META-ANALYSES OF THE EFFECT OF ERGONOMIC INTERVENTION ON LOW BACK PAIN OUTCOMES AND WHETHER LBP LEADS TO ABSENTEEISM AMONG MANUAL MATERIAL HANDLING WORKERS

by

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Abstract

Low back pain (LBP) is experienced by 80% of population at some point in their working life. Previous research has demonstrated that musculoskeletal loading in manual material handling (MMH) workplaces results due to interaction between biomechanical factors and human factors. Loading then causes changes in spinal tolerance, ultimately LBP. Repetitive MMH activities are considered high risk activities for LBP and sequential absenteeism. Absenteeism drains funds not only from MMH industry but also from the health industry as well, with a simultaneous effect on the quality of life of a particular MMH worker. Ergonomics has the potential to reduce the LBP and can also restore human functioning to a maximum level. Ergonomic interventions such as engineering solutions and administrative controls can decrease the effect of risk factors on loading and in-turn LBP.

Individual studies tend to support that ergonomic interventions decrease the effect of LBP in MMH workers and also, the fact LBP causes absenteeism in MMH workers. There are still few quality studies that address these issues. It is therefore beneficial to combine such individual studies in a meta-analysis. Studies measuring the effect of ergonomics on LBP and effect of LBP on absenteeism in MMH workers are combined to find the pooled effect. The results show that ergonomics has no significant effect in decreasing LBP in MMH workers but absenteeism due to LBP is reported less in workers having ergonomic intervention in MMH workplaces.

dedicated to my Maa and Papa …

and my brothers Vishal Lakra and Aakash Lakra ...

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My dear friends who stood with me, in joy and sorrows, ups and downs, days and nights. Friends who accepted me with all my goodness and faults; and those who taught me life.

Contents

Table of Contents

List of Tables

List of Figures

Chapter- 1

Introduction

Low Back Pain (LBP) is experienced by many people, up to 80% by some estimates (Garofalo, 1999; “Low Back Pain Fact Sheet,” n.d.). The complex interaction of structures in the lower back combined with excessive workplace activities sometimes produces LBP. This usually develops after sudden twisting, bending or any activity that overloads tissues beyond their strength tolerance limit. LBP is worthy of attention for its significance in the working population. The lower back plays an important role in manual material handling (MMH) occupations as most of the load is placed on the lower back while performing repeated activities involved in blue-collar workplaces.

1.1 LBP relation with MMH

LBP is present in occupations with both sitting and standing. Sitting occupations are carried out mainly by white collar workers, and standing occupations are mostly performed by blue collar workers or Manual Material Handling (MMH) workers. The difference between white collar workers and MMH workers reporting LBP and sequential absenteeism could be due to physical demands at work (Hoogendoorn et al., 1999; Schreuder et al., 2008). Sitting jobs typically involve the adoption of awkward postures with lower loads whereas standing jobs include the adoption of awkward postures combined with lifting, pushing, pulling, carrying with higher loads; leading to accumulation of loading with the potential of producing low back injuries. Low back injuries can eventuate with every activity associated with loading. MMH jobs have reported eight times higher risk of low back injuries as compared to sedentary jobs (Manchikanti, 2000).

According to the Government of Canada, three of every four Canadians performing MMH jobs report LBP at some point. This accounts for one-third of lost work and more than one-third of all compensation costs (CCOHS, 2016). MMH jobs comprised of a variety of workers including carpenters, laborers, shipyard workers and nursing aides, etc. During the working life span, load, genetics, and other factors, biomechanical changes occurring in the tissues of the lower back are inevitable (Section 1.2.1). It is the through the knowledge of these causes and risk factors that ergonomists can perhaps help to modulate the negative impact of LBP, if present.

