A SYSTEMATIC REVIEW OF EXERCISES, USED IN A WORKPLACE SETTING, FOR THE MANAGEMENT OF OCCUPATIONAL LOWER BACK PAIN

Petronella D van der Merwe

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Physiotherapy.

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DECLARATION

I Petronella D van der Merwe declare that this research report is my own work. It is being submitted for the degree of Masters of Physiotherapy in the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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……………………..Day of…………………, 2007

DEDICATION

Thank you for all your love and support.

My Husband, Levouy, and adoring boys, Jared and Liam

You are my inspiration

“ All things are possible in God who strengthens me…”

ABSTRACT

Aim:

The aim of this study was to determine the most effective exercise program for the management of occupational lower back pain.

Background:

Occupational lower back pain accounts for 25% of workdays lost. The annual occurrence of occupational related lower back pain among blue collar workers in South Africa has shown to be between 55,7% and 63,9%.

Methodology:

Primary studies were searched with the use of the Entrez-cross-database search tool. Methodologies were assessed and critiqued. Data which included exercise detail, outcome measures of lower back pain intensity, painful episodes, sick leave and physical measures with statistical p-values was then extracted.

Results:

Nine primary studies, which included 11 exercise groups, complied to the inclusion and exclusion criteria. These studies proved to be of high methodology quality with quality scoring 70% on the quality assessment checklist. Exercise regimes, which included stretching, strengthening, endurance exercises and the combination use of stretching, strengthening and endurance exercises were identified and grouped according to the corresponding outcome measures. No meta-analysis could be done as no similar exercises with similar outcome measures could be found.

Discussion:

The limitations in the nine selected studies methodological quality were the lack of blinding of the assessors and subjects, and in six of the nine studies the lack of adequate participation rate among the intervention subjects. The validation process is acknowledged as a weakness within this study. Stretching, dynamic strengthening and endurance exercises were not statistically significant. Isometric exercise was statistically significant for lower back pain relief when the control group ($p<0,0001$) was compared to the experimental group. Isometric exercise however had no significant effect on abdominal strength at 9 months follow up period. Functional exercises were statistically significant when the exercise group was compared to the control group with lower back pain intensity relief ($p<0,018$), painful episodes ($p<0,018$), sick leave ($p< 0,0044$). Functional exercises also had a long-term statistically significant effect on back muscle strength. A meta analysis could not be done due to insufficient similar studies.

Conclusion:

Although the methodology quality of the nine primary studies showed to be of high quality the validation process was a weakness within this study. Functional strengthening exercises were the most effective type of exercise for the management of occupational lower back pain among blue-collar workers. Future similar randomized control trails on exercise as an intervention to occupational lower back pain are needed to conduct a meta analysis. A meta analysis will be able to provide more evidence to establish which exercise regime is most effective for the management of occupational lower back pain.

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DEFINITION OF TERMS

Lower back pain:

Lower back pain is a neuro-musculoskeletal disorder of the lumbar region, L1 to L5, caused by inflammation or mechanical strain of the surrounding structures. It can originate from vertebral zygopophyseal joints, discs, muscles, ligaments and neural tissue due to trauma or repetitive strain, which can lead to degenerative changes of the lumbar spine (Maitland, 1986).

Occupational lower back pain:

Occupational lower back pain is pain in the lower region of the spine, which is caused by mechanical strain due to activities, which are performed in a work situation. Occupational low back pain is statistically significant for activities where there is daily lifting of more than ten kilograms, (Palmer *et al.*, 2003), number of hours spent on repetitive actions, (Guo, 2002), and the degree of lumbar flexion attained with frequent excessive weight lifting. (Hoogendoorn *et al.*, 2000)

Blue-collar worker:

Blue-collar workers are according to the computerized Hutchinson dictionary (2006, first edition) “a working class employee who performs manual labor as in an industry or factory”.

Systematic review:

A systematic review is an overview of primary studies that contain specific statements of objectives, and it is according to a specific and reproducible methodology. It has the advantage to limit bias in identifying and rejecting studies thus making the conclusions more reliable and accurate (Greenhalgh, 1998).

Meta-analysis:

Meta-analysis is a statistical synthesis of the numerical results of several trials that examined the same question (Greenhalgh, 1998)

CHAPTER 1

1. INTRODUCTION

1.1. Background

Lower back pain is a neuro-musculoskeletal disorder of the lumbar region caused by inflammation and/ or mechanical strain. It can originate from vertebral zygopophyseal joints, disc, muscles, ligaments and neural tissue due to trauma or repetitive strain, leading to degenerative changes of the lumbar spine (Maitland, 1986). Occupations involving heavy physical work are found to be a significant statistical risk factor in the development of lower back pain (Hartvigsen *et al.,* 2001). Heavy physical work activities can lead to mechanical straining of the lumbar structures, if done in an improper ergonomically manner. Mechanical straining of the lumbar structures causes inflammation, and this leads to lower back pain via the activation of the unmyelinated C nociceptors (Johnson, 1997).

The phenomenon, of lumbar pain originating due to physical work activities, is significant especially in situations where there is daily lifting of more than ten kilograms (Palmer *et al.,* 2003); excessive hours spend on repetitive actions, (Guo, 2002) and extreme lumbar flexion when doing heavy lifting activities, (Hoogendoorn *et al.,* 2000). These actions lead to accumulation of neuromuscular damage and inflammation of the lumbar spinal structures (Williams *et al.,* 2000; Zedka *et al.,* 1999). Blue-collar male workers involved in long distant driving, manual labor and lifting activities are found to be the highest risk group of employees who can develop lower back pain (Gluck and Oleinick, 1998).

According to a 2004 employment equity report published by the South African Department of Labour in 2006, plant operators, also called blue-collar workers, form 12,5% of the formally employed workforce population in South Africa. According to this report 14,2% of these workers were disabled, and unable to perform their regular work duties, due to injuries acquired at work in 2004 (SA Dep. of Labour, 2006).

A survey done at a South African car seat assembly plant in 2005, revealed that of the sixty-five employees surveyed, 20% indicated lower back pain symptoms. Of these 20% employees, 10% had been on sick leave due to lower back pain during the previous year (The Johnson Control report, 2005). A study by, Lotters and Burdorf (2006) indicated that blue-collar workers are prone to high incidence of short and long-term sick leave absence due to the high-risk of developing lower back pain.

Devereaux (2004) indicated that lower back pain is the second leading cause for absence from work in the Unites States, and accounted for 25% of all workdays lost. The lifetime prevalence for lower back pain, with each incident lasting for two to more weeks, is 13,8% in China and from 60% to 90% in the Unites States (Devereaux, 2004). This condition is also prevalent in South Africa were an annual occurrence of occupational related lower back pain been found to the between 55,7% and 63,9%, among the employees of two South African steel manufacturing companies (Van Vuuren *et al.*, 2003).

A global survey indicated that occupational related lower back pain cause 818 000 disability-adjusted life years to be lost annually (Punnett *et al.*, 2005). According to the American College of Occupational and Environmental Medicine (2003), 73% of the employees with lower back pain, which originated at work, were still absent a month after the original onset of the lower back pain symptoms.

Absenteeism from work due to occupational induced lower back pain is an expensive health issue, (Murphy *et al.,* 1999; Borenstein, 2000), due to the high compensational medical expenses and disability claims (Fransen *et al.,* 2002; van Tulder *et al.,* 1995). A study by Fransen *et al.,* (2002) indicated that 23,9% of claimants were still receiving compensational payments for lower back pain three months after their initial assessment. The claiming for compensational back injuries has the highest rates in manual labour occupations (Gluck and Oleinick, 1998). Blue-collar male occupations were among the highest group of workers involved in these claims (Gluck and

Oleinick, 1998). Widespread muscular skeletal disorders and lower back pain are the cause of a loss of a 45% of working days by blue-collar workers (Morken *et al.*, 2003). Systematic reviews have been done to determine which intervention is most appropriate in the management of occupational lower back pain to decrease complications of absenteeism and financial expenses (Tveito *et al.*, 2004; van Tulder *et al.*, 2000)

According to a systematic review done by Tveito *et al.* (2004) only exercises and comprehensive multidisciplinary treatment at the workplace have a documented effect on the reduction of lower back pain. Long *et al.* (2004) indicated that exercises were helpful for chronic lower back pain patients who may as a result return to work sooner. In addition, these exercises have good results in rapid decrease of pain and use of medication.

In addition, to exercises other lower back pain interventions are also utilized. In the Unites States and Europe, employers of high-risk blue-collar of workers, for occupational lower back pain, are considering various lower back pain interventions. These include the use of back belts, back care education, medical examination and -treatment and early morning exercise programs, in order to prevent and reduce the onset of lower back pain among their employees (Hochanadel and Conrad 1993; Elders and Burdorf 2004; Hagen *et al.*, 2000;Tveito *et al.*, 2004). As much as exercise is desirable for the prevention of lower back pain and has been shown to be effective, there is limited information concerning exercises, which are used by blue-collar workers as revealed by previous systematic reviews (van Tulder *et al.*, 2000; Tveito *et al.*, 2004).

1.2. Problem statement

Systematic reviews, conducted previously by, van Tulder *et al.*, 2000 and Tveito *et al.*, 2004, on the use of exercise and interventions for the prevention of occupational lower back pain do not show or give specific exercise programs that could be effective for workers subjected to high-risk factors of occupational lower back pain. The specifics of an exercise program for a high-risk blue-collar employee are lacking.

1.3. Aim of study

The aim of this study was to determine which exercises, used among workers subjected to manual labour in a workplace setting were most effective in the management of lower back pain. This systematic review covered an overview of primary studies concerning exercise as an intervention and management of lower back pain in an occupational setting.

1.4. Objectives

The objectives of this study were to

1.4.1. review the quality of the methodologies used in the identified studies. Assessing the methodological quality used in these primary studies, has been advantageous in limiting bias in the selection of the identified primary studies, obtaining a more reliable and accurate conclusion (Greenhalgh, 1998).

1.4.2. establish details of the exercises used in the management lower back pain among blue-collar workers in the identified studies,

1.4.3. identify similar outcome data, in terms of lower back pain relief, painful episodes, sick leave and physical measures, across all the studies to identify the specific exercise significance in the management of occupational lower back pain and,

1.4.4. re-analyse the outcome data in a Meta analysis.

1.5 Significance of the study

The significance of the study was to give a better guideline to which therapists, employers and/ or the blue-collar employees themselves can utilize exercises as a lower back pain intervention. This study will also identify which exercise is most appropriate to use among blue-collar workers for the management of lower back pain.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Introduction

This literature review was conducted with the use of Pubmed and the University of the Witwatersrand library computerized databases search engines. Keywords: *lower back pain, blue-collar workers, risk factors, epidemiology, postural influences and exercises* were used. A wide variety of research was found as lower back pain affects many people daily all over the world (Devereaux, 2004; UK health statistics, 2000; Borenstein, 2000). The epidemiology of lower back pain will be discussed and how it relate to blue-collar workers (Punnett *et al.,* 2005; Hartvigsen *et al.*, 2001).

These employees are subjected to lower back pain risk factors, which cause absenteeism (Devereaux, 2004; Harvigsen *et al.,* 2001; Guo, 2002; van Vuuren *et al.,* 2005). High incidence of sick leave could be due to occupational lower back pain, found among blue-collar workers. Occupational lower back pain has many consequences such as high medical cost, loss of production and unemployment (Lotter and Burdorf, 2006 and Morken *et al.,* 2003). Many interventions have been used to reduce these consequences.

Among these interventions exercises were identified to be most cost effective and to have a documented effects on lower back pain (Tveito *et al.,* 2004). In order to develop a lower back pain exercise program, an understanding of the source and origin of lower back pain are essential (Jull And Janda, 1987; Jacobs, 2005). The mechanism of injury, risk factors and biomechanics of the spine involved among blue-collar workers gives an insight into the extent of the structural damage (Maitland, 1986; Jull and Janda, 1987; Jacobs, 2005; David, 2005). Therapists also need to know what physiological and anatomical effect each exercise has on the patient in order to obtain the desirable effect on back pain. The different exercise regimes used such as stretching (Moore, 1998), strengthening (Alexandre *et al.,* 2001) and endurance exercises (Linton *et al.,* 1998) and their individual effect on the pain pathways (Johnson, 1997) will be discussed.

2.2. The epidemiology of lower back pain

Lower back pain is defined as pain in the lower regions of the spine from L1 to L5 vertebrae level (Maitland, 1986). Pain that originates from the lumbar spine may also cause referred and/ or radiating pain to the legs (Maitland 1986; Jull and Janda, 1987). Fifteen million people in the United States of America is annually experiencing lower back pain. The lifetime prevalence (expressed per 1 000 000), of lower back pain among Unites States' population is 60% to 90% (Devereaux, 2004). A survey was carried out among Great Britain's households, which estimated that over one million people were suffering from musculoskeletal disorders caused by work. Seventy-nine percent (508 000), of these people reported that pain was mostly located in the lower back and not in other body parts (UK statistics, 2000).

In a study done by van Vuuren *et al,* (2003) in two South African industrial populations, a steel factory of 336 employees and a manganese metal factory of 109 employees, indicated the lifetime prevalence of lower back pain to be 63,9% and 71,6% respectively. The annual prevalences were 55,7% and 63,9% respectively and the monthly prevalences were 41,3% and 55% respectively. This South African survey was confined to the steel- and metal factories and was very small in comparison to the surveys done in Great Britian (UK statistics, 2000) and Unites States of America (Devereaux, 2004). Larger population surveys are needed in South Africa.

Similar surveys were conducted among industrial employees, in Finland, during 28 years. Employees with lower back pain symptoms at baseline were re-assessed at the 5 years, 10 years and 28 years follow-up period. Over a period of 5 years, 10 years and 28 years lower back pain re-occurred 75%, 73% and 88% respectively (Kaaria *et al.,* 2006). A large percentage of the populations in the Unites States, Great Britian, Africa and Europe are thus affected by lower back pain as shown in the above mentioned statistics.

Punnet *et al.* (2005) estimated the global burden of occupational disease and injury by extracting data from the International Labour Organization and the World Bank. Punnet's global survey showed that 37% of lower back pain is caused by occupational factors and it is prevalent especially among blue-collar males (Punnett *et al.,* 2005; Harvigsen *et al.,* 2001; Gluck and Oleinick, 1998). Several studies confirm a high risk for lower back pain among blue-collar worker (Gluck and Oleinick, 1998; Punnett *et al.,* 2005; UK statistics, 2000; van Vuuren *et al.,* 2005). This leads to many consequences such as high insidence of sick leave, unemployment and high medical cost (Hochanadel *et al.,* 1993; Elders and Burdorf, 2004).

2.3. The consequences of occupational lower back pain

Occupational lower back pain among blue-collar workers leads to many consequences, which affect the employee as well as the employer (Hochanadel *et al.,* 1993, Elders and Burdorf, 2004). These consequences involve loss of productive life years, high medical claims, sick leave, and unemployment (Punnett *et al.,* 2005, Murphy *et al.,* 1999, Lotter and Burdorf, 2006, Morken *et al.,* 2003). Punnett's global survey indicated that lower back pain is estimated to cause 818 000 disability-adjusted life years lost annually (Punnett *et al.,* 2005). In 1995, the rate of filing low back claims in the Unites States of America, was 1,8 per 100 workers. An estimated $8,8 billion was spent on these low back pain claims (Murphy *et al.,* 1999). Sick leave also leads to high costs, like loss of production and loss of income (Lotter and Burdorf, 2006; Morken *et al.,* 2003).

Morken *et al.* (2003) and Lotters and Burdorf (2006) looked at the prevalence and prognostic factors of sickness absence among industrial workers. They found that blue-collar workers have a high risk for both short- and long-term sickness absences due to musculoskeletal disorders, which included lower back pain (Lotters and

Burdorf, 2006 and Morken *et al* 2003). Morken's study however lack adequate follow-up of the participants. Only 60% of baseline participants were measured at follow-up. The PEDro scale recommends an 80% follow-up or participation rate (Appendix C). These results, which stated that blue-collar workers are at risk in developing lower back pain, are supported by a survey among Michigan workers (Gluck and Oleinick, 1998).

Gluck and Oleinick's (1998) survey indicated that the claim rate for lower back pain peaks in men in the 24 to 34 year range. The highest rates are in manual labor occupations. These claim rates give one an insight into the manual workers' need to compensate for lost income due to sick leave, unemployment and/ or disability (Gluck and Oleinick, 1998)

Sick leave and unemployment are indicated in a survey of interviews and literature reviews by Pransky *et al.* (2002), who found that 60% of people who suffer with lower back pain lose one week of work per year. Only half of these employees return to their pre-injury job a year after injury and 20% are unemployed due to their injury (Pransky *et al.,* 2002). Using a logistical regression model the American College of Occupational and Environmental medicine predicted that 73% of employees, with occupational lower back pain, were unable to resume their work one month after initial assessment.

To prevent back pain and its added cost, risk factors need to be identified and subsequently addressed to prevent the high cost, sick leave and unemployment. These risk factors also give one insight into which medical intervention is necessary for the effective management of occupational lower back pain at minimal medical cost (Devereaux, 2004; Harvigsen *et al.,* 2001).

2.4. Risk factors in the development of occupational related lower back pain

2.4.1. Heavy physical work

Heavy physical work, heavy lifting, twisting and vibration, are significant work-related risk factors (Devereaux, 2004). A cross-sectional and five year prospective study conducted by Harvigsen *et al.* (2001) indicated that blue-collar workers that are subjected to physical workload, over a five-year period, are prone to lower back pain. A relative lower proportion of workers who do sedentary work, experienced lower back pain in contrast to a significant proportion of workers who do heavy physical work (Harvigsen *et al.,* 2001). Thus, a sedentary job has a statistically significant protective or neutral effect in relation to lower back pain. In contrast, a heavy physical job constitutes a statistically significant risk factor (Harvigsen *et al.,* 2001).

2.4.2. Repetitive activities

Workers who spend time on both repeated strenuous physical activities and repeated bending, twisting or reaching on a typical job have higher prevalence of lower back pain than those who do not ($p< 0,05$) (Guo, 2002). This occurrence of repeated strenuous physical activities and repeated bending, twisting or reaching is also prevalent among South African steel workers (van Vuuren *et al.,* 2005). There is a significant ($p<0,05$) risk to develop lower back pain when the employee is exposed to twisting, bending, sitting, kneeling, squatting, caring load and handling bulky material (van Vuuren *et al.,* 2005). Hoogendoorn *et al.* (2000) states that workers who lift a load of at least 25kg repetitively, (more than 15 times per working day), fall at risk of developing lower back pain.

