.	OPERATOR
BUSSINESS	PERSONAL TRAINER		PANEL BEATER
BUYER X2	PETROL ASSISTANT		PHYSIO ASSISTANT
C. A. X2	PORTER X2		PHYSIO X4
CIVIL ENGINEER X2	PRODUCTION FOREMAN		SHEET METAL WORKER
CIVIL SERVANT	RETAIL		SHOPFITTER
CLERK X3	SALES REP.		SPRAY PAINTER
CLIENT SERVICE MANAGER	SALESMAN X5		STUDENT NURSE X2
CLOTHING DESIGNER	SALESPERSON		TECHNICIAN
COMPUTER CONSULTANT X2	SUPERVISOR		
CONSULTANT X2	TEACHER X15		
COUNSELLOR	VET		
DEVELOPMENT MANAGER			
DIRECTOR ADMIN SERV.			
DIETICIAN			
DIRECTOR			
SPORTS RETAIL			
DOCTOR X2			
EDUCATION RESEARCH			
ELECTRICAL ENGINEER			
ENGINEER X3			
FINANCIAL CLERK			
FINANCIAL MANAGER			
HEALTH ECONOMIST			
HEALTH OFFICIAL			
HEALTH POLICY ANALYST			
INSURANCE			
INSURANCE ASSESSOR			
INSURANCE CLERK			
LIBRERIAN X2			
MANAGER X2			
MARKET MANAGER			
MARKETING MANAGER			
NAVY			
OFFICE			
OPTOMETRIST			

P. A.
PILOT
PRODUCTION MANAGER X2
PROFESSOR
PROJECT MANAGER
PROOF READER
PSCHOLOGIST
QUANTITY SURVEYOR
RETAIL MANAGER
RETIRED
SALES CONSULTANT X2
SALES DIRECTOR
SALES EXECUTIVE
SCHOLAR X5
SCIENTIST
SECRETARY
SPOILS ADMINISTRATOR
STUDENT X5
SYSTEMS ANALYST
TABACCO RESEARCHER
TECH CLERK
TRANSPORT MANAGER
TYPIST
UNEMPLOYED

Appendix 4

Lower Back Pain in Runners Questionnaire 2

Subject No. _______________(for office use)

Name ______________________________

Please place a cross on the appropriate block(s) i.e.

X

Training History

1) Do you follow a structured training program?

Y	N

2) Do you usually include various training sessions into your program?

Y	N

3) If "yes" please indicate which sessions and how many of each in an average week.

Session	Amount	Session	Amount
long run		time trials	
hill sprints		easy runs	
hill circuit		rest days	
intervals		track	

4) Over what surface(s) do you usually train?

grass	flat
terrain (X-C)	undulating
road	hilly
dirt road	sand
	treadmill

5) If you partake in any other athletic / sporting activities, please give details.

____

____

____

____

6) Do you take rest periods during your year of running?

Y	N

7) If "yes", for how long? _______________weeks

8) During the course of a year, you are likely to run in a variety of different weather conditions. Does any particular weather condition affect your back pain? If not, ignore this question.

rain	drizzle
wind	humid
hot	cold
sunny	dry
cloudy	

9) How many times a week do you run? _______________days

10) How many times a week do you stretch? _______________days

11) If you stretch regularly, please indicate which muscle groups you stretch.

feet / toes	hamstrings	upper backs
ankles	buttocks	shoulders
shins	ITB	neck
calves	groin	
achilles tendons	hips	
quads	lower backs	

12) Nature of your stretching regime?

short hold	long hold
PNF	ballistic
externally applied	

13) Before a hard training session / race, do you warm-up?

Training	**Racing**
Always	Always
Usually	Usually
Sometimes	Sometimes
Never	Never

14) After a hard training session / race, do you cool-down?

Training	**Racing**
Always	Always
Usually	Usually
Sometimes	Sometimes
Never	Never

15) Do you have a history of any other previous medical conditions?

Y	N

16) If "yes", please give details.

17) If you wear an orthotic, why was it initially prescribed? Please specify.

Running-related back pain

18) When affected by your back pain, does it affect you in any of the following ways? (Please tick the corresponding blocks).

	Rarely	Sometimes	Regularly
Forces retirement			
Reduced intensity			
Reduced distance			
Reduced intensity and distance			

19) Are any of the following factors associated with your lower back pain?

increases in mileage	increases in training intensity
decreases in mileage	decreases in training intensity
increases in hill running	increases in frequency of sessions
decreasesin hill running	decreases in frequency of sessions
onset of fatigue	commencement of training

20) On the diagram below, mark off exactly where you feel your backache.

21) How would you describe your pain?

burning	throbbing
sharp	shooting
dull ache	discomfort
feeling vulnerable	irritation
other	

22) On a scale of 0 (being no pain) to 10 (being the most excruciating pain you have ever felt), give your back pain a rating of severity? ______________________________

23) When the pain comes on, does it follow any of the following patterns?