1.2 Relation between MMH and LBP

Manual Material Handling is defined as "any task which requires a person to lift, lower, push, pull, hold or carry any object or material" (Worksafe, 2010). Rotation of the body, heavy physical work, prolonged sitting and bending postures, long-standing postures, sitting postures (Gheldof, Vinck, Vlaeyen, Hidding, & Crombez, 2005) makes workers more prone to LBP risk factors (Chen, Yu, & Wong, 2005). Physical work factors in MMH jobs present themselves as risk factors of LBP, some of which are: repetitiveness, poor workstation design and awkward postures (Carayon & Smith, 2000). The interplay and interaction of these factors contribute to loading and biomechanical strain on the spine (Carayon & Smith, 2000). Waters et al. stated, "The assessment of health risk for MMH hazards has focused on the analysis of a single event or condition that may precipitate an acute back injury" (Waters et al., 2006); however, the effects of cumulative physical loading which can also progress acute LBP to chronic LBP, are associated with MMH, have been quantified and are related to the pathogenesis of low back disorders (Waters et al., 2006). According to Statistics Canada (1991), manual material handling (MMH) and push/pull activities resulted in 20% of all back injuries and this trend is considered consistent with the trend observed in UK and US (Jones & Kumar, 2001). MMH occupations are highly associated with low back injuries. For this reason and also because a high risk of other musculoskeletal injuries also exists, MMH occupations are always considered a high-risk (W. S. Marras, 2000).

1.3 Causes of LBP

Interaction of MMH activities and risk factors give rise to LBP. Risk factors play a crucial role in increasing the toll of MMH workplace injuries, in particular, low back injuries. With proper knowledge; one can perhaps modify the development of workplace low back injuries. Loading in the lower back dominates occupation related LBP. In it's most basic form, "Injury occurs when body tissues are exposed to more load than they can withstand" (Neumann et al., 2001). MMH activities, in particular, as they depend on several factors which combine with loading, such as frequent bending, twisting, pushing and pulling, contribute to injury. It is important to understand the nature and impact of these contributing factors and how they contribute to the risk of low back pain through mechanical effects like compression force, shear force, load rates, the spinal posture during loading and frequency of loading because these factors are found prominently in MMH workers (Marras, 2008).

Jones and Kumar (2001) specified three categories of risk factors in the workplace:

Genetic factors/traits: Genetic traits causing LBP are found to be associated with conditions such as ankylosing spondylitis, osteoporosis, scoliosis, spinal arthritis and degenerative diseases ("Low Back Pain Fact Sheet," n.d.). Genetic components are mostly treated by addressing symptoms with pain therapy and Non Steroidal Anti-inflammatory Drugs (NSAIDs) and are unalterable except possibly by surgery.

Psychosocial factors/traits: Psychosocial issues such as; depression and anxiety influence the perception of back pain. Emotional stress due to such psychological problems can cause muscle tension and other changes progressing acute back pain to chronic back pain (Langevin & Sherman, 2007) and may or may not be alterable.

Biomechanical factors/traits: Biomechanical factors (Table 1.1) are more noticed because of their clearer association with risk factors and the potential for alteration with the help of ergonomics recommendation and assessment for any job task and type (Jones & Kumar, 2001).

Biomechanical Factors	**MMH Activity**
Awkward movement	Bending, Twisting
Repetitive motion	Reaching, Carrying, Lifting
Forceful exertion	Carrying/Pushing/Pulling/Lifting heavy loads
posture	Static posture for a long time

Table1.1. Classification of biomechanical factors and MMH activities [Ergonomic Guidelines for Manual Material Handling (2007)]

1.3.1 Biomechanical Factors

Risk factors of LBP could result due to a combination of biomechanical factors, human factors, and MMH activities. Human factors include load history, the rate of the load applied on workers (according to the strength of a particular worker) and work intensity of a particular worker (Hsiang et al., 1997; Marras, 2000; Pope et al., 2002). Human factors interact with biomechanical factors which consist of MMH activities (Table 1.1). Biomechanical factors such as forceful exertions and repetitive movements require strong muscle contractions which result in compression on the spine. Compression on the spine accumulates over time, which increases the risk of disc herniation or end plate fracture (Adams, 2004). The spine's "weak link" in compression is the vertebral body which tends to fail with micro fractures before the disc, locating the damage in the vertebral end plates (Adams, 2004). During lifting, the co-contraction of both hip muscles and trunk muscles determine the distribution of compressive and shear forces in the lower back (Hsiang et al., 1997). Compressive force on the low back results from the combination of force produced by torso muscles and the force produced by the weight of object held by the worker. Shear force is the force that acts perpendicular to the compressive force. Factors such as, asymmetry of weights being lifted, body posture, unstable objects, poor hand coupling, and inability to stabilize the body with both feet while standing with the lifted object (Hoozemans et al., 2004) causes a stronger contraction in trunk muscles causing the back muscles to burden which results in increased compression, thereby increasing the risk of low back injuries even further (Adams, 2004; Hsiang et al., 1997; Pope et al., 2002).