2.4.3. Vibration and lifting

Palmer *et al.* (2003) investigated whole body vibration and occupational lifting as potential risk factors for lower back pain. Significant associations were found at work between daily lifting of weights greater than 10kg (Palmer *et al.,* 2003). There is, however, little relevance to the exposure and amount of vibration, during driving of industrial vehicles.

Fransen *et al.* (2002)'s study, in which borderline significance, ($p<0,05$, OR: 1,6) was found for vibration during driving, confirms the above finding. Job requirement of lifting for three-quarters of the day or more, has been found to be a significant, independent determinant for chronicity of lower back pain, $p<0,05$. (Fransen *et al.,* 2002). In addition, carrying a load, handling bulky material, kneeling and squatting when doing any lifting activity, among South African industrial workers, are significant risk factors for lower back pain (van Vuuren *et al.,* 2005). Lifting thus seems to be a major risk factor for the development of lower back pain.

In order to understand the mechanism of occupational lower back pain injury, due to the above-mentioned risk factors, knowledge of the biomechanics and muscle action involved in the lumbar spine, is essential. Different biomechanics and muscle function are involved during the above-mentioned risk factors of bending, twisting and lifting. The biomechanics of the lumbar spine, is becoming increasingly understood as revealed by previously done studies (Bos *et al.,* 2002; Gagnon and Gagnon, 1992; Mayer *et al.,* 1994). It is important to understand how risk factors predispose blue-collar workers to lower back pain and how they affect the normal function of the spine.

2.5. Function of the lumbar spine

The main function of the lumbar spine is to provide support for the weight of the upper part of the body in static and dynamic situations (Jacobs, 2005). Compressive forces, which are experienced when lifting and bending, are resisted and transmitted from the vertebral body and the nucleus pulposus to the vertebral end plates. Vertical compressive forces are then translated into the circumferential tensile forces of the annulus fibrosis. The spinous processes also resist compression and transmit these forces to the laminae, which then transmit it to the pedicles. The annulus fibrosis and the zygopophyseal facets resist tensile, torsional and shear forces. When bending, the pedicles transmit these forces, which are exerted by the muscles attached to the spinous and transverse processes to the vertebral body (Levangie and Norkin, 2001).

Excessive compressive and tensile forces on these structures cause imbalance of the spine function thus causing irritation of pain sensitive structures. Continued irritation of the above mentioned structures result in biomechanical changes of the lumbar spine and inflammatory processes (Zedka *et al.*, 1999).

2.6 Biomechanics and muscle function of the lumbar spine during: bending, lifting and twisting

2.6.1. Biomechanical changes during bending

Bending involves forward flexion and/ or flexion with rotation as when transferring objects to the side. An adjusted odds ratio of 2,81, 95% Cl 1,02 to 7,73, has been found for twisting and bending, among South African steel workers, showing that it has a correlation to lower back pain (van Vuuren *et al.*, 2005). This study indicated twisting and lifting and/ or flexion with rotation, as significant risk factors in the development of lower back pain (van Vuuren *et al.*, 2005).

During flexion and rotation, for example when transferring objects from side to side, the disc loses hysteresis i.e. its ability to return to its original form after it has borne weight, (Chow *et al.*, 2004). This loss of hysteresis result in more radial tears in the annular fibroses as opposed to disc herniation (Thompson *et al.*, 2004). In addition, the disc loses its ability to facilitate motion due to the loss of hysteresis and this leads to a marked change in the measurable mechanics of the spinal joint. Intersegmental motion changes then result (Thompson *et al.*, 2004). The intersegmental motion determines the neutral zone, and/ or stability function, of the lumbar spine. If the intersegmental motion and/or neutral zone is disturbed the lumbar structures are subject to irritation, inflammation and pain (Panjabi, 1989).

Dickey *et al.* (2002) found that there is a correlation between chronic pain and intersegmental motion. Intersegmental motion is more prominent with flexion than extension. During flexion of the lumbar spine, there is an increase in the central foramen dimensions (Fujiwara *et al.*, 2000; Fujiwara *et al.*, 2001). The neural tissue also moves cephalically within the neural foramen, which increases the superior/ inferior diameter and decreases the antero-posterior diameter. Flexion activities, example bending to remove an object from a shelf and picking up an object with the use of a poor lifting technique lead to this neural changes within the lumbar spine (Levangie and Norkin, 2001). This makes the lumbar neural tissue perceptive to accumulative tissue damage and irritation during repetitive bending (Fujiwara *et al.,* 2001; Levangie and Norkin, 2001). The other lumbar structures such as the disc, ligaments and muscles are also subject to biomechanical changes (Levangie and Norkin, 2001).

During flexion of the lumbar spine the intervertebral disk compresses anteriorly, while it is stretched posteriorly and the nucleus pulposus is pushed backwards. This result in high intradiscal pressure posteriorly in what occurs when the blue-collar worker is bending forward to pick-up an object and or when he works in a flexed position at a working surface that it below hip height. This was confirmed by a study done by

Hoogendoorn *et al.* (2000). They found that blue-collar workers have an increased risk of developing lower back pain when they work with their trunk in a minimum of 60° of flexion for more than 5% of their daily working time (Hoogendoorn *et al.,* 2000). The lumbar muscles' activity and function change during different degrees of flexion.

Flexion is controlled by the postvertebral muscles' eccentric muscle action on both sides when standing (Levangie and Norkin, 2001). Lumbar flexion usually involves activation of erector spinae and multifidis muscles. During a 60% to 100% flexion, an eccentric erector spinae activity can be observed (Zedka *et al.,* 1999). However, with repetitive static flexion (Williams *et al.,* 2000), as seen in some job activities of blue-collar workers (Bos *et al.,* 2002; Giorcelli *et al.,* 2001) tension-relaxation or reflexive EMG muscle spasm can be observed in the multifidis and other posterior muscles (Williams *et al.,* 2000). Tension also develops in the disc and ligaments, which surround the vertebral segment.

Bending or flexion is limited by tension in the posterior part of the intervertebral disc, posterior longitudinal ligament, ligamentum flavum, interspinous and supraspinous ligaments (Levangie and Norkin, 2001). The resultant muscle spasm, (due to repetitive flexion) causes an increased laxity of these viscous-elastic structures when attempting to increase intervertebral stability. This leads to sub-acute damage that involves ligamentous sprains, strains and disc degeneration. This resultant muscle spasm also results in creep (Zedka *et al.,* 1999; Williams *et al.,* 2000).

Creep is the progressive deformation of a structure under the influence of a constant load (Paris and Loubert, 1990). An increase in repetitive lumbar flexion causes an increased "creep" effect. Creep results in an increased duration of muscle spasm. These are observed when the blue-collar worker need to work in a fixed flexed posture, example while adjusting or inserting motor-vehicle parts under the bonnet or vehicle, in a motor-vehicle assembly plant (Levangie and Norkin, 2001). This leads to the accumulation of neuromuscular damage and an inflammatory response. Thus leading to pain (Zedka *et al.,* 1999; Williams *et al.,* 2000).

Lumbar pain, which develops due to repetitive bending, originates from mechanoreceptors (Williams *et al.,* 2000). The polysynaptic pathways of C fibers and A delta fibers mainly cause this pain (Zedka *et al.*, 1999). More light has been shed on pain pathways. This has given a better understanding of the origin of pain and the mechanism of pain modulation in which exercise decreases pain (Johnson, 1997). Pain pathways, are later defined in this section. The same type of biomechanical changes is found when the blue-collar worker is subjected to lifting activities (Palmer *et al.,* 2003; Fransen *et al.,* 2002).

2.6.2. Biomechanical changes during lifting

The lumbar structures of blue-collar workers are loaded when they perform, flexion of the spine via their daily, lifting activities. This is confirmed by several studies (Palmer *et al.,* 2003; Fransen *et al.,* 2002). According to Bos *et al.* (2002) and Levangie and Norkin, (2001). Lifting with the trunk in full forward flexion causes a diminished muscle action of the lumbar extensor muscles (Levangie and Norkin, 2001). It also increases the intradiscal pressure and can lead to disc prolapse (Levangie and Norkin, 2001). The global mobilisers of the spine need to contract more to support the disc and vertebrae. Consequently more pressure is applied to the disc. Flexion muscle activity also increases the compression and anterior shear on the lumbar vertebrae (Bos *et al.,* 2002; Levangie and Norkin, 2001).

A study by Gagnon and Gagnon, (1992) confirmed that the torsional, extension/ flexion and lateral bending forces and net muscular movement at the L5 and S1 joints increased significantly more with lifting at a fast and accelerated movement than with a slow movement. The lumbar spine’s structures are thus subjected to repetitive irritation of pain sensitive structures. The same is found with twisting activities (Bos *et al.,* 2002).

2.6.3. Biomechanical changes during twisting

Blue-collar workers perform twisting or trunk rotation when transferring objects or when reaching to objects on their side or back. Their spine is therefore subjected to different shear and compression forces.

Twisting of the lumbar spine can involve lateral flexion and/ or rotation. The lateral part of the disc is subjected to compressive forces with lateral flexion and more torsion forces and shear is applied to it with rotation (Bos *et al* 2002; Levangie *et al* 2001).

During twisting of the blue-collar worker's trunk shear forces act on the midplane of the disc and cause the vertebrae to move anteriorly, posteriorly and side-to-side in relation to each other (Levangie and Norkin, 2001). Thus, compressive forces are also applied on the zygopophyseal joints, during rotation, the ipsilateral joint ligaments is stretched and the contralateral joint compressed. The opposite happens with lateral flexion, when the ipsilateral zygopophyseal joint is compressed and the contralateral joint stretched (Levangie and Norkin, 2001). As with repetitive flexion, the same accumulation of neuromuscular and osteoligamentus micro-trauma can happen with repetitive shear and torsion forces applied to the lumbar spine (Williams *et al.,* 2000*;* Zedka *et al.,* 1999*)*

The compression, tension, bending, torsion and shear stresses that the vertebral column is subjected to during repetitive actions can affect the stability, or neutral zone, of the lumbar spine and can distort normal lumbar function. The disruption of normal lumbar function or lack of neutral zone leads to continued irritation and inflammation of pain irritable structures therefore leading to pain (Panjabi, 1989).

2.7. Sources of mechanical lumbar pain

Localised back pain is transmitted primarily through the posterior ramus of the spinal nerve and the sinuvertebral nerve (Johnson, 1997). The spinal nerve divides into a posterior ramus and anterior ramus (Meyer *et al.,* 2002). Branches of the posterior ramus provide sensory fibers to the fascia, ligaments, periosteum, facet joints, and paraspinous muscles of the spine, whereas the anterior ramus descends to the lower extremity. The sinuvertebral nerve arises from the rami communicantes and enters the spinal canal through the foramina to supply structures within the spinal canal. These spinal structures have a high concentration of pain receptors (Devereaux, 2004)

Activities like bending, twisting and lifting can lead to tension and strain of the fascia, ligaments, periosteum, facet joints, and paraspinous muscles of the spine and cause pain.

2.8. Pain and pain pathways

One needs to have an understanding of the origin of pain due to the disturbed biomechanics of the lumbar spine (Teasell and Bombardier, 2001). In addition, the understanding of pain pathways makes it clear how exercise promotes pain relief.

Pain is described as an unpleasant sensory and emotional experience associated with actual or potential tissue damage (Merskey, 1991). Noxious damaging stimuli like repetitive micro-trauma and strain of the lumbar spine muscles, ligaments and neural tissue cause activation of the unmyelinated C nociceptors. The polymodal C nociceptors respond by releasing prostaglandins, bradykinins and histamines secondary to the tissue damage (Meyer *et al.,* 2002; Zedka *et al.,*1999) . This can lead to tonic contraction of the agonist and antagonist (Meyer *et al.,* 2002). The C fibers synapse in the dorsal horn, Lamina 2 (substantia gelatinosa), which releases substance P, a primary excitatory neurotransmitter. The pain impulse then travels via the paleo-spinothalamic tract to the thalamus and then to the frontal cortex where it is recognise as pain (Johnson 1997).

Well-localised pain, such as pinprick and heat above 45°, is transmitted via the fast myelinated A-delta nociceptors in the dorsal horn of lamina I and V (Meyer *et al.,* 2002). This is particularly found with overuse or straining of the lumbar structures (Williams *et al.*, 2000; Zedka *et al.*, 1999). The neo-spinothalamic tract carries the pain impulse to the periaquaductal grey mater in the midbrain where pain is modulated. This pain impulse synapses in the thalamus and the sensory cortex. The pain impulse is carried from lamina V, wide dynamic range cells, via the spinoreticular tract to the hypothalamus, limbic system (which is responsible for affective and emotional response) and the frontal lobe (which is responsible for cognitive responses) (Johnson, 1997).

Healing and pain inhibition are accomplished by the descending inhibitory system. Stimulation of A- delta and A-beta mecahanoreceptors leads to facilitation of the descending inhibitory system (Johnson, 1997). Exercises decrease or modulate lower back pain by means of the following principles: the stimulation of A-beta mechanoreceptors, found in the joints, skin and muscles, via movement or stretch performed during exercises.

The descending inhibitory system represents two areas: the periaquaductal grey mater in the midbrain and the nucleus raphe magnus in the medulla. The beta endorphinergic projects from the cells in the hypothalamus and activate the neurons in the periaquaductal grey mater. It then projects to the serotinergic, nucleus raphe magnus. The pain signal is diminished or inhibited at the ends of the axons, enkephalinergic interneurons, which borders between lamina I and II in the dorsal horn. (Johnson,1997; Meyer *et al.*, 2002).

Pain modulation can also take place by means of the gate control theory (Melzack and Wall, 1965). In normal conditions the small diameter A delta and C fibers “open” the gate and allow the transmission of noxious stimuli to the brain. Activation of large diameter A beta afferents, through touch, pressure and stretch, “close” the pain gate and prevent noxious stimuli to reach the brain (Melzack and Wall, 1965). Inhibitory neurotransmitters are released by the inter-neurons in the dorsal horn and have an inhibitory action on the central nociceptor transmitter cells, for example, the wide dynamic range cells. This decreases the amount of noxious stimuli reaching the brain and reduces sensory experience of pain. It also stimulates certain pathways of the descending inhibitory pathway from the brain to the spinal cord that cause an inhibitory action of the central nociceptor pathways. The periaquaductal grey and nucleus raphe magnus produce analgesia, which dampen pain in humans (Johnson, 1997). Pain has different effects on muscle action and activity that must be understood in order to select appropriate interventions (Meyer *et al.,* 2002).

2.9. Lumbar muscle response to lower back pain

There is a significant weakening of the multifidus muscles when lower back pain is experienced (Hides *et al.,* 1994). The multifidus muscles strength do not recover spontaneously when painful symptoms disappear. It is hypothesised that this lack of localized muscle support is one of the reasons for the high recurrence rate of lower back pain following an initial episode (Hides *et al.,* 1994; Hides *et al.,* 1996). In addition, this may lead to a stability dysfunction due to the abnormal increase in the range of the neutral zone owing to the lack of dynamic control (Jacobs, 2005). This increase of the range of the neural zone range can cause repetitive straining of osteo-ligamentus and muscular structures in-between adjacent vertebrae. The lack of spinal stability increases shear and bending forces on the vertebrae structures during bending, twisting and lifting (Levangie and Norkin, 2001).

According to Hodges and Richard (1995) the transversus abdominus muscle contracts before a limb is moved. The transversus abdominus therefore functions as a stabilizer of the spine because of its action to contract firstly before any other muscle when a movement is initiated (Hodges and Richard, 1995). In a patient suffering from lower back pain, the contraction of transversus abdominus, however is delayed and fails to be active before the limb activity (Hodges and Richard, 1995). Thus, where blue-collar workers need to lift, bend and twist, spinal stability is off vital importance and it needs to be addressed to relieve lower back pain efficiently.

2.10. Stability of the lumbar spine

The ability of the lumbar spine to resist an applied load is determined by the degree of stiffness of the vertebral column (Levangie and Norkin,, 2001). Stiffness of the lumbar spine becomes apparent when examining the small motion segments of which the lumbar spine consists. The lumbar spine is divided into small motion segments, which consist of two adjacent vertebrae and intervening soft tissue. The stiffness of a particular segment can be determined when a specified load is applying to this motion segment (Levangie and Norkin,, 2001).

Panjabi, (1989) used the size of a neutral zone to provide a clinical measure of spinal stability. He defines the neutral zone as "the range of intervertebral motion within which spinal motion is produced with minimal internal resistance of the collagen tissue around the joint". The abnormal increase in the range of the neutral zone or lack of dynamic control of the neutral zone causes a stability dysfunction. Inter-segmental injury and intervertebral disc degeneration lead to an increase of the neutral zone range. Any muscle contraction and/ or muscle spasm across a motion segment, cause a decrease of the neutral zone range (Panjabi, 1989). These changes depend mostly on the age, posture, type, duration and rate of load carried by the worker (Levangie and Norkin, 2001).

Local and global muscle systems are used to maintain the neutral zone (Jacobs, 2005). The local muscles, which are the multifidus, transversus abdominus, pelvic floor muscles and diaphragm, control the position and stability of the lumbar vertebrae as well as the inter-segmental motion (Jacobs, 2005; Jull and Janda, 1887). The global muscles, which are the lattissimus dorsi abdominal oblique, rectus abdominus and thoracolumbar fascia, which control the transfer of load between the thoracic cage and pelvis, are divided into stabilizers and mobilisers (Jacobs, 2005; Jull and Janda, 1987). These global muscles insert and originate on the thorax or pelvis; they lack segmental vertebral attachment and are mainly superficial or outer layers of muscles (Jacobs, 2005). In conclusion, pain therefore, causes the weakening of core stabilizers, which in turn, leads to postural imbalances due to a compensation mechanism.

Muscle imbalances with compensatory shortening and weakening of postural muscles can take place due to repetitive injury and pain of the lumbar spine (Jacobs, 2005). Jull and Janda (1987) classified muscles as postural or phasic, according to their reaction to physical stress and injury. Postural muscles show a tendency to tighten. They are stronger than their phasic counterparts and have a lower irritability (Jull and Janda, 1987). The muscles prone to tightness are gastrocnemius, tibialis posterior, short hip adductors, hamstrings, rectus femoris, iliopsoas, tensor fascia lata, piriformis, erector spinae, quadratus lumborum, pectoralis major, the upper portion of trapezius, levator scapulae, sternocleidomastoid, scalene and the flexors of the upper arm (Jull and Janda, 1987).