- No pain initially which later worsens (0)
- Initial pain which gradually fades (1)
- Periods of pain / no pain throughout the run (2)
- No pain initially, pain felt once well into the run which gradually fades as the run continues (3)
- Pain only at the end of a run (4)

0
1
2
3
4

24) Is the above description of the nature of your pain appropriate for racing, training or both racing and training?

racing	training	both

Appendix 5

Clinical Evaluation form for the Physical Assessment

1) Spinal Flexion: (Distance in cm.) Standing Erect Full Flexion

	Standing Erect	Full Flexion
S2 - L1	__________	__________
S2 - T1	__________	__________

2.1 A) Hip Flexor Flexibility: (measured in degrees)

Left__________ Right__________

2.1 B) Rectus Femoris Flexibility: (measured in degrees)

Left__________ Right__________

2.1 C) ITB Flexibility: (measured in degrees)

Left__________ Right__________

2.1 D) Medial Femoral Rotation: (measured in degrees)

Left__________ Right__________

2.1 E) Lateral Femoral Rotation: (measured in degrees)

Left__________ Right__________

2.2) Hamstring Flexibility: (measured in degrees)

Left__________ Right__________

2.3) Adductor Flexibility: (measured in mm.)

Left__________ Right__________

3.1) Leg Lengths: (measured in cm.)

i) ASIS - Medial Malleolus

Left__________ Right__________

ii) Tibial Tuberosity to Medial Malleolus

Left__________ Right__________

3.2) Q - Angle: (measured in degrees)

Left__________ Right__________

3.3) Valgus / Varus at the Knee: (measured in mm.)

(circle either) **Valgus** **Varus**

____

3.4) Rearfoot Valgus / Varus: (measured in degrees)

(circle either) **Valgus** **Varus**

Left__________ Right__________

3.5) Forefoot Valgus / Varus: (measured in degrees)

(circle either) **Valgus** **Varus**

Left__________ Right__________

4) PPIVMS Score:

4.1) Rotation:

Right: L3/4__________ L4/5__________ L5/S1__________

Left: L3/4__________ L4/5__________ L5/S1__________

4.2) Flexion-Extension:

L3/4__________ L4/5__________ L5/S1__________

5) PAVIMS Score:

L3_______ L4_______ L5________ S1_______

6) SIJ Provocation tests: (circle) + -

7) Functional Tests:

Leg-lowering Score________

Trunk Curl Score________

8) Dynamic stability (use biocuff: one-minute hold). Followed by:

- One minute hold_______mmHg

- Add unilateral leg flexion / extension

Deviation (R)______mmHg (L)_______mmHg

- Add unilateral abduction / adduction

Deviation (R)______mmHg (L)_______mmHg (Wohlfahrt et al, 1993)

Visually observe for:

9) Able to recruit the transversus abdominus: Y N

10) Transversus abdominus contraction: strong fair weak

11) Stabilising ability: good fair poor

12) Loosing the contraction: Right Y N Left Y N

13) Compensating: (circle) obliques rectus abdominus pelvic tilting using legs breath holding

14) Overcompensating: Right Y N Left Y N

15) Recovering the contraction: Right Y N Left Y N

16) Sudden jerks: Right Y N Left Y N

17) Small swings: Right Y N Left Y N

18) Large swings: Right Y N Left Y N

19) Steady drop: Right Y N Left Y N

20) Improved contraction with practice: Right Y N Left Y N

Appendix 6

The Intra-Tester Repeatability of Clinical Test Procedures in the examination of runners with Lower Back Pain

Introduction

All of the clinical tests performed in chapter 5 of the study were tested for their reliability. The tests were administered to 19 individuals who partook in regular sporting exercise and who had never had any previous lower back pain.

Aim of the study

The aim of this pilot study was to assess the intra-tester repeatability of commonly used clinical tests used to assess spinal flexibility, lower limb muscle flexibility, lower limb biomechanics, abdominal strength and proximal stability.

Method

These assessments was performed by the same examiner (a physiotherapist), a trained assistant and used the same equipment. Subjects were assessed once and then again 3 – 4 days later. The examiner was blinded to the results of the previous tests. The details of each successive test are described in chapter 5, section 5.3.2.2.2.

Statistical Analysis

The statistical analysis was performed at the Medical Research Council in Cape Town. For the continuous variables, Pearsons intra-class co-efficient was used, while for the categorical variables, a KAPPA test was used. For this latter test, a score of between 0 and 0.4 was considered marginally repeatable, between 0.4 and 0.75 good reproducibility and greater than 0.75 showed excellent repeatability.

Results

The results of Pearson's intra-class correlation test for all the continuous variables are depicted in Table A.