In postures involving a combination of rotation and awkward movements, the level of muscle activity contralateral to the direction of postural asymmetry are high and ipsilateral to the activity are low (Pope et al., 2002). This causes co-contraction of antagonistic muscles and increased intra-discal pressure (IDP), and can increase the risk of LBP. In MMH industries, forward flexing and lifting activities frequently cause loading. Lariviere et al. (2002) considered lumbar loading as a risk factor associated with lifting and lowering action in MMH workers. For instance, postures involving forward flexing with pushing and lifting of heavy weight can potentially cause micro/macro trauma (depending upon the flexibility and strength of the worker at the initial stage). The daily continuation of such awkward postures during work hours accounts for the accumulation of micro-traumas and subsequent loading which progresses to decreased tolerance. MMH workplaces require workers to adopt awkward postures, causing generation of loading (Fig 1.1) and in-turn production of micro-injury (Fig 1.2) (Langevin & Sherman, 2007). In static conditions, the weight of the upper body and the force produced by muscle contractions is supported by lumbar region (Adams, 2004) which causes decreased perfusion and disorganized tissue architecture because of compromised blood and lymphatic flow, inducing pain (Langevin & Sherman, 2007). Pain results in stiffness where each cycle of pain increases restriction and fibrosis which set workers up for more painful episodes (Langevin & Sherman, 2007).