The phasic muscles are antagonistic to the postural muscles and show a tendency to weaken and lengthen with inactivity and following an injury. They are peronei, tibialis anterior, vastus medialis and –lateralis, glutea, transversus abdominus and obliques, serratus anterior, rhomboids, lower portion of trapezius, short cervical flexors and extensors of the upper arm (Jull and Janda, 1987).

It is thus of great importance to assess all of these muscles when developing an exercise program for lower back pain, since the body could have compensated by weakening and/ or shortening of these postural muscles. Richard and Jull (1995) and O’Sullivan’s (2000) exercise models, are used by orthopedic manual therapy physiotherapists to develop a lumbar exercise program (David, 2005; Jacobs, 2005).

2.11. Principles of lumbar exercise programs

Richard and Jull (1995) suggest that when developing a lower back exercise program one needs to assess and identify tight overactive muscle. These tight muscles must then, be stretched and inhibited. The weakened muscles must there after be stimulated and strengthened. This influences and corrects the basic impairment of the central neural system motor regulation and muscle imbalances (Richard and Jull, 1995).

In addition, Richard and Jull (1995), recommend a four-stage exercise sequence to strengthen the weakened muscles:

Stage 1 involves re-education and facilitation of the core stabilizers, transversus abdominus and multifidus. Hides *et al.* (1996) demonstrate in their study that multifidus muscle recovery is more rapid and complete in patients who do receive exercises.

During **Stage 2**, the exercise progresses with static stabilization of the spine in neutral position. Load is imposed on the trunk; with the patient placed in different starting positions while, limb movements are added.

In **Stage 3:** proprioception and balance re-education are added by using unstable surfaces as an exercise progression, for dynamic stabilization.

Stage 4 involves more occupational orientated exercise, specifically for lumbar stabilization (Richard and Jull, 1995).

O’Sullivan (2000) follows the same principle of lumbar segmental instability management. Figure 2.1, demonstrates this.

Figure 2.1, demonstrates O’Sullivan (2002)’s different stages: Stage 1: isolated local muscle system, Stage 2: train local muscle system and Stage 3: train local muscle system functionally.

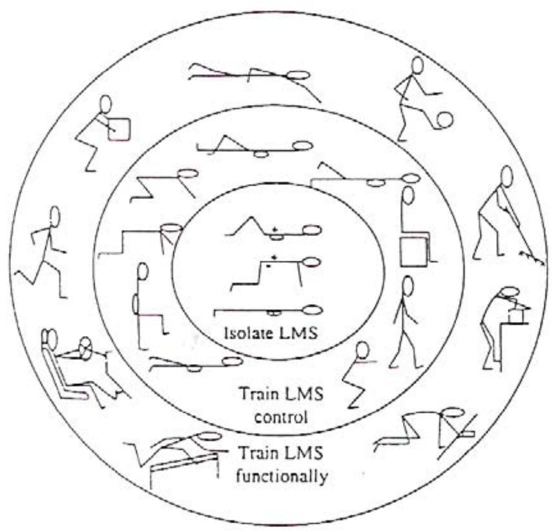

Figure 2.1 Stages of rehabilitation based on a motor learning model (LMS- local muscle system) (O’Sullivan, 2000)

Figure 2.1, of O’Sullivan (2002) model is very similar to Richard and Jull (1995)’s four-stage exercise regime. Richard *et al.,* (1995)’s Stage 1 and O’Sullivan (2002)’s isolated local muscle system stage involve isometric exercises, Richard and Jull (1995)’s Stage 2 and Stage 3 and O’Sullivan (2002)’s train local muscle system stage involve dynamic strengthening exercises. Richard and Jull (1995)’s Stage 4 and O’Sullivan (2002)’s train local muscle system functionally stage involve functional exercises. The main difference between O’Sullivan (2002)’s and Richard and Jull (1995)’s exercise regime is the number of stages as explained above.

Stage 1 of the training according to O'Sullivan (2000) involves isolation of co-contraction of the local muscles with specific isometric contraction of transversus abdominus and multifidis with controlled respiration. These exercises are done in weight bearing positions with a neutral spine lordosis.

Progression for **Stage 1** involves the training of the lower lumbar spine and pelvis independently without the substitution of the global muscles, (obliques, rectus abdominus and thoraco-lumbar erector spinae). Central and lateral costal diaphragm breathing is also included with facilitation of segmental multifidis and transversus abdominus in supine, prone, sitting and standing with postural corrections. Training must be performed once a day. Strengthening exercises consisting of only single set exercises are sufficient to enhance muscle function and physical performance (Galvao and Taafe, 2005).

Stage 2: of the O'Sullivan's (2000) program involves movement patterns. The aim is to breakdown the movement pattern that causes the pain. The patient needs to isolate the local muscle while maintaining the spine in a neutral lordotic posture and then to perform this specific movement pattern. Patients normally report that they can perform the previously aggravating activities without pain during this stage. They are able to cease the formal specific exercise program.

In **Stage 3** the patients are able to dynamically and appropriately stabilize their spines in an automatic manner with functional daily task.

2.12. Stretching as an intervention for lower back pain

Stretching programs are intent on reducing the incidence and or severity of injuries by increasing flexibility. Studies have indicated that stretching results in elongation of the muscle tendon unit, reduction in peak force, rate of force production, and tensile stress on the muscle tendon unit (McHugh e*t al.*, 1999 and Magnusson *et al.*, 1996).

Therefore, stretching appears to alter the visco-elasticity of the muscle tendon unit, resulting in less stiff tissue. In addition, stretching has also been shown to have a strong anti-fibrotic effect after a muscle laceration injury (Hwang *et al.,* 2006). The presumption is that for individuals with short or "tight" muscles, stretching increases flexibility by elongating tissues to a more physiologically normal range, promoting optimal function and reducing the risk of musculoskeletal injury (Hwang *et al.*, 2006).

Stretching programs were shown to be effective in the prevention of injuries at work (Moore, 1998 and Hilyer *et al.,* 1990). When a stretch-program which included stretches of the neck, hips, legs and back, was conducted among a manufacturing population it proved to result in an increased spinal flexibility and reduced musculoskeletal injuries (Moore, 1998). In addition, a statistical significant increase in perception of physical conditioning, body attractiveness, and overall self worth were found (Moore, 1998).

A longitudinal study among 3020 aircraft-manufacturing employees confirmed the benefits of a stretch program when spinal flexibility was investigated as a risk factor for future occupational back pain (Battie *et al.,* 1990). A statistically significant relationship was found between decreased flexibility and reports of current or previous back problems (Battie *et al.,* 1990). The differences in flexibility between subjects with and without a history of back problems, however, were too small to be of practical significance.

A decrease in spinal flexibility means that there is a shortening of the postural muscles, (the erector spinae), and weakening of the phasic muscles, (the transvers abdominus, multifidis and obliques) (Jull and Janda, 1987). It is hypothesised that Battie *et al.* (1990)'s results could have a agreement with the studies done by Hides *et al.* (1994 and 1996). These studies indicated that there is a significant weakening of the multifidus muscle, a core stabilizer after the experience of back pain and no spontaneous recovery of these muscles are found on remission of painful symptoms. Skeletal muscle strength, however, does not always fully recover due to muscle regeneration being hindered by fibrosis development. In addition, stretching does not enhance the recovery of damaged muscles because it does not consistently reduce soreness, swelling and/ or muscle damage (Jayaraman *et al.,* 2004). Therefore, stretching is recommended for lengthening the muscles that have shortened due to postural and structural compensation of postural muscles and muscles that have been affected by somatic referral patterns from the lumbar spine injury. Strengthening is recommended as an approach in the treatment of lower back pain (Richard and Jull, 1995).

2.13. Strengthening as an intervention for lower back pain

Strengthening exercises cause hypertrophy of white, type II muscle, thus increasing its strength as well as the velocity of contraction (Meyer *et al,* 2002). There is a 60% increase of diameter of the muscle's fibers; number of myofibrils and the phosphogen stores when a muscle is strengthened (Meyer *et al,* 2002).

Lindstrom *et al.* (1992)'s study a graded activity program, which included use of dynamic back, abdominal, arm and leg exercises as well as an endurance exercise component. The sick leave period was reduced with this graded activity program among blue-collar workers with mechanical lower back pain. They were able to resume work sooner than the control group (Lindstrom *et al.,* 1992).

The same results, were achieved, in a randomized, parallel-group study, which included two home exercise groups and a control group (Ljunggren *et al.,* 1997). Ljunggren *et al.* (1997)'s study used theraband resistance exercises and dynamic exercises, in the respective groups. Both groups used exercises to strengthen the lower back, abdominal, shoulder and leg muscles. A highly significant reduction in absenteeism from work ($p<0,001$) was observed in both groups but no significant difference between these two groups was found in terms of a reduction in sick leave (Ljunggren *et al.,* 1997).

In a randomized control trial for chronic/ sub chronic lower back pain patients with different types of occupations, Hansen *et al.* (1993) found that patients responded differently to different treatment regimes. Patients with moderate or hard physical occupations tended towards a better response to conventional physiotherapy and isometric back and abdominal muscle exercises. An intensive exercise program which included dynamic back extension, leg lifts and lateral pull-down exercises for the arms was most effective for those with sedentary job functions (Hansen *et al.,* 1993).

Genaidy *et al.* (1994) used progressive resistance exercises that focus on job simulation and include lifting, lowering, pushing and pulling, among manufacturing plant employees (Genaidy *et al.,*1994). This study showed that endurance time and frequency of handling (the amount of repetitions a certain part is handled during the day) did not improve equally in the two exercise groups. Dynamic muscle strength improved among these blue collar employees by 60%. However, there was no substantial improvement in static back strength or lower back flexibility (Genaidy *et al.* (1994). When trunk flexibility exercises (flexion and extension, lateral bending, trunk twisting and sit and reach) were added to the above type of exercises in another group, more significant improvement were found in muscle endurance, strength (dynamic (86%) and static (back: 59%) and trunk flexibility (lower back flexibility: 11% and trunk rotation: 48%). This showed the benefits of adding flexibility exercises to a strengthening program. However, the limitation of this study was that the exercise groups were very small and consisted of only four to six participants each (Genaidy *et al.,* 1994).

The combination of strengthening and flexibility with ergonomic education among nursing aids reduced lumbar pain, on the visual analogue scale in the last seven days of a two-month follow-up period (Alexandre *et al.,* 2001). There is, however, no feedback on the exercises implemented in order to assess the exercise principles used in this study. Blinding of the assessors and patients as well as statistical details were also lacking.

Static strengthening exercises in combination with conventional physiotherapy, which involved manual mobilization techniques of the spinal vertebrae, massage and electrotherapy modalities, showed to be effective in the reduction of lower back pain among moderate to hard physical occupations (Hansen *et al.*, 1993). In contrast intensive dynamic strengthening exercises decreased lower back pain more effectively among workers with sedentary job functions (Hansen *et al.*, 1993). Dynamic exercises were found to decrease sick leave (Lindstrom *et al.*, 1992; Ljunggren *et al.*, 1997). Dynamic muscle strength and productivity improved when exercises were used which simulated the job function (Genaidy *et al.*, 1994). Lower back pain also improved when flexibility exercises were added to strengthening exercises (Genaidy *et al.*, 1994; Alexandre *et al.*, 2001).

2.14. Endurance exercises as an intervention for lower back pain

Lower back pain patients are encouraged to carry out regular aerobic exercise such as walking, while maintaining correct postural alignment, low-level local muscle system contraction and controlled respiration (O'Sullivan, 2000). There are numerous physiological benefits of endurance exercises, such as increasing the number of mitochondria in red Type I fibers (Meyer *et al.*, 2002). Mitochondria play a major role in energy production through ATP formation in the cells. Cells obtain about 95% of their ATP through aerobic synthesis of ATP by the mitochondria. The enzymes involved in oxidative metabolism, the concentration of phosphagen and glycogen also increase when doing endurance exercises. However no change has been found in the diameter of muscle fibers (Meyer *et al.*, 2002).

Endurance exercises have a significant impact on the pattern of expression of myosin heavy chain isoforms during regeneration of fast-twitch white muscle fibers (Bigard *et al.*, 1996). In addition, there is a significant increase in proportion of myosin heavy chain type IIa fibers (Kim *et al.*, 2005). This increases the binding sites for actin and ATP and therefore improving muscle contraction (Meyer *et al.*, 2002).

Bigard *et al.* (1996) and Kim *at al.* (2005)'s studies concluded that endurance exercises improved the resistance of older individuals to exercise-induced muscle injury due to the above mentioned increase of myosin heavy chain fibers. Kim *et al.,* (2005) also indicated that age-related reduction in muscle oxidative capacity of horses is also overcome by endurance exercises. Kim *et al.* (2005) stated that this reduction in muscle oxidative capacity proves that there is an attenuation of the severity of exercise-induced ultra structural cell damage in aged skeletal muscles. If this is true to humans, it still needs to be proven. Endurance training as an intervention to lower back pain proved to be an efficacious therapy for chronic lower back pain and has the potential to relieve huge financial burden associated with this condition (Mannion *et al.,* 1999).

A physical fitness program among fire fighters, over a 14-year period, has proved to be of great value by increasing the physical work capacity of the fire fighters by 16%, decreasing disabling injuries and decreasing the worker's compensation cost by 25% (Cady *et al.,* 1985). The program, however, had little effect on spinal flexibility and no effect on muscle strength. In addition, this study also lacked exercise details.

Another randomized control trial among nurses, indicated a significant reduction, (p=0,007), of lower back pain (Linton *et al.,* 1998). This trial mainly consisted of cardiovascular activities such as walking, swimming and jogging (Linton *et al* 1998). No South African study has been done before which involved exercises as an intervention to lower back pain, in a workplace setting.

2.15 Assessing the methodology quality of a study

When doing a systematic review the primary studies' methodology must be assessed in limiting bias and obtaining a more reliable and accurate conclusion (Greenhalgh, 1998). Greenhalgh (1998) recommend that one needs to include six important headings when looking at primary studies when doing a systematic review. These six points include the originality of the study, the population of the study, if the study design was sensible, if systematic bias, preconceived notion and partiality were avoided, if there was blinding and if preliminary statistical questions were dealt with (Greenhalgh, 1998).

For randomized control primary studies the Pedro scale (Appendix 4) is highly recommended in assessing the quality of the studies's metholologies (Moseley *et al.*, 1999). Moseley *et al.*, (1999) showed that this scale has acceptable interrater reliability. The Pedro scale (Appendix 4) item components were empirically validated in relation to randomization (Colditz *et al.*, 1989; Miller *et al.*, 1989), concealment (Moher, 1998; Schultz *et al.*, 1995) and blinding (Schultz *et al.*, 1995).

In conclusion since a systematic review was done of randomized control trails, both of the above mentioned methodology quality assessment tools were looked at and utilised.

2.15. Conclusion

The literature that was reviewed showed that blue-collar workers are a population that are prone to developing lower back pain due to occupational demands of heavy physical labour. Repetitive bending, twisting, and lifting are significant risk factors in the development of lower back pain. Repetitive bending, twisting and lifting excessively cause shear and bending forces on the osteoligamantus and muscular structures of adjacent vertebrae. Neuromuscular damage and an inflammatory response cause pain, due to desensitized mechanoreceptors and stimulation of polysynaptic pathways of C fibers and A delta fibers.

There is a significant weakening of the multifidus muscle after an experience of low back pain and no spontaneous recovery of these muscles has been found on remission of painful symptoms. This can lead to stability dysfunctions that cause the loss and/ or lack of dynamic control of the neutral zone. Exercises of the multifidus and transversus abdominus muscle however, proved to be an effective intervention in the restoration of muscle strength. Pain is decreased when spinal stability is restored. External forces caused by repetitive bending and lifting, have less harmful stresses on the neutral zone of the lumbar spine when no dysfunction exists.

Pain modulation can also take place using the Melzack and Wall (1965), “gate control” theory through stimulation of the mechano-receptors when exercising which then facilitate the descending inhibitory pathways. Physical conditioning or endurance exercises, stretching programs and strengthening exercises seem to have positive effects on lower back pain relief. There are however a number of different approaches with different outcomes to lower back pain. A systematic review is necessary to determine which of these exercises are most effective for blue-collar workers, as they are the highest occupation group that is prone to the development of work related lower back pain. A thorough methodology quality assessment is however necessary to limit bias.

CHAPTER 3

3. METHODOLOGY

3.1. Introduction

Computerised databases were searched with the use of the Entrez-cross-database search tool, in which 23 databases are covered, for any primary study that might involve exercises as an intervention to lower back pain. Medline database was not identified with the Entrez-cross-database search tool, it was therefore also subjected to a search for primary studies that used exercises as an intervention to lower back pain. The abstracts were checked for any references to exercises as an intervention for lower back pain in a work place setting. These articles were then selected and subjected to a more detailed review and analysis that included the compliance to the inclusion- and exclusion criteria of this study. Once the articles, which did not comply with the inclusion and exclusion criteria were eliminated, the remaining articles were analysed. The quality of the methodologies used in these identified studies was also critiqued. This limited bias and made the conclusions more reliable and accurate. Outcome statistical p-values, of $p<0,05$, that applied to lower back pain were then extracted from these identified primary studies. The p-values of each outcome measure from the different exercise regimes were then compared, to determine the strength of statistical significance.