Table A: Pearson's intra-class correlation tests for all continuous variables tested in the clinical evaluation of chapter 5

TEST PERFORMED	PEARSON's I-CC
SFS2-L1St (spinal flexion from S2 to L1 in standing)	0.977
SFS2-L1FLEX (spinal flexion from S2 to L1 in full flexion)	0.985
SFS2-T1St (spinal flexion from S2 to T1 in standing)	0.989
SFS2-T1FLEX (spinal flexion from S2 to T1 in full flexion)	0.989
HFF left (hip flexor flexibility on the left)	0.975
HFF right (hip flexor flexibility on the right)	0.976
RFF left (rectus femoris flexibility on the left)	0.986
RFF right (rectus femoris flexibility on the right)	0.985
ITB left (ITB flexibility on the left)	0.963
ITB right (ITB flexibility on the right)	0.948
MFR left (medical femoral rotation flexibility on the left)	0.903
MFR right (medical femoral rotation flexibility on the right)	0.949
LFR left (lateral femoral rotation flexibility on the left)	0.973
LFR right (lateral femoral rotation flexibility on the right)	0.950
Hflex left (hamstring flexibility on the left)	0.988
Hflex right (hamstring flexibility on the right)	0.973
Ad left (adductor flexibility on the left)	0.973
Ad right (adductor flexibility on the right)	0.959
LLAS-MM left (leg length, ASIS to medial malleolus)	0.999
LLAS-MM right (leg length, ASIS to medial malleolus)	0.999
LLTT-MM left (leg length, tibial tuberosity to medial malleolus)	0.993
LLTT-MM right (leg length, tibial tuberosity to medial malleolus)	0.996
Qa left (Q-angle of knee on left)	0.949
Qa right (Q-angle of knee on right)	0.924
VAL/VARMM (valgus/varus measurement in millimeters)	0.794
REARFOOTleft (measurement of rearfoot angle on left)	0.937
REARFOOTright (measurement of rearfoot angle on right)	0.909
FOREFOOTleft (measurement of forefoot angle on left)	0.805
FOREFOOTright (measurement of forefoot angle on right)	0.719
DS1Min (dynamic stability, I minute hold)	0.792
DSF/E left (dynamic stability with leg flexion/extension on the left)	0.838
DSF/E right (dynamic stability with leg flexion/extension on the right)	0.934
DSAB/Ad left (dynamic stability with leg abduction/adduction on the left)	0.780
DSAB/Ad right (dynamic stability with leg flexion/extension on the right)	0.822

The results of the KAPPA tests for the categorical variables are depicted in Table B.

Table B: KAPPA tests for all categorical variables tested in the clinical evaluation of chapter 5

TEST PERFORMED	KAPPA TEST
KNEEVAL (knee being valgus)	1.00
KNEEVAR (knee being varus)	1.00
REARFOOTVAL(rearfoot being valgus)	1.00
REARFOOTVAR(rearfoot being varus)	1.00
FOREFOOTVAL (forefoot being valgus)	1.00
FOREFOOTVAR (forefoot being varus)	1.00
ROTL3/4left (lumbar rotation of the L3/4 joint on the left)	0.771
ROTL3/4right (lumbar rotation of the L3/4 joint on the right)	0.642
ROTL4/5left (lumbar rotation of the L4/5 joint on the left)	0.815
ROTL4/5right (lumbar rotation of the L4/5 joint on the right)	0.827
ROTL5/S1left (lumbar rotation of the L5/S1 joint on the left)	1.00
ROTL5/S1right (lumbar rotation of the L5/S1 joint on the right)	0.891
F/EL3/4 (lumbar flexion/extension of the L3/4 joint)	1.00
F/EL4/5 (lumbar flexion/extension of the L4/5 joint)	0.587
F/EL5/S1 (lumbar flexion/extension of the L5/S1joint)	0.596
PAVL3 (PAVIM test of the 3rd lumbar vertebra)	1.00
PAVL4 (PAVIM test of the 4th lumbar vertebra)	0.743
PAVL5 (PAVIM test of the 5th lumbar vertebra)	0.883
PAVS1 (PAVIM test of the sacrum)	1.00
LLS (leg-lowering score)	0.862
TCS (trunk curl-up score)	1.00
TABD (ability to recruit transversus abdominus muscle, Y / N)	1.00
STRENGTH (strength of transversus abdominus contraction, 1 - 3)	0.898
ABILITY (stabilising ability, 1 - 3)	0.898
CONTRACTIONleft (loosing the stabilising contraction on the left, Y / N)	0.850
CONTRACTIONright (loosing the stabilising contraction on the right, Y / N)	0.870
COMPOBL (compensating with the obliques)	0.629
COMPRA (compensating with rectus abdominus)	0.640
COMPPT (compensating with pelvic tilting)	0.289
COMPUL (compensating with using the legs to push)	0.769
COMPBH (compensating with breathe holding)	0.550
O-COMPleft (overcompensating the contraction with leg movement on the left)	0.259
O-COMPright (overcompensating the contraction with leg movement on the right)	0.366
RECleft (recovering the contraction with leg movements on the left)	1.00
RECright (recovering the contraction with leg movements on the right)	1.00
JERKleft (sudden jerks in contraction with leg movements on the left)	0.455
JERKright (sudden jerks in contraction with leg movements on the right)	0.455
SMALLSWINGleft (small swing with leg movements on the left)	0.679
SMALLSWINGright (small swing with leg movements on the right)	0.679
LARGESWINGleft (large swing with leg movements on the left)	1.00
LARGESWINGright (large swing with leg movements on the right)	1.00
STEADY DROPleft (steady drop with leg movements on the left)	0.753
STEADY DROPright (steady drop with leg movements on the right)	0.609
IMPROVEleft (improved stabilising contraction with practice in tests on the left)	0.471
IMPROVEright (improved stabilising contraction with practice in tests on the right)	0.571