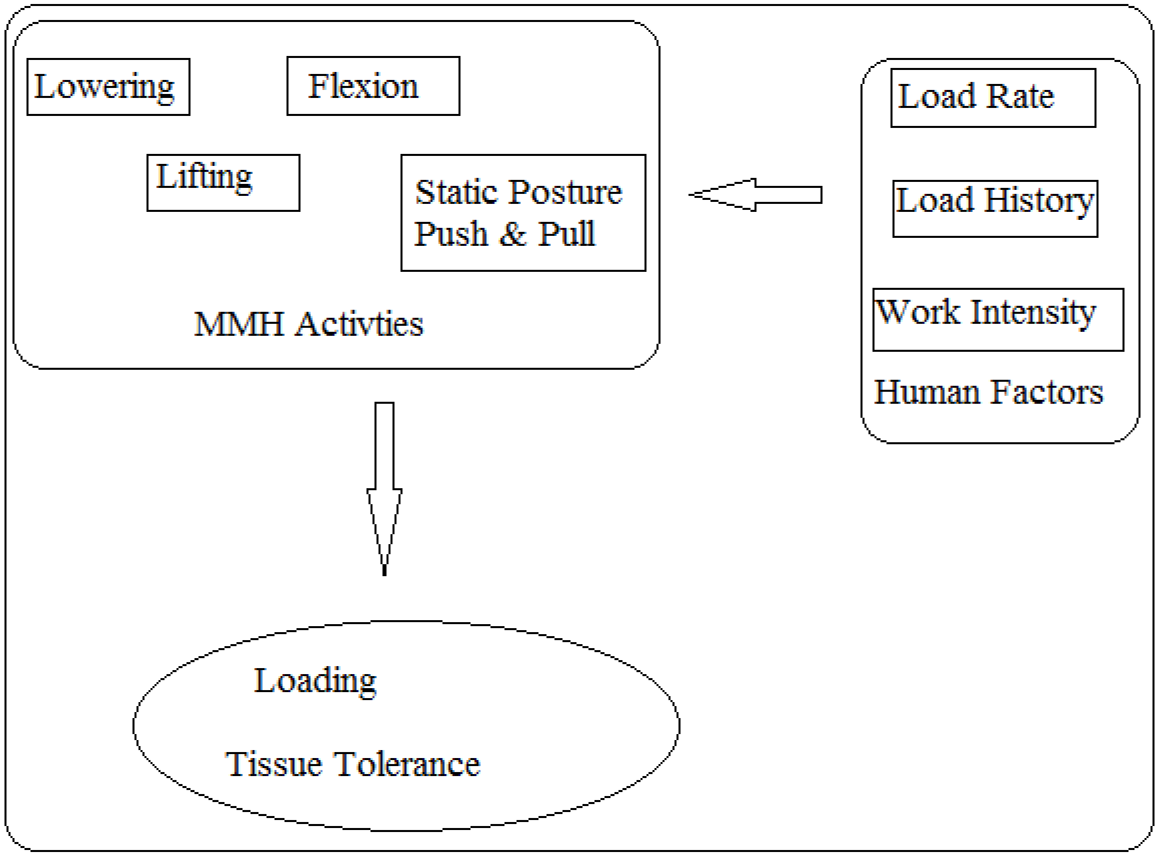

Fig1.1. Relation between MMH activities and Loading

Ergonomics can be used for protecting the weakest worker but at the same time it could also be used for increasing the productivity of the future workforce. Biomechanical factors in MMH workplaces should be analyzed at an individual level as no two workers will have been subjected to the same human factors despite being on the same job for years. Lumbar loading can potentially cause proportionate lumbar injury, the extent of which depends on human factors of work intensity and load history (Pope, Goh, & Magnusson, 2002). Loading in the spine is modulated by internal forces, the forces generated on the spine by muscles and connective tissues in reaction to external forces, as well as the forces produced in response to mechanical factors (Marras, 2000). LBP risk is also influenced by loading rate i.e. the speed at which the workers are handling load associated forces applied on the body. “The risk of injury due to postures adopted at work depends not only on loads applied to the spine but also on loading rate and loading history (Pope et al., 2002).” For proper evaluation of LBP risk factors, there should be an adequate understanding of “how variability in the presentation of work affects the risk of low back disorder” in which variability can be defined in terms of work intensity, loading, loading rate (Marras, 2000).

1.3.2 Human Factors

Low back injury (and subsequent LBP) can result due to the combination of biomechanical and human factors. Loading rate, work intensity and loading history of the workers regulate the extent of micro-injury. Loading of a particular MMH worker depends on their experience in using a particular pattern as experienced workers use patterns that aim to reduce their overall loading (Marras, 2008). The load puts tension on the muscle fibres and forces out interstitial fluid until the muscle fibres bear all the load in tension (Adams, 2004; Manchikanti, 2000). This is also demonstrated as creep.

High loading rates increase biomechanical stresses on the back which result from acceleration and deceleration forces during MMH activities. “Application of loads at faster speeds causes marked increase in compression force in the lumbar region and a significant decrease in torque producing capability of spinal muscles (Hsiang et al., 1997).” Increased compressive force and decreased strength of spinal muscles to counter the speed at which the load is applied causes increased mechanical stress and loading in the lower back which in-turn increases the risk for LBP (Hsiang et al., 1997; Kumar, 2001). Work intensity also influences lower back loading while performing MMH jobs. While handling heavy loads at faster speeds (loading rate), there will be decreased mechanical stress on the spine initially, but as working intensity increases, the amount of load that a worker can safely handle will decrease due to a decrease in torque producing capability of muscles (Hsiang et al., 1997). Increased pace of work does not provide workers enough rest time in between performing individual tasks, as a result of which there are increased chances for a particular worker becoming fatigued (CCOHS, 2016). “Rest breaks are a potential fatigue counter-measure, and hence a means of controlling risk” (Tucker, 2003). Rest breaks facilitate recovery periods for muscles to prevent fatigue and injury during physically demanding activities. Repetitive MMH activities, when maintained for a prolonged time without breaks rapidly decreases workers' ability by speeding up muscular fatigue which then adds up over time, causing discomfort and serious injuries (McGill, 1997; Tucker, 2003; CCOHS, 2016).