3.2. Database search procedure

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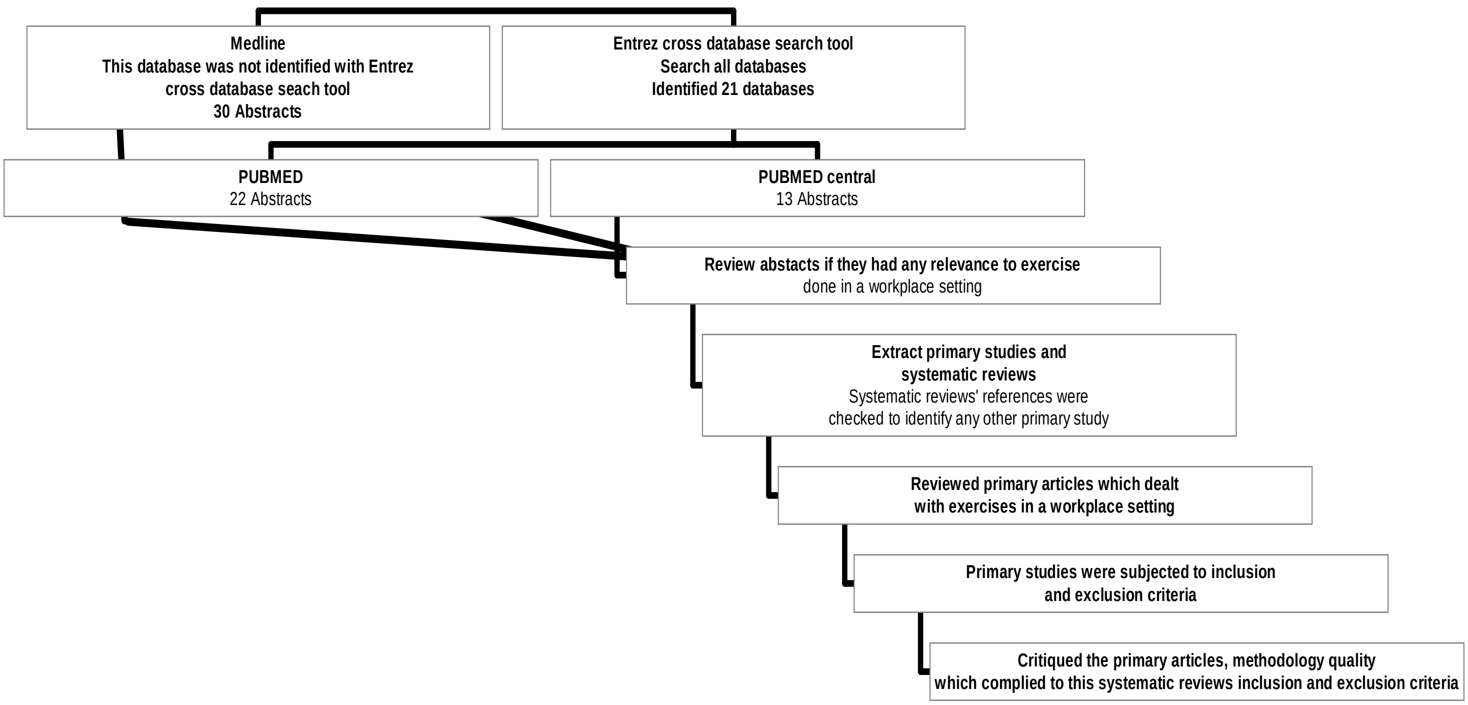

Figure 3.1 Database search procedure

The data search procedure was done according to Greenhalgh (1998)'s recommended search procedure for a systematic review. A computerized database search were done with the use of Entrez-cross-database search tool. Twenty-three databases were identified which also included Pubmed, Pubmed central, Cocharane, PeDro, CINAHL, MeSH, GenBank, Embase, Genome, SNP, Books (online books), Journals (detailed information about journal indexed), Structure, SwetsWise, Gene, HomoloGene, PubChem Compound, OMIM, OMIA, PopSet, GENSAT, Probe and GEO DataSets. This search tool only identified abstracts in Pubmed and Pubmed central. Medline data base was not included in the Entrez-cross-database search tool, thus it was also searched with the key words: *lower back, exercises and workplace*. The articles' abstracts, which involved exercises, were reviewed to identify if they had any relevance to exercises done in a workplace setting. The identified primary articles were then extracted for further detailed review to conclude if they complied with this systematic review's inclusion and exclusion criteria. Previous systematic reviews which also dealt with exercise as an intervention to lower back pain in a workplace setting's references were also checked to identify any other primary articles that met the inclusion criteria. These primary articles were then subjected to this systematic review's inclusion and exclusion criteria. All of the identified articles' methodological quality, were then assessed with the use of this systematic review's methodological quality 15-point checklist (See page 38).

3.3. Inclusion criteria

Inclusion criteria of the primary studies reviewed were:

- Primary studies published in peer reviewed published literature from 1980 to 2006.
- Participants' ages ranging between 18 and 65 years.
- Randomized control trials and case controlled trials of exercises, as an intervention for treatment of lower back pain in a workplace setting were selected.
- Citation of the type of exercises and any specific detail of the exercise programs, in the study.
- Follow-up periods of three, six, twelve and eighteen months
- Those that covered at least one of the outcome measures on pain, physical measurements and sick leave (See table 3.1).

Table 3.1 lists all of the outcome measures that could have been cited in the identified studies as part of the inclusion criteria. Once the outcome measures were identified, the statistical p-values were then extracted in relation to the type of exercise program used. Statistical p-values of $p<0,05$ were identified as being statistically significant.

Table 3.1 Inclusion criteria outcome measures for exercise as a lower back pain intervention

Pain • Pain visual analogue scale (rating pain intensity from 0-10 in severity) • Pain area identification : use of Nordic muscular questionnaire • Days in pain: amount of days complaining of pain. • Number of patients with pain: at baseline and end of intervention
Physical measurements • Flexibility measurements: finger-to-floor and/ or sit-and-reach, modified Schober test • Muscle strength • Endurance: cardiovascular fitness
Sick leave • Amount of days absent from work before and after intervention • Work days lost due to pain, impairment and/ or disability

3.4. Exclusion criteria

Exclusion criteria of the primary studies reviewed were:

- Specific pathological conditions: that is malignancies, infections and fractures.
- Lower back pain managed with surgical interventions.
- Exercise therapy with additional medical and/ or physiotherapy interventions like: mobilization techniques which include Maitland, manupilations, Cyriax, other mobilization techniques and electrotherapy modalities, with the exception of educational advice.

3.5. Quality critique of the identified articles' methodologies

An assessment of the quality of the methodologies used in the identified primary studies limited any bias. Greenhalgh's model, (Appendix B), and PeDro 10 point scale, (Appendix C) were included into this checklist to assure validity.

These two critique forms and/or scales were incorporated for assessing the methodologies to ensure limit of bias. The Pedro scale (Appendix C) was used as this has acceptable high interrater reliability (Moseley *et al.*, 1999). The PeDro scale items components, (Appendix C), were empirically validated in relation to randomization (Colditz *et al.,* 1989; Miller *et al.,* 1989), concealment (Moher, 1998, Schulz *et al.,* 1995) and blinding (Schulz *et al.,* 1995*).* Greenhalgh, (1998), who is an author for systematic reviews, recommend a specific checklist for systematic reviews (Appendix B) to assure good quality and to limit bias. The items, which were not included in Gree0nhalgh's checklist but were included in PeDro's scale were also included in the author's redesigned checklist.

The modified checklist structure, developed by van der Windt *et al.* (2000), (Appendix A), in their systematic review on the occupational risk factors for shoulder pain, was used. Only the structure and not the content of van der Windt *et al.* (2000) checklist was used since not all of its contents could be applied to randomized control trials. This gave more structure and order to the assessing process, thus making it user friendly. The tool was informed by combining the framework of van der Windts checklist with the detailed contents of the from Greenhalgh and Pedro scale. This frame work included this systematic review's inclusion and exclusion criteria and outcome measures. The contents included items used by Greenhalgh (1998) and the Pedro scale (Appendix C), which were subheaded under study objectives, exercise assessment and analysis (Table 3.2, pg 38). All of the items used in this checklist were already previously checked for construct validity as well as intra-rater reliability (Greenhalgh, 1998; Moseley *et al.*, 1999; Colditz *et al.*, 1989; Miller *et al.*, 1989; Moher, 1998; Schulz *et al.*, 1995). The researcher was the only assessor involved in analysing these articles. The researcher piloted the tool on thirteen studies to test the scoring system. No validity was established for the adapted tool and this is acknowledged as a potential weakness for this study.

Table 3.2 outlines the re-designed methodology-assessment checklist, which consisted of fifteen items, (page 38). Each study was scored out of fifteen points thus providing a percentage depicting quality of methodology used for each primary study.

Table 3.2 Quality critique of identified articles methodologies: checklist

Study objective	+	-
1. A specific, clearly stated objective is stated.		
2. The main feature of the study population is described (sampling frame and distribution of population by age and sex.)		
3. Did the population differ in any way: ethnic group, ages and gender. (Greenhalgh, 1998)		
4. Case and controls are drawn from the same population with a clearly define cause or diagnoses of lower back pain.		
5. Participation rate (data presented is >80%)		
6. The study was big enough: > 20 participants (As adviced by the statistician MRC, Prof Piet Bekker)		
7. Study fitted into inclusion criteria. (Had to comply to all) a. Peer reviewed published literature: 1980-2006 b. Ages of participants in studies: 18-65 years c. Randomized and case-control trails d. Exercise as a intervention in a workplace setting e. Exercise programs mentioned		
8. **Study excluded all of the author's exclusion criteria**. a. Pathological conditions: malignancies, infection and fractures b. Surgical interventions c. Additional physiotherapy and/ chiropractic/ medical interventions: with the exception of educational advice.		
Exercise assessment		
9. Type of exercise is reported		
10. Duration and progression criteria are reported.		
11. Blinding of patients.		
12. Assessors were blinded		
Results		
13. At least one of the following primary outcome measures are reported.		
• **Pain** • Pain visual analogue scale (rating pain intensity from 0-10 in severity) • Pain area identified: use of Nordic muscular questionnaire • Days in pain: amount of days complaining of pain • Number of patients with pain: at baseline and end of intervention		
• **Physical measurements** • Flexibility measurements: finger-to-floor, sit and reach, • Muscle strength: isometric strength of selected muscle groups • Endurance: cardiovascular fitness	+	-
• **Sick leave and medical cost** • Amount of days absent from work before and after intervention • Number of days lost due to pain, impairment and or disability • Medical cost		
Analysis		
14. Appropriate statistical models were used: if statistical questions were dealt with: size of sample and duration of intervention.		
15. Significance are reported: P-value, mean values and risk ratios		

Adapted and modified from van der Windt *et al.* (2000) evaluation form framework. Including all of Greenhalgh (1998)'s and PeDro 10 point scale assessment items

3.6. Data extraction

The data and results concerning baseline and post-exercise information, were extracted from the reviewed studies as follows:

- Patient numbers and participation rate in the exercise and control groups
- Type of exercises: whether strengthening, stretching and or endurance exercises as well as any specific details of these exercises
- O'Sullivan (2002)'s and Richard and Jull (1995)'s different stages exercise regime were used to subdivide the different strengthening groups according to static- dynamic- and functional exercises.
- Any detailed information on frequency, duration and progression of exercises
- Description of the exercises and the muscles involved during the specific exercise
- Post exercise values and statistical significant p-values of 0,05 and less on the outcome measures, (Table 3.1), namely: pain, sick leave, and physical-measurements of flexibility, strength and cardiovascular fitness.
- Similar outcome measures' statistical results, within similar follow-up periods for each type of exercise program or exercise group. By pooling these statistical results of the different exercise groups, this allowed reanalysation in a meta analysis.

3.7. Data analysis

The primary studies that complied to above 70% in the methodology checklist were accepted as high standard for methodology quality (Greenhalgh, 1998). Once the different exercise types were extracted from the primary articles, they were grouped according to their corresponding outcome measures namely: pain, sick leave and physical measurements. A review was made of the statistically significance of the outcome measures used in each exercise type.

CHAPTER 4

4. RESULTS

4.1. Introduction

This systematic review was conducted to identify which exercise, used in a workplace setting, are most effective in the prevention and treatment of lower back pain among workers subjected to manual labor. This chapter will outline the results of the systematic review conducted on nine articles that complied with the inclusion and the exclusion criteria of this study. Using the stringent criteria with strict adherence to the use of exercises in the management of back pain, nine studies met the inclusion criteria. This is inline with previously done systematic reviews that have shown similar numbers (Sheer *et al.*, 1995; Van Poppel *et al.*, 2004)). The articles that were excluded are presented, detailing the criteria that rendered them to be excluded from the analysis. Thirty-four primary studies that had relevance to lower back pain intervention among populations with occupations that involve heavy labor and repetitive actions were identified with the use of the Entrez-cross-database-search tool and Medline database search engines. The studies were published between 1980 and 2006. The methodologies of these nine studies were critiqued to determine the quality of these studies. Exercise types and detail were extracted from these identified studies.

4.2. Selection of study sample

The results of the process of selecting the study sample are illustrated in Figure 4.1

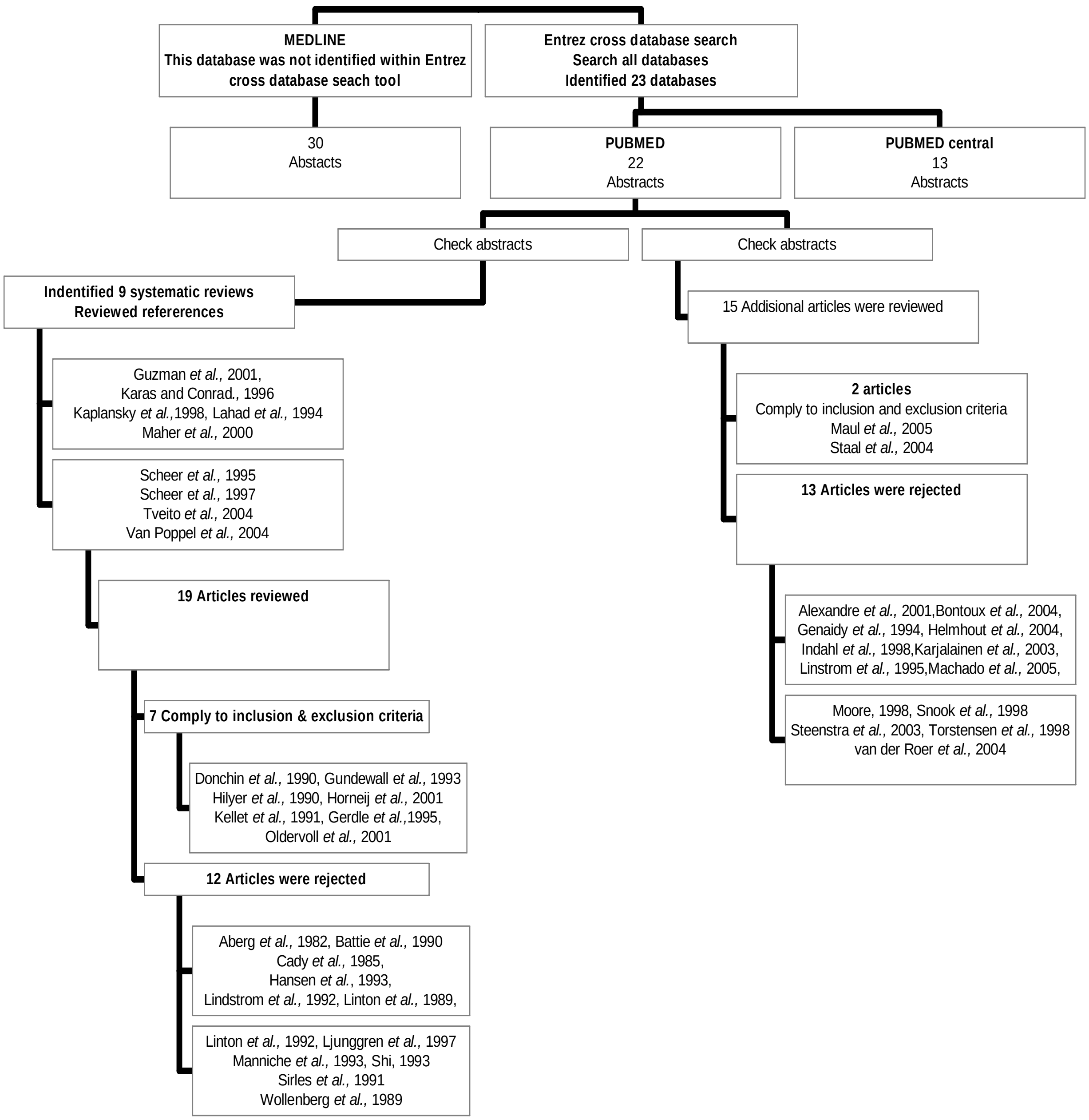

Figure 4.1 Database search results

Sixty-five articles were identified when using the keywords: *lower back, exercise and workplace;* Medline: 30, Pubmed: 22 and Pubmed central 13. The abstracts of these articles were reviewed for any relevance to exercises in a workplace setting. Some of these abstracts had no relevance to exercises and/ or lower back pain. Firstly fifteen primary studies, were extracted and reviewed according to the inclusion and exclusion criteria of this systematic review and only two studies (Maul *et al.,* 2005; Staal *et al.,* 2004) complied with the inclusion and exclusion criteria. Secondly, nine systematic reviews (Table 4.1) were identified and their references were checked and reviewed for any relevance to exercises done in a workplace setting. Nineteen primary studies within these systematic reviews were identified. Only seven articles, (Donchin *et al.,* 1990; Gerdle *et al.,* 1995; Gundewall *et al.,* 1993; Hilyer *et al.,* 1990; Horneij *et al.,* 2001; Kellet *et al.,* 1991 and Oldervoll *et al.,* 2001) complied with the inclusion and exclusion criteria of this systematic review

Table 4.1. Systematic reviews assessed

Study	Title	No of studies	Objective of review	References
Guzman *et al.*, 2001	Multidisciplinary rehabilitation for chronic lower back pain review	10	To assess the effect of multidisciplinary biopsycosocial rehabilitation on chronic outcomes in patients with chronic low back pain	Aberg *et al.*, 1982
Karas and Conrad, 1996	Back injury preventions in the workplace, An integrated review	15	To describe the state of knowledge about the effect of worksite back injury prevention programs on selected study outcomes.	Donchin *et al*, 1990; Gundewall *et al.*, 1993; Hilyer *et al.*, 1990; Shi , 1993; Sirles *et al.*, 1991; Wollenberg *et al.*, 1989
Kaplansky *et al.*, 1998	Prevention strategies for occupational low back pain	16	To assess the effect of education, exercise and ergonomics on lower back pain in a workplace setting	Battie *et al.*, 1990; Cady *et al.*, 1985; Gundewall *et al.*, 1993; Kellet *et al.*, 1991, Lindstrom *et al.*, 1992; Linton *et al.*, 1989; Ljunggren *et al.*, 1997; Mannich *et al.*, 1993
Lahad *et al.*, 1994	The effectiveness of four interventions for the prevention of lower back pain	64	This review evaluated the effectiveness of four stratigies to prevent low back pain for asymptomatic individuals: back and aerobic exercises, education, mechanical supports and risk factor	Battie *et al.*, 1990; Linton *et al.*, 1992; Gundewall *et al.*, 1993; Donchin *et al*, 1990; Kellet *et al.*, 1991; Linton *et al.*, 1989; Cady *et al.*, 1985
Maher *et al.*, 2000	A systematic review of workplace interventions to prevent low back pain	13	A systematic review of randomized controlled trails was undertake to evaluate the effectiveness of workplace interventions to prevent low back pain.	Shi, 1993; Donchin *et al.*, 1990; Gundewall *et al.*, 1993; Kellet *et al.*, 1991; Gerdle *et al.*, 1995; Hansen *et al.*, 1993; Linton *et al.*, 1989