Discussion

The results of this study show that the tests used for the determination of the continuous variable are highly repeatable. A similar trend was observed for the categorical variables measured. However, special mention is made with regard to the spinal segmental palpation (PPIVM and PAVIM) tests. The repeatability of these tests was found to vary from 0.587 to 1.00. The repeatability of these tests are therefore variable and the results of these tests should be interpreted with caution. Furthermore, the tests for the stability patterns that were used in the abdominal stabilisation tests showed a large variation from poor repeatability of 0.259 to very good repeatability of 1.00. Again, because of the nature of the testing procedure, these tests need to be interpreted with caution.

Appendix 7

Pilot Study Results

Subjects	SFS2-L1St Tst1	SFS2-L1St Tst2	SFS2-L1Flex Tst1	SFS2-L1Flex Tst2
1) PAUL	12.5	12	17.5	18
2) ANNE	11	11	15	15
3) ALLAN	10.5	11	16	16
4) ALAN	11.5	12	18	18.5
5) CHARLES	12	12	18	19
6) VANNESSA	12	12	17.5	17
7) GAVIN	11.5	11.5	17	17
8) IAN	10	10.5	14.5	15
9) RODNEY	12	12	18.5	19
10) NICOLE	12	12	15.5	15.5
11) CAREY	13.5	13.5	18.5	18.5
12) STEVEN	11	11	16	16
13) WAYNE	12.5	12.5	17.5	17.5
14) GREG	13	13	19.5	19.5
15) MORAG	12.5	12.5	18	18
16) JANET	9	9	12.5	12.5
17) RORY	13	13	18	18
18) CARLYN	9.5	9.5	12.5	12.5
19) DARRYL	13.5	13	19	19
	0.977		**0.985**	

SFS2-T1St Tst1	SFS2-T1St Tst2	SFS2-T1Flex Tst1	SFS2-T1Flex Tst2	HFF left tst1	HFF left tst2
46	46.5	55.5	54	5	4
43	43	51.5	52	9	10
43	44	53	53	-8	-9
43.5	44	54.5	54.5	-3	-3
47.5	48	58	58	3	4
47	46.5	53	53.5	0	1
49.5	49	58	58	-3	-5
47.5	47	57	57	3	5
49	49	57	58	3	3
49	49	56	56	6	6
44	44	52	52	5	5
49.5	49.5	56	55.5	5	3
53	53	62.5	62	5	5
48	47.5	58	58.5	-5	-4
46	46	53.5	53.5	5	7
41.5	41	49.5	49.5	5	5
47.5	47.5	56	56.5	-5	-4
42.5	42.5	48	48	-7	-6
48	47.5	57	57	-5	-4
0.989		**0.989**		**0.975**	

HFF right tst1	HFF right tst2	RFFleft tst1	RFFleft tst2	RFFright tst1	RFFright tst2	ITBleft tst1
6	5	77	78	81	80	6
9	8	75	75	88	90	5
1	2	71	71	90	88	2
-5	-5	95	95	80	83	8
2	3	96	95	98	94	8
-4	-3	104	102	93	94	8
-8	-6	90	94	94	95	6
-4	-4	74	73	73	73	5
4	2	104	108	110	110	13
9	9	118	116	120	122	-7
5	5	110	105	105	105	3
4	3	100	100	105	104	6
0	1	90	90	92	95	10
-7	-8	90	92	95	93	3
8	7	120	120	120	117	-5
6	5	100	100	103	99	-7
-8	-6	95	95	88	87	8
-5	-3	95	98	100	100	10
-2	-2	91	94	95	93	4
0.976		**0.986**		**0.985**		**0.963**

