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Lower limb MSD

Scoping work to help inform advice and research planning

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Scoping work to help inform advice and research planning

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This work was commissioned to examine more closely the nature and extent of workplace lower limb musculoskeletal disorders and injuries (LLD) and the causal agents with the aim of informing evidence based guidance and advice for workers and employers.

LLD are a problem in many workplaces and they tend to be associated with conditions in other areas of the body. There are consequences for society, the economy and industry in terms of lost working time, medical treatment and hospitalisation, and effects on quality of life. There is appreciable evidence for kneeling/squatting, climbing stairs or ladders, heavy lifting, walking/standing, and slips and trips hazards as causal risk factors for LLD.

Further work is recommended to clarify the inter-relationships between injury/pain at different regions of the body; to provide more detailed measures of workplace ergonomics risk exposures; to determine the suitability of existing control strategies and prevention interventions that have been proposed against conditions in other regions of the body (back and upper limbs); to explore the benefits of exercise regimes and coping programmes for those with a condition; and to identify strategies other than regulation that would aid increased awareness of the problems in workplaces and encourage commitment of employers.

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EXECUTIVE SUMMARY

Objectives

Relative to work-related musculoskeletal disorders of the upper extremity and lower back area, much less investigative focus has been placed on the prevention of lower limb musculoskeletal disorders and injury (LLD) in the workplace. This work was commissioned to examine more closely the nature and extent of workplace lower limb problems and the causal agents with the aim of informing evidence based guidance and advice for workers and employers. It had the following objectives:

- To identify the nature and extent of work related LLD that are suffered by workers as well as key risk factors.
- To identify strategies for risk control and injury prevention.
- To identify knowledge gaps and viable directions for research.

Main Findings

LLD, particularly knee conditions, are a problem in many workplaces and they tend to be associated with conditions in other areas of the body. Both acute and overuse injuries, may be suffered by workers, although overuse injuries tend to be more common.

There are consequences of occupationally caused LLD for society, the economy and industry in terms of lost working time, medical treatment and hospitalisation, decreased ability to carry out the work, and effects on quality of life. The particular impact depends on the condition and the number of joints affected.

The risk factors for LLD are not specific to any of the sites of the lower extremities and they are also associated with disorders in other regions of the body such as the upper limb and torso.

There is appreciable evidence of a causal association for kneeling/squatting, climbing stairs or ladders, heavy lifting, walking/standing, and slips and trips hazards as risk factors for LLD. The evidence of a causal association is plausible but less clear for jumps from height (e.g., from a vehicle's bed or cabin to the ground), driving and sitting.

There is appreciable evidence for implementation of workplace redesign/modification initiatives, implementation of protection equipment and participatory programmes as interventions for control and prevention of LLD risks, and it was possible to identify useful strategies that may be applied.

Based on the risk factors, key LLD and interventions identified, it was possible to develop a framework of the issues and to identify knowledge gaps as well as directions for future research.

Recommendations

Further work in this area is recommended to:

Clarify the inter-relationships between injury/pain at different regions of the body, i.e. to determine whether persons who suffer back pain are also likely to suffer pain in the lower extremity and vice versa and to determine whether or not the relationships are dependent on the type of injury suffered.

Provide more detailed measures of workplace ergonomics risk exposures, including tasks/actions such as standing, jumps from height and driving, which showed poor causal association in studies, but are often identified by workers as being problematic in the workplace. This type of research will enable clearer definitions of "safe" exposures, e.g. acceptable standing time.

Determine the suitability of existing control strategies and prevention interventions that have been proposed against conditions in other regions of the body (back and upper limbs).

Clarify the relationship between symptoms and the different dimensions that characterise risk exposure, i.e., the physical stress imposed on the body.

Explore the benefits of exercise regimes and coping programmes for those with a condition.

Identify strategies other than regulation that would aid increased awareness of the problems in workplaces and encourage commitment of employers.

1 INTRODUCTION

1.1 BACKGROUND

Musculoskeletal disorders (MSD) are a major cause of work-related disability and account for absence from the workplace in many occupational groups. However, relative to work-related MSD of the upper extremities and lower back area, much less attention has been given to the epidemiology of lower limb musculoskeletal disorders and injuries (LLD) (D'Souza *et al.*, 2005).

There is evidence that LLD are contributing to the overall prevalence of MSD. Jones *et al.* (2006) found that out of 1,012,000 people who reported suffering a work-related MSD, 18% (185, 000) reported disorders that mainly affected the lower limb. However, these self-reported results concerning LLD and symptoms have not yet been subjected to the level of analysis given to MSDs of the back and upper limbs. This can be attributed to the smaller numbers of suffers involved, and a lack of understanding of the nature and extent of the problems. It is not surprising that the Regulations, guidance and advice that have been provided to date, are largely targeted at the musculoskeletal health of workers' backs and upper limbs. Therefore, their suitability for application to the musculoskeletal health of worker's lower limbs is questionable.

LLD are distinct from MSDs affecting the back, the neck and the upper limbs, in that they can often give rise to greater degrees of immobility and thereby can degrade quality of life substantially (Bruchal, 1995; Lohmander *et al.*, 2004).

1.2 STUDY AIMS

This work was commissioned to examine more closely the nature and extent of workplace lower limb problems and the causal agents with the aim of informing evidence based guidance and advice for workers and employers. It had the following objectives:

- To identify the nature and extent of work related LLD that are suffered by workers as well as key risk factors.
- To identify strategies for risk control and injury prevention.
- To identify knowledge gaps and viable directions for research.

2 NATURE AND BURDEN OF LLD

There has been extensive discussion of various LLD in the literature relating to sports medicine and the military (Ross, 1993; Lavender and Andersson, 1999; Sulsky *et al.*, 2002; van Middlelkoop *et al.*, 2008). Similarly, LLD are also discussed in relation to occupational settings, where the intensity of the activities is greatly reduced compared to that of sports and military training activities. Like disorders of the upper limb and axial skeleton (neck and trunk), LLD involve the muscles, tendons or nerves, ligaments and other tissues, and they are generally manifested by inflammation, pain, discomfort or tingling.

2.1 PREVALENCE/INCIDENCE

Table 1 presents typical prevalence of LLD that have been reported in the literature.

Studies based on general populations or archival data (for example, Jones *et al.*, 1993; Chen *et al.*, 2004; Smith *et al.*, 2006), report the prevalence of workplace related LLD as being between 10% and 30% of all MSD cases identified. Jones *et al.* (1993) reported 28.4% prevalence of overuse injuries (stress fractures, Achilles tendonitis and patella-femoral syndrome), based on a group of military recruits. The cumulative incidences for the different sites of the extremity were: 10.9% for the feet and ankles respectively, 10.2% for the knees and 8.6% for the calves. D'Souza *et al.* (2005) opined from their review of the literature surrounding general worker populations that the low prevalence reported in the studies, could be due to other factors because true prevalence is not totally captured. For instance, workers who had withdrawn from the workplace or transferred to other jobs due to chronic injuries are likely to have been excluded from surveyed data, as has previously been suggested by Walker-Bone and Palmer (2002).

Studies that were based on specific worker populations reported higher prevalence ratios of between 20% and 60% (Jensen and Kofoed, 2002; Forde *et al.*, 2005; Quansah, 2005; Galis, 2006). In terms of the comparative percentage ratios (Table 1), higher prevalence was also generally reported for symptoms and disorders of the knee than for symptoms and disorders of other regions of the lower extremity, i.e., (Lemasters *et al.*, 1998; Cromie *et al.*, 2000; Yeung *et al.*, 2005). Chen *et al.* (2006) suggested that the higher rates of occupational disease reported for specific worker groups may reflect both a shrinking study denominator, and the high coverage and investigation of work-related illness by the occupational health services.

Reports of LLD symptoms tend not to be independent of reports of symptoms in other areas of the body (Gamperiene and Stigum, 1999; da Silva *et al.*, 2006). Haukka *et al.* (2006) found that widespread occurrence of pain was common among female kitchen workers. In fact, having pain in one anatomical area of the body (upper extremity, lower extremity or axial body [neck and trunk]) was associated with an increased occurrence of pain in another site. Also, within one anatomical area, more than one site of pain was often mentioned. The occurrence of concurrent pain in the lower limbs and upper limbs was however, less than 4%, compared to concurrent pain in the axial body and upper extremity (which was 53%), and in the axial body and lower extremity (48%). Gamperiene and Stigum (1999) found that symptoms of injury to the legs were the most common musculoskeletal symptoms in their study of spinning industry workers (61.2%) and that most of those who reported symptoms in the legs had additional symptoms in other areas of the body (such as the lower back area and arms). Nahit *et al.* (2001) found that exposure to mechanical factors (such as repetitive movement of the limbs, postures adopted and lifting and carrying of loads) was most strongly associated with pain at multiple sites rather than with pain at individual sites, in their study of twelve occupational groups of newly employed workers.

Table 1 Prevalence of LLD symptoms reported for different populations

Source	***Study population***	***Prevalence of symptoms according to region of the lower extremity (%)***						
		LL	***Leg***	***Thigh***	***Hip***	***Knee***	***Ankle***	***Feet***
Chau *et al.* (2006)	Construction		9.5					24.6
da Silva *et al.* (2006)	Construction	27.4						
Welch *et al.* (1999)	Construction		14.0				20.0	
Merlino *et al.* (2003)	Construction – Apprentices				9.4	38.4		23.2
Forde *et al.* (2005)	Construction – Ornamental Iron work	58.9			18.9	43.9	26.7	
Forde *et al.* (2005)	Construction – Structural Iron work	58.1			20.8	40.4	31.0	
Forde *et al.* (2005)	Construction – Reinforcing Iron work	53.0			19.7	36.9	26.9	
Jensen and Kofoed (2002)	Construction – Apprentices				5.0	48.0	8.0	
Jensen and Kofoed (2002)	Construction – Floor layers				11.0	56.0	19.0	
Jensen and Kofoed (2002)	Construction – Compositors				8.0	22.0	16.0	
Lemasters *et al.* (1998)	Construction – Carpenters				10.5	18.6	7.1	
da Silva *et al.* (2006)	Distribution – Retail	43.2						
Sobti *et al.* (1997)	Distribution – Postal				30.4	50.0		
da Silva *et al.* (2006)	Distribution – Transport	28.2						
Quansah (2005)	Food process – Fishery			48.0		50.0	45.0	
Haukka *et al.* (2006)	Food process – Kitchen staff			19.0		29.0	30.0	
Smith *et al.* (2006)	General workers			2.8		7.3	11.0	
Chen *et al.* (2006)	General workers		6.0				10.0	

Table 1 Prevalence of LLD symptoms reported for different populations (continued)

Source	***Population***	***Prevalence of symptoms according to regions of the lower extremity***						
		LL	***Leg***	***Thigh***	***Hip***	***Knee***	***Ankle***	***Feet***
Seifert *et al.* (1997)	Industry – Bank tellers		79.0				19.0	67.0
Gallis (2006)	Industry – Forestry			30.7		61.5	30.7	
Morken *et al.* (2007)	Industry – Petroleum	16.0				12.0		
Chau *et al.* (2006)	Industry – Railway		4.0				8.1	19.4
Chee *et al.* (2004)	Industry – Semi-conductor		31.9				41.9	
Gamperiene and Stigum (1999)	Industry – Textile			14.9		39.4	30.9	
de Zwart *et al.* (1997)	Industry – Heavy work	28.0	10.0		12.0	14.0	5.0	7.0
Hilderbrandt *et al.* (2000	Industry – General population	31.0						
Roelen *et al.* (2008)	Industry – General population (Male)		16.0					
da Silva *et al.* (2006)	Labourers	40.0						
Woods and Buckle (2006)	Labourers – Cleaners					24.0		
da Silva *et al.* (2006)	Labourers – Domestic	51.2						
da Silva *et al.* (2006)	Labourers – Rag pickers	45.0		10.2		19.7	14.6	34.2
Choobinah *et al.* (2006)	Medical – Nurse	45.1		29.3		48.4	52.1	
Lagerstrom *et al.* (1995)	Medial – Registered Nurse					27.0		
Lagerstrom *et al.* (1995)	Medical – Enrolled Nurse					31.0		
Lagerstrom *et al.* (1995)	Medical – Auxiliary Nurse					35.0		
Yeung *et al.* (2005)	Medical – Nurse			20.6		29.9	19.6	
Engels *et al.* (1996)	Medical – Nurse	15.7			6.9	10.2	3.7	
Smith *et al.* (2004)	Medical – Student Nurse			5.3		12.3		19.3
Smith *et al.* (2003)	Medical – Tropical area Nurse			29.7		27.0	8.1	18.2

Table 1 Prevalence of LLD symptoms reported for different populations (continued)

Source	***Population***	***Prevalence of symptoms according to regions of the lower extremity***						
		LL	***Leg***	***Thigh***	***Hip***	***Knee***	***Ankle***	***Feet***
Akesson *et al.* (1999)	Medical – Nurse				15.0			
Akesson *et al.* (1999)	Medical – Dentists (Female)				23.0			
Akesson *et al.* (1999)	Medical – Hygienists (Female)				23.0			
Akesson *et al.* (1999)	Medical – Assistants (Female)				8.0			
Bork *et al.* (1996)	Medical – Physical therapists				4.7	10.9	10.7	
Cromie *et al.* (2000)	Medical – Physical therapists				7.3	11.2	7.1	
Jones *et al.* (1993)	Military – Infantry recruits			8.6		10.2	10.9	
Mattila *et al.* (2007)	Military – Conscripts			4.0		27.0	20.0	
Taneja and Pinto (2005)	Military – Aircrew	30.0	22.0					
Ross and Woodward (1994)	Military – Recruits		13.0			23.4	26.8	4.1
Rudzki (1997)	Military – Recruits (walk group)	62.3				8.8		
Rudzki (1997)	Military – Recruits (run group)	79.8				18.8		
Bennell and Crossley (1996)	Sports – Track/field athlete		27.7	21.5	13.0	16.2	7.3	14.6
Langran (2002)	Sports – Ski-board	10.2		1.2		35.7	14.3	1.2
Schiber *et al.* (1996)	Sports – In-line skating	13.0				6.0		
Grant *et al.* (1995)	Teachers – Pre-school	33.0						

2.2 TYPES OF LLD CONDITIONS

LLD conditions often arise from two types of trauma, acute trauma and cumulative (overuse) trauma (Whiting and Zerrnicke, 1998). Acute traumas occur when the load imposed on the body during an occupational task exceeds the tolerance of the body structures supporting it. They are typically associated with large single loading conditions such as a violent lateral impact to the knee or infrequent extreme force exertions such as occur during operation of some machines. The second type of trauma, overuse trauma, occurs when the load imposed on the body during an occupational task is not large enough to cause sudden failure of one or other of the underlying body structures (bone, the muscles, tendons and ligaments). Instead these structures are worn down and their tolerance lowered with repeated application of the load (Carter and Banister, 1994). The overuse injuries therefore represent more of a "wear and tear" on the body structure over time; these may be caused by almost any activity involving rapid and repeated movement. Factors such as awkward posture, muscular load and leverage action may also contribute.