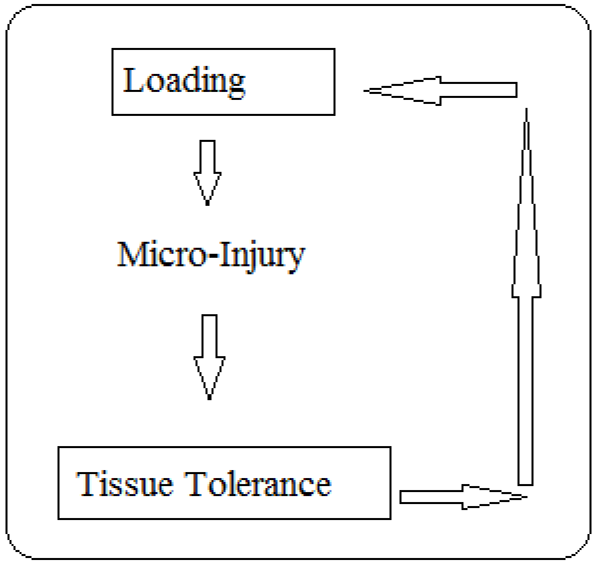

Fig 1.2: Relation between loading and tissue tolerance

1.3.3 Tissue tolerance

The ability of tissues to withstand a load without physical disruption is called tissue tolerance (Marras, 2008). Spinal tolerance can be modulated by the load, repetition, and posture of the spine while under applied load (Adams, 2004). Loading can exceed the tissue tolerance either by an increase in load on tissue or decrease in the tolerance of the tissue. Strain in the tissues results due to the application of mechanical stress. The type and extent of tissue damage are determined by tissue properties-, load rate, rest or recovery cycles, mode of compression and bending. Injury occurs when the applied load is more than tissue tolerance. The margin of safety exists as long as applied load is below the tissue tolerance (Fig 1.3). Injury can then result due to a combination of decreased tissue tolerance and/or overloading which can possibly cause the failure of back muscles in response to physical stress (Adams, 2004).

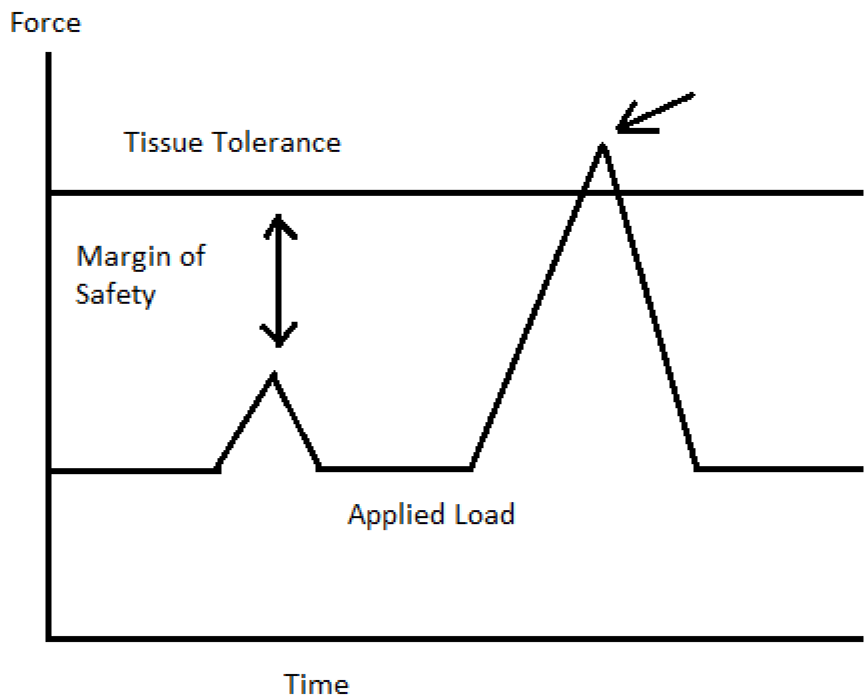

Fig 1.3: Failure tolerance of the tissues (McGill, 1997)

In occupational settings, injury can result from sub-failure magnitude loads from cumulative trauma produced by either repeated application of low load or application of sustained low load for long duration (fig 1.4) (McGill, 1997). Increased physical stress due to increased/repetitive movement, hyper-mobility and decreased physical stress due to immobilization/hypo-mobility causes changes in connective tissues (Langevin & Sherman, 2007; Marras, 2008). Repetitive loading decreases the spinal tolerance to the level where previously acceptable loads can now cause injury because the relative stress of loading increases in proportion to the number of loading cycles and causes a decrease in spinal tissue tolerance (Potvin, 2008).