ITBleft tst2	ITBright tst1	ITBright tst2	MFRleft tst1	MFRleft tst2	MFRright tst1	MFRright tst2
5	7	6	3	2	2	2
6	8	7	3	2	6	6
2	5	5	4	5	0	0
8	6	7	0	0	0	0
7	7	5	0	0	0	0
5	5	6	10	11	9	10
5	5	5	7	4	3	3
5	7	4	0	0	0	0
14	15	16	0	0	0	0
-5	-4	-4	0	0	4	5
5	8	9	5	6	0	1
8	9	6	4	2	0	0
11	8	10	0	0	0	0
4	4	7	3	4	2	3
-5	-6	-5	0	2	5	6
-6	-6	-5	4	4	3	2
7	5	6	0	0	0	0
10	3	5	2	3	1	3
7	5	4	3	5	6	4
	0.948		**0.903**		**0.949**	

LFRleft tst1	**LFRleft tst2**	**LFRright tst1**	**LFRright tst2**	**Hfleft tst1**	**Hfleft tst2**	**Hfright tst1**	**Hfright tst2**
0	0	0	0	60	62	61	6
0	0	0	0	60	58	60	5
0	0	0	1	62	63	70	7
5	5	6	6	73	75	70	6
4	4	6	4	65	66	60	5
0	0	0	0				
0	0	0	0	51	50	54	5
3	4	2	2	45	46	45	4
3	4	4	6	55	58	57	6
0	0	0	0	55	54	55	5
0	0	0	0	50	53	50	5
0	0	0	0	38	40	40	4
5	5	6	7	68	67	65	6
0	0	0	0	56	54	58	5
0	0	0	0	63	65	64	6
0	0	0	0	68	66	77	7
9	7	2	2				
0	0	0	0	70	67	70	6
0	0	0	0	64	66	70	7
0.973		**0.950**		**0.988**		**0.973**	

Adleft tst1	**Adleft tst2**	**Adright tst1**	**Adright tst2**	**LLAS-MMleft tst1**	**LLAS-MMleft tst2**
220	220	230	230	88	88
210	215	230	230	80.5	80.5
275	275	260	260	96.5	96.5
280	270	240	235	89	89
260	260	240	240	85	85
255	255	250	255	89	89
240	240	240	240	98.5	98.5
295	285	275	265	90.5	90.5
210	210	195	205	87	87
275	280	265	255	86	86
230	230	250	245	78	78.5
240	250	280	280	96	96
210	205	215	210	100	100
205	215	225	230	93.5	94
235	230	230	220	88.5	88.5
205	210	225	220	81	81
230	225	260	260	89.5	89.5
225	230	220	220	88.5	88.5
250	240	260	250	94.5	94.5
0.973		**0.959**		**0.999**	

LLAS-Mmright tst1	LLAS-Mmright tst2	LLTT-Mmleft tst1	LLTT-Mmleft tst2	LLTT-Mmright tst1
88	88	31.5	32	32
80.5	80	29.5	29.5	29.5
96.5	96.5	35.5	35.5	35.5
89	89	34	34	34
85	85	32	32	32
89	89	32	32	32
98.5	98.5	37	37	37
90.5	90.5	32	32.5	32.5
87	87	31	31	31
86	86	31	30.5	31
78.5	78.5	28.5	28.5	28.5
95.5	96	34.5	34	34
100	100	37	37	37.5
93	93.5	34	33.5	33.5
88.5	88.5	32	32	31.5
80.5	80.5	29.5	29.5	29.5
89	89	33.5	33.5	33
88.5	88.5	32	32	32
94	94	34	34	33.5
0.999		**0.993**		**0.996**

LLTT-Mmright tst2	Qaleft tst1	Qaleft tst2	Qaright tst1	Qaright tst2	KNEEVAL tst1	KNEEVAL tst2
32	14	14	14	14	0	
29.5	22	22	21	20	1	
35.5	15	15	16	16	0	
34	15	15	13	14	1	
32	13	12	14	16	1	
32	18	18	19	18	1	
37	15	15	14	14	1	
32	14	14	11	12	0	
31	8	9	8	10	1	
31	11	12	13	10	1	
28.5	10	9	10	11	1	
34	6	7	8	10	0	
37	15	15	13	13	0	
33.5	9	12	11	13	1	
31.5	17	18	20	21	0	
29.5	10	10	8	10	0	
33	14	16	15	15	0	
32	17	19	18	20	1	
34	10	12	11	11	0	
	0.949		**0.924**		**1.00**	

KNEEVAR tst1	KNEEVAR tst2	VAL/VARMM tst1	VAL/VARMM tst2	REARFOOTVAL tst1
1	1	20	22	1
0	0	18	18	1
1	1	17	16	1
0	0	22	22	1
0	0	22	21	1
0	0	19	21	1
0	0	17	18	1
1	1	21	24	1
0	0	15	17	1
0	0	18	21	1
0	0	19	20	1
1	1	23	25	1
1	1	20	18	1
0	0	16	17	1
1	1	24	23	1
1	1	19	20	1
1	1	15	14	1
0	0	18	20	1
1	1	21	24	1
1.00		**0.794**		**1.00**