Both acute and overuse injuries have been identified among populations of industrial workers, as well as populations of athletes and military personnel (Milgrom *et al.*, 1992; Bennell and Crossley, 1996; Rudzki, 1997; Akesson *et al.*, 1999). However, acute injuries tend to be more common among athletes and military personnel than among occupational groups (Olsen *et al.*, 2005). Ross and Woodward (1994) identified 123 cases of overuse injuries and 115 cases of acute injuries in their surveyed population of military recruits (N = 8644). The injuries were determined by medical diagnosis, and included: for example stress fractures and shin splints (overuse injuries) and such as ankle and metacarpal fractures (acute injuries). Cherry *et al.* (2001) found for a general worker population that 82% of the cases reported to MOSS (musculoskeletal occupational surveillance scheme) between 1997 and 2000 were related to repetitive (overuse) rather than single (acute) injury. Bruchall (1995) reviewed the prevailing literature concerning occupational knee disorders and identified for those who habitually kneel at work (miners and construction workers) bursitis, rheumatism and skin infections as the commonly suffered overuse injuries and cartilage tear as the commonly suffered acute injury.

Table 2 presents a list of medically diagnosed LLD conditions that have been reported on or investigated in the literature. Only a subset of these disorders has been associated with industrial work situations and overviews of the most commonly reported injuries are provided in the following sections.

Table 2 Medically diagnosed LLD conditions that have been reported in occupational populations

Variable	***LLD conditions according to the regions of the lower extremity***		
	Hip/thigh	***Knee / lower leg***	***Ankle/foot***
Overuse injuries	Osteoarthritis (OA)	Beat knee/Hyperkeratosis	Achilles tendonitis
	Piriformis syndrome	Bursitis	Blisters
	Trochanteritis	Meniscal lesions	Foot corns
	Hamstring strains	Osteoarthritis (OA)	Halux valgus (bunions)
	Sacroiliac pain	Patellofemoral pain syndrome	Hammer toes
		Pre-patellar tendonitis	Pes traverse planus
		Shin splints	Plantar fasciitis
		Infra-patellar tendonitis	Sprained ankle
		Stress fractures	Stress fractures
			Varicose veins
			Venous disorders
Acute injuries		Meniscal tear	Ankle fractures
			Metacarpal fractures
			Scaphoid fracture

2.2.1 Hip/thigh conditions

Many of the studies concerning work-related hip conditions have been focused on osteoarthritis (OA), and the indication is that hip OA is more common among male workers than female workers (Cooper *et al.*, 1998). OA is a condition that affects the joints of the body (e.g., knees, hips and spine), and occurs when the cartilage coating at the end of bone becomes damaged and worn away (Whiting and Zernicke 1998). Two broad mechanisms are believed to underlie the pathogenesis of OA at any joint site: Mechanical stress and a generalised genetic disposition to the disorder. According to Sandmark (1999), the relative importance of these two mechanisms to the aetiology of OA is unknown, but the indications from the literature are that both play a role (Felson *et al.*, 1997; Coggon *et al.*, 1998; Lau *et al.*, 2000; Jarvholm *et al.*, 2005).

Walker-Bone and Palmer (2002) examined the epidemiological evidence that working in farming causes or aggravates MSDs (hip and knee OA) and estimated the likely scale of the risk. They concluded that there was compelling evidence of an increased risk of hip OA for farm workers when compared to other occupational groups (OR ranging between 1.5 and 15.0) and that hip OA is a considerable public health burden.

Aside from hip OA, other underlying medical conditions have been reported, though not as widely. Akesson *et al.* (1999) for example, reported Piriformis syndrome, Trochanteritis and Sacroiliac pain among their studied population of dental personnel (N = 90). Piriformis refers to a condition in which the piriformis muscle irritates the sciatic nerve, causing pain in the buttocks and propagating pain along the course of the sciatic nerve. Trochanteritis is a similar condition relating to lateral hip pain, sometimes radiating distally and causing palpable tenderness of the trochanter major. Sacroiliac pain is often described as pain that is focused in the lower portion of the back and hip. It may radiate out to the buttocks and lower back and in some cases it may travel down the legs or around to the front, in the groin area.

Bennell and Crossley (1996) reported hamstring muscle strain though this was in a population of athletes and not occupational workers. The condition was found to be significantly more common in sprint/hurdle event athletes than in the other group athletes surveyed. Hamstring injuries are sometimes known as a 'pulled Hamstring’ due to how they usually occur; the Hamstring muscle is forcibly stretched beyond its limits and the muscle tissue becomes torn.

These observations suggest that only a few types of hip conditions are work-related, and the most frequently implicated is OA.

2.2.2 Knee conditions

As with the hip, many of the studies concerning work-related knee conditions have been focused on OA. Other conditions that are suggested to be work-related are, Bursitis, Beat knee (Hyperkeratosis), and Meniscal lesions/damage.

Osteoarthritis

Unlike hip OA, work-related knee OA is more often linked with female workers than male workers (Cooper *et al.*, 1998) and the condition appears to be the most widely suffered type of knee disorder. Hart *et al.* (1999) analysed paired radiographic films of female knees and found that 95 of 715 women (13.3%) developed incident knee OA within a 4 years follow-up period. Therefore, the incidence rate of this injury was determined as 3.3% per year on average. Additionally, it was found that 81 of 644 (12.6%) females developed a characteristic of knee

OA (knee joint space narrowing [JSN]), which is an average of 3.1% per year. The study by Rossignol *et al.* (2005) investigated occupations with excess prevalence of primary knee OA amongst other conditions in relation to occupational exposure and found that female cleaners had the greatest prevalence rate ratio (OR 6.2, 95% CI 4.6-8.0).

The study by Jarvholm *et al.* (2007) found a significantly increased risk of surgically treated knee OA among floor layers, asphalt workers, sheet-metal workers and concrete workers. The relative prevalence of the condition among floor layers was 4.7 (95% CI 1.8-12.3) compared to the other groups of workers. Lemasters *et al.* (1998) found that those who reported recurring symptoms in the knee (pain, aching, and numbness) were significantly associated with positive findings for degenerative joint disease (patellar compression, joint line tenderness or effusion). From the physical examination of the knees of their participants, the authors identified a non-significant presence of prepatellar and infrapatellar tendonitis. Although the findings were similar for both control and case groups, the risk of degenerative disease of the knee joint was more than six times higher in the cases [38.1%] than in the controls [5.7%].

Bursitis (Adventitious, pre-patellar, etc)

After OA, Bursitis has been the most widely investigated condition for knee injury. It can commonly be referred to as coal miners, carpet layers or housemaids' knee, as it has historically been linked to these professions, where workers perform tasks, which involve knee-straining activities. Forde *et al.* (2005) reported that, 12% of the 121 participants who reported knee symptoms had been diagnosed with knee bursitis by a doctor and that many more (the specific percentage was not given) reported seeing a doctor for knee related problems where a diagnosis other than knee bursitis was given.

Generally, Bursitis develops in response to frictional stress that is applied directly over the bursae of the knees, such as that caused by repetitive kneeling. A variant form, pyogenic bursitis, develops as a result of penetrating skin injury. The large prepatellar bursa, which lies between the patella and the skin, is most commonly involved in bursitis conditions. Bursae are very small, soft, fluid-filled sacs surrounding muscles, bones and tendons. Their function is to cushion the motion between bones, tendons and muscles near the joints in order to allow the joints to slip and slide over one another with reduced friction, thereby reducing potential pain. Workers who develop bursitis generally present with tenderness and swelling directly over the patella and have decreased range of motion of the knee due to pain and tightening of the skin over the patella.

Hyperkeratosis

Once referred to as 'Beat Knee', Hyperkeratosis refers to the thickening of the skin due to pressure. It is an acute and extreme form of bursitis, and is common amongst those whose work involves knee-straining activities such as kneeling and squatting. Hyperkeratosis often results from prolonged kneeling and may result in chronic pain. Jensen *et al.* (2000) found this condition to be more prevalent among floor layers (69-84%) and carpenters (54-69%) than among compositors (8-14%), though the condition could not be directly associated to work activities.

Meniscal lesions/damage

Meniscal lesions/damage usually occurs due to high rates of force being applied to the knee, or heavy rotational force, e.g. when the knee is bent or twisted while bearing load. The acute condition is known to occur more frequently as a result of certain types of sports, such as football and handball (Jensen *et al.*, 2000), but overuse trauma (for example, occupationally linked repetitive squatting or kneeling) can also cause meniscus injury or damage. Meniscal lesions/damage predisposes the injured knee to degenerative changes characteristic of OA (McMillan and Nichols, 2005). The study by Baker *et al.* (2003) investigated the association of meniscal injury with occupational activities in a nested case-control design and found that many of the respondents had sought medical treatment; 438 (31%) consulted a general practitioner, 222 (16%) attended a hospital clinic and 182 (13%) had seen an orthopaedic surgeon.

Other knee conditions

Aside of the conditions discussed above, other underlying medical conditions have been reported for the knee, though not as widely. Feuerstein *et al.* (1997) for example, analysed 41,750 disability cases for the associations between occupation, gender and disability and identified degenerative arthritis and knee impairment as two of the five highest diagnoses for lower limb pain among the studied population of military personnel.

2.2.3 Lower leg conditions

Two groups of conditions have been widely suggested as being work-related: Stress fracture/stress reaction injuries and venous disorders and varicose veins.

Stress fracture/stress reaction injuries

The term 'stress reaction' describes bone with evidence of remodelling but with an absence of radiological evidence of fracture. The process leading to stress reaction and subsequent stress fracture actually involves physiological adaptation of bone to mechanical loading (Whiting and Zernicke, 1998). Stress reaction/fracture is the result of repeated micro-injuries to bone, which occur when its maximum strength is exceeded by an applied force (such as may occur during marching or stamping of the feet) and the natural process by which bone adapts to stress is prevented. It is more common in people undergoing military training and in athletes, particularly long distance runners, and much of the information has derived from studies focused on these populations. Only one study was found that associated the condition with occupational workers (Jensen and Dahl, 2005). Jensen and Dahl, (2005) reported that cases of stress fracture of the tibia and fibula had previously been reported in ballet dancers and they presented the case of a 59 year-old male welder who presented with a stress fracture to the left distal tibia and fibula due to heavy lifting at work.

In the lower leg, stress fracture is usually associated with the tibia rather than with the fibula, as the fibula tends to play a minor role during axial loading of the limb.

Venous disorders and varicose veins

Varicose veins refer to any dilated tortuous and elongated subcutaneous veins of the leg. Subjective complaints of varicose veins and chronic venous insufficiency are often described as a feeling of heaviness and pain, a sensation of swelling of the legs, night time calf cramps and restless legs. These complaints increase during the course of the day, especially after prolonged standing (Krijnen *et al.*, 1997). Carpentier *et al.* (2004) investigated the prevalence of varicose veins, skin trophic changes and venous symptoms in a sample of the general population and found high occurrence of symptoms of varicose veins among women (50.5% of the female population studied) but no significant variation due to the geographic location of the participants.

2.2.4 Ankle and foot conditions

Various conditions of the ankle and feet have been identified such as sprained ankle, anterior compartment syndrome, Plantar Fasciitis, Achilles Tendonitis, foot corns, and Halux Valgus (bunions), but the aetiology of many as work-related is still in question. Guyton *et al.* (2000) for example, critically reviewed the literature on the aetiology of foot and ankle disorders commonly involved in compensation litigation, i.e., Hallux valgus, interdigital neuroma, tarsal tunnel syndrome, lesser toe deformity, heel pain, adult acquired flatfoot and foot and ankle OA. The authors concluded from the results that the current literature did not support the view that they are caused by cumulative trauma such as may occur in industrial workplaces.

2.2.5 Summary

The efforts to characterise the work-relatedness of LLD have identified various types of conditions for the different regions of the lower extremity, but the evidence is most reliable for the following: Hip OA; knee OA, knee Bursitis, Meniscal lesions/tears; stress fracture/reaction injury and venous disorders/varicose veins of the lower legs.

2.3 CONSEQUENCES OF THE INJURIES

The consequences of LLD for the economy/industry are varied, but the particular impact depends on the specific disease, number of joints affected, the work system design, and the job demands (Kumar 2001). The consequences may also depend on how concerned the worker is about their condition (tolerance of individual), as has previously been suggested by Cromie *et al.* (2000). These authors investigated the responses (reported musculoskeletal symptoms, risk factors, injury prevention strategies and consequences of injury) of physical therapists to work related MSDs and found that the participants responded with varying degrees of detail. While some simply recorded the presence of symptoms, others identified the specific symptoms and reported that their symptoms required treatment and/or that they interfered with leisure activities, activities of daily living (ADL) and work. In these regards, 3.1% of the respondents identified that LLD prevented working, 12.9% identified that LLD prevented performance of ADL and 16.6% identified that they had sought treatment for their LLD. The typical consequences of LLD reported in surveys of occupational workers are days of restricted duty, sick leave and days receiving hospital treatment (Rudzki, 1997; Welch *et al.*, 1999; Merlino *et al.*, 2003; Jarvholm *et al.*, 2008).

2.3.1 Lost work time and duration of pain

Compared with workers who suffer conditions of the upper extremities and torso (back), workers with LLD (knee/leg/hip/groin) are more likely to have symptoms beyond two months and require time off work.

Welch *et al.* (1999) reported that, of the respondents for whom a doctor recommended no time off for a LLD condition, 58% still had symptoms after two months, and for the respondents that took more than one day off on the recommendation of a doctor 80% still had symptoms after two months. Similarly, Smith *et al.* (2006) found that ankle or foot conditions were the most likely to last longer than two days (OR 8.4, CI 1.5-71.5) and Merlino *et al.* (2003) identified that between 6% of their respondents indicated missing work because of a hip/thigh condition, 18% indicated that they missed work because of a knee condition and 22% indicated missing work because of a condition of the feet. Furthermore, Hilderbrandt *et al.* (2000) found that 25 % of respondents required short-term sick leave (< one month) and 12 % required long-term sick leave (> 1 month) due to a LLD.

2.3.2 Medical treatment and hospitalisation

Compared with workers in light jobs (involving sedentary tasks with little or no manual handling of loads), those in heavy jobs often involving heavy or physically demanding tasks who suffer a LLD condition, particularly a knee condition, are more likely to seek medical treatment and require hospitalisation.

Jarvholm *et al.* (2008) identified for workers in heavy jobs that, even modest pain may cause problems at work and result in the worker seeking medical consultation, whereas, a lower percentage of workers in less demanding jobs are likely to see a doctor even if they experience similar pain. Merlino *et al.* (2003) investigated the prevalence and consequences of musculoskeletal symptoms among young construction workers (N = 996) and identified that between 20% and 45% of those who had a lower limb condition needed to see a doctor. Furthermore, Smith *et al.* (2006) found that knee conditions were most commonly associated with the need for medical treatment (OR 4.6, CI 1.1-21.7) in the general working population.