Table 4.1. Systematic reviews assessed (continue)

Study	Title	No of studies	Objective of review	References
Scheer *et al.*, 1995	Randomized controlled trails in industrial low back pain related to return to work	10	The objective was to perform thorough scrutiny and methodologic comparison among all obtained, published randomized and controlled studies on low back pain interventions leading to return to work	Kellet *et al.*, 1991; Cady *et al.*, 1985; Linton *et al.*, 1987
Scheer *et al.*, 1997	Randomized controlled trails in industrial low back pain	12	Objective was to assess the effect of non surgical interventions, including multidisciplinary pain clinics, exercise and cognitive behavioral strategies on occupational related low back pain	Aberg *et al.*, 1982; Manniche *et al.*, 1993; Hansen *et al.*, 1992; Lindstrom *et al.*, 1992; Linton *et al.*, 1989
Tveito *et al.*, 2004	Low back pain interventiosn at the workplace: a systematic review	31	To assess the effect of controlled workplace interventions on low back pain through a review of controlled studies	Donchin *et al*, 1990; Gundewall *et al.*, 1993; Hilyer *et al.*, 1990; Horneij *et al.*, 2001; Kellet *et al.*, 1991; Oldervoll *et al.*, 2001; Shi, 1993
Van Poppel *et al.*, 2004	An update of a systematic review of controlled clinical trails on the prmary prevention of back pain at the workplace	11	To update the evidence on the effectiveness of lumbar supports, education and exercise in the primary prevention of lower back pain at the workplace	Donchin *et al*, 1990; Gundewall *et al.*, 1993; Hilyer *et al.*, 1990; Horneij *et al.*, 2001; Kellet *et al.*, 1991

The majority of the primary studies that were excluded lacked inclusion criteria of exercises done at a workplace setting. These studies also provided limited detail on exercises done and had no control groups or outcome values. In addition, the exclusion criteria, which included, surgical interventions and exercise therapy with additional physiotherapy interventions were identified in some of the excluded studies.

Table 4.2 outlines the twenty-five studies, which were excluded. The negative mark against each study, indicates which criteria the study did not comply with. The studies, which were excluded, (Table 4.2, page 46), didn't comply with the inclusion or exclusion criteria of this systematic review.

Table 4.2 Illustration of the studies that were excluded and the criteria that they did not meet. (- : Study did not comply to the above mentioned inclusion and exclusion criteria and/or lack of statistical outcome measures)

ARTICLE	**INCLUSION CRITERIA**					**Exclusion Criteria**	**Stat-istical values**
	1980-2006	**AGES: 18-65**	**Randomised/ Case-control**	**Workpl. setting**	**Exercise program**		
Aberg *et al.*, 1982				-	-		
Alexandre *et al.*, 2001					-		
Battie *et al.*, 1990			-		-		
Bontoux *et al.*, 2004				-			
Cady *et al.*, 1985			-				
Genaidy *et al.*, 1994							-
Hansen *et al.*, 1992				-		-	
Helmhout *et al.*, 2004							-
Indahl *et al.*, 1998				-	-		
Karjalainen *et al.*, 2003				-	-		
Lindstrom *et al.*, 1992				-			
Lindstrom *et al.*, 1995					-		
Linton *et al.*, 1989				-			
Linton *et al.*, 1992				-			
Ljunggren *et al.*, 1997				-		-	
Machado *et al.*, 2005				-			
Manniche *et al.*, 1993				-		-	
Moore, 1998			-				
Shi, 1993							-
Sirles *et al.*, 1991				-			
Snook *et al.*, 1998				-	-		
Steenstra *et al.*, 2003							-
Torstensen *et al.*, 1998				-	-		
Van der Roer *et al.*, 2004				-			
Wollenberg *et al.*, 1989			-				-

A summary for the reasons of exclusion is as follows:

a) Four studies had no control group
b) Fifteen studies were not conducted in a workplace setting
c) Eight studies had no exercise description
d) Three studies indicated surgical interventions and/ or other physiotherapy modalities
e) Five studies had no statistical outcome measures and/ or p-values.

The articles that were suitable for inclusion into the systematic review were assessed for their methodological quality.

4.3. Quality of Methodology Results

4.3.1. Methodology quality assessment

The 15-point research tool checklist (Table 3.2, page 38) was used to critique the quality of the methodologies of the nine identified primary studies. The aspects that were used in the checklist include the study objective, exercise assessment, results and analysis of the statistics. These are denoted by numbers in Table 4.3 (page 48).

Table 4.3 Quality assessment of the article's methodologies.

Article	**1**	**2**	**3**	**4**	**5**	**6**	**7a**	**7b**	**7c**	**7d**	**7e**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**%**
Donchin *et al.*, 1990	+	+	+	+	+	**Exercises group 1: 46 Exercise group 2: 46 Control group: 50 1.Isometricexercises 2.Dynamic exercises**	+	+	+	+	+	+	+	+	-	-	+	+	+	**(12/15) (80%)**
Gerdle *et al.*, 1995	+	+	+	+	-	**Exercises group : 32 Control group : 45**	+	+	+	+	+	+	+	+	-	-	+	+	+	**12/15 80%**
Gundewall *et al.*, 1993	+	+	+	+	-	**Exercises group : 28 Control group : 32**	+	+	+	+	+	+	+	-	-	+	+	+	+	**12/14 80%**
Hilyer *et al.*, 1990	+	+	+	+	+	**Exercises group: 251 ex 218: ctl**	+	+	+	+	+	+	+	+	-	-	+	+	+	**13/15 87%**
Horneij *et al.*, 2001	+	+	+	+	-	**Exercises group 47: Control group 62**	+	+	+	+	+	+	+	-	-	-	+	+	+	**11/15 73%**
Kellett *et al.*, 1991	+	+	+	+	-	**Exercises group: 58 Control group: 53:**	+	+	+	+	+	+	+	+	-	-	+	+	+	**12/15 80%**
Maul *et al.*, 2005	+	+	+	+	-	**Exercises group: 97, Control group : 86**	+	+	+	+	+	+	+	+	-	-	+	+	+	**12/15 80%**
Oldervoll *et al.*, 2001	+	+	+	+	-	**Endurance exercises group22, Strengthening exercises group 2: 24 Control group : 19**	+	+	+	+	+	+	+	+	-	-	+	+	+	**12/15 80%**
Staal *et al.*, 2004	+	+	+	+	+	**Exercises group: 67, Control group: 67**	+	+	+	+	+	+	+	+	-	+	+	+	+	**14/15 93%**

(+: met critique checklist set standard, -: did not meet critique checklist set standard, Checklist, Table 3.2, page 38)

Each study was scored out of 15 points and the percentage was calculated. These articles already complied to points 7 and 8 since this sub sections covered the inclusion and exclusion criteria of this study. Using this research tool checklist, the scores of these studies ranged from 73% and 93%. Their methodologies proved to be of high quality. The minimum accepted percentage for a good quality study was 70% (Greenhalgh, 1998). Limitations that affected the quality of the methodologies most are shown in table 4.2, were the participation rate of subjects in the exercise groups and lack of blinding of the assessors and patients. Only two of the nine studies had a participation rate of more that 80% and their assessors were blinded. None of the patients in the excluded studies were blinded. From these identified studies the type of exercises were extracted in answer to the research question.

4.3.2 Type of exercises

This section presents the different exercises that were identified as used within the reviewed studies. The common outcome measures that were compared using the p values under each exercise regime are presented.

Within these nine primary studies that were reviewed, eleven exercise study groups were identified (Table 4.4).

Table 4.4 Types of exercises used in the identified studies (n=11)

Type of exercise regime	**Groups N (%)**	**Studies**
Exclusive use of stretch exercises	1 (9)	Hilyer *et al.,* 1990
Exclusive use of strengthening exercises	5 (46)	Donchin *et al.,* 1990 Gundewall *et al.,* 1993 Maul *et al.,* 2005 Oldervoll *et al.,* 2001
Exclusive use of endurance-training	1 (9)	Oldervoll *et al.,* 2001
A combined use of stretches, strengthening- and endurance exercises	4 (36)	Gerdle *et al.,* 1995 Horneij *et al.,* 2001 Kellet *et al.,* 1991 Staal *et al.,* 2001

Four exclusive exercise regime types were identified within nine studies. These included one article (Hilyer *et al.,* 1990), which exclusively used stretch exercises. Four articles (Donchin *et al.,* 1990, Gundewall *et al.,* 1993, Maul *et al.,* 2005 and Oldervoll *et al.,* 2001) used strengthening exercises exclusively in which five groups, were identified. Oldervoll *et al.,* (2001) had an exclusive endurance-training group.

Four studies (Gerdle *et al.*, 1995; Horneij *et al.*, 2001; Kellet *et al.*, 1991 and Staal *et al.*, 2001) used a combination of exercises which consisted of stretching, and strengthening-, coordination-, endurance training involving four exercise groups

The exercises were further, analyzed to identify which muscle groups and exercise regimes were used in the different exercise groups.

4.3.2.1. Stretching exercises

Stretching exercises were either used exclusively or in combination with other types of exercises and these were found in five groups within the studies. The exercises were grouped according to targeted muscle groups. The muscle groups which were stretched in the above mentioned studies are depicted in Figure 4.2.

n = 6

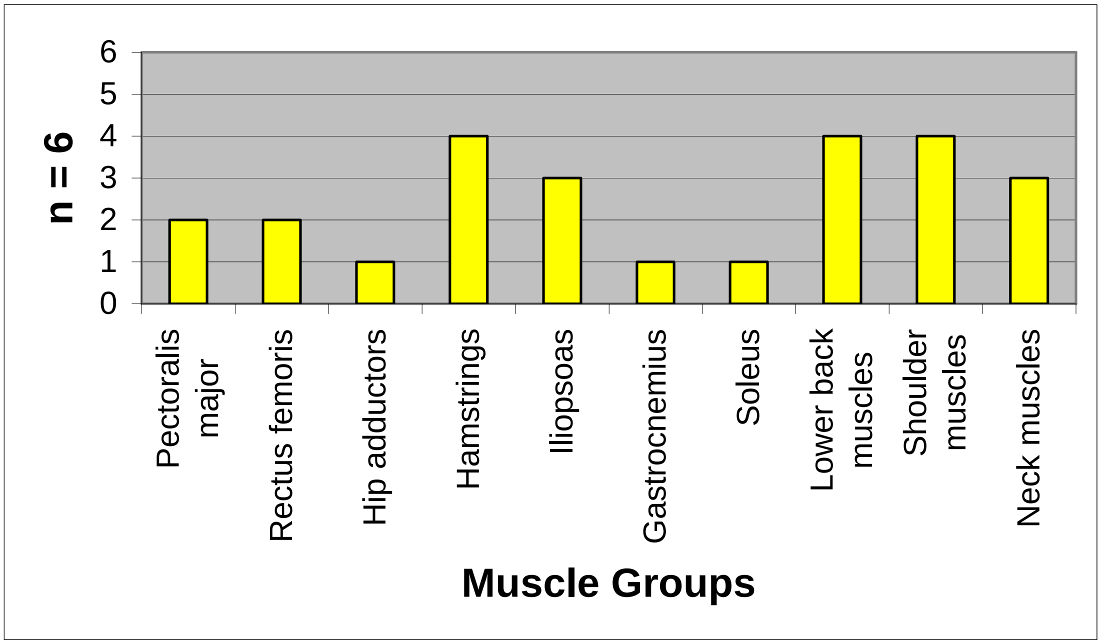

Figure 4.2. The muscles that were stretched in the identified exercise groups

The same analysis procedure was done for strengthening exercises. The strengthening exercises were grouped according to different exercises done and then these exercise regimes were sub-grouped according to Richard and Jull (1995)'s and O' Sullivan (2000)'s stages of rehabilitation.

4.3.2.2. Strengthening exercises

Nine strengthening exercise groups were identified in eight studies. These included Donchin *et al.* (1990), Gerdle *et al.* (1995), Gundewall *et al.* (1993), Horneij *et al.* (2001), Kellet *et al.* (1991), Maul *et al.* (2005), Oldervoll *et al.* (2001) and Staal *et al.* (2004). Five of these nine studies used strengthening as an exclusive part of their program. The remaining four (44%) exercise groups used strengthening in combination with other types of exercises.

The eight identified studies used different exercise approaches i.e. the use of isometric exercises, dynamic exercises and functional exercises. Figure 4.3, depicts the different exercise approaches which included static and dynamic exercises. Functional exercises are analysized separately in Figure 4.4.

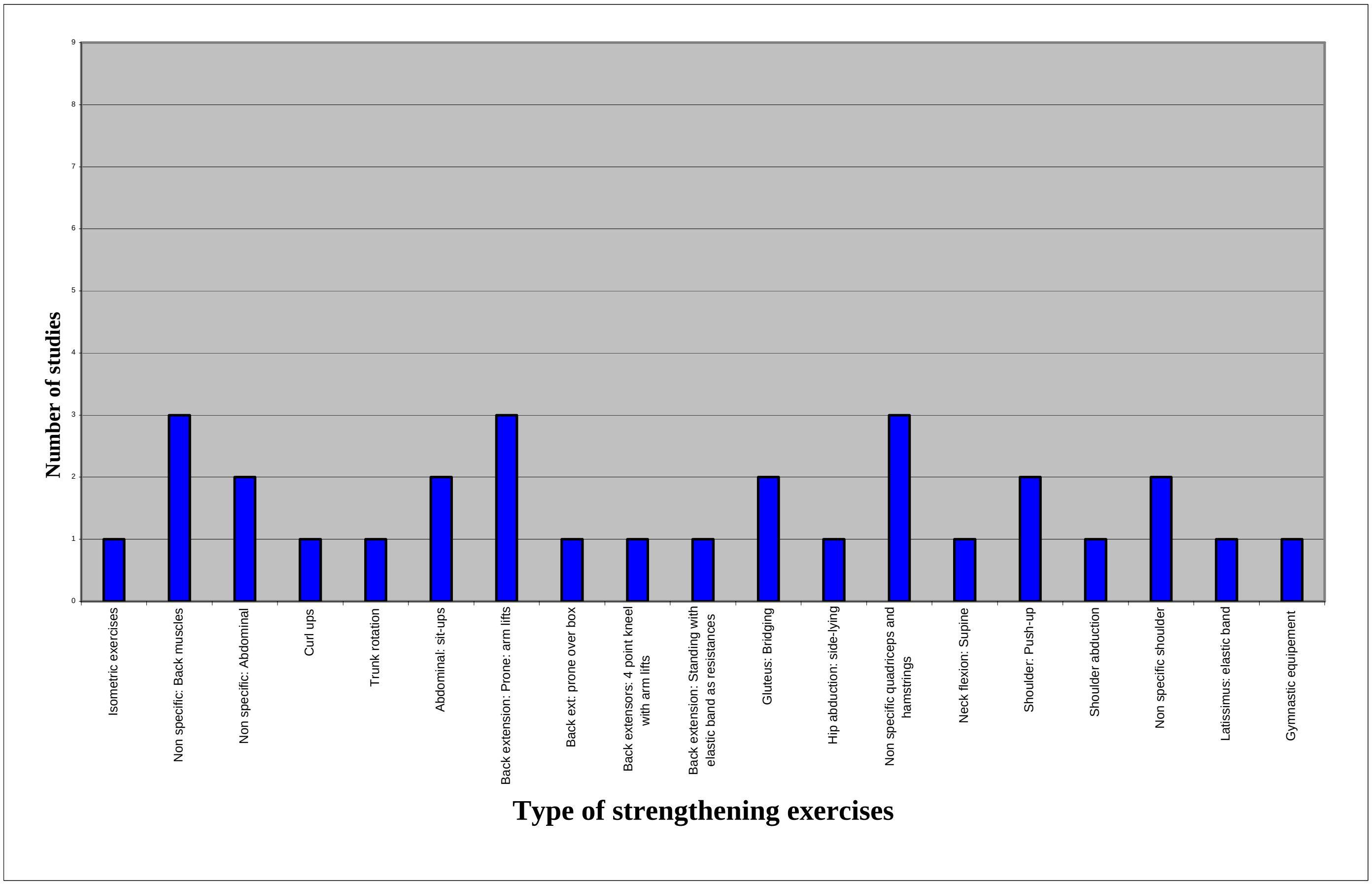

Figure 4.3 The strengthening exercises that were used in the identified exercise groups

The exercises used by the majority of the identified exercise groups were: back extension in prone with arm lifts, non-specific back exercises and non-specific leg exercises that involved the quadriceps and hamstring muscles and shoulder push-ups.

The use of a functional approach as an exercise-regime was also assessed in the strengthening exercise groups. Three studies reported on using functional exercises, which simulated the employees working actions. Pulling and pushing an elastic band (Figure 4.4) were identified in two of these three studies while lifting and transferring objects, were conducted by only one study. These exercises simulated the employees work actions.