REARFOOTVAL tst2	REARFOOTVAR tst1	REARFOOTVAR tst2	REARFOOTleft tst1
1	0	0	16
1	0	0	17
1	0	0	15
1	0	0	7
1	0	0	16
1	0	0	14
1	0	0	9
1	0	0	12
1	0	0	12
1	0	0	9
1	0	0	8
1	0	0	8
1	0	0	8
1	0	0	9
1	0	0	16
1	0	0	12
1	0	0	8
1	0	0	8
1	0	0	13
	1.00		**0.937**

REARFOOTleft tst2	REARFOOTright tst1	REARFOOTright tst2	FOREFOOTVAL tst1
14	14	14	0
16	15	15	0
16	17	17	0
6	8	10	0
15	15	15	0
15	11	12	0
10	7	8	0
13	9	11	0
14	10	11	0
8	7	10	0
9	9	10	0
9	5	5	0
9	9	10	0
10	8	10	0
16	14	14	0
12	10	10	0
8	8	7	0
9	9	10	0
11	10	12	0
	0.909		**1.00**

FOREFOOTVAL tst2	FOREFOOTVAR tst1	FOREFOOTVAR tst2	FOREFOOTleft tst1
0	1	1	11
0	1	1	10
0	1	1	10
0	1	1	4
0	1	1	11
0	1	1	13
0	1	1	9
0	1	1	9
0	1	1	10
0	1	1	7
0	1	1	9
0	1	1	8
0	1	1	6
0	1	1	8
0	1	1	9
0	1	1	9
0	1	1	7
0	1	1	6
0	1	1	9
	1.00		**0.805**

FOREFOOTleft tst2	FOREFOOTright tst1	FOREFOOTright tst2	ROTL3/4left tst1	ROTL3/4left tst2
10	9	8	2	2
10	10	10	2	2
9	11	10	2	2
5	5	5	2	2
10	10	10	2	2
13	10	10	2	2
10	7	7	2	2
11	7	9	2	2
9	10	10	2	2
8	7	8	2	2
7	8	9	3	2
7	5	4	3	3
8	7	9	2	2
9	7	10	2	2
8	11	10	2	2
10	10	8	2	2
8	9	7	2	2
6	7	5	2	2
11	8	9	3	3
	0.719		**0.771**	

ROTL4/5left tst1	ROTL4/5left tst2	ROTL5/S1left tst1	ROTL5/S1left tst2	ROTL3/4right tst1
1	1	3	3	2
3	3	2	2	2
1	1	1	1	2
1	1	2	2	2
2	2	2	2	2
1	1	2	2	2
2	2	2	2	2
2	2	2	2	2
2	2	3	3	2
2	2	2	2	2
1	1	1	1	2
2	2	3	3	3
2	2	2	2	2
3	2	1	1	2
2	2	1	1	2
2	2	2	2	2
1	2	1	1	2
2	2	2	2	2
3	3	3	3	2
0.815		**1.00**		**0.642**

ROTL3/4right tst2	ROTL4/5right tst1	ROTL4/5right tst2	ROTL5/S1right tst1	ROTL5/S1right tst2
2	3	3	3	3
2	3	3	2	2
2	1	1	1	1
2	1	1	2	2
2	2	2	2	2
2	1	1	2	2
2	2	2	2	2
2	2	2	2	2
2	2	2	1	2
2	2	2	2	2
2	1	1	1	1
3	2	3	2	2
2	3	2	2	2
2	2	2	1	1
2	2	2	1	1
2	2	2	2	2
2	1	1	1	1
2	2	2	2	2
3	3	3	2	2
	0.827		**0.891**	

F/EL3/4 tst1	F/EL3/4 tst2	F/EL4/5 tst1	F/EL4/5 tst2	F/EL5/S1 tst1	F/EL5/S1 tst2	PAVL3 tst1
2	2	1	2	1	1	2
2	2	2	2	2	3	2
2	2	1	1	1	2	2
2	2	2	2	2	2	2
2	2	2	1	2	2	2
2	2	2	2	2	2	2
2	2	2	2	2	2	2
2	2	2	2	1	2	2
2	2	2	2	3	3	2
2	2	2	2	2	2	2
2	2	2	1	1	1	2
2	2	2	2	2	2	3
2	2	2	2	2	2	2
2	2	2	2	2	2	2
2	2	2	2	1	1	2
2	2	2	2	2	2	2
2	2	1	1	1	2	2
2	2	2	2	1	1	2
2	2	3	3	2	2	2
1.00		**0.587**		**0.596**		**1.00**