2.3.3 Difficulty in carrying out normal work and recreational activities

Various studies have identified effects that LLD may have on ability to carry out normal work tasks and recreational activities (Bork *et al.*, 1996; Engels *et al.*, 1996; Welch *et al.*, 1999; Cromie *et al.*, 2000) and it is generally suggested that ability for work and recreation could be considerably affected, particularly when the condition is chronic.

The study by Welch *et al.* (1999) of chronic symptoms in construction workers treated for musculoskeletal injuries found that of those with persistent symptoms (lasting more than 2 months) about one quarter (24% to 28%) reported major or substantial effects of their symptoms on personal and work-related activities. Similarly, Engels *et al.* (1996) reported that between 21% and 48% of the participants indicated substantial intrusive effects of the leg injuries suffered i.e., daily activities could no longer be performed as usual and they had to stop working or they had to take some time off work.

2.3.4 Summary

The social and economic impact of LLD have been highlighted in studies, however the consequences are rarely discussed in relation to the specific conditions that are suffered.

3 RISK FACTORS FOR LLD

Various studies have reported on the risk factors for LLD including from an occupational (industrial work) perspective (for example, Felson *et al.*, 1991; Jones *et al.*, 1993; de-Zwart *et al.*, 1997; Gamperiene and Stigum, 1999; Nahit *et al.*, 2001; Murphy *et al.*, 2003; Choobineh *et al.*, 2006; Jarvholm *et al.*, 2008).

These studies suggest that the risk factors are diverse and generally identify three broad categories: Occupational (physical) risk factors, Personal (and demographic) risk factors and psychosocial risk factors. Many of the factors identified are not specific to the lower extremities, as they have also been associated with disorders of the upper extremities and trunk. Choobineh *et al.* (2006) found that awkward posture; moving/lifting heavy loads and awkward/static posture were significantly associated with reported upper limb and back symptoms as well as lower limb symptoms (Table 3). Lau *et al.* (2000) presented results that were suggestive of interactions between factors, particularly an interaction of previous injury, repetitive use, and load bearing in the aetiology of lower limb injury.

Table 3 Significant risk factors associated with MSD symptoms in different sited of the body (odds Rations [OR] and 95% confidence interval [CI]) according to Choobineh et al., (2006)

Site of body	***Risk factor***	***OR***	***95% CI***
Neck	Job tenure (length of time in job)	2.12	1.46–3.08
	Moving/lifting heavy loads	2.09	1.15–3.80
	Awkward head or arm posture	2.20	1.09–4.45
Shoulders	Awkward body posture	2.01	1.20–3.38
Elbows	Job tenure (length of time in job)	2.34	1.47–3.71
	Static posture	2.15	1.24–3.72
	Moving/lifting heavy loads	2.51	1.10–5.69
Wrists/hands	Job tenure (length of time in job)	1.81	1.21–2.70
	Apply pressure with hands/fingers	2.38	1.18–4.80
	Intensive physical efforts	2.62	1.02–6.73
Upper back	Awkward body posture	2.14	1.24–3.70
	Bent or twisted at waist	1.74	1.06–2.85
Lower back	Bent or twisted at waist	2.42	1.41–4.15
	Awkward Body posture	1.17	1.25–3.75
Thighs	Static posture	2.24	1.44–3.49
	Job tenure (length of time in job)	1.57	1.06–2.33
Knees	Job tenure (length of time in job)	1.59	1.12–4.08
	Static posture	1.49	1.02–2.17
Legs/feet	Bent or twisted at waist	2.66	1.67–4.24
	Static posture	1.56	1.18–2.30

Tables 4 – 6, summarise the data obtained from the literature concerning the risk factors for occupational LLD and symptoms. The factors shown are those for which significant associations were found after adjustment for confounding variables in multivariate analysis and they are presented according to the regions of the limb.

Table 4 Physical risk factors for LLD in industrial workers

Reference/population	*Region of LL/LLD*	*Risk factor*	*Measure of risk*	*Trend*	*Design/Exposure evaluation*
Akesson *et al.* (1999) Dental personal - Females	LL (Hip, knee, ankle-foot) / Symptoms, pain	Job (dental personnel)	RR 2.1, 0.3-17		Prospective (5 year follow-up), case control / Questionnaire survey, clinical examination
Andersen *et al.* (2007) Industry and service workers	LL/Symptoms	Push loads (>355 kg/hr total) Stand (> 30 min/hr)	HR 1.6, 1.0-2.5 HR 1.6, 1.2-2.3		Prospective (24 months follow-up), cohort / Questionnaire survey
Bork *et al.* (1996) Physical therapists	LL (Hip-thigh, knee, ankle-foot) /Symptoms, pain	Lift/transfer patients (yes) Place of work (hospital) Job task (neurological/child)	PR 25.7 PR14.5/8.4 OR 3.5, 1.8-7.0		Cross-sectional, questionnaire survey
Chau *et al.* (2006) Construct and rail workers	LL (Leg, ankle-foot) / Fracture	Years worked (< 5)	OR 2.5, 1.3-4.9		Case-control, matched / Questionnaire survey
Chee *et al.* (2004) Semi-conductor industry - Females	LL/Pain	Standing (yes>4 hr) Sitting Years worked (>5) Job (fabricator/end of line)	OR 2.7, 1.9-3.9 OR 0.5, 0.4-0.8 OR 2.0, 1.1-4.0 OR 2.6, 1.0-7.1		Cross-sectional/Questionnaire and walk-through survey
Chen *et al.* (2006) General worker population	LL/Illness cases	Whole-body movement Heavy manual handling Stand/walk Kneel	IR 25.0 IR 17.0 IR 59.0 IR 23.0		Cross-section/ labour force data base survey
da Silva *et al.* (2006) Rag pickers	LL (Lower extremity)/Pain	Lie down (frequently) Lift loads Repeated activity	PR 1.9, 1.1-2.2 PR 1.1, 1.0-1.3 PR 1.1, 1.0-1.3		Cross sectional-matched/Questionnaire survey
de Zwart *et al.* (1997) Industrial population - Males	LL/Symptoms	Job (heavy physical/mental)	PR		Prospective (4 year follow-up), case-control/ Questionnaire survey

HR – Hazard Ratio, OR – Odds Ratio, IR – Incidence Ratio, PR - Prevalence Ratio, RR - Relative Risk, RIR – Relative Incidence Risk

Table 4: Physical risk factors for LLD in industrial workers (continued)

Reference/population	***Region of LL/LLD***	***Risk factor***	***Measure of risk***	***Trend***	***Study design/Exposure evaluation***
Engels *et al.* (1996) Nursing personnel Female	LL (Leg)/Perceived pain	Posture (awkward) Walk Stand	OR 1.9, 1.1-3.3 OR 2.5, 1.4-4.7 OR 2.5, 1.2-5.2		Cross-sectional/Questionnaire survey
Forde *et al.* (2005) Union Iron workers	LL (Hip-thigh, knee, ankle-foot) /Complaints	Years worked-WD (>5)	OR 2.0-3.3		Cross-sectional, case-control/Questionnaire survey, interview, workers data base list
Fowkes *et al.* (2001) General population	LL/Venous reflux	Sit (duration)	OR 0.8, 0.6-0.9	*	Cross-sectional/Questionnaire survey
Gamperiene and Stigum (1999) Spinning industry workers	LL (Thigh, knee, ankle-foot) / Complaints	Job (spinners) Sit (often) Strained posture	OR 3.1, 1.6-5.8 OR 0.3, 0.1-0.8 OR 2.1, 1.2-3.7		Cross sectional/Interview, questionnaire survey, workplace observation
Lemasters *et al.* (1998) Union carpenters	LL (Hip, knee, ankle) / Symptoms -12 months	Years worked (>20 yrs)	OR 3.5, 1.3-9.2	*	Cross-sectional/Questionnaire survey
McBeth *et al.* (2003) General population	LL/Symptoms	Push/pull (heavy weight) Kneel	RR 1.8, 1.1-3.0 RR 2.2, 1.2-4.1		Prospective-population based/ Questionnaire Survey, telephone interview
Roelen *et al.* (2008) Industrial workers Male	LL (Legs)/Perceived pain	Prolonged standing Heavy lifting Regular bending	OR 3.0, 1.5-5.8 OR 2.0, 1.0-3.8 OR 2.4, 1.3-4.4		Cross-sectional/Questionnaire survey
Seifert *et al.* (1997) Bank workers, tellers	LL (Leg)/Symptoms	Stand (>84% of work time)			Cross-sectional/Questionnaire, Interview, work observation
Tuchsen *et al.* (2000) General population	LL/varicose veins	Stand most of time	OR 2.6, 2.3-3.0		Cohort/Telephone interview

HR – Hazard Ratio, OR – Odds Ratio, IR – Incidence Ratio, PR - Prevalence Ratio, RR - Relative Risk, RIR – Relative Incidence Risk, PI – Previous injury, x – interaction, * - significant dose-response trend

Table 4 Physical risk factors for LLD in industrial workers (continued)

Reference/population	*Region of LL/LLD*	*Risk factor*	*Measure of risk*	*Trend*	*Study design/Exposure evaluation*
Woods and Buckle (2006) Cleaners	LL/Aches and pain	Lift equipment Carry loads Push items (furniture/equip) Poor environment (frequent) Vibrating equipment	OR 3.4, 2.5-5.1 OR 4.1,2.8-6.1 OR, 3.4-7.6 OR 2.1, 1.5-3.1 OR 4.0, 2.8-5.8		Cross-sectional/Questionnaire survey, direct observation
Choobineh *et al.* (2006) Hospital nurses	Thigh/Symptoms	Years worked (high) Static posture	OR 1.6, 1.1-2.3 OR 2.2, 1.4-3.5		Cross sectional/Questionnaire survey
Coggon *et al.* (1998) Patients/general population	Hip/OA	Heavy lift (>25 kg, >10yrs) Drive (> 4hrs, <10yrs) Walk (>2miles, >20yrs) Climb stairs (>30 flights)	OR 2.7, 1.4-5.1 OR 4.0, 1.2-13. OR 1.5, 1.0-2.3 OR 1.7, 1.0-3.1	* *	Case-control, matched/Questionnaire, interview survey
Croft *et al.* (1992) General population	Hip/OA-JSN	Lift load (>25 kg, +20 yrs)	OR 2.5, 1.1-5.7		Case-control-matched/Interview survey
Jarvholm *et al.* (2008) Construction workers Males	Hip/OA-Surgically treated	Job (manual work)	IR 1.3, 1.0-1.8		Cross-sectional, cohort/Questionnaire survey
Lau *et al.* (2000) Patients/general population	Hip/OA	Climb stairs (>15 flights/day) Lift (>10kg 10x/wk) F	OR 12.5, 1-104 OR 2.4, 1.1-5.3		Case-control/Questionnaire survey, Clinical examination
Pope *et al.* (2003) General population	Hip-thigh/Symptoms	Sit (>2 hrs/day, 18+ yrs) Lift loads (> 23kg, 13+ yrs) Walk (> 2miles/day, 15+ yrs) Walk rough (> 2mile, 7 +yrs)	OR 1.8, 1.2-2.8 OR 1.9, 1.3-2.8 OR 1.7, 1.1-2.4 OR 2.7, 1.4-4.9		Case-control/Questionnaire survey
Sobti *et al.* (1997) Post office pensioners	Hip/Perceived pain Hip/Replacement	Lift >25 kg/day (20+ yrs) Climb >30 steps	RR 1.5, 1.2-1.8	* *	Cross-sectional/Questionnaire survey

OA – Osteoarthritis, OR – Odds Ratio, IR – Incidence Ratio, RR – Relative Risk, * - significant dose-response trend, JSN – Joint space narrowing

Table 4 Physical risk factors for LLD in industrial workers (continued)

Reference/population	*Region of LL/LLD*	*Risk factor*	*Measure of risk*	*Trend*	*Study design/Exposure evaluation*
Tuchsen *et al.* (2003) General population	Hip-thigh/Symptoms	WB Vibration High demand physical work Squat	OR 1.9, 1.1-2.7 OR 1.8, 1.2-2.7 OR 0.6, 0.4-0.9		Prospective, cohort/Interview study
Baker *et al.* (2003) General population	Knee/Symptoms	Kneel (>1 hr total) Squat (>1 hr total) Up from kneel/squat (>30x) Climb stairs (>30 flights) Job (knee stressing)	OR 2.5, 1.3-4.8 OR 2.5, 1.2-4.9 OR 1.9, 1.0-3.8 OR 2.0, 1.0-4.1 OR 2.3, 1.1-4.8		Cross sectional, case-control/Questionnaire survey
Chen *et al.* (2004) Taxi drivers	Knee/Pain (symptoms)	Drive (8-10 hrs/day) Drive (>10 hrs/day) Job stress (moderate/severe)	OR 2.5, 1.3-4.9 OR 3.1, 1.6-6.1 OR 1.8, 1.1-2.5	*	Cross sectional/Questionnaire survey, Clinical examination
Choobineh *et al.* (2006) Hospital nurses	Knee/Symptoms	Years worked (high) Static posture	OR 1.6, 1.1-4.1 OR 1.5, 1.0-2.2		
Felson *et al.* (1991) General population	Knee/Symptoms	Bend demand (≥medium)	OR 2.2, 1.4-3.6	*	Prospective, cohort/Questionnaire survey
Jensen *et al.* (2000) Floor layers, compositors, carpenters	Knee/Symptoms 12 month, 7 days, >30days	Trade (floor layer/carpenter)	OR 10.9, 6.3-11		Cohort/Questionnaire survey, interview, video observation, clinical examination
Merlino *et al.* (2003) Apprentice construction	Knee/Symptoms	Years worked (>1.5) Work position (awkward) Work position (static) Work condition (inclement)	OR 1.5, 1.1-2.3 OR 1.3, 1.0-1.8 OR 2.1, 1.5-2.9 OR 1.5, 1.0-2.1	*	Cross-sectional/Questionnaire survey

OR – Odds Ratio, * - significant dose-response trend, WB – Whole body

Table 4 Physical risk factors for LLD in industrial workers (continued)