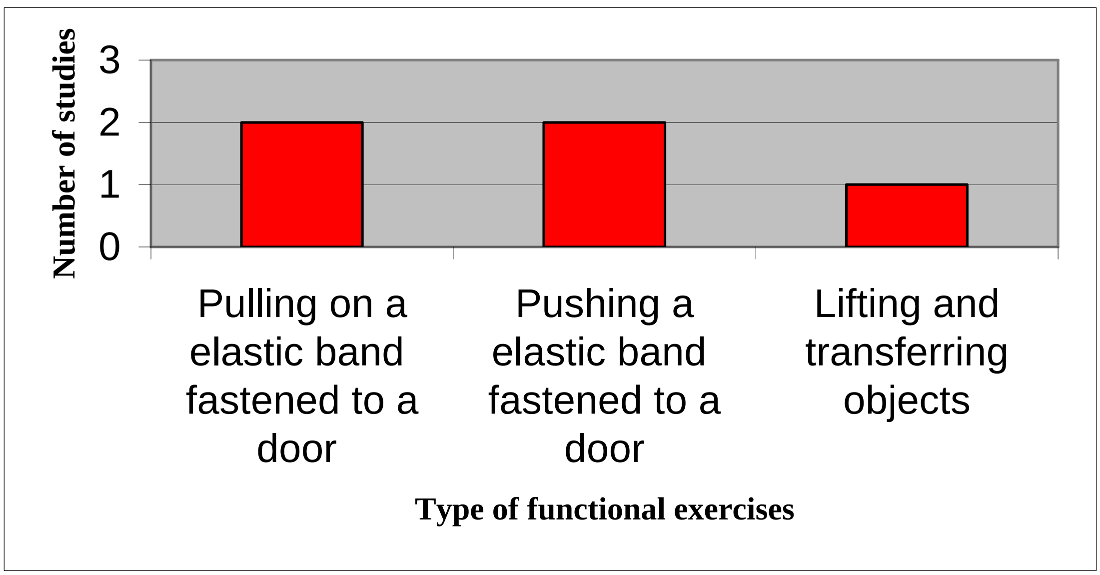

Figure 4.4 Functional exercises used in three identified exercise groups

The exercise subgroups, static- dynamic- and functional exercises are summarized in Table 4.5, to show how they applied to Richard and Jull (1995)'s and O'Sullivan (2000)'s lower back pain rehabilitation progression model.

Table 4.5 Strengthening exercises grouped according Richard and Jull (1995)'s and O'Sullivan (2000)'s rehabilitation stages (n=11)

Type of exercise	Frequency distribution N (%)
Static/ isometric exercises (n=9) Richard and Jull *(*1995): Stage 1 and O'Sullivan (2000): stage 1	
Calisthenics: flexion and pelvic tilt	1 (11)
Dynamic exercises (n=9) Richard and Jull *(*1995): Stage 2 & 3 and O'Sullivan (2000): stage 2	
1. Back exercises:	
• Extension over a box,	1 (11)
• Four point kneeling	1 (11)
• Standing: use of a elastic band	1 (11)
• Non specific	3 (33)
• Prone with a combination of arm lifts	3 (33)
2. Abdominal exercises	
• Curl-ups	1 (11)
• Trunk rotation	1 (11)
• Non-specific and sit-ups	2 (22)
3 Lower extremities	
• Non-specific quadriceps and hamstrings	3 (33)
• Hip abduction	1 (11)
• Gluteal bridging	2 (22)
4. Upper extremities	
• Non-specific	2 (22)
• Push-ups	2 (22)
• Shoulder abduction	1 (11)
• Push-ups	2 (22)
• Latissimus dorsi exercises with the use of elastic band	1 (11)
5. Cervical	
• Neck flexion in supine	1 (11)
6. Full body gym program, The author of this gym program, Maul *et al* (2005), was unable to supply any specific details when the researcher requested it via e-mail.	1 (11)
Functional exercises (n=3) (Richard and Jull *(*1995): Stage 4 and O'Sullivan (2000): stage 3)	
1. Pulling on a elastc band fastened to a door	2 (67)
2. Pushing a elastic band fastened to a door	2 (67)
3. Lifing and tranfering objects	1 (33)

4.3.2.3. Endurance training

The same analysis as above was done for the studies that used endurance training exercises. Five studies reported use of endurance-training exercises for the management of lower back pain (Gerdle *et al.*, 1995; Horneij *et al.*, 2001; Kellet *et al.*, 1991; Oldervoll *et al.*, 2001 and Staal *et al.*, 2004). Of these studies only Oldervoll *et al. (*2001)'s study used endurance exercises exclusively as part of their program. The rest of the remaining exercise programs (80%) consisted of stretches, coordination, balance, strengthening, and endurance exercises.

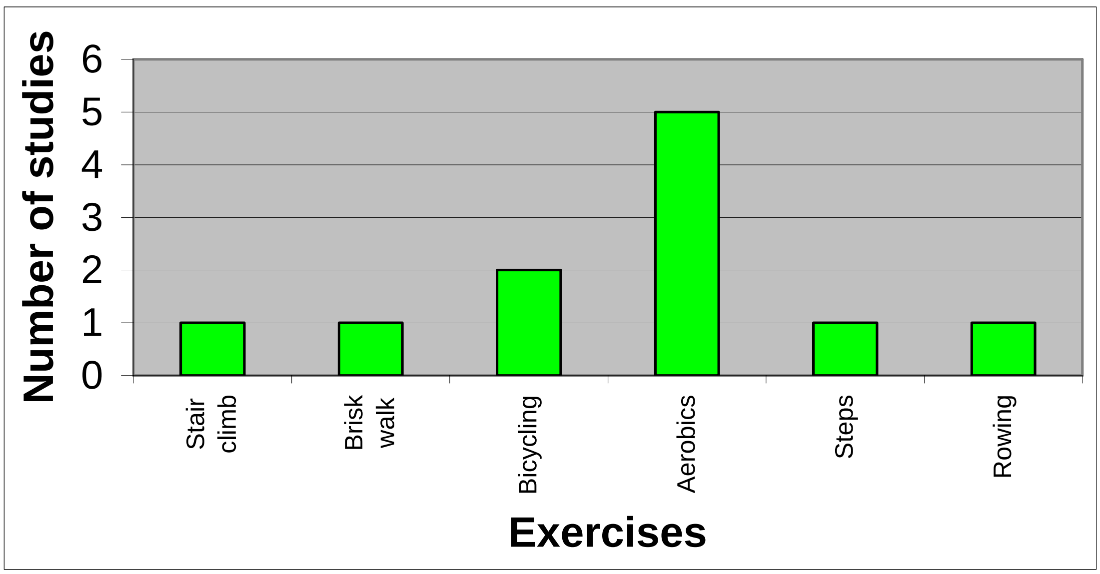

Figure 4.5 Endurance exercises used in the identified studies.

Aerobics were used in all of the five studies. Bicycling were used in two of the five studies and stair climbing, brisk walking, steps and rowing were used in only one study each (Figure 4.5).

4.4. Outcome values

The different outcome values are reported in this section. These include lower back pain intensity, painful episode's and/ or painful days due to lower back pain, sick leave due to lower back pain and physical outcome measurements due to the exercise intervention are reported in this section. The physical outcome measurements involved lumbar flexibility, trunk and abdominal strength and cardiovascular fitness. All of these different exercise regimes were group under the corresponding outcome measures. The exercise groups were stretches, strengthening exercises, endurance training and the combine use of stretches, strengthening and endurance training in one exercise group.

4.4.1. Pain intensity outcome measurement

Table 4.6, indicates seven studies, which reported on pain intensity as an outcome measurement. Outcome variables for pain intensity were identified in three of the five exclusive strengthening exercise groups, in the one identified exclusive endurance exercise group, and in three of the four identified combination type exercise groups, (Table 4.6). Exercises that exhibited statistical p-values of 0,05 and less were identified as significant and were extracted at any follow-up period of 3-, 6-, 12- and 18 months.

Table 4.6 Pain intensity outcome variables with-in the identified studies (n=7)

Study	**Exercise regimes**	**p-value: within exercise group**	**p-value: between exercise group and control group**	**Follow-up period**
Gundewall *et al* 1993	Strenghtening	None reported	p< 0,018	12 months
Maul *et al* 2005	Strengthening	p=0,02	p= n/s	12 months
Oldervoll *et al* 2001	Strenghtening	p= 0,05	p=n/s	3 months
Gerdle *et al* 1995	Combination	p=n/s	None reported	12 months
Horneij *et al* 2001	Combination	Non. reported	p=0,02	12 months
Staal *et al* 2001	Combination	p=n/s	p=n/s	6 months
Oldervoll *et al* 2001	Endurance	p=0,0001	p=n/s	3 months

(n/s: not statistically significant, no actual values given in the primary study)

Significant reduction of lower back pain was found in all of the strengthening groups. These strengthening exercise groups used the following exercise regimes: A general resistance gymnastic program (Maul *et al.*, 2005) and functional strengthening exercise program with back extension exercises (Gundewall *et al.*, 1993). These were sufficient to reduce pain intensity over a 12 month follow-up period. Oldervoll *et al.* (2001) used non-specific dynamic abdominal- back and lower extremity exercises. This study indicated a statistical significance difference in lower back pain intensity within the exercise group but there were no statistical significance when the exercise group were compared with the control group at 3 months follow-up. The endurance-training group of Oldervoll *et al.* (2001) showed a significant difference in pain intensity relief in the lower back within the exercise group but not when the exercise group was compared with the control group (Table 4.6).

The studies that used a combination of different types of exercises in their programs had mixed outcomes. Two-thirds (n=3) of the combination type studies showed no significance (Gerdle *et al.*, 1995; Staal *et al.,* 2004). However, Horneij *et al.* (2001) had a between-group (of the exercise and control group) and within-exercise-group significant p-value of pain intensity relief in the lower back at 18 months follow period. Different exercises in the combination exercise groups (Table 4.7) were compared to see if there were any major difference in their exercise approaches and/ or combinations according to Richard and Jull (1995)'s four stage rehabilitation model.

Table 4.7 Comparison between the combination types exercise groups, which assessed pain intensity

	Stretches	**Strengthening exercises**	**Endurance exercises**
Gerdle *et al,* 1995	Rectus Femoris Hamstrings Iliopsoas Lower back Shoulder muscles Neck	**Non-specific** back muscles, quadriceps and hamstrings, non-specific shoulder muscles	Aerobics
Horneij *et al* 2001	Pectoralis major Rectus femoris Hamstrings Iliopsoas	**Functional:** **Pulling and pushing elastic band** **Abdominal: curl-ups and trunk rotation** Back prone: arm lifts, neck flexion in supine, shoulder abduction	Stair climbing Brisk walking Bicycling Aerobics
Staal *et al* 2001	none	Functional: lifting and transferring objects Abdominal sit-ups, back extension prone: arm lifts, **non-specific** leg exercises, latissimus dorsi	Bicycling Aerobics Rowing

When looking at the table above the following can be observed. Only Horneij *et al.* (2001)'s study provided a detailed description of the strengthening exercises that were used with in the study The studies (Gerdle *et al.,* 1992; Staal *et al.,* 2004) that did not give a detailed description of the strengthening exercises were also found to be not statistically significant This was also shown by in Oldervoll *et al.* (2001) where no statistical significance was found in the pain index with group comparisons using non specific strengthening exercise group. Horneij *et al.* (2001) specific exercises are the same as Richard and Jull (1995)'s rehabilitation model's stage 1 and 4.

4.4.2. Painful episodes and painful days outcome values

Table 4.8, indicates four exercise groups which were reported according to painful episodes or painful days that interfered with the patients' work.

Table 4.8 Painful episodes and/ or painful days outcome: p values with-in the identified studies (p<0,05 is significant) (n= 5)

Study	**Exercise regimes**	**p-value: within exercise group**	**p-value: between exercise group and control group**	**Follow-up period**
Hilyer *et al.*, 1990	Stretching	P=0,026	Not reported	18 months
Donchin *et al.*, 1990	Strengthening -isometric -dynamic	Not reported p=n/s	p< 0,001	12 months
Gundewall *et al.*, 1993	Strengthening	Not reported	p< 0,018	12 months
Kellet *et al.*, 1991	Combination	p=n/s	p=n/s	18 months

(n/s: not statistically significant, no actual values given in the primary study)

Donchin *et al.,* (1990)'s study included two types of strengthening exercise approaches which were isometric and dynamic strengthening exercise groups. The isometric exercise group showed statistical significance ($p<0,001$) but the dynamic exercise group had no statistical significance.

4.4.3. Sick leave outcome values

Table 4.9, indicates four exercise groups which reported on sick leave as an outcome measure to lower back pain.

Table 4.9 Sick leave statistical significant outcome values with-in the identified studies (p<0,05 is significant) (n=4)

Study	**Exercise regimes**	**p-value: within exercise group**	**p-value: between exercise group and control group**	**Follow-up period**
Gundewall *et al.*, 1993	Strengthening	None reported	p<0,0044	12 months
Gerdle *et al.*, 1995	Combination	p=n/s	p=n/s	12 months
Kellet *et al.*, 1991	Combination	p<0,05	p= n/s	18 months
Staal *et al.*, 2001	Combination	None reported	p=0,009	6 months

(n/s: not statistically significant, no actual values given in the primary study)

Gundewall *et al. (*1993)'s functional strengthening program showed that reduced sick leave and/ or days lost due to lower back pain were statistically significant, when compared to the control group (p< 0,004). The combination exercise groups, (Table 4.9) indicate dissimilar results concerning sick leave outcome p-values. These combination exercises groups were again analysed and compared according to the exercises (Table 4.10) they used to see why Staal *et al.* (2001)'s exercises were more significant than Gerdle *et al.* (1995)'s and Kellet *et al.* (1991) 's exercises.

Table 4.10 Comparison between the combination types exercise groups, which assessed sick leave

	Stretches	**Strengthening exercises**	**Endurance exercises**
Gerdle *et al.*, 1995	Rectus Femoris Hamstrings Iliopsoas Lower back Shoulder muscles Neck	Non-specific back muscles, quadriceps and hamstrings, non-specific shoulder muscles	Aerobics
Kellett *et al.*, 1991	Pectoralis major, Hip adductors, hamstrings, iliopsoas, gastrocnemius, soleus	Abdominal sit-ups, back extension: prone and four point kneeling, bridging, hip abductors, push-ups	Aerobics
Staal *et al.*, 2001	none	**Functional: lifting and transferring objects** Abdominal sit-ups, back extension prone: arm lifts, non-specific leg exercises and latissimus dorsi exercises	Bicycling Aerobics Rowing

Gerdle *et al.*, (1995)'s study used non specific exercises and was no statistically significant difference (Table 4.10). Kellet *et al.* (1991)'s study and Staal *et al.* (2004) both used dynamic exercises which fit into Richard and Jull (1995)'s stage 2. There was a statistical significant reported within Kellet *et al.* (1991)'s exercise group but none were reported in the article on statistical differences between the exercise group and control group. The biggest difference found in Staal *et al.* (2004)'s exercise group was the use of functional exercise, which showed a statistical significance when the exercise group was compared to the control group (p =0,009).

4.4.4. Physical measurement outcome variables

Physical measurements, which include lumbar flexibility, trunk and abdominal strength and cardiovascular fitness were also assessed. Statistical significant p-values were extracted and grouped according to stretch-, strengthening exercise-, endurance training and combination exercise groups

4.4.4.1. Lumbar flexibility

Table 4.11 indicates two exercise groups which reported on lumbar flexibility with the use of the sit-and-reach forward flexion assessment tool.

Table 4.11 Lumbar flexibility statistical outcome values (n=2)

Study	Exercise regime	p-value: within exercise group	p-value: between exercise group and control group	Follow-up period
Hilyer *et al.*, 1990	Stretching	p=0,0005	None reported	3 months
Donchin *et al.*, 1990:	Strengthening Isometric group	p<0,0001 p< 0,0001	p<0,003 p< 0,019	3 months 9 months

Lumbar flexibility significantly improved in comparison to the control group within the stretching exercise group (Hiljer *et al.,* 1990). Flexibility only improved with forward flexion within the isometric exercise group of Donchin *et al.* (1990) and significant difference was found when it was compared to the control group (Table 4.11). Flexibility was not measured in the combination type and endurance training studies.

4.4.4.2. Trunk and abdominal strength

Table 4.12 indicates the statistically significant p-values which were reported for strength measurements in the identified studies.

Table 4.12 Trunk and abdominal strength statistical outcome values (n=4)

Study	**Exercise regime**	**p-value: within group**	**p-value: between groups**	**Follow-up period**
Donchin *et al.*, 1990	Strengthening(Abdominal) Isometric Dynamic Isometric Dynamic	 None reported p = n/s p = n/s p = n/s	 p<0,002 p=n/s p = n/s p = n/s	 3 months 3 months 9 months 9 months
Gundewall *et al.*, 1993	Strengthening (Back muscle)	p<0,01	p<0,04	12 months
Maul *et al.*, 2005	Strengthening: (Isokinetic trunk)	None reported	p=0,01	6 months

(n/s: not statistically significant, no actual values given in the primary study)

Three strengthening exercise groups reported on abdominal-, back and trunk strength (Table 4.12). Isokinetic trunk strength was significantly improved when a resistance gymnastic program was implemented (Maul *et al.,* 2005). Functional strengthening which simulated work actions, which included pushing and pulling a elastic band, showed a significant improvement in back muscle strength compared to the control group and within the exercise group alone (Gundewall *et al.,* 1993). Abdominal strength improved significantly after 3 months, but no statistical significance was found after 9 months in the isometric strengthening group (Donchin *et al.*, 1990).

4.4.4.3. Cardiovascular fitness

The statistical p-values for cardiovascular fitness were extracted from all of the identified studies and were grouped according to the different types of exercises. Table 4.13 indicates the p-values for cardiovascular fitness measured in VO2 max values.

Table 4.13 Cardiovascular VO2 max statistical outcome values (n=5)

Study	**Exercise regime**	**p-value: within exercise group**	**p-value: between exercise group and control group**	**Follow-up period**
Oldervoll *et al.*, 2001	Strengthening	p=n/s Control group ↓ VO2 max p=0,009	p=n/s	3 months
Gerdle *et al.,* 1995	Combination	p=n/s	None reported	12 months
Horneij *et al.,* 2001	Combination	p=n/s	None reported	12 months
Kellet *et al.,* 1991	Combination	p=n/s control group ↓ VO2 max p=0,02	None reported	18 months
Oldervoll *et al.*, 2001	Endurance	p=0,005	p=0,00043	3 months

(n/s: not statistically significant, no actual values given in the primary study)

Five exercise groups reported on cardiovascular fitness. The improvement of VO2 max values was non-significant within the strengthening group and during combination types of exercise programs. There was a significant improvement of VO2 max within the endurance-training group.