PAVL3 TST2	PAVL4 tst1	PAVL4 tst2	PAVL5 tst1	PAVL5 tst2	PAVS1 tst1	PAVS1 tst2	LLS tst1
2	1	2	1	1	2	2	0
2	2	2	2	1	2	2	0
2	1	1	1	1	2	2	0
2	2	2	2	2	2	2	0
2	2	2	2	2	2	2	1
2	1	1	2	2	2	2	0
2	2	2	2	2	2	2	0
2	2	2	2	2	2	2	0
2	2	2	2	2	2	2	1
2	2	2	2	2	2	2	0
2	2	1	1	1	2	2	0
3	2	2	3	3	2	2	0
2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	0
2	2	2	2	2	2	2	0
2	2	2	2	2	2	2	0
2	2	2	2	2	2	2	0
2	1	1	2	2	2	2	0
2	3	3	3	3	2	2	1
	0.743		**0.883**		**1.00**		**0.862**

LLS tst2	TCS tst1	TCS tst2	DS1Min tst1	DS1Min tst2	DSF/Eleft tst1	DSF/Eleft tst2	DSF/Eright tst
1	3	3	4	5	6	5	
0	3	3	3	3	5	5	
0	3	3	3	3	8	9	
0	3	3	1	2	8	8	
1	3	3	1	1	8	8	
0	3	3	2	3	15	14	
0	5	5	5	5	19	14	
0	3	3	2	4	14	15	
1	5	5	1	1	18	17	
0	3	3	2	1	10	10	
0	3	3	2	4	5	7	
0	5	5	1	2	22	22	
2	5	5	4	6	13	12	
0	5	5	0	1	20	22	
0	2	2	1	1	11	13	
0	5	5	1	1	2	11	
0	5	5	7		6		
0	2	2	4	4	11	11	
1	5	5	5	7	17	11	
	1.00		**0.792**		**0.838**		**0.9**

DSF/Eright tst2	DSAB/Adleft tst1	DSAB/Adleft tst2	DSAB/Adright tst1	DSAB/Adright tst2
5	4	5	6	5
4	5	4	3	3
10	9	8	6	6
10	4	4	4	3
11	5	6	4	5
11	7	4	5	4
18	6	4	10	10
20	8	9	5	6
11	10	12	12	14
8	2	4	3	3
7	3	5	14	10
22	3	5	5	9
14	7	6	4	3
22	18	14	7	10
18	6	8	6	6
10	9	4	6	3
	4		5	
9	5	4	4	3
8	10	8	9	11
	0.780		**0.822**	

TABD tst1	TABD tst2	STRENGTH tst1	STRENGTH tst2	ABILITY tst1	ABILITY tst2
1	1	2	2	2	2
1	1	2	2	2	2
1	1	3	3	3	3
1	1	3	3	2	2
1	1	3	3	3	3
1	1	2	2	2	2
1	1	3	3	3	3
0	0	3	3	3	3
1	1	3	3	3	3
1	1	3	3	3	3
1	1	1	1	1	1
1	1	3	3	3	3
1	1	2	2	2	2
0	0	3	3	3	3
1	1	3	3	2	2
1	1	1	3	3	3
1		1		1	
1	1	2	2	2	2
1	1	2	2	2	3
1.00		**0.898**		**0.898**	

CONTRACTIONleft tst1	CONTRACTIONleft tst2	CONTRACTIONright tst1	CONTRACTIONright tst2
0	0	0	
0	0	0	
1	1	1	
1	1	1	
1	1	1	
0	0	0	
1	1	1	
1	1	1	
1	1	1	
1	1	1	
1	1	1	
1	1	1	
0	0	0	
1	1	1	
1	0	1	
3	1	1	
0		0	
1	1	0	
1	1	1	
		0.870	

COMPOBL tst1	COMPOBL tst2	COMPRA tst1	COMPRA tst2	COMPPT tst1	COMPPT tst2
1	1	1	1	1	0
1	1	1	1	1	0
1	1	1	1	0	0
1	1	1	1	0	1
1	1	1	1	1	1
0	1	1	0	1	0
1	1	1	1	0	0
1	1	1	1	0	0
1	1	1	1	1	1
1	1	0	0	0	0
1	1	1	1	1	0
1	1	1	1	0	0
1	1	1	1	0	0
1	1	1	1	0	0
1	1	1	1	0	0
1	1	1	1	1	0
1		1		1	
1	1	1	1	0	0
1	1	1	1	1	1
		0.640		**0.289**	

COMPUL tst1	COMPUL tst2	COMPBH tst1	COMPBH tst2	O-COMPleft tst1	O-COMPleft tst2
0	0	0	0	0	1
0	0	0	1	1	1
0	0	1	1	1	0
0	0	1	1	1	1
0	0	1	0	0	0
0	0	0	0	1	1
1	1	1	1	1	0
0	0	1	0	0	0
1	0	1	1	0	0
0	0	0	0	0	0
0	0	0	0	1	0
1	1	1	1	0	0
0	0	0	0	1	0
0	0	1	1	1	0
0	0	1	1	0	0
0	0	0	1	1	0
1		0		1	
0	0	0	0	0	0
0	0	1	1	1	1
0.769		**0.550**		**0.259**	