Reference/population	*Region of LL/LLD*	*Risk factor*	*Measure of risk*	*Trend*	*Study design/Exposure evaluation*
Miranda *et al.* (2002) Forestry workers	Knee/ Incident Pain	Trunk flexion (> 1/2hrs) Lift (frequency 31-150)	OR 1.7, 1.2-2.4 OR 1.5, 1.0-2.6	*	Prospective, case-control/Questionnaire Survey
	Knee/ Persistent Pain	Trunk (twist moderately)	OR 3.6, 1.1-11		
Nahit *et al.* (2001) New employees (industrial)	Knee/Pain	Carry load (>23 kg) Kneel (>15 minutes a time)	OR 3.5, 2.2-5.5 OR 1.8, 1.2-2.6		Cross sectional/Questionnaire survey
Sobti *et al.* (1997) Post office pensioners	Knee/Pain	Climb >30 steps (>15 yrs)	RR 1.2, 1.0-1.4		Cross-sectional/Questionnaire survey
Coggon *et al.* (2000) Patients/general population	Knee/OA	Heavy lift (>10kg, >10x/wk) Kneel (>1hr/day total, >30x) Squat (>1hr/day total, >30x) Up kneel/squat (>1hr/d total) Walk (>2 miles/day total) Climb ladder/step (>30x/day)	OR 1.9, 1.0-3.3 OR 2.0, 1.1-3.5 OR 2.8, 1.1-7.2 OR 2.0, 1.1-3.5 OR 2.1, 1.4-3.2 OR 2.3, 1.3-4.0		Case-control/Questionnaire survey, clinical Examination
Cooper *et al.* (1994) General population	Knee/OA	Squat (>30 min/day) Kneel (>30 min/day) Climb stairs (>10 flights/day)	OR 6.9, 1.0-2.6 OR 3.4, 1.3-9.1 OR 2.7, 1.2-6.1		Case-control-matched/Questionnaire survey
Dawson *et al.* (2003) Patients/general population Female	Knee/OA	Bend trunk (>21 years)	OR 7.0, 1.5-9.9		Case-control-matched/Questionnaire survey, Interview
Jarvholm *et al.*(2008) Construction workers-Male	Knee/OA-Surgically treated	Job (blue collar work)	RR 4.7, 1.8-12		Cross-sectional, cohort/Questionnaire survey
Lau *et al.* (2000) General population	Knee/OA	Climb stairs (>15 flights/day) Lift (>10kg 10x/wk)	OR 2.5, 1.0-6.4 OR 5.4, 2.5-12		Case-control/Questionnaire survey, Clinical Examination

OA – Osteoarthritis, OR – Odds Ratio, RR - Relative Risk, * - significant dose-response trend, K/S – Kneel/Squat, HL – Heavy Lift, BMI – Body Mass Index, x – interaction

Table 4 Physical risk factors for LLD in industrial workers (continued)

Reference/population	*Region of LL/LLD*	*Risk factor*	*Measure of risk*	*Trend*	*Design/Exposure evaluation*
Manninen *et al.* (2001) Patients/general population	Knee/OA	Work stress (heavy)	OR 0.4, 0.2-0.9		Case-control/Questionnaire survey, Interview
Manninen *et al.* (2002) General population	Knee/Severe OA	Physical workload (high) F Stand (long duration) Climb stairs (medium) Kneel/Squat	OR 2.0, 1.0-4.0 OR 3.1, 1.3-7.5		Case-control/questionnaire
Rytter *et al.* (2007) Floor layers, graphic designers	Knee/OA-Complaints	Job (floor layer/designer)	OR 2.9		Cross-sectional/Questionnaire survey,
Sandmark *et al.* (2000) General population	Knee/OA	Lift loads Squat or knee bending Kneel Jump Active outside work	OR 3.0, 1.6-5.5 OR 2.9, 1.7-4.9 OR 2.1, 1.4-3.3 OR 2.7, 1.7-4.1 OR 2.2, 1.3-3.6		Cohort, Case-referent/Questionnaire survey
Yoshimura *et al.* (2004) Patients/general population (Female)	Knee/OA	Sit (>2hrs/day) Other jobs Years in Job (> 1 year)	OR 0.4, 0.2-0.8 OR 1.2, 1.0-1.5 OR 1.1, 1.0-1.1		Case-control/Questionnaire survey
Zhang *et al.* (2004) General population	Knee/OA	Squat (>180 min/day)	OR 2.4, 1.3-4.4		Case-control/Questionnaire, survey
Choobineh *et al.* (2006) Hospital nurses	Ankle-foot/Symptoms	Bent or twisted trunk Static posture	OR 2.7, 1.7-4.2 OR 1.6, 1.0-2.3		
Riddle *et al.* (2003) General population	Ankle-Foot/Plantar fasciitis	Standing (>80 % work time)	OR 3.6, 1.3-10	*	Matched case-control/Questionnaire survey and direct measurement

OA – Osteoarthritis, OR – Odds Ratio, F – Female, * - significant dose-response trend

Table 5 Personal (Demographic and health) risk factors for LLD in industrial workers

Reference/population	***Region of LL/LLD***	***Risk factor***	***Measure of risk***	***Trend***	***Exposure determination***
Chau *et al.* (2006) Construct and rail workers	LL (Leg, ankle-foot) / fracture	After work activity (none) Sleep quality (< 6hr/day)	OR 1.8, 1.0-3.6 OR 2.4, 1.2-4.7		Case-control, matched / Questionnaire survey
de Zwart *et al.* (1997) Industrial population - Males	LL/Symptoms	Age (40-49 years)	PR		Prospective (4 year follow-up), case-control/ Questionnaire survey
Fowkes *et al.* (2001) General population	LL/Venous reflux	Height Weight		* *	Cross-sectional/Questionnaire survey
Hilderbrandt *et al.* (2000) Industrial occupations	LL/Prolonged sick leave	Sports activity (little/none)	OR 1.4, 1.0-1.9		Cross-sectional/Questionnaire survey
Forde *et al.* (2005) Union Iron workers	LL (Hip/thigh, knee, ankle/feet) / Symptoms	Age Prior injury (acute)	OR 1.0, 1.0-1.1 OR 5.1, 3.5-7.2		Cross-section, interview, questionnaire
Lemasters *et al.* (1998) Union carpenters	LL (hip)/Symptoms	Previous injury	OR 2.5, 1.1-5.9		Cross-sectional/Questionnaire survey
McBeth *et al.* (2003) General population	LL/Symptoms	Illness behaviour (variable) Fatigue Previous injury	OR 2.9 OR 1.9 OR 2.5		Prospective, population based, questionnaire survey
Andersen *et al.* (2007) Industry and service workers	Hip, knee, foot	BMI (>30) Other chronic disease (yes)	HR 2.3, 1.3-3.9 HR 1.7, 1.1-2.5		Prospective (24 months follow-up), cohort / Questionnaire survey
Cooper *et al.* (1998) Patients/general population	Hip/OA	BMI (> 28.0) Herbenden's nodes (definite) Previous injury Other physical activity	OR 1.7, 1.1-3.3 OR 1.6, 1.2-4.6 OR 4.3, 2.2-8.4 OR 1.6, 1.1-2.2	*	Case control, Matched/Questionnaire survey, Clinical examination of joint

HR – Hazard Ratio, OA – Osteoarthritis, OR – Odds Ratio, PR - Prevalence Ratio, BMI – Body Mass Index

Table 5 Personal (Demographic and health) risk factors for LLD in industrial workers (continued)

Reference/population	***Region of LL/LLD***	***Risk factor***	***Measure of risk***	***Trend***	***Exposure determination***
Lau *et al.* (2000) General population	Hip OA	Body height (2/4th Q) F Body weight (2nd Q) F Previous injury	OR 3.8, 1.5-9.1 OR 2.5, 1.0-6.2 OR 25.1, 3.5-43		Case-control/Questionnaire survey, Clinical examination
Sobti *et al.* (1997) Post office pensioners	Hip/Pain	BMI (>25)	RR 1.2, 1.1-1.4	*	Cross-section, questionnaire survey
Tuchsen *et al.* (2003) General population	Hip-thigh/Symptoms	Gender (Female) BMI (high)		 *	Prospective, cohort/Interview study
Cromie *et al.* (2000) Physical therapists	Knee/Symptoms	Age	χ^2 12.4	*	Case-control,/ Questionnaire survey
Dawson *et al.* (2003) Patients/general population Female	Knee OA	BMI (>25.0) Previous Injury	OR 5.5, 1.0-9.8 OR 3.0, 1.2-7.5		Matched case-control, questionnaire, interviews
Hart *et al.* (1999) General population-Female	Knee/OA-radiographs	BMI (high) Age (High)	OR 2.4, 1.3-4.4 OR 1.9, 1.0-3.4		Prospective (4 year follow-up), case control/ Questionnaire survey, radiographic examination
Langerstrom *et al.* (1995) Nursing personnel	Knees	Age (per 10 yrs) BMI (high)	OR 1.5, 1.1-1.9 OR 3.2, 1.7-5.9		Cross-sectional/Questionnaire survey
Lau *et al.* (2000) General population	Knee OA	Body weight (3/4th Q) History of injury Regular sports	OR -2.8, 1.7-4.4 OR 7.6, 3.8-15 OR 7.4, 2.6-20		Case-control/Questionnaire survey, Clinical examination

χ^2 – Chi-squared coefficient, OA – Osteoarthritis, OR – Odds Ratio, RR - Relative Risk, * - significant dose-response trend, Q – Quartile range of variable

Table 5 Personal (Demographic and health) risk factors for LLD in industrial workers (continued)

Reference/population	***Region of LL/LLD***	***Risk factor***	***Measure of risk***	***Trend***	***Exposure determination***
Manninen *et al.* (2001) Patients/general population	Knee-OA	Age-female BMI (at 40 years)-F Previous injury (M) Non-work activity (high)	OR 1.1, 1.0-1.1 OR 1.1, 1.1-1.2 OR 3.1, 1.4-6.4 OR 0.3, 0.1-0.9		Case-control/Questionnaire survey, interview
Miranda *et al.* (2002) Forestry workers	Knee pain/ Incident-I and Persistent-P	Age (>45)-P Gender (female)-I BMI (>26.0)-I Smoking (ex-smoker)-I Previous injury-I	OR 2.7, 1.1-6.6 OR 1.6, 1.0-2.4 OR 1.9, 1.2-3.2 OR 1.8, 1.2-2.7 OR 2.7, 1.8-4.1	* * *	Prospective, case-control, questionnaire
Sobti *et al.* (1997) Post office pensioners	Knee pain Knee pain Knee Replacement	BMI (>25) Previous injury Previous injury	RR 1.3, 1.2-1.5 RR 2.1, 1.9-2.4 RR 5.3, 2.6-11	*	Cross-section, questionnaire survey
Yoshimura *et al.* (2004) General population	Knee OA (F)	Body weight (high) Previous injury	OR 4.4, 1.2-16 OR 6.8, 2.4-20		Case-control, questionnaire survey
Yoshimura *et al.* (2006) General population	Knee OA (M)	Body weight (high) Previous injury	OR 6.0, 1.2-31 OR 7.5, 2.4-24		Case-control, questionnaire survey
Riddle *et al.* (2003) General population	Foot/Plantar fasciitis	BMI (> 30) Ankle dorsiflexion (<= 0º)	OR 5.6 OR 23.3		Matched case-control, questionnaire survey, direct measurement

OA – Osteoarthritis, OR – Odds Ratio, RR - Relative Risk, BMI – Body mass index, M – Male, F – Female, * - significant dose-response trend

Table 6 Psychosocial risk factors for LLD reported for industrial workers

Reference/population	***Region of LL/LLD***	***Risk factor***	***Measure of risk***	***Trend***	***Exposure determination***
Andersen *et al.* (2007) Industry and service workers	LL (Hip, knee, foot) / Symptoms	Support from colleague (low) Fear physical activity	HR 1.6, 1.0-2.4 HR 1.8, 1.1-3.2		Prospective (24 months follow-up), cohort / Questionnaire survey
Engels *et al.* (1996) Nursing personnel	LL/Symptoms	Work rate (high) Work pace (disturbed)	OR 2.4, 1.2-4.7 OR 2.4, 1.4-4.2		Cross-section/Questionnaire survey
Leino and Hanninen (1995) Engineering factory workers	LL/Symptoms	Work content Social relations (high) Overstrain	CC 0.17 CC 0.31 CC 0.24		Prospective (10 year follow-up) / Questionnaire survey, clinical examination
Jensen and Kofoed (2002) Floor layers and compositors	LL (Hip, knee, ankle-foot)/ Symptoms	Physical work strain (high) Psychological strain (high)	OR 9.1, 1.1-78 OR 2.5, 1.0-6.0		Cross-sectional/Questionnaire, interview survey
Roelen *et al.* (2008) Industrial workers Male	LL/Perceived pain	Physical workload (high) Mental workload (high)	OR 2.6, 1.3-5.2 OR 1.2, 0.6-2.3		Cross-sectional/Questionnaire survey
Seifert *et al.* (1997) Bank workers, tellers	LL/Symptoms	Work pattern (full-time) Superiors (unsatisfied)	OR 2.3, 1.3-3.9 OR 2.6, 1.3-5.3		Cross-sectional/Questionnaire, Interview,
Woods and Buckle (2006) Cleaners	LL/Aches and pain	Work pressure Repetitive task	OR 5.8, 3.0-11 OR 2.5, 1.8-3.5		Cross-sectional/Questionnaire, observation
Lemasters *et al.* (1998) Uniom carpenters	Hip/Symptoms Knee/Symptoms Knee/Symptoms	Work control (low) Feel exhausted (at work end) Work control (low)	OR 2.9, 1.1-7.2 OR 1.8, 1.1-3.1 OR 2.3, 1.2-4.1		Cross-sectional/Questionnaire survey
Chen *et al.* (2007) Community-based population	Knee OA/Symptoms	Paid sick leave (yes) Disability payment (yes)	OR 0.7, 0.5-0.9 OR 0.7, 0.5-0.9		Cross-sectional/Questionnaire, interview survey, clinical examination

HR – Hazard Ratio, OA – Osteoarthritis, OR – Odds Ratio, CC – Correlation coefficient

Table 6 Psychosocial risk factors for LLD reported for industrial workers (continued)

Reference/population	***Region of LL/LLD***	***Risk factor***	***Measure of risk***	***Trend***	***Exposure determination***
Miranda *et al.* (2002) Forestry workers	Knee/Pain (Persistent)	Job satisfaction (low)	OR 2.8, 1.0-7.8		Prospective, case-control/Questionnaire survey

OR – Odds Ratio

3.1 OCCUPATIONAL (PHYSICAL) RISK FACTORS

3.1.1 Occupational group/Job

Occupational group and job title have been investigated with the underlying assumption that they reflect the exposures to the associated risk factors in a job (Jensen and Eenberg, 1996; Holmstrom and Engholm, 2003; Holmberg *et al.*, 2004; Rossignol *et al.*, 2005). The studies indicate that there is an increased risk of LLD for workers in occupations that include tasks, which specifically strain the lower limbs, such as fire fighters, farmers, construction workers, forestry workers, miners, carpet and floor layers and tillers, athletes and military (combatant) personnel.