4.5. Meta analysis

The objective to reanalyse the outcome data in a meta analysis could not be achieved due to an insufficient number of similar studies and exercise groups that correlated with similar outcome variables and follow-up periods.

4.6. Conclusion

Nine primary studies, met this systematic reviews' inclusion and exclusion criteria. A minimum of 70% was viewed as a high standard for their methodology quality which was measured with the 15 point methodology quality check list. Each of the nine studies reviewed obtained the 70% mark. Although the nine primary studies seemed like a small sample size, smaller study numbers have been previously used in other systematic reviews. Some of these studies used had limits in their methodologies where they lacked in participation rate and blinding of the assessors and patients.

The exercises which were used in the primary studies were grouped in four exercise regime groups which included stretching, strengthening, endurance exercises and the combination use of stretching, strengthening, endurance exercises. Details of these exercises were also extracted which included exercise description and / or muscle group targeted. Outcome data that included pain relief, sick leave and physical measurements of lumbar flexibility, abdominal and trunk strength and cardiovascular fitness were also extracted. The different exercise regimes were grouped and compared according to corresponding outcome measures. All the different exercise regime however did not report on all of the outcome values. This was accepted since it was not expected to have all of the outcome measures. The objective to reanalyse the outcome data in a meta-analysis could not be achieved due to an insufficient number of similar studies and exercise groups that correlated with similar outcome variables and follow-up periods.

The stretching exercise group had only a significant effect within the group with painful episodes and pain days (p=0,026) due to lower back pain. Stretching, however, proved to be the only type of exercise that shows a significant, (p=0,0005), improvement on lumbar flexibility when compared to the control group.

Strengthening exercises which involved isometric strengthening exercise had an effect on painful episodes and painful days (p<0,001) and on lower back pain relief (p=0,031) (Donchin *et al.,* 1990). In addition, lumbar flexibility, (p<0,0001), is improved with isometric type of exercises. These exercises however indicated a significant improvement on abdominal strength at 3-month follow-up, (p<0,002) but not at 9-month follow-up (p=n/s). Resistive strengthening exercises, with the use of gymnastic equipment, have a significant effect on lower back pain intensity (p=0,001) only within the exercise group but no statistical significance when the exercise group was compared to the control group after a one-year follow up period. Resistive strengthening exercises however improved isokinetic trunk strength significantly, (p=0,02) when the intervention results was compared to the control group's results. Dynamic abdominal and back exercises used in a back school program by Donchin *et al.,* (1990) also had no statistical significance on lower back pain episodes and abdominal strength. The use of non specific exercise showed no statistical significance to lower back pain relief (p=n/s) when the exercise group was compared with the control group (Oldervoll *et al.,* 2001). Non specific exercises were also non significant on sick leave and lower back pain relief when used in combination with other exercises.

The combination use of stretch, strengthening and endurance exercises outcome values showed to be inconsistent. The combination however had statistical significant results when functional exercises were included.

Strengthening exercises, (Gundewall *et al.,* 1993, Horneij *et al.,* 2001 and Staal *et al.,* 2001) with a functional exercise approach had a significant effect on lower back pain intensity relief ($p<0,018$ and $p<0,05$), painful episodes and days ($p<0,018$), and sick leave($p<0,0044$ and $p=0,009$). Functional exercise approach also improved back muscle strength significantly ($p<0,04$) and had a positive result on postural muscle strength. Functional exercises showed they relieved lower back pain, reduced painful episodes and/ or painful days as well as sick leave. They also had positive results on postural muscles strength. Therefore functional exercise seems to be an effective exercise approach to manage occupational lower back pain.

Endurance exercise approach had significant effect on lower back pain intensity relief ($p=0,0001$) within the exercise group but there were no significant group differences noted in the pain index scores. Endurance exercises were the only exercise group type, that showed a significant improvement in VO2 max values ($p=0,005$).

It can thus be concluded that stretching, dynamic abdominal and back exercises, non specific leg and trunk exercises, resistive exercises and endurance exercises were not statistically significant when used in the management of lower back pain when the exercise groups were compared to the control groups.

Isometric strengthening exercises and exercises with a functional approach were effective in the reduction of lower back pain episodes. Functional exercises were also significant in the reduction of lower back pain intensity and sick leave. Functional exercises had a statistical significance in postural muscle strength improvement ($p< 0,04$) at 12 months follow up. However, isometric exercises lacked statistical significance in improving postural muscles strength at 6 months follow up. Functional exercise therefore can be considered an effective exercise approach to manage occupational lower back pain.

CHAPTER 5

5. DISCUSSION

5.1. Introduction

The aim of this systematic review was to identify which exercises, used among workers subjected to manual labor, in a workplace setting are most effective in the management of lower back pain. The study extracted nine primary published studies, which met the methodological quality criteria set by the researcher. The studies' methodology quality scored a 70% when using the 15 point quality checklist. The major limitations in the nine selected studies methodological quality were the lack of blinding of the assessors and the subjects, and in six of the nine studies the lack of adequate participation rate among the intervention subjects. As a meta analysis was not done a comparison could not be made on the effectiveness of the interventions but conclusions can only be drawn on the specific exercises of each study

Details of exercises were extracted from eleven exercise groups in the above-mentioned nine primary studies. Some of the primary studies had more than one exercise group. The exercises were divided in to exercise regimes, which consisted mainly of stretches, strengthening, endurance training or the combination of stretches, strengthening and endurance training exercises. These exercise regimes were then grouped under the correlating outcome measures. Each exercise regime will be discussed to demonstrate how effective it proved to be using the statistically significant outcome measures. Not all outcome measures could be used for all the exercise regimes since some of the exercise groups did not report or use all of the outcome measures. Only functional exercises and combination types of exercises measured lower back pain intensity, painful episodes and sick leave. The rest of the studies measured only one or two of the outcome measures such as Donchin *et al.*, (1990)'s study which only measured painful episodes within strengthening exercise study groups. The statistical p-values of the outcome measures: pain intensity, painful episodes and painful days, sick leave and physical measurements, of each exercise regime were extracted from the primary studies. The outcome measures that were statistically significant were noted and extracted. Statistical p-values of <0,05 were accepted as having a significant value to the outcome measure.

A meta analysis could not be done due to insufficient similar studies. Similar studies would involve similar exercise regimes with comparable outcome measures. A meta-analysis recommends the use of more than one study with similar exercise approaches and outcome values. This would have furthered the researcher's cause in the sense that, that it would have pooled the extracted data from numerous similar studies to get a new, much narrower, confidence interval of the relative risk value and p-value between exercise regimes. Thus making the correlations and statistical significance found for the exercise regimes in relation to lower back pain more reliable. This also makes the outcome values more evidence based. In other meta-analyses, study results that were not significant when pooled produced a statistically significant result (Greenhalgh, 1998).

The use of stretches, strengthening and endurance training exclusively or in combination in an exercise program has different clinical implications. This systematic review looked at which of the above-mentioned exercise regimes were effective in the management of lower back pain among a heavy labour population.

Each exercise type found in the studies within the review is discussed separately to illustrate its results against the outcome measures found in the systematic review. The subsequent clinical implications are discussed.

5.2. Clinical implications of a stretch program

The implementation of an exclusive stretching program had a positive statistical significant effect on painful episodes and/ or painful days (p=0,026), due to lower back pain, within the intervention group (Hilyer *et al.*, 1990). This, however, had no significance when the intervention group was compared to the control group. Stretches also indicated a significant improvement in lumbar flexibility (p=0,0005). The significant improvement of lower back pain episodes and painful days are hypothesised to be due to pain modulation (Johnson, 1997) and/ or the correction of muscle imbalances (Richard and Jull, 1995; Jacobs, 2005) that are a result of lower back pain. If one first considers that pain relief was achieved due to the correction of muscle imbalance, one needs to understand how muscle imbalance originates primarily and develops into lumbar pain.

When an employee works with a poor posture and/ or when repetitive activities are done, muscle imbalances result with compensational shortening of the postural muscles (Jacobs, 2005). This in turn can lead to accumulation of neuromuscular injuries (Zedka *et al.*, 1999). The muscles that were stretched in Hilyer *et al.* (1990)'s study stretching program, hamstrings, lower back and shoulder muscles, were all postural muscles. Postural muscles show a tendency to tighten and are also very irritable (Jull and Janda, 1987). Muscle imbalances are corrected when the shortened muscle is stretched and this leads to the correction of compensational postural alignment (Richard and Jull, 1995).

By stretching these postural muscles the excessive shear and compressive forces on the lumbar segment structures, which cause continuous irritation and chronic inflammation, are also decreased (Levangie and Norkin, 2001; Zedka *et al.*, 1999) As an result these muscle imbalances are corrected and neutral zone instability corrected (Panjabi 1989) and lumbar pain thus relieved. This can explain why lower back pain were relieved within the stretch exercise group of Hilyer *et al.* (1990)'s study.

Although stretching had a significant effect on lumbar flexibility other studies show that stretch had no effect on lower back pain (Moore, 1998; Battie *et al.,* 1990). In Battie *et al.* (1990)'s study no statistical significance was found for lower back pain relief when comparison was made between poor lumbar flexibility and the history of lower back pain (Battie *et al.,* 1990). This study was however not randomized and it lacked blinding.

Repetitive bending, which also requires spinal flexibility, has been found to be a significant risk factor to reducing occupational lower back pain among blue-collar workers (Guo, 2002; Hoogendoorn *et al.,* 2000). This repetitive action leads to accumulation of inflammation and mechanic strain of the lower back (Zedka *et al.,* 1999). Pain modulation can be explained through the pain gate theory (Melzack and Wall, 1965). One can therefore conclude that although stretches decrease lower back pain episodes and painful days, they are not the most effective intervention for lower back pain among a blue-collar employee population due to a lack of significant difference in the outcome of pain when it is compared to the control group (Hilyer *et al.,* 1990). The significant improvement of lumbar flexibility had no attribution to lower back pain management. The fact that this systematic review found only one stretch exercise primary study showed that more research is needed for conclusive cause effect conclusions to be made.

5.3. Clinical implications of an endurance program

Endurance exercise reduced pain intensity (p=0,0001) within the exercise group significantly. However, no statistically significant reduction in lower back pain intensity was found when the intervention group was compared to the control group (Oldervoll *et al.,* 2001).

Lower back pain patients are encouraged to participate in regular aerobic exercises (O'Sullivan 2000). Previously done studies also obtained a reduction in back pain (Cady *et al.,* 1985, Linton *et al.,* 1998). Both studies looked at the effect of endurance training on back pain but unfortunately were not randomised and therefore had no control group. Frost *et al.* (1998)'s endurance training study among chronic back pain patients was randomised and demonstrated a significant difference in the disability scores between the treatment and control group. Therefore further research is needed to assess all of outcome measures with endurance training exercises. Only lower back pain relief was assessed in Oldervoll *et al.,* (2001) study.

In addition, endurance training proved to be the only exercise type that increased cardiovascular fitness (VO2 max) values significantly (p=0,005) in this review (Oldervoll *et al* 2001). Under normal circumstances endurance-exercise, increases the number of mitochondria in red, type-1 fibers. Cells obtain about 95% of their ATP through aerobic synthesis by the mitochondria. This attenuates the severity of exercise-induced ultra structural cell damage (Kim *et al.,* 2005). No study however connects VO2 max and cell oxidative capacity to pain relief. Inspite of lower back pain relief in the exercise group it cannot be concluded that this is due to the proven effects of endurance which are an increase in VO2 max and cardiovascular fitness, The logical conclusion would therefore be due to Melzack and Wall (1965)'s pain gate theory. There were however, no statistically significant differences found in pain intensity reduction when the exercise groups were compared to the control group. Endurance exercises are therefore not an effective management intervention to use for occupational lower back pain.

5.4. Clinical implications of strengthening exercises

Richard and Jull (1995) recommend following the four-stage program in the rehabilitation of lower back pain. The strengthening exercises used in the studies reviewed were grouped according to the above mentioned four stages. The different exercise stages' statistical p-values, were then presented with their corresponding outcome measure. This was done to see which stage of strengthening exercise had the most significant effect on the management of occupational lower back pain.

Stage 1 involves isometric exercises of the core stabilizers, multifidus, transfer abdominus, diaphragm and pelvic floor. One of the identified primary studies (Donchin *et al.,* 1990), with an isometric approach to core stabilizers showed that it had a significant effect on lower back painful episodes and painful days (p<0,001).

However, this study indicated a temporary significant improvement in abdominal strength at 3 months (p<0,002) and no significance improvement at 9 months (p=n/s).

The contraction of the transversus abdominus, a core stabilizer, is delayed when a lower limb is moved in lower back pain patients according to Hodges and Richard (1995) and Norris (1995). Good contraction of transversus abdominus is required before lower limb movements during lifting, bending and twisting activities among blue-collar workers to prevent lower back pain and neutral zone dysfunction (the range of intervertebal motion within which spinal motion is produced with minimal internal resistance of the collgen tissue around the joint) (Panjabi, 1989; Jacobs, 2005). Neutral zone dysfunctions developed due to the lack of muscle control by the core stabilizers or increased muscle action, muscle spasm, around the intervertebral segment. Unnecessary straining of the lumbar structures, and pain, are thus due to the neutral zone dysfunction. Neutral zone dysfunction also originates from weak core stabilizers, for example transversus abdominus. This results in an increase of the neutral zone (Panjabi 1989).

In this systematic review, isometric exercise did not prove to be effective in the management of lower back pain among blue-collar workers as it did not strengthen the transversus abdominus, a vital core stabilizer, over a long period (Donchin *et al.*, 1990). Donchin *et al.* (1990)'s study was the only study, which utilized isometric abdominal exercises, and which reported on abdominal strength as an outcome measure.

Johannsen *et al.* (1995) recommend that isometric exercise should not exclusively form part of a chronic lower back pain rehabilitation program. However, isometric exercises improved forward flexion flexibility significantly (p<0,0001) within this systematic review. As discussed earlier (the effect of stretches, 5.2. pg 76) there was no correlation between the improvement of lumbar flexibility and lower back pain (Johannsen *et al* 1995 and Battie *et al* 1990). Isometric exercises are therefore not an effective intervention for lower back pain among blue collar workers. More studies are needed to conclude this as only one isometric exercise primary study was found in this systematic review.

No study within this systematic review used stage 2 exercises exclusively which required static stabilisation of the spine in neutral while the patient was placed in different starting positions and limb movements are added. Stage 2 exercises were used with stage 3 dynamic exercises and in combination with other exercise regimes ((Gerdle *et al.*, 1995; Staal *et al.*, 2001; Kellett *et al.*, 1991)

Stage 2 and **3** involves dynamic exercises, of the global muscles. Dynamic exercises which included non specific abdominal, back and leg as well as resistive exercises showed a significant improvement in the exercise groups (p=0,02 and p=0,05 respectively) for lower back pain relief (Maul *et al.,* 2005; Oldervoll *et al.,* 2001). It however, showed no statistical significance in lower back pain relief or painful episodes when the exercise groups were compared to the control groups. No consistent positive outcome was achieved when combining dynamic exercises of the global muscles and/ or the extremities with stretches or cardiovascular training (Gerdle *et al.,* 1995; Staal *et al.,* 2001; Kellett *et al.,* 1991). The most significant difference found when comparing the different combination exercise regimes was the significant improvement of those who included functional dynamic exercise. These functional exercises simulated the work actions of the employees (Gerdle *et al.,* 1995; Staal *et al.,* 2001; Kellett *et al.,* 1991).

Horneij *et al.* (2001)'s study included functional pulling and pushing off an elastic band tied to a door and this significantly reduced lower back pain intensity (p<0,05). Significant reduction of sick leave (p=0,009) due to lower back pain was recorded in Staal *et al.* (2001)'s study which used functional lifting and transferring of objects as part of their combination type exercise approach. Gundewall *et al.* (1993)'s study using functional exercise showed a statistical significance in reducing lower back pain intensity, painful episodes, sick leave and back muscle strength.

Richard and Jull's (1995) rehabilitation program's **stage 4** involve occupational simulated exercise. Functional exercises proved to be effective in other randomized control trails (Jousset *et al.,* 2004 ; Genaidy *et al.,* 1994)

A functional restoration program, that included work simulation exercises among a workforce who suffered from occupational related chronic lower back pain was effective in reducing sick leave and proved more effective than individual physiotherapy sessions (Jousset *et al.,* 2004). Another job-simulated exercise program among industrial workers improved work endurance time with an average increase of 124% and 134% for employees in the two plants. The improved endurance of the employees led to an improvement of production since they could handle the material at a faster speed and thus finishing the production cycle faster. The frequency of handling improved by 31% for employees in one plant and the cycles increased by 199% and 105% in both plants. In addition, this program also improved 60% of the employees dynamic strength. Dynamic strength was defined in this study as the maximum amount of load in a 38cm×38cm×25cm box that is handled during the job simulated exercises. Back static strength also improved in this study (Genaidy *et al.,* 1994). Although an increase in production and strength were identified in this study it however, lacked good methodological quality due to its small sample size and lack of statistical analysis it was therefore not included in this systematic review.

A functional training regime and strengthening of the back extensors were the underlying reasons for the significant results in the improvement of back muscle strength ($p<0,04$) in Gundewall *et al.* (1993)'s study. Decreased activation, rapid fatiguing and alteration of the multifidus muscle fiber after onset of pain are prominent among lower back pain patients (Hides *et al.,* 1994; Hodges and Richard., 1995). Core stability is restored when the local back muscles (multifidus muscle) regain their strength. The multifidus muscles a back extensor which weaken during the onset of lower back pain is only restored when exercised (Hides *et al.,* 1996). It can be concluded that the increase in back extensor strength within Gundewall *et al.* (1993)'s study restored core stability leading to the decrease in lower back pain (Hides *et al.,* 1994; Hodges and Richard 1995).

This improvement of back strength (multifidus muscle), leads to restoration of the neutral zone stability (Panjabi, 1989). Noxious damaging stimuli such as repetitive micro-trauma and straining of the lumbar spine muscle, ligaments and neural tissue, during manual labor, cause activation of the unmyelinated C nociceptors, thus causing pain (Johnson ,1997) When the neutral zone is restored via strengthening of the the multifidus muscle, fewer chances of irritation of the lumbar structures can happen (Panjabi, 1989). Lower back pain is also improved through Melzack and Wall's (1965) pain gate theory via stimulation of A-beta afferents through movement and stimulation of joint mechanoreceptors. The noxious stimuli, via C nociceptors are thus prevented to reach the brain (Johnson, 1997).