O-COMPright tst1	O-COMPright tst2	RECleft tst1	RECleft tst2	RECright tst1	RECright tst2
0	1	0	0	0	0
1	1	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0
1	1	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	1	1	1	1
0	0	0	0	0	0
1	0	0	0	0	0
1	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
1		1		1	
0	0	1	1	1	1
1	1	0	0	0	0
0.366		**1.00**		**1.00**	

JERKleft tst1	JERKleft tst2	JERKright tst1	JERKright tst2	SMALLSWINGleft tst1
0	0	0	0	1
0	0	0	0	1
0	0	0	0	1
0	0	0	0	0
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	0
0	0	0	0	1
0	0	0	0	1
0	0	0	0	1
1	0	1	0	1
1	0	1	0	1
0	0	0	0	1
0	0	0	0	1
0		0		1
0	0	0	0	1
1	1	1	1	1
0.455		**0.455**		**0.679**

SMALLSWINGleft tst2	SMALLSWINGright tst1	SMALLSWINGright tst2	LARGESWINGleft tst1
1	1	1	0
1	1	1	0
1	1	1	0
0	0	0	0
1	0	1	0
1	1	1	0
0	0	0	1
1	1	1	0
0	0	0	0
1	1	1	0
1	1	1	0
1	1	1	0
1	1	1	0
0	1	0	1
1	1	1	0
1	1	1	0
	1		0
1	1	1	0
1	1	1	0
	0.679		**1.00**

LARGESWINGleft tst2	LARGESWINGright tst1	LARGESWINGright tst2	STEADYDROPleft tst1
0	0	0	1
0	0	0	0
0	0	0	1
0	0	0	0
0	0	0	0
0	0	0	0
1	1	1	1
0	0	0	1
0	0	0	1
0	0	0	1
0	0	0	0
0	0	0	1
0	0	0	1
1	1	1	1
0	0	0	1
0	0	0	1
	0		1
0	0	0	1
0	0	0	1
	1.00		**0.753**

STEADYDROPleft tst2	STEADYDROPright tst1	STEADYDROPright tst2	IMPROVEleft tst1
1	1	1	1
0	0	0	1
1	1	1	0
0	0	0	1
0	0	1	1
0	0	0	0
1	1	1	0
1	1	1	1
1	1	1	0
1	1	1	1
0	0	0	0
1	1	1	0
0	1	0	1
1	1	1	1
1	1	1	0
1	1	1	0
	1		0
1	1	1	1
0	1	0	1
	0.609		**0.471**

IMPROVEleft tst2	IMPROVEright tst1	IMPROVEright tst2
1	1	1
0	1	0
0	0	0
0	1	0
1	1	1
0	0	0
0	1	1
1	1	1
0	0	0
1	1	1
0	0	0
0	0	0
0	1	0
0	0	0
0	0	0
0	0	0
	0	
1	1	1
0	1	0
	0.571	

Appendix 8

Lower back pain and its aetiology in other sports

Lindgren and Twomey (1988) note the frequency of occurrence of lower back pain in hockey players to simulate that of the general population. In their questionnaire investigating lower back pain in hockey players, Lindgren and Twomey (1988) found that lower back pain was common in hockey players but these athletes rarely required intensive physical and medical treatment. A similar trend seems to be associated with the runners in the present study. Lindgren and Twomey (1988) found that their subjects exhibiting lower back pain presented with mild intermittent symptoms that settled with rest or modification of training regimes. The running-related lower back pain presented similarly. However, Fenety and Kumar (1992) found hockey players with lower back pain to have a loss of lumbar-sacral range of movement and reduced peak eccentric extension.

Locke and Allen (1992) found boardsailors to be more prone to the development of lower back pain compared to the general population because of prolonged body postures kept. They inferred that limited flexibility might be causative. On the contrary, Paananen and Jyvaskala (1995) found back pain to be less common in athletes (runners) compared to control subjects in their long-term follow-up of former athletes. The incidence of lower back pain in cross-country skiers was evaluated by Erikson et al (1996) and found to be 67%. However, they determined that anthropometric and training variables were of little value in predicting lower back pain. The present study certainly confirins these findings of Erikson et al (1996).

O'Connor and Marlowe (1993) found military recruits to have an incidence of lower back pain of 17% while 26.5% of fit college students were found to suffer from lower back pain (Gemmell and Jacobson 1990). In evaluating wrestling, gymnastics, soccer and tennis, Sward et al (1990) found high incidences of 50 - 85% of lower back pain. However, these incidences actually mirror that of the general population similarly to the results determined in this study.