Chee *et al.* (2004) reported significantly higher risk (OR>3.0) of lower limb pain for wafer-fabrication workers who spent most of their work time standing in one place compared to front of the line and middle of the line workers who frequently changed their work position. They attributed the increased risk of pain to lifting and other such exertion tasks which were often done while standing and intermittently walking short distances. Similarly, Jarvholm *et al.* (2008) found that manual workers had an increased risk of surgically treated knee OA and hip OA compared with office (white collar) workers. The highest relative risk (OR 1.6, 95% CI 1.0-2.7 and OR 4.7, 95% CI 1.8-12.3 respectively for knee OA and hip OA) was found for floor layers who spent much time working on their knees. Based on the findings, the authors opined that for every four cases of surgically treated Knee OA, at least two are related to occupational factors and for every three cases of surgically treated hip OA one is related to occupational factors.

The use of occupational group or job title as a measure of work exposure is, however, subject to error, as job titles do not commonly represent the true exposure of the worker (D'Souza *et al.*, 2005); workers with the same job title can have different exposures based on the workplaces particular needs. Forde *et al.* (2005) amongst others, has called for careful evaluation of task content and exposure profiles inherent in different jobs through direct observation and measurement instead of relying on job nomenclature as representative of exposure. They found that, regardless of anatomical region, work speciality did not associate significantly with current self-reported MSD symptoms. Unfortunately, to date, only few of studies investigating the risk factors for MSDs have included direct observation procedures for evaluation of the workplace exposures (Klussman *et al.*, 2008).

Based on the observations from the literature, the strength of evidence for occupational group/job by itself as a risk factor for LLD is considered to be low.

3.1.2 Duration of employment

Concerning duration of employment, the indications from the literature are generally that many years of working is a risk for experienced workers and that inexperienced workers' are more at risk in the early years of their employment (0-5 years).

Lemasters *et al.* (1998) found, for their studied population of carpenters, that duration of employment (> 20 years) was significantly associated with prevalence of knee disorders (OR 3.5, 95% CI 1.3-9.2). Chee *et al.* (2004) reported significantly higher prevalence of LLD for workers who had spent more than 5 years in their present job (OR 2.0, 95% CI 1.1-4.0). On the other hand, Chau *et al.* (2006) found significantly increased risk of a fracture injury (OR 2.5, 95% CI 1.3-4.9) for railway workers with less than 5 years in the present job compared to those with more than 5 years experience. The study also showed an increased (but non-significant) risk for construction workers with less than 5 years in their present job. Forde *et al.* (2005) reported that the effect of duration of employment might be modified by prior acute injury. Results from the study suggested for the respondents who had a previous LLD increased susceptibility to LLD with longer duration of working with a significant linear trend effect demonstrated. The authors opined that the results indicated a possible long-term disease process, i.e., increased vulnerability to injury over the long-term only.

It may then be that long-term exposure carries little extra risk compared with short-term exposure (only a year or two) as has previously been suggested by Coggon *et al.* (2000). These authors assessed the risk of knee OA for different occupational activities based on work histories, which were ascertained at interview. They opined from the results that when cross-sectional study designs are used to investigate risk associations, the true level of risk might be missed, due to inability to completely randomise the sampling procedure.

Based on the observations from the literature, strength of evidence for duration of employment as a risk factor for LLD is considered to be moderate.

3.1.3 Kneeling/squatting

Kneeling and/or squatting are generally identified as an important risk factor for development of some knee conditions (Cooper *et al.*, 1994; Coggon *et al.*, 2000; Nahit *et al.*, 2001; Baker *et al.*, 2003; Zhang *et al.*, 2004). The risks are found to be higher when kneeling/squatting is sustained for at least half an hour, or it occurs intermittently (on two or more occasions) for more than 2 hours a day. Bending of the knees, such as occurs when loads are lifted from low positions, has also been identified as a risk factor for knee conditions (Felson *et al.*, 1991; Roelen *et al.*, 2008), particularly when it occurs more than 50 times during the workday.

Jensen *et al.* (2000) examined the relationships between knee-straining work, self-reported knee complaints and physical signs of knee disorders for three groups of workers (floor layers, compositors and carpenters). The results showed that floor layers who spend more than half their working day in knee straining positions have a higher prevalence of knee conditions compared to carpenters and compositors (65%, 47% and 14% respectively) and about a fourfold increased risk of knee conditions compared to compositors. Coggon *et al.* (2000) compared patients who were listed for surgical treatment of knee OA and an equal number of control participants from the same communities matched for sex and age. The histories of knee injury and occupational activities were ascertained at interview and the data were analysed by logistic regression. They found that after adjusting for body mass, history of knee condition and the presence of Heberden's nodes as confounding variables, the risk was elevated (OR 2.0, 95% CI 1.1-3.5) for those who reported prolonged kneeling or squatting. The authors concluded from the results that where an excess of kneeling and squatting is reported by cases (injured persons) across a wide range of occupations, confounding factors are not likely to affect the risk associated with kneeling or squatting. Roelen *et al.* (2008) found that those who reported regular bending of the knees associated significantly with reported cases of pain in the legs.

The literature review carried out by Jensen (2008a) concluded that there was moderate evidence for a positive association of the above factors with knee conditions. Of twelve studies, which reported associations between knee OA and kneeling or squatting, six were deemed of sufficiently high quality in respect of the applied methodology.

Based on the observations from the literature, the strength of evidence for kneeling/squatting during work as a causal factor for LLD is considered to be moderate.

3.1.4 Climbing stairs and ladders

Climbing of steps and/or ladders has been identified as a risk factor for the development of hip and knee conditions (Croft *et al.*, 1992; Sobti *et al.*, 1997; Coggon *et al.*, 1998; 2000; Lau *et al.*, 2000; Manninen *et al.*, 2002; Baker *et al.*, 2003). The indications from the studies are that the risks are high when the activity occurs more than 30 times a day or 10 times in an hour, or when more than 30 flights of steps/rungs of ladder are traversed at a time.

Coggon *et al.* (1998) examined associations of prevalence of hip OA with climbing of stairs/ladders in a case-control study. They found that, after adjustment for potential confounding factors, the risk of hip OA was significantly increased (OR 1.7, 95% CI 1.1-3.1) for those who reported that they climbed stairs regularly during work. Also, of all the factors considered, only frequent climbing of stairs showed a pattern that was suggestive of a causal relation.

Coggon *et al.* (2000) reported increased risk of knee OA for males who regularly climbed stairs, but not females (OR 2.7, 95% CI 1.2-6.1). They opined that the absence of an association in women could be because their exposure is different (less use of ladders/stairs than reported by men) or simply due to chance. The review by Jensen (2008a), found five studies, which investigated the relationship between knee OA and climbing stairs, and considered four of the studies to be high quality studies in respect of the applied methodologies. The author, however, concluded from the review that the evidence for stair climbing, as a risk factor for knee OA was low and the evidence for ladder climbing was ambiguous.

Based on the observations from the literature, the strength of evidence for climbing stairs during work as a risk factor for LLD is considered to be low/weak.

3.1.5 Manual handling of loads

Lifting of loads, particularly those weighing more than 20 kilograms, is indicated in several studies as a risk factor for hip and knee conditions, but more so for males than females (Bork *et al.*, 1996; Sobti *et al.*, 1997; Sandmark *et al.*, 2000; Dawson *et al.*, 2003; Chen *et al.*, 2006). It has also been suggested that the risks are increased when lifting is done simultaneously with knee bending, kneeling or squatting, though this association is less clear (Jensen, 2008b).

Dawson *et al.* (2002) found a high prevalence of foot problems (83%) including foot pain, corns and bunions, but only for those who had spent several years in occupations requiring regular lifting of loads. Coggon *et al.* (1998) reported significantly increased risk of hip OA in males (but not females) who regularly lifted weights of 10 kg or more while at work, increasing progressively with the duration and heaviness of such lifting. The absence of an association of hip OA with occupational lifting for females suggested a greater impact of confounding by non-occupational factors. Jensen and Dahl (2005) reported the case of a 59 year-old male welder who presented with a stress fracture to the left distal tibia and fibula after engaging in daily repeated heavy lifting at work without bending of the knee. Coggon *et al.*, (2000) opined that the association of load lifting alone with a LLD condition tends to be weaker than those suggested for kneeling and squatting alone.

A literature review (Jensen, 2008b) concerning load lifting as a risk factor for hip conditions amongst other factors, found 17 studies that were directly relevant. Of these, only six studies were considered to be of high quality. The alternate review (Jensen, 2008a), which concerned the risk factors for knee conditions, found four studies that assessed the evidence for the combination of heavy lifting and kneeling/squatting. Of these, two studies were considered to be high quality studies, though none of the identified studies for hip and knee conditions had investigated a dose-response relationship either in relation to the amount lifted (kg), frequency of lifting, duration of lifting or the cumulative years of lifting. Jensen concluded from the two reviews that the evidence for a causal relationship of manual handling alone or in combination with kneeling/squatting was moderate.

Based on the observations from the literature, the strength of evidence for manual handling of loads during work as a risk factor for LLD is considered to be low/weak.

3.1.6 Walking or Standing (working on feet)

According to Bzovi (2000), when static standing occurs, it decreases the circulation of blood and reduces the nutrient supply to muscles, thus allowing muscular fatigue to set in. The consequences of fatigued legs include increased tendency to fall by slipping and tripping, and development of chronic lower back pain in some workers. Furthermore, a worker's productivity is also thought to decline after they are forced to stand on hard work surfaces for more than four hours.

Additionally, standing for long periods (>2 hours per day) has generally been associated with development of venous disorders of the lower limbs and discomfort at the ankle/foot (Ryan, 1989; Seifert *et al.*, 1997; Tuchsen *et al.*, 2000; Chee *et al.*, 2004; Andersen *et al.*, 2007). Walking long distances (> two miles per day) and over rough terrains has been associated with development of stress fracture (of the lower leg) and conditions of the knee and ankle/foot (Engels and Gulden, 1996; Coggon *et al.*, 2000; Pope *et al.*, 2003; Chen *et al.*, 2006).

Tomei *et al.* (1999) opined that professions involving prolonged standing (>50% of the work shift) could influence the development of venous pathologies. Reina *et al.* (1997) concluded from a literature review that apart from the generally accepted risk factors of age, sex, race, and parity, other risk factors such as profession (particularly those involving prolonged standing) play a role in the development of varicose veins and CVI. Ryan (1989) found an association between the amount of time spent standing and the number of lower leg complaints, and that when workers spent most of the work time standing they had the highest prevalence of lower leg complaints. The analysis did not adjust for BMI, work history and other possible confounders but the method of occupational exposure assessment was a major strength. Riddle *et al.* (2003) found significant association (OR 3.6, 95% CI 1.3-10.0) of the reported cases of foot/ankle disorders (Achilles tendonitis and Plantar fasciitis) with time spent working on feet (> 80% of work day). There was however, no data presented on the extent and duration of the exposure, nor on the particular occupations and work histories of the cases and controls.

Conversely, studies by Evans *et al.* (1994) and Hobson (1997) did not find consistent associations between standing and varicose veins (VV) though the latter concluded that evidence existed to support association between prolonged standing at work and venous disease. Jawien (2003) concluded that the contribution of standing to development of VV was unclear, though more participants who were diagnosed with chronic venous insufficiency (CVI) had occupations that required prolonged standing, than those who were not so diagnosed. Furthermore, Chee and Rampal (2004) reported that, of 55% of the cohort who were exposed to prolonged standing at work, a large proportion (52%) experienced pain in the lower limbs and there was a clear association between the two variables. Flore *et al.* (2007) showed that healthy workers who stood for prolonged periods during their working day had significantly higher levels of reactive oxygen species (ROS) in their systemic circulation after work than controls. ROS was measured as an indicator of oxidative stress, which is thought to be a risk factor for chronic venous insufficiency and other systemic diseases.

Based on the observations from the literature, the strength of evidence for standing during work as a causal factor for LLD is considered to be moderate.

3.1.7 Sitting

The evidence for sitting at work as a risk factor is contradictory, with some suggesting increased risk, particularly for sitting more than 2 hrs (for example, Pope *et al.*, 2003), and others suggesting decreased or no risk, though this is often in comparison to standing (Yoshimura *et al.*, 2000; Fowkes *et al.*, 2001; Baker *et al.*, 2003).

Pope *et al.* (2003) examined the prevalence of hip pain and its association with occupational activities in a population based case-control study. They found a significant association between prevalence of hip pain and sitting for greater than two hours without break after adjustment for age, and gender. Yoshimura *et al.*, (2000) performed a case-control study of hip OA and found that the participants who reported spending more than two hours each day sitting during their first job (first actual employment) were statistically less likely to have the condition. Yoshimura *et al.* (2004) made a similar observation in respect of the risk factors for development of knee OA. They found from a case-control study of women including those who had been diagnosed with knee OA that sedentary work during initial employment was one of the independent factors associated with knee OA after controlling for potential confounding factors (OR = 0.35, 95% CI 0.15-0.84). Chee *et al.*, (2004) conducted a cross-sectional survey of semi conductor factories to identify risk factors in the work processes, the prevalence of body pain among workers and the relationship between body pain and work processes. A total of 906 female workers were involved. The results showed that in the semiconductor assembly end-of-line work section, chip inspection workers who were exposed to prolonged sitting without back support had 36.7% prevalence of lower limb pain. Though the sitting durations were assessed by direct observation (a walk though survey), the association of lower limb pain prevalence and duration of sitting was not statistically investigated.

Based on the observations from the literature, it is opined that there is plausible but limited evidence to support sitting as a risk factor for LLD, particularly knee and ankle injury.

3.1.8 Driving

Driving, particularly for long durations (> 4 hours at a time), has been suggested as a risk factor for hip and knee conditions.

Jarvholm *et al.* (2004) tested the hypothesis that driving vehicles with high levels of whole-body vibration is associated with an increased risk of hip OA (in terms of subsequent joint replacement) with a cohort study of male operators of heavy vehicles. The results showed a non-increased risk of joint replacement due to OA for the operators who were exposed to whole body vibration. On the other hand, Tuchsen *et al.* (2003) investigated the prevalence of hip pain and occupational exposure to risk factors among a general population of employed persons, with a prospective (five year follow-up) study. The results showed a significant association of whole body vibration with hip pain after adjustment for confounding factors (OR = 1.9, 95% CI

1.1-2.7). Chen *et al.* (2004) explored the association of daily driving with knee pain in a cross-sectional study involving 1242 taxi drivers and four categories of driving duration (< 6 hours, 6-8 hours, 8-10 hours, > 10 hours). In comparison with the first duration category of < 6 hours, the results showed increased risk for the other three categories (OR = 2.5, 95% CI 1.3-4.9 and OR = 3.1, 95% CI 1.6-6.1 respectively), and a dose-response association.

Based on the observations from the literature, the strength of evidence for driving as a risk factor for LLD is considered to be plausible but not conclusive.