It has been observed that blue-collar workers adapt different movement patterns and/ or compensational ways to perform their daily work activities such as lifting and bending to reach objects (Bos *et al.,* 2002). The global muscles, lattissimus dorsi, abdominal oblique, rectus abdominus and thoracolumbar fascia control the transfer of load between the thoracic cage and pelvis during these daily activities. Dynamic muscle strengthening of the global muscles with the use of functional patterns, such as seen in this systematic review (Gundewall *et al.,* 1990), restore neuro-dynamic patterns, correct the abnormal compensation movement, and muscle imbalances that the blue-collar worker adapt to, to avoid lower back pain while performing his daily work activity (Jacobs, 2005; Teasell and Bombardier, 2001).

5.5.Conclusion

This systematic review concludes the following:

After reviewing and noting the different exercise regimes, stretching, strengthening, endurance exercises and the combination use of stretching, strengthening, endurance exercises according to their corresponding outcome measures and p-values, this systematic review concludes the following:

Stretching as an exercise intervention for lower back pain is effective for the reduction of painful episode and/ or painful days within Hilyer *et al.* (1990)'s study. There was, however, no significant difference when this result, was compared to the control group. Thus, stretching does not prove to be an effective intervention to use to reduce lower back pain among a blue-collar worker population. It however effectively did improve lumbar flexibility.

Endurance training exercises proved to be of significant value in the reduction of lower back pain intensity within the exercise group but no significance was found when the exercise group was compared to the control group.

Different strengthening exercise regimes' results were extracted in this systematic review. Isometric strengthening significantly reduced low back painful episodes and painful days. This regime, however, was not able to maintain core stability strength over a long period, therefore proving not to be able to maintain the neutral zone and also maintain the relief of lower back pain according to Panjabi (1989)'s principles. He showed that core stability must be regained to restore neutral zone and spinal stability and thus preventing any irritation around the intervertebral segment structures.

Dynamic muscle strengthening, of the global muscles was not statistically significant when the exercise groups were compared to the control groups. The exercise regimes which used functional exercise proved to be effective in the reduction of lower back pain intensity, painful episodes, painful days and sick leave due to lower back pain. In addition, these functional exercise programs were able to maintain core stability. This restored the neutral zone and reduced lower back pain over a long period.

It can be concluded that functional exercise proved to be an effective intervention to use among a blue-collar worker population.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The following conclusions can be drawn from the results of this study. This study established that functional exercises are an effective exercise intervention in the management of occupational lower back pain among blue-collar industrial workers.

The nine primary studies that were identified proved to be of high methodology quality of above 70% on a 15 point quality checklist. Future randomised control trials on exercise as an intervention to occupational lower back pain are needed. The methodology quality of the primary studies in this systematic review lack blinding of the assessors and the subjects and some of them also lack adequate participation rate among the intervention subjects. This also needs to be addressed in future studies.

Details of different exercise were extracted from the primary studies. These exercises were then categorised according to the different exercise regimes. This included stretching, strengthening and endurance exercises and the combination use of stretching, strengthening, endurance exercises. Eleven exercise groups were identified in the nine studies since some of the studies included more than one exercise group. Lower back pain intensity, painful episodes, sick leave and physical measures were identified as outcome measure in each of above mentioned exercise regimes. Not all of the exercise regimes reported on all the outcome measures. This proved to be a major limitation in this study and future studies need to address this. The exercise regimes were reviewed in order to extract which specific exercises had statistical significance within each of the outcome measures. This showed which exercise was effective in the management of occupational lower back pain.

Stretches showed significant improvement in lower back painful episode reduction (p=0,026) and lumbar flexibility (p=0,0005). The improvement was however, only within the intervention group. There was no significance when the intervention groups' result was compare to the control group's (Hilyer *et al.,* 1990). However, other studies showed that there is no correlation of lower back pain relief with an improvement of lumbar flexibility (Johannsen *et al.,* 1995 and Battie *et al.,* 1990).

Endurance training exercise significantly reduced lower back pain intensity (p=0,0001) in the intervention group but not when the intervention group was compared to the control group. Endurance exercises had no record of the other outcome measures, which included painful episode and/ or sick leave due to lower back pain which were found by this systematic review. A big limitation to do a meta analysis was the fact that only one study that used endurance exercises could be found. It is recommended that future studies are needed to investigate these outcome measures for endurance training.

Isometric strengthening exercises had a significant effect on the reduction of lower back pain episodes and painful days. This exercise approach, however, showed only a temporary improvement in abdominal strength. Abdominal strength is of vital importance as a core stabiliser, (Hodges and Richard, 1995; Norris, 1995) to prevent lower back pain and neutral zone dysfunctions (Panjabi, 1989). Thus, this exercise regime did not prove to an effective intervention for the prevention of occupational lower back pain among blue-collar workers.

Dynamic strengthening exercises with resistance reduce lower back pain intensity significantly within the exercise groups but not when the exercise groups were compared to the control groups. No outcome values of lower back painful episodes and painful days and sick leave with dynamic strengthening exercises as an intervention were found by this systematic review.

Functional strengthening exercises played a major role in the significant outcome values of pain intensity and reduction of sick leave and painful episodes. This resulted in reduced loss of productivity, medical costs and improved the patients' quality of life. Gundewall *et al.* (1993)'s study also showed a significant improvement in back strength ($p<0,01$) which is of vital importance when relieving back pain according to Hides *et al.*, (1994) and Hodges and Richard (1995). According to these two studies strengthening the multifidus, back extensor and local muscles, leads to restoration of core stability. Core stability is important for the restoration of the intervertebrae neutral zone (Panjabi, 1989), the elimination of unnecessary accumulative tissue damage and decreasing any intervertebral tissue strain due to neutral zone dysfunctions (Panjabi, 1989, Jacobs, 2005). Thus, functional exercises showed to be an effective type of exercise to manage occupational related lower back pain among workers that are subjected to repetitive bending, twisting and lifting activities. More similar functional exercise randomised control trials are needed to strengthen this statement.

The objective to reanalyse the outcome data in a meta analysis could not be achieved due to an insufficient number of similar studies and exercise groups, which utilized similar outcome variables and follow-up periods (Greenhalgh 1998). This systematic review found only one primary study, which used stretches and one primary study, which used endurance exercises. The primary studies, which used strengthening exercises also did not match according to their different exercise approaches and outcome values.

The conclusion reached in this study is that better quality research is needed for exercises as an intervention for lower back pain among blue collar employees. The methodological quality of future studies needs to include a larger sample population of workers, a better participation rate and blinding of the assessors, instructors and workers. It is also recommended that more than one author critique the methodological quality (Greenhalgh 1998).

Future studies must provide a detailed description of their exercise regime, since this is absent in most of the excluded studies. The inclusion of all the outcome values i.e. lower back pain intensity, lower back painful episodes, lower back painful days and sick leave due to lower back pain, is essential in studies that use endurance training and static and dynamic strengthening exercises as interventions. Regular follow-up periods at 3-months, 6-months, 12-months and 18-months are also essential to get objective measurements of lower back pain's outcome values over a short- and long term period. This will enable the clinician to provide the blue-collar worker with an, evidence based exercise program to prevent lower back pain.

The functional exercise regime can easily be applied in a workplace setting since it is cost effective and need minimal time and equipment to implement (Hochanadel and Conrad, 1993). The employer can determine which activity forms the major part of the employee's daily working actions for example lifting, pulling or pushing. The functional exercise can then be formulated for example with the use of the theraband for pulling and pushing actions and light foot stools for lifting actions. The employees could participate in an early morning exercise program of five to ten minutes which involves ten to twenty repetition of each exercise as recommended by Galvao and Taafe (2005). This could lead to a reduction in lower back pain incidents, sick leave and improve general productivity due to improved physical muscle strength.

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APPENDICES

APPENDIX A

Van der Windt *et al,* 2000, methodology-quality-assessment tool

Only the structure and framework of this assessment tool were used and not the contents since it was not relevant to randomized control trails.

Table 1 Standardised checklist for the assessment of methodological quality of cross sectional studies (CS), case-control studies (CC), and prospective cohort studies (PC)

Study objective	
1 Positive if a specific, clearly stated objective is described	CS/CC/PC
Study population	
2 Positive if the main features of the study population are described (sampling frame and distribution of the population by age and sex)	CS/CC/PC
3 Positive if cases and controls are drawn from the same population and a clear definition of cases and controls was stated, and if people with shoulder pain in the past 3 months are excluded from the controls	CC
4 Positive if the participation rate is ≥80% *or* if participation rate is 60%-80% and non-response is not selective (data presented)	CS/CC/PC
5 Positive if the response at main moment of follow up is ≥80% *or* if the non-response is not selective (data presented)	PC
Exposure assessment, physical load at work (if not included in the design, not applicable (NA))	
6 Positive if data are collected and presented about physical load at work	CS/CC/PC
7 Method for measuring physical load at work: direct measurement and observation (+), interview or questionnaire only (−)	CS/CC/PC
8 Positive if more than one dimension of physical load is assessed: duration, frequency, or amplitude	CS/CC/PC
Exposure assessment, psychosocial factors at work (if not included in the design, NA)	
9 Positive if data are collected and presented about psychosocial factors at work	CS/CC/PC
10 Positive if more than one aspect of psychosocial factors is assessed: work demands, job control, social support	CS/CC/PC
Exposure assessment, other	
11 Positive if data are collected and presented about physical or psychosocial exposure during leisure time	CS/CC/PC
12 Positive if data are collected and presented about occupational exposure in the past	CS/CC/PC
13 Positive if data are collected and presented about a history of shoulder disorders	CS/CC/PC
14 Positive if exposure is measured in an identical manner in cases and controls	CC
15 Positive if the exposure assessment is blinded to disease status	CS/CC
16 Positive if the exposure is assessed at a time before the occurrence of the disease	CC
Outcome assessment	
17 Positive if data were collected for ≥1 year	PC
18 Positive if data were collected at least every 3 months	PC
19 Method for assessing shoulder pain: physical examination blinded to exposure status (+), self reported: specific questions relating to shoulder disability or use of manikin (+), single question (−)	CS/CC/PC
20 Positive if incident cases are used (prospective enrolment)	CC
Analysis and data presentation	
21 Positive if the appropriate statistical model is used (univariate or multivariate model)	CS/PC
22 Positive if a logistic regression model is used in the case of an unmatched case-control study and a conditional logistic regression model in the case of a matched case-control study	CC
23 Positive if measures of association are presented (OR/RR), including 95% CIs and numbers in the analysis (totals)	CS/CC/PC
24 Positive if the analysis is controlled for confounding or effect modification is studied	CS/CC/PC
25 Positive if the number of cases in the multivariate analysis is at least 10 times the number of independent variables in the analysis (final model)	CS/CC/PC

APPENDIX B

T. Greenhalgh's model for doing a primary study's methodology assessment with systematic reviews (Greenhalgh, 1998)

Was the study original?

- How big was the study?
- Was it more substantial than previous studies done?
- Did it cover any specific methodology criticism of previous studies?
- Will the numerical results add significance to a meta-analysis of previous studies?
- Did the population studied differ in any way: ethnic groups, ages and gender?

Who the study about?

- How were the subjects recruited?
- Who was included in the study?
- Who was excluded from the study?
- Did the subjects receive lengthy and detailed explanations of potential benefits of intervention?

Was the design of the study sensible?

- What specific intervention or manoeuvre was considered and what was is being compared with?
- What outcome was measured and how?

Was systematic bias avoided or minimized?

Was assessment "blind"?

Were preliminary statistical questions dealt with?

- Size odd sample
- Duration of intervention/ manoeuver.

APPENDIX C

PeDro 10 point quality- assessment scale

PeDro SCALE	+	-
1. Eligibility criteria were specified		
2. Subjects were randomly allocated to groups.		
3. Allocation was concealed		
4. The groups were similar at baseline regarding the most important prognostic indicators.		
5. There was blinding of all subjects		
6. There was blinding of all therapist who administrated the therapy.		
7. There was blinding of all assessors who measured at least one key outcome.		
8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups.		
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"		
10. The results of between-group statistical comparisons are reported for at least one key outcome.		
11. The study provides both point measures and measures of variability for at least one key outcome.		

APPENDIX D: Detail of the stretches used in the identified articles

Article	Exercise program:	Duration	Repetitions & Progression	Pectoralis mayor	Rectus femoris	Hip adductors	Hamstrings	Iliopsoas	Gastrocnemius	Soleus	Lower back	Shoulder muscles	Neck
Gerdle ***et al.***, 1995	Combination	2/week	7-8 minutes		+		+	+			+	+	+
Hilyer ***et al.***, 1990	100% Stretches	30 minutes /day	Not mentioned				+				+	+	
Horneij ***et al.***, 2001	Combination	2/week	20-30 second hold	+	+		+	+					
Kellett ***et al.***, 1991	Combination	60 minutes/ week	20 seconds hold	+		+	+	+	+	+			
Oldervoll ***et al.***, 2001	10% as a warm up to endurance group and strengthening	2/week	5-10 minutes								+ +	+ +	+ +

APPENDIX E: Detail of the strengthening exercises used in the identified articles

Article	Exercise program	Duration	Repetitions & Progression	Cal: Flexion	Cal: Pelvic tilt	Non-specific. Back muscles	Non specific Abdominal	Abdominal: Curl ups	Abdominal: trunk rotation	Abdominal: sit-ups	Back ext: Prone: arm lifts	Back ext: prone over box	Back extensors: 4 pt kneel with arm lifts	Back extension: Standing with elastic band as resistance	Gluteus: Bridge	Hip abductors: side-lying	Non specific quadriceps and hamstrings	Neck flexion: Supine	Shoulder: Push-up	Shoulder abduction	Non specific shoulder	Latissimus: elastic band	Norsk machine: pulleys and weights: whole body
Donchin ***et al.,*** 1990	100% Calisthenics group	45 minutes, 2/week	Not mentioned	+	+																		
Donchin ***et al.,*** 1990	100% Back school	90 minutes	Not mentioned			+	+																

APPENDIX E: Detail of the strengthening exercises used in the identified articles

Article	Exercise program	Duration	Repetitions & Progression	Cal: Flexion	Cal: Pelvic tilt	Non-specific. Back muscles	Non specific Abdominal	Abdominal: Curl ups	Abdominal: trunk rotation	Abdominal: sit-ups	Back ext: Prone: arm lifts	Back ext: prone over box	Back extensors: 4 pt kneel with arm lifts	Back extension: Standing with elastic band	Gluteus: Bridge	Hip abductors: side-lying	Non specific quadriceps and hamstrings	Neck flexion: Supine	Shoulder: Push-up	Shoulder abduction	Non specific shoulder	Latissimus: elastic band	Norsk machine: pulleys and weights: whole
Gerdle ***et al.,*** 1995	Combination	17 min of 1 hour: 2/week	Not mentioned			+											+				+		
Gundewall ***et al.,*** 1993	100%	20 minutes/ day	10- 30 repetitions, 3 times									+		+									

APPENDIX E: Detail of the strengthening exercises used in the identified articles

Article	Exercise program	Duration	Repetitions & Progression	Cal: Flexion	Cal: Pelvic tilt	Non-specific. Back muscles	Non specific Abdominal	Abdominal: Curl ups	Abdominal: trunk rotation	Abdominal: sit-ups	Back ext: Prone: arm lifts	Back ext: prone over box	Back extensors: 4 pt kneel with arm lifts	Back extension: Standing with elastic band	Gluteus: Bridge	Hip abductors: side-lying	Non specific quadriceps and hamstrings	Neck flexion: Supine	Shoulder: Push-up	Shoulder abduction	Non specific shoulder	Latissimus: elastic band	Norsk machine: pulleys and weights: whole
Horneij ***et al.,*** 2001	Combination	2/week	10 rep each, 20 second hold					+	+		+							+	+	+			
Kellet ***et al.,*** 1991	Combination	2/week30-35 minutes								+	+		+		+	+			+				
Maul ***et al.,*** 2005	Strengthening	2/week, 1 hour	15 repetitions, twice																				+

APPENDIX E: Detail of the strengthening exercises used in the identified articles

	Exercise program	**Duration**	**Repetitions & Progression**	**Cal: Flexion**	**Cal: Pelvic tilt**	**Non-specific. Back muscles**	**Non specific Abdominal**	**Abdominal: Curl ups**	**Abdominal: trunk rotation**	**Abdominal: sit-ups**	**Back ext: Prone: arm lifts**	**Back ext: prone over box**	**Back extensors: 4 pt kneel with arm lifts**	**Back extension: Standing with elastic band**	**Gluteus: Bridge**	**Hip abductors: side-lying**	**Non specific quadriceps and hamstrings**	**Neck flexion: Supine**	**Shoulder: Push-up**	**Shoulder abduction**	**Non specific shoulder**	**Latissimus: elastic band**	**Norsk machine: pulleys and weights: whole**
Oldervoll ***et al.,*** 2001	Strength training	2/week, 60 minutes	12-15 repetitions			+	+								+		+				+		
Staal ***et al.,*** 2004	Combination: with endurance	2/week, 1 hour	Not mentioned							+	+						+					+	

APPENDIX F: Detail of the endurance exercises used in the identified articles

Article	Exercise program	Duration	Repetitions & Progression	Stair climb	Brisk walk	Bicycling	Aerobics	Steps	Rowing
Gerdle ***et al.,*** 1995	Combination	2.week	4 minutes				+		
Horneij ***et al.,*** 2001	Combination	2/week	Adapted for each subject	+	+	+	+		
Kellet ***et al.,*** 1991	Combination	2/week: 30 minutes	9 minutes				+		
Oldervoll ***et al.,*** 2001	90% endurance with stretches	2/week: 1 hour	70-85% heart rate				+	+	
Staal ***et al.,*** 2004	Combination	2/week, 1 hour	Not mentioned			+	+		+

APPENDIX G: Detail of the functional exercises used in the identified articles

Article	Exercise program	Duration	Repetitions & Progression	Pulling on an elastic band fastened to a door	Pushing an elastic band fastened to a door	Lifting and transferring objects
Gundewall ***et al.,*** 1993	Strengthening	20 minutes/ ward shift	As many times as possible	+	+	
Horneij ***et al.,*** 2001	Combination	2/week	10 repetition, 3 times	+	+	
Staal ***et al.,*** 2004	Combination	2/week: 1 hour				+