3.1.9 Jumps from height

"Jumps from height" can be considered as a risk for LLD. This action is often performed within the workplace, particularly by drivers of large vehicles (when exiting the cab). This means that various body joints could be subject to excessive levels of force during the landing phase, which may in turn lead to acute or chronic injuries (Fathallah and Cotnan, 2000). The indications are that there is an increased risk when the jump is from a position > 1 metre high from ground level or it is performed more than 20 times a day.

Fathallah and Cotnan (2000) investigated the impact forces of ten male participants while exiting two tractors, a step-van, a box-trailer and a cube-van. They found that impact forces as high as 12 times bodyweight were generated when exiting was done without use of provided accessories (steps, grab-rails); however, full utilisation of the steps and grab-rails resulted in impact forces that were on average less than twice body weight. Giguere and Marchand (2005) investigated the impact forces and biomechanical stress on the lower limbs of fire fighters when they stepped down from various parts of their emergency vehicle, backing the street (facing the truck) and facing the street. The results showed that stepping down from the cab facing the street produced impact forces that were about 3.2 times body weight, whereas, stepping down backing the street (facing the vehicle) produced significantly less impact force and better distribution of the energy over time, which they attributed to better control of the descending leg, and ability to utilise the provided assist aids (grab rails).

Some sources have opined that "jumps from height" may account for an appreciably high fraction of reported occupational injuries (for example, Champoux and Cloutier, 1996), but no data that specifically addressed the association of occupational jumping from heights with lower limb injury could be found.

It can then be considered that while demonstrating appreciable face validity as a risk factor, there is only limited evidence available for "jumps from height" as a causal risk factor for LLD.

3.1.10 Slips and trips hazards

These ergonomic stressors refer to the presence of raised edges and gaps in floor levels, uneven nature of floors and low friction characteristics of the floor surfaces in the workplace.

McMillan and Nichols (2005) opined that other factors such as prolonged kneeling and squatting might predispose the knees to damage (of the menisci) when the worker slips, trips or seeks to avoid falling objects and so forcibly rotates the knee joint. Kumar (2001) reported the case of a 34 year-old male roofer who sustained an injury when he was stepping on some gravel and his right knee twisted and "popped". Thereafter, he could not straighten the knee and he could not bend down. Medical diagnoses for the condition were right knee medial meniscus tear and intra-cruciate ligament tear. The case of a 42-year-old labourer who injured his right knee when his ‘leg fell in a hole’ was also reported. This patient was diagnosed with medial collateral ligament strain. Both of these workers often adopted kneeling and squatting postures during their work.

Some sources have suggested a predisposing effect of work factors (for example, Bruchal, 1995). This author reported a link between kneeling at work and laxity of the knee joint and that this laxity appeared to be responsible for initiation of most cartilage tears that mine workers at the time suffered.

Based on the observations from the literature therefore, there is sufficient evidence for slips and trips hazards to be considered as a risk factor for LLD.

3.2 PERSONAL AND PSYCHOSOCIAL RISK FACTORS

A number of personal and psychosocial factors, are identified in the literature as associated with risks for LLD (Table 5 and Table 6) but those that have been most often associated with increased risk are: Previous injury, physical condition (no activity outside work), obesity, gender, lack of job satisfaction, low level of control over work, little or no social support from colleagues and no support from supervisor. Gallis (2006) suggested that personal risk factors help to mitigate pain suffered and do not play a direct role in symptom development; Miranda *et al.* (2002) on the other hand, opined that psychosocial factors tend to be associated more with persistence of pain rather than incidence of symptoms.

3.2.1 Previous injury and physical activity (outside of work)

It is generally accepted that previous injury of the lower limb increases the risk of a person suffering a new injury (Lemasters *et al.*, 1998; Cooper *et al.*, 1998; Manninen *et al.*, 2001). Cooper *et al.*, (1998) analysed the role of different individual risk factors for hip OA and opined that previous injury is an important independent factor.

Previous injury is considered to present a long-term risk, and the effect has been attributed to the fact that performance of physical activities outside of work improves work ability and balance control (Chau *et al.*, 2006). Hilderbrandt *et al.* (2000) found that non-participation in sport associated with prolonged sickness leave due to symptoms of the lower extremity. Additionally they found that workers in inactive jobs who reported many non-sedentary activities outside of work tended to have fewer symptoms and less sickness leave due to lower extremities injuries and pain. The study by Lau *et al.* (2000), a case-control investigation on hospital patients with hip OA (n = 138) and knee OA (n = 658), found that amongst other risk factors, history of joint injury was significantly associated with the two conditions in both males and females ($p < 0.05$). Cooper *et al.* (1998) explored individual risk factors for hip OA in a population-based case-control study. A total of 611 patients (210 men and 401 women) listed for hip replacement because of OA over an 18-month period were compared with an equal number of controls selected from the general population and individually matched for age, sex, and family practitioner. The results showed that previous hip injury was an independent risk factor for hip OA among men and women and there was a weak positive association with prolonged regular sporting activity.

Therefore, based on the observations from the literature, there is appreciable evidence that previous injury predisposes the worker to further injury, particularly when they engage in little or no physical activity outside of work.

3.2.2 Age, gender and obesity

The evidence for age as a risk factor is contradictory, in that some identified significant association while others did not. Notwithstanding, it is generally reported that older workers are more predisposed to MSD conditions than younger workers (Callum, 1994), due to the natural degradation of the body that occurs with aging.

In respect of gender as a risk for LLD, Sandmark (2000) reported a higher prevalence of symptomatic knee OA, earlier injury and surgery to the knee in female than in male PE teachers, such that the rate ratio for sick leave due to knee conditions was 1.7 (95% CI 1.2 to 2.5) for the male, and 1.6 (95% CI 1.1 to 2.5) for the female PE teachers. The female PE teachers also had a rate ratio of 3.7 (95% CI 1.5 to 9.1) of having had to change work due to knee dysfunction, and among the men the increased rate ratio was 2.2 (95% CI 0.9 to 5.6).

In respect of obesity, the indications are those of a strong association with knee OA (Langstrom *et al.*, 1995; Hart *et al.*, 1999; Miranda *et al.*, 2002; Dawson *et al.*, 2003) and a plausible but inconclusive association with hip OA (Cooper *et al.*, 1998; Lau *et al.*, 2000). The study by Callum (1994) concluded that the epidemiological evidence at the time did not support an association of obesity with VV for females. Though the observed associations of obesity with different conditions have often been attributed to increased loading of the lower limb joints in obese persons, the association is also compatible with a generalised systemic predisposition to the disorder.

Based on the observations from the literature, there is compelling evidence for advanced age, female gender and obesity (high body mass index [BMI]) as risk factors for hip and knee OA; the evidence is plausible but not conclusive for most other conditions.

3.2.3 The psychosocial factors

Few studies have investigated the role of job related psychosocial stressors and work organisation issues in the occurrence of work-related MSDs including LLD.

Lemasters *et al.* (1998) found that minimal influence over work schedule was significantly associated with prevalence of hip and knee conditions and that feeling exhausted at the end of the day was significantly associated with prevalence of knee conditions and having previous illness with prevalence of hip conditions. Chau *et al.*, (2006) reported an association of fatigue/sleep disorder with different conditions, which they attributed to altered health status and work ability. Leino and Hanninen (1995) investigated the association of work content, work control, social relationships at work, mental overstrain with conditions of the neck, shoulder and upper limb region, the low back or the lower limbs and whether the possible associations were independent of physical workload. After controlling for age, gender, social class and physical workload, the results showed that mental overstrain and most of the other factors were associated with both the symptoms and clinical findings of LLD. Additionally, it was found after a ten-year follow-up period that, social relations and work content score predicted the change in several morbidity scores thereby suggesting a causal relation of the factors. Furthermore, the associations identified were independent of physical workload.

Poor satisfaction with the social relationships at work, lack of control over work, feeling exhausted after work and work content are shown as the psychosocial factors most likely to impact on LLD.

3.3 SUMMARY

Various factors have been investigated as work-related ergonomics stressors for lower limb disorders, but it is the physical factors that are suggested to contribute most (as causal agents) to incidence of symptoms. In respect of the physical factors, there is medium evidence of a causal association for the following:

- Kneeling/squatting,
- Climbing stairs or ladders,
- Heavy lifting,
- Walking/standing
- Slips and trips hazards.

The evidence of a causal association is plausible but less clear for the following factors:

- Jumps from height
- Driving, particularly continuously for more than four hours
- Sitting, in an awkward position or for long durations at a time (>2 hours), particularly for hip pain. It must be mentioned however, that, sitting, as a work posture, has often been investigated comparatively with standing, and generally showed a negative association with lower limb (knee and ankle/foot) pain. This indicated that it is a preventive rather than a causative factor, when compared with standing.

4 RISK REDUCTION AND CONTROL

A goal of ergonomics is to match the work environment/job to the limitations and capabilities of the human operator (Carter and Banister, 1996); the goal of occupational safety and health intervention is to prevent disease and injury through combinations of techniques, such as control technologies, exposure guidelines and regulations, and worker participation programmes. Various interventions have been proposed for the control and reduction of MSD risks in workplaces, and their effectiveness has been evaluated in prospective studies and systematic reviews (Finestone *et al.*, 1992; Handoll *et al.*, 2001; Rivara and Thompson, 2000; Gillespie and Grant, 2000; van der Molen, 2007). Findings in respect of different strategies are presented in this chapter.

4.1 WORK REDESIGN/MODIFICATION

Work redesigns/modifications as approaches to risk reduction, are introduced to reduce the risk of MSDs and to facilitate return to work of employees already suffering a work related injury (Brooker *et al.*, 2001). In itself, however, modified work may not influence the total duration of sick leave due to musculoskeletal complaints as has previously been suggested by van Duijn *et al.* (2005). Two questions may be asked, first, is the task or particular technique necessary or can it be done away with? Secondly, can the associated operations be automated or mechanised, if this is reasonably practicable? Introduction of automation or mechanisation may, however, create other new risks, which would need to be guarded against (Mital, 1992; Bust et al., 2005).

Jensen and Friche (2008) investigated implementation strategies for introducing new work tools and work methods in the floor laying trade and concluded that one consisting of different measures was most effective. The new working method, which required the workers to stand instead of kneel or squat, showed a reduced risk of severe knee disorders and a reduced level of perceived knee pain in those who already had knee pain. Furthermore, the new work method did not appear to cause musculoskeletal health problems in other parts of the body. The authors opined that the strategy may also succeed in other trades in the construction industry, but it takes time to implement and requires very good collaboration between the employers and trade union.

Wergeland *et al.* (2003) examined the relationship between daily work hours in physically demanding care work and the occurrence of MSDs with particular emphasis on neck-shoulder and back pain. The data were collected from three independent projects involving a pre-interventions group and a post-interventions group of participants. The intervention trialled was a reduction in work hours from ≥ 7 hours to 6 hours per day (or 30 hours weekly). The results showed a significant decrease in the prevalence of neck-shoulder pain (from 40.9% to 25.6%), but not back pain, after 1.5 years for those allocated to the 6-hour daily workday program but not for those who maintained the traditional ≥ 7 hours workday program. Yeung and Yeung (2001) assessed the available evidence for different prevention strategies for LLD though this was in relation to injuries from running and concluded that there was sufficient evidence for the effectiveness of redesign strategies that reduce the intensity of the activity.

Brooker *et al.* (2001) investigated the prevalence of work modification interventions and policies applied for rehabilitation of injured workers and identified that transfer to lighter jobs was the most common type of modified work, followed by flexible schedule and reduced hours.

Actual change to the workplace layout or the work equipment was however, reported as uncommon. The authors concluded that there was need for consideration of societal factors that might encourage increased implementation of redesigned work and develop related return to work programs.

The work by Nicholson *et al.* (2006) discussed benefits of twenty-nine case studies of ergonomics workplace redesign/modification interventions to reduce the risks of MSDs of which five were specifically in respect of LLD. Benefits were established by calculating the investment cost of the intervention and comparing that cost with quantified gains (before-and-after intervention analysis), such as changes to sickness absence, productivity rates, staff turnover, reduced waste of materials and quality of output. Where benefits were difficult to quantify, testimonials (informed statements and comments of workers, managers and/or health and safety staff) were used to describe the benefits. The results showed clear benefits for most of the interventions (in terms of perceived worker satisfaction and demographic data such as sickness absence), particularly where the company had already started to incur costs due to sub-optimal task design or workplace organisation.

These observations suggest that workplace redesign/modification interventions can help prevent/control LLD in the workplace, particularly when the worker is thereby encouraged to adopt optimal work positions/postures and to exert reduced levels of tasks forces. Barring societal factors that might discourage implementation of the measures, there are also real cost benefits to be gained.

4.2 PROTECTION EQUIPMENT

Two groups of protection equipment are differentiated: Personal protection equipment and handling assist devices.

4.2.1 Personal protection equipment

The protection equipment that have often been reported on in respect of lower limb injuries are: Hip protectors and knee pads, shoe insoles, limb supports and anti fatigue matting.

Hip protectors and knee pads

The efforts to provide protection devices for the hip have largely been in relation to falls of the elderly. Minns *et al.* (2004) for example, discussed different designs of hip protectors available at the time and assessed their effectiveness at providing impact resistance during falls of patients in geriatric wards/nursing homes. They found that when properly positioned on the joint, many of the protectors reduced the impact pressures on the hip. No study could be found that considered their use in an occupational setting, as such, appart from impact forces that may act on the hip during a fall, the devices may not be useful for preventing injury in an occupational setting.

Knee pads are useful for protection of the knee while kneeling on hard floor surfaces, particularly against bursitis conditons, but they do not mitigate the risks of exteme flexion of the knee. Their benefit is largely in respect of preventing lacerations and penetrating injuries, as well as improving comfort by reducing contact stresses (Marras *et al.*, 2004); it is not known whether they reduce the risk of other disorders such as OA and meniscal lesions (Coggon *et al.*, 2000; Marras *et al.*, 2004). Also, one style of protection device is not likely to fit all needs, as has previously been report by Tanaka (2000). This author identified that knee pads used by tile setters must be resistant to the moisture, while carpenters would seldom work on wet surfaces and roofers probably should not wear pads with a slippery outershell. Some caution is therefore required during their selection. However, favourable worker comments indicated that when they are applied they do eliminate some of the strain associated with work (Sanders *et al.*, 1981; Tanaka, 2000; Marras *et al.*, 2004).

Shock-absorbing insoles and modified shoes

These devices have been recommended for the prevention of stress reactions or fractures and various studies have reported on their effectivenes (for example, Milgrom *et al.*, 1992; Torkki *et al.*, 2002; Rome *et al.*, 2005; Shaffer and Uhl, 2006).

Torkki *et al.* (2002) for example, investigated the effectiveness of individually fitted sports shoes against overuse injuries to the lower limb among newspaper carriers and found a difference in favour of the test group with respect to lower limb pain intensity and number of pain days when compared with the control group. There was no difference in the number of diagnosed overuse injuries between the groups. The authors concluded from their study that individually adjusted shock-absorbing shoes offer slight health benefits for lower limb overuse injuries. Milgrom *et al.* (1992) on the other hand found that military recruits who trained in shoes modified with shock-absorbing insoles had a statistically significant lower incidence of metatarsal stress fractures and foot overuse injuries, compared with those who trained in standard infantry boots. These authors concluded that the positive effect seemed to be only in respect of injuries that result from vertical impact loads.

The indications from the studies, are first that the evidence for the effectiveness of shoe insoles is limited and secondly, that the positive effects are largely only in respect of injuries that result from vertical impact loads.

Limb support devices

Limb supports have been recommended for relieving the strain on the knees and on the ankle/foot, there do not appear to be any feasible support devices for the hip.

The support devices that were proposed for releaving stress on the knee are aimed at providing support for the weight of the trunk and buttock/thigh during kneeling. Secondly, they are aimed at preventing maximal flexion and load bearing at the knee(s). Kumar (2001) describes such a device (a customised shin pad) which was introduced for use by roofers and labourers who had been diagnosed with a knee problem, as an intervention to eliminate both contact pressure on the knee during kneeling and compression of the knee joint with stretching of the collateral ligaments (illustrated in Figure 1). Major benefits associated with application of the device were that the workers were enabled to adopt kneeling positions during work without any contact pressure on their knee, that the occurrence of contact pressure points on the lower leg due to load bearing is eliminated and that the ankle is kept free of any load bearing.

Ankle supports have often been proposed for prevention of sports injuries, and primarily consist of ankle braces and various techniques of ankle tapeing. They tend to be recommended for post injury return of individual sports persons to work (Lewis, 2006). Their suitability for preventing occupational injuries has not been demonstrated.

These observations indicate that implementing limb support devices can be an effective intervention against LLD in occupational workplaces or aggravation of injury, particularly against knee injury.

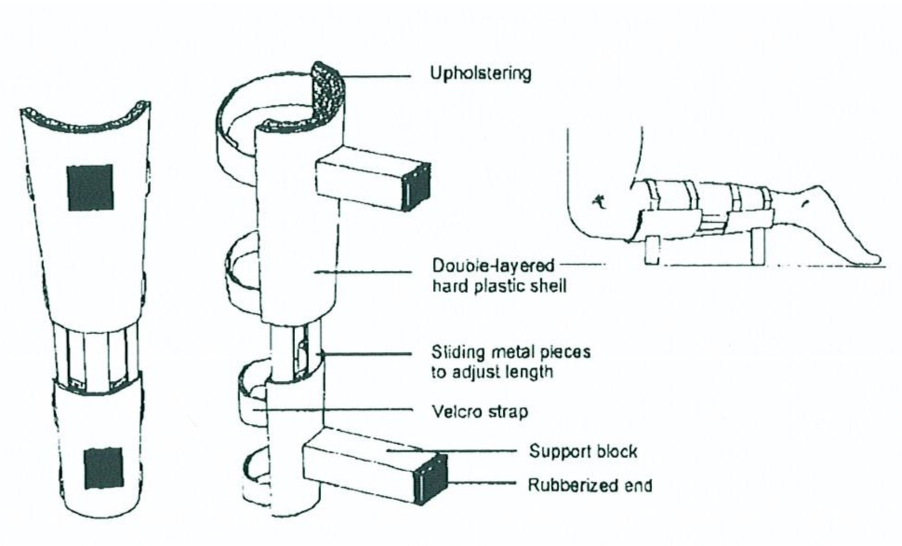


Figure 1 The adjustable shin pad device for relieving knee pain (Kumar, 2001)

Anti-fatigue matting (and compression stockings)

Anti-fatigue mats and compression stockings have been recommended for use in situations where workers have to stand for long periods and several studies have reported on their effectiveness (Kim *et al.*, 1994; Bzovi, 2000; King, 2002; Zander *et al.*, 2004; Flore *et al.*, 2007). According to Bzovi, (2000), anti-fatigue mats help reduce fatigue in the legs by encouraging muscular motions; the cushioned support provided by matting promotes muscular motion, which minimises blood pooling in the feet and legs and reduced muscular fatigue.

Flore *et al.* (2007) showed that the vascular pressure increases in the legs from prolonged standing could be reduced through the use of compression stockings. This was such that during the second day of wearing compression stockings, no increase in mean venous pressure was observed after work in both the study and control groups. The authors stated that compression stockings seem to be a useful and easy preventive measure against oxidative stress in healthy workers who stand for long periods, especially when other preventive measures, such as rest breaks, mini breaks or chances for ambulation while working, are not possible. Zander *et al.*, (2004) examined the effects of different flooring conditions (wood block floor, anti-fatigue mat) on standing fatigue in the workplace in terms of changes in lower leg volume over an 8-h shift. They noted that leg volume increased for all subjects following exposure to each of the interventions. The findings suggested that implementation of the fatigue mat alone may have little effect on controlling leg oedema for workers exposed to standing for 8-h shifts.

These observations suggest that there is plausible but not conclusive evidence for the effectiveness of anti-fatigue matting and compression stockings as interventions against LLD that are due to prolonged standing. Implementing such measures in the workplace may therefore require careful consideration.

4.2.2 Handling assist devices

The usual selection of manual handling aids such as trolleys, carts, etc., to move loads may be used to try to miminise lower limb injuries. Portable adjustable tables, lifting aids, extended handle bars and other even simple low-cost tools may also be introduced to enable performance of operations at better working heights (Cromie *et al.*, 2000; Marras *et al.*, 2004). Cromie *et al.*, (2000) reported height-adjustable beds, lifting belts, slide boards, splints and stools on casters as strategies used by physical therapists to avoid the development of work related MSD including LLD.

While use of assistive devices and handling aids may be effective for controlling risks in a regular work place or work situation, there is evidence that they may not be applied even when available. Jensen and Kofoed (2002) found for their surveyed group, consisting of floor layers, that handling aids may not be applied when they are cumbersome to operate or they are perceived as causing the working time to be increased. Also, the presence of wires and cables on the floor often made it impracticable for mechanical aids to be used.

4.3 SOCIO-ORGANISATIONAL REGIMES AND/OR TRAINING

The influence of workplace policies as interventions for preventing injury and controlling risks has been reported on appreciably in the literature; particularly exercise regimes and participatory initiatives (Nurminen *et al.*, 2002; Proper *et al.*, 2003; Olsen *et al.*, 2005; Chen *et al.*, 2007; Schwarz *et al.*, 2008). Others have considered the role of regulations and codes of practice (McLean and Richards 1998; van der Molen *et al.*, 2007).

Nurminen *et al.* (2002) evaluated the effect of worksite exercise intervention (participation in worksite exercise, sixty minute sessions once every week) on perceived work ability and sick leave for a group of women engaged in physically demanding laundry work. The results showed a greater increase in the number of workers with good/excellent work ability (11.0%, 95% CI 0.2-21.9), as well as the health-related prognosis of work ability (8.1%, 95% CI 0.5-16.3) in the intervention group when compared with the control group after a 12-month period. Furthermore, there were no statistically significant differences between the two groups as regards job satisfaction, work ability index, or sick leave.

Chen *et al.* (2007) demonstrated the importance of looking beyond individual-level risk factors and examining organisational level workplace characteristics in relation to knee symptoms and OA. They found that individuals employed in workplaces offering better policies for occupational health had less knee symptoms and lower prevalence of symptomatic or asymptomatic knee OA. Roquelaure (2008) pointed out that designing effective interventions to alter physical work demands and MSD symptoms is necessary but insufficient to prevent MSDs, since results depend on the implementation strategy. They identified a need to develop research on intervention studies, which improve our understanding of different prevention strategies particularly those that are usable in the workplace. Hilderbrandt *et al.* (2000) concluded from their study that stimulation of participation in sport and other leisure activities in order to avoid inactivity, could be one of the means to reduce musculoskeletal morbidity in sedentary workers.

The literature review by van der Molen (2007) assessed the effects of three types of regulatory interventions for preventing injuries among workers at construction sites: Regulations, safety campaigns and drug-free workplace programs. They concluded that, the vast majority of technical, human factors and organisational interventions, which are recommended by standard texts of safety, consultants and safety courses, have not been adequately evaluated.

4.4 SUMMARY

The efforts to understand the causes of MSDs in the workplace have proposed a range of different interventions for controlling risks and preventing injuries, particularly back and upper limb injury. These include workplace redesign/modification initiatives, regulations, safety campaigns, guidelines, implementation of protection equipment (personal protective equipment and handling devices), and training and participatory programs.

Workplace redesign/modification initiatives, implementation of protection equipment and participatory programmes appear to be the most suited interventions for control of LLD risks. Although individual engineering and administrative contols showed positive effects in themselves, the greatest results appear to be achieved when a combination of measures are applied (Wesgaard and Winkel, 1997; Carrivick et al., 2001; Jensen and Fritch, 2008).

5 DISCUSSION

This work was undertaken to examine more closely the nature of workplace related LLD towards informing evidence based guidance and advice. The literature reviewed has confirmed that LLD, are a problem in many workplaces and that there are real consequences of the injuries for society, the economy and industry in terms of lost work time, medical treatment and hospitalisation, decreased work ability of employees and decreased quality of life. Three key observations were made:

- First, both acute and overuse injuries may be suffered by occupational workers, but overuse injuries tend to prevail, particularly, hip OA, knee bursitis and meniscal lesions/damage, and stress fractures and venous disorders of the lower legs and feet,
- Secondly, factors related to the work itself, to the worker and to the work environment may contribute to LLD occurrence.
- Thirdly, despite the efforts to understand MSDs and several interventions developed to control the risks and prevent their occurrence, there are still doubts about the efficacy of many of the control strategies.

5.1 FRAMEWORK OF LLD AND THE RISK FACTORS

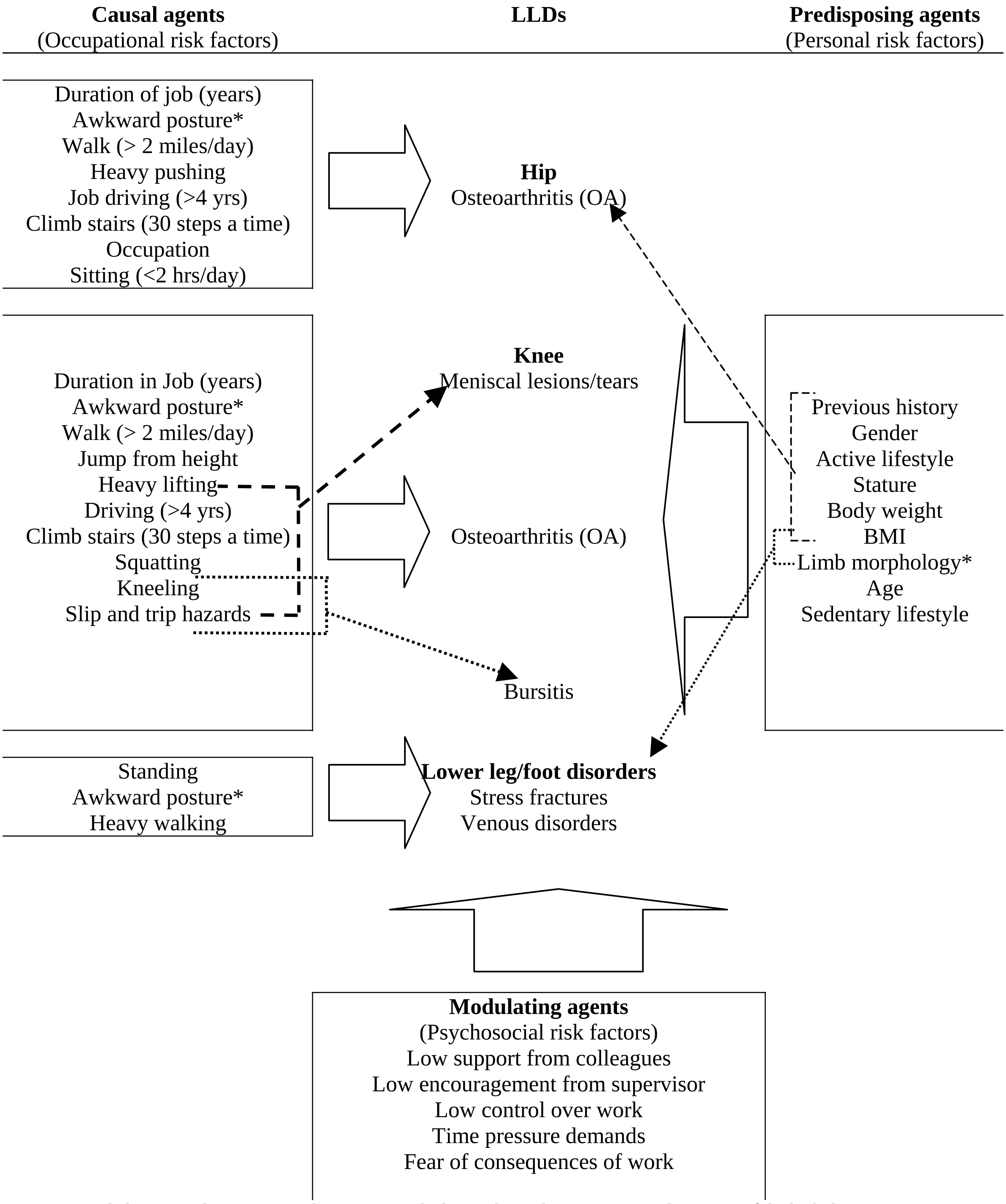
A framework for LLD and the risk factors has been developed based on the observations from the literature and this is shown in Figure 2. The framework provides an overview of the likely risk factors for regional conditions of the limb and how they might act. All the factors featured have been found to associate significantly with pain and other symptoms of LLD or have been associated with specific disorders and the focus is on the most commonly reported conditions.

It can be seen from Figure 2 that the risk factors for LLD conditions are not specific to any region or type of condition and that more factors have been identified as risk factors for knee conditions than for either hip or lower leg/ankle conditions. This could be due to a number of factors such as study design; the majority of the studies that investigate risk factors generally applied cross sectional and case-control study designs, and defined the conditions in terms of spurious effects such as perceived fatigue, perceived pain and complaints. Only a few studies applied prospective study design methodologies. Furthermore, the conclusions about the risk factor associations were largely based on uni-variate analyses and often precluded consideration of dose-response effects, which are strong indicators of causal associations.

Anderson *et al.* (2007) opined that self-reports of physical exposure could easily be influenced by the person’s pain status and common beliefs held in different occupational groups about the occupational hazards experienced could influence self-reporting of exposure. Coggon *et al.*, (1998) opined for case-control studies that a spurious association could occur when individuals with injury recall past exposures more completely than those without injury.

Various systematic reviews that evaluated the evidence concerning risk factors for LLD (for example D’Souza *et al.*, 2005; Jensen, 2008a,b) identified important drawbacks with the cross-sectional design methodology, such as, poor assessment of the physical exposures to risk factors and an inability to make causal inferences from the results. Furthermore, a prospective cohort study is generally judged as the preferred design, followed by a case-control study and then by cross-sectional studies.

Thus, the suggestion that there are many more risk factors for knee conditions generally than for hip and lower leg/foot conditions and for knee OA than for other specific knee conditions, may be attributed to the fact that many more of the studies concerning LLD have been focused on the knee as the region of injury and OA.



* Anatomical alignment, this is suggested to impact on the biomechanical stresses imposed on joints of the limb during activity.
*Awkward posture, constrained or twisted positions of the limbs

Figure 2 The developed framework of LLDs and the risk factors

A third implication of Figure 2 is that the causal risk factors for specific medical conditions are much fewer in number than those in respect of non-specific symptoms. Studies regarding this, generally applied prospective cohort or case-control study designs (considered to be better for investigating causality), included clinical/physical examination of the cases for definition of the conditions as well as direct observation of procedures for evaluation of the exposures (for example, Jensen *et al.*, 2000; Miranda *et al.*, 2002; Riddle *et al.*, 2003; Andersen *et al.*, 2007).

Though causality was often not clearly established for many of the risk factors, the framework of Figure 2 can help identify workers at risk and guide future research.

5.2 STRATEGIES FOR REDUCING OCCUPATIONAL LLD

Interventions and strategies for control and prevention of LLD need to be based on key risk factors within the context of the specific occupational setting. Despite the heterogeneity of the methodologies and the associated shortfalls, a number of the risk factors identified (Figure 1) repeatedly emerged as significantly associated with pain (or other symptom of LLD) and in some of the studies, also indicated dose-response relationship.

This was particularly true for physical and personal factors, many of which have been directly implicated in the aetiology of MSDs. The physical and personal factors that showed the strongest evidence of causality or association with LLD were kneeling/squatting, climbing stairs or ladders, heavy lifting (particularly with kneeling or squatting), walking/standing, slips and trips hazard, gender, age, obesity and personal lifestyle. Those for which there was plausible but less clear evidence included jump from height, driving (as part of job) and sitting.

Psychosocial factors often did not show direct causality of LLD, but they do contribute to determine the social dynamics of work groups (attitude to problem solving, use of tools and new work methods). Additionally, they are increasingly considered to act as modifiers of pain associated with injury rather initiators of injury (Figure 2) and therefore these aspects cannot be ignored. Prevention of LLD in the workplace therefore requires the creative use of control strategies to balance the physical and psychosocial demands with the characteristics of the individual(s).

Various interventions have been proposed for controlling the risks and preventing MSDs in the workplace (as discussed in Chapter 4 of this report). Those that have been shown to be useful for LLD include implementing protective equipment, changing work surfaces (flooring), redesign and modification of work methods, training and retraining, and participatory programmes. Indeed, work redesign and/or modification along human factors principles proved most effective for encouraging behaviour change, rehabilitation and return to work of injured workers; benefits in terms of changes in sickness absence and increase productivity rate were also identified. Implementation of protection equipment was effective for preventing development of some specific conditions and for protection against further damage.

Workplace policies such as workplace exercise regimes and participatory initiatives have also shown to be quite useful for encouraging improved general work ability of employees and reduce symptoms and prevalence of MSD, particularly back and upper limb injuries. Other interventions, such as Regulations, safety campaigns and guidelines, which were developed for specific work situations and against back or upper limb disorders have increased general awareness of the issues and provided logical approaches (hierarchy of control) for managing health and safety in workplaces.

Based on the observations from the literature and in accordance with the hierarchy of control suggested in Regulations, the following have been identified as useful strategies for reducing and controlling the occurrence of occupational LLD.

Eliminate/redesign

- Arrange that the work can be done in a different position (requiring less effort or awkward postures) by changing the working methods and/or introducing new tools. This may however, require a long-term structured approach (including scientific research), the provision of information for employees, employers and trade unions, training, and participatory ergonomics with direct involvement of workers.
- Arrange the pathways and surfaces so that the risks of slipping, tripping or falling will be reduced.

Reduce exposure

- Impose restrictions by reducing the time at a particular task, the frequency of task performance and possible transfer and rotation of workers between other less demanding tasks.
- Use appropriate protecive equipment (knee pads, shock absorbing shoe in-soles, limb support(s), anti-fatigue matting).
- Use appropriate handling assist device or other suitable equipment.

Organisational/training/exercise regimes

- Ensure that workers are educated (well informed) about the hazards for injury to the lower limb from the work done and what can be done to prevent them.
- Ensure that workers are well trained (in terms of technique) in the tasks they perform.
- Ensure that workers are able to work normally with little time pressure.
- Encourage participation in therapeutic exercises and/or participation in sports and other leisure activities, particularly for workers in sedentary jobs. This measure improves the physical conditions of the worker, and can also contribute to avoid obesity (Coggon *et al.*, 2000).

5.3 KNOWLEDGE GAPS AND VIABLE RESEARCH DIRECTIONS

The literature suggested that workers may suffer a range of LLD and that the influence of the risk factors for their occurrence is quite complex. If prevention in the workplace is to be successful, the nature of the disorders and the specific role of each factor need to be appreciated. This requires:

- A clear definition of the LLD, i.e., their nature, prevalence and incidence, and any relationships with disorders in other regions of the body.
- Accurate characterisation of the workplace exposures.
- Clear understanding of how various aspects of the physical workload or activity act as risk factors.
- General commitment of the employer and employees.

5.3.1 Knowledge gaps

Definition of the conditions

Key findings from the literature described in Chapter 2 were that reports of LLD symptoms tend not to be independent of reports of symptoms in other regions of the body. Although the social and economic impact of LLD has been illuminated in studies, the consequences are rarely discussed in relation to specific conditions that are suffered.

Various outcomes were defined for investigation of LLD ranging from specific medical diagnoses such as OA, plantar fasciitis, bursitis, meniscal lesions and venous diseases, to spurious measures such as fatigue, symptoms, pain and complaints. In the majority of the studies ascertainment of pain, symptoms and fatigue was mainly obtained through self-reporting, including the use of the Nordic Questionnaire and Borg-CR10 scale. The few studies that involved clinical examination or medical diagnosis and investigated relationships between the medical conditions and symptoms, generally reported poor correlations. These suggest that gaps remain in our knowledge of the underlying causes of pain and may also explain why identified consequences were rarely discussed in relation to specific conditions. The observations further suggest that there are gaps in our knowledge of the relationships between pain in the different regions of the body and between different types of disorders. Knowledge of this kind can enable efficient use of resources, as interventions found to be useful for prevention of injury in one region of the body may also help prevent injury in another.

The workplace exposures

The literature described in Chapter 3 suggested that the risk factors for LLD of different parts of the limb are not peculiar to any site but generally tend to be similar. Additionally, the factors associated with specific conditions, tend to be fewer in number when the condition is defined objectively (by clinical examination or medical diagnosis) than when defined as pain or other subjective measure of symptom.

To completely quantify exposure to a risk factor, the following three dimensions are needed: The amplitude of the exposure (e.g. magnitude of forces, degree of postural deviations from neutral), the duration (length of time maintained) and the repetitiveness (number of occurrences per unit of time) (Wiktorin *et al.*, 1993). However, a major drawback of many studies related to assessment of the physical exposures to risk factors, was that this was often self-reported and focused on one of the three dimensions identified above. While some self-reported exposures are reproducible and may be quite valid, some are not, in particular, those relating to lifting and awkward postures (D'Souza *et al.*, 2005). Indeed, according to Coggon *et al.* (1998) people are generally less reliable in their reporting of loads heavier than 10 kg in weight, and recalled information about earlier jobs is unlikely to be better. Furthermore, a spurious association could occur if those with injury recall the past exposures more completely than controls (those without injury). Differences in the motivation of cases and controls could also lead to false/differential reporting of past occupational activities, with cases recalling exposures that they link with their illness more completely than control. Anderson *et al.* (2007) identified that, even though the temporal relationship between measures may fulfil an acceptable standard procedure, the self-reporting of physical exposure could easily be flawed by the subjects' pain status. Furthermore, common beliefs in different occupational groups about the occupational hazards experienced by their group could also influence self-reports of exposure.

Thus, more detailed data are needed to identify the specific occupational exposures. The data should be objective and based on observation, not subjective or recall. Considering that direct observation of occupational exposure has only been performed exceptionally (Klussman et al.

2008), there is a gap in our knowledge of the workplace risk exposures for LLD, particularly how the different dimensions (amplitude, frequency and duration) act alone and in combination as risk factors, to enable effective control.

Prevention strategies

Key findings from the literature described in Chapter 4, were that workplace redesign/modification interventions and protection equipment are interventions most suited for prevention of LLD, and that an intervention suited for one type of disorder may be ineffective for protection against another. There was also the question of how societal factors and group 'norms' in a workplace, may impact on the acceptance and success of many prevention measures, as well as the role of exercise or keeping active programmes.

Some studies had shown that workplace redesign/modification including use of handling assist devices, successfully decreased the awkwardness of the working postures adopted and the magnitudes of task forces required; also that worker morale was thereby improved as evidenced by records of worker opinion. These outcomes were equated to decreased risk of LLD, but it was not clear which specific disorders were prevented by the measures.

Other studies had shown the benefits of protection devices, e.g. kneepads, for providing an effective barrier against lacerations and penetration of the knee during kneeling, as well as for improving comfort by reducing contact stresses, and thereby decreasing risk of compression injuries of the joints, such as bursitis. However, it was not clear whether the devices provided protection against all types of disorders, or against only a subset, i.e., those with similar aetiology. These observations suggest that there are gaps in our knowledge about the relationship between symptoms and loading of the body due to hazard exposures. Furthermore, there were doubts about the effectiveness of human factors and organisational interventions, such as guidance, regulations and safety campaigns for encouraging compliance of employers and workers to the safety measures. The results from studies of exercise and keep fit regimes were quite contradictory with some supporting the practices and calling for coping programmes for those with injury, and others arguing against. There are therefore gaps in our knowledge of the benefits of guidance and coping programmes for those with injury, and the suitability of protection equipment strategies for preventing LLD needs further investigation.

5.3.2 Further work

From the identified gaps in the knowledge, the following are recommended as viable directions for future research:

- Investigations to clarify the inter-relationships between injury/pain at different regions of the body, i.e., to determine whether persons who suffer back pain are also likely to suffer pain in the lower extremity and vice versa and to determine whether the relationships are dependent on the type of injury suffered or not.
- Investigations to provide more detailed measures of workplace ergonomics risk exposures, including tasks/actions such as standing, jumps from height and driving, which often showed poor causal association in studies, but are often identified by workers as being problematic. This type of research will enable clearer definitions of "safe" exposures, e.g. acceptable standing time.
- Investigations to determine the suitability of existing control strategies and prevention interventions that have been proposed for injuries in other regions of the body (back and upper limbs).

- Investigations to clarify the relationship between symptoms and the different dimensions of the risk exposure, i.e. the physical stress imposed on the body.
- Investigations to further explore the benefits of exercise regimes and coping programmes for those with injury.
- Investigations to identify strategies that would aid increased awareness of the problems in workplaces and the commitment of employers other than following regulations.

6 CONCLUSIONS

Lower limb musculoskeletal disorders and injuries, particularly knee conditions, are a problem in many workplaces and they tend to be associated with conditions in other areas of the body. Both acute and overuse injuries, may be suffered by workers, although overuse injuries tend to be more common. The LLD most commonly identified as being work-related are:

- Hip, Osteoarthritis (OA).
- Knee, OA, Bursitis and Meniscal lesions/damage.
- Stress fracture and venous disorders.

There are consequences of occupationally derived LLD for society, the economy and industry in terms of lost working time, medical treatment and hospitalisation, decreased ability to carry out the work, and effects on quality of life. The particular impact depends on the condition and the number of joints affected.

The risk factors for LLD are not specific to any of the sites of the lower extremities and they are also associated with disorders in other regions of the body such as upper limb and torso. This suggests that efforts to control injury/pain to the area of the body with highest reported prevalence among a population of workers might suffice for control of injury/pain to other areas of the body. It may therefore be the case that the principles of risk control applied to address upper limb and back musculoskeletal complaints are equally applicable for LLD.

There is appreciable evidence of a causal association for kneeling/squatting, climbing stairs or ladders, heavy lifting, walking/standing, and slips and trips hazards as risk factors for LLD. The evidence of a causal association is plausible but less clear for jumps from height (e.g., from a vehicle's bed or cabin to the ground), driving and sitting.

There is appreciable evidence for implementation of workplace redesign/modification initiatives, implementation of protection equipment and participatory programmes as interventions for control of LLD risks, and it was possible to identify useful strategies that may be applied for prevention.

Based on the risk factors, key LLD and interventions identified, it was possible to develop a framework of the issues and to identify knowledge gaps as well as directions for future research.

7 RECOMMENDATIONS

Further work in this area is recommended to:

Clarify the inter-relationships between injury/pain at different regions of the body, i.e., to determine whether persons who suffer back pain are also likely to suffer pain in the lower extremity and vice versa and to determine whether or not the relationships are dependent on the type of injury suffered.

Provide more detailed measures of workplace ergonomics risk exposures, including tasks/actions such as standing, jumps from height and driving, which showed poor causal association in studies, but are often identified by workers as being problematic in the workplace. This type of research will enable clearer definitions of “safe” exposures, e.g. acceptable standing time.

Determine the suitability of existing control strategies and prevention interventions that have been proposed against conditions in other regions of the body (back and upper limbs).

Clarify the relationship between symptoms and the different dimensions that characterise risk exposure, i.e., the physical stress imposed on the body.

Explore the benefits of exercise regimes and coping programmes for those with a condition.

Identify strategies other than regulation that would aid increased awareness of the problems in workplaces and encourage commitment of employers.

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Lower limb MSD

Scoping work to help inform advice and research planning

This work was commissioned to examine more closely the nature and extent of workplace lower limb musculoskeletal disorders and injuries (LLD) and the causal agents with the aim of informing evidence based guidance and advice for workers and employers.

LLD are a problem in many workplaces and they tend to be associated with conditions in other areas of the body. There are consequences for society, the economy and industry in terms of lost working time, medical treatment and hospitalisation, and effects on quality of life. There is appreciable evidence for kneeling/squatting, climbing stairs or ladders, heavy lifting, walking/standing, and slips and trips hazards as causal risk factors for LLD.

Further work is recommended to clarify the inter-relationships between injury/pain at different regions of the body; to provide more detailed measures of workplace ergonomics risk exposures; to determine the suitability of existing control strategies and prevention interventions that have been proposed against conditions in other regions of the body (back and upper limbs); to explore the benefits of exercise regimes and coping programmes for those with a condition; and to identify strategies other than regulation that would aid increased awareness of the problems in workplaces and encourage commitment of employers.

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