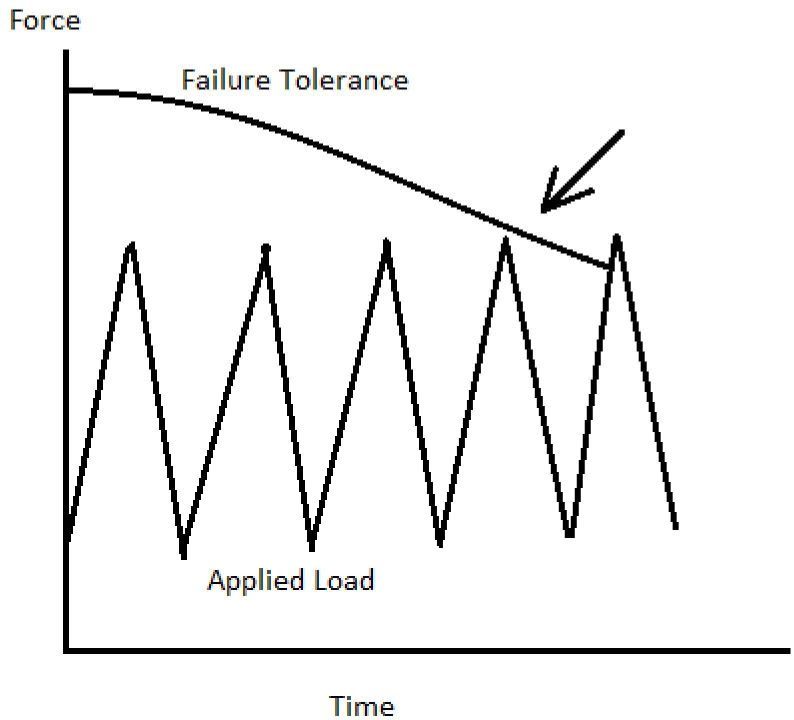

Fig 1.4: Repetitive load leading to tissue fatigue and failure (McGill, 1997)

Cumulative trauma and adaptation work as the tissues fatigue during repetitive loading. Continuation of repetitive MMH activities despite the tissue fatigue generates micro-injury in the spinal tissues. Micro-injury produces lesions in avascular supporting structures and perturbation in the proprioceptive functioning of receptors causes prolonged muscle activation (Marras, 2000). Increases in trunk muscle co-activation leads to injury during increased level of activity as poorly vascularized tissues may be struggling to strengthen the adjacent bones and muscles (Adams, 2004; Marras, 2000; Moseley & Hodges, 2005). Repetitive loading results in micro-injury to a tissue until gross failure occurs i.e. margin of safety is brought to zero [shown in Fig. 1.4] (Adams, 2004; McGill, 1997). In addition, perceived stress from faulty biomechanics can increase loading and when loading persists for long periods, it results in pain (Chen, Yu, & Wong, 2005).

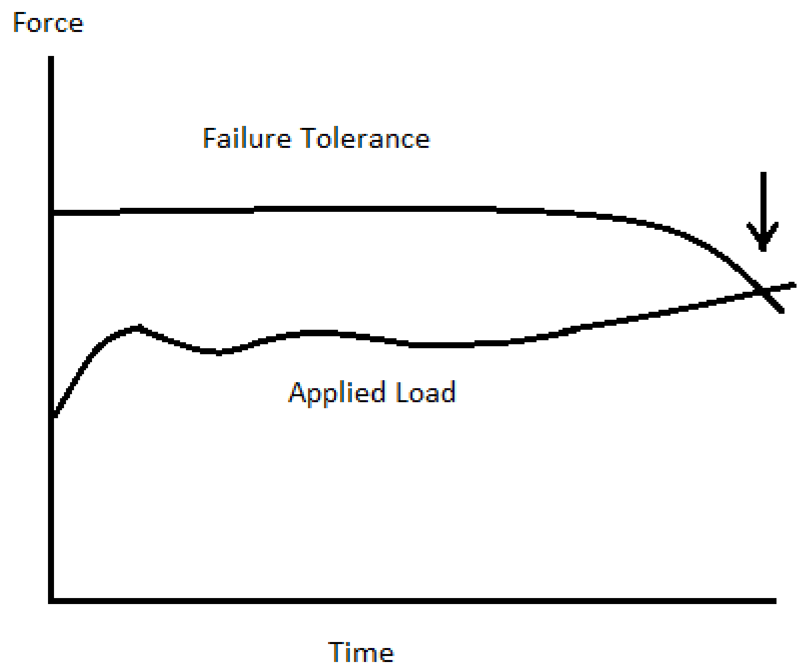

Fig 1.5: Effect of longer duration on tissue tolerance (McGill, 1997)

Biomechanical factors make tissue susceptible to injury by crossing safety margin limits to the point of tissue tolerance in a particular worker (Fig 1.3). "Wolff's law states that exposure to loads makes a tissue or structure stronger. However, adaptation has limits (Marras, 2003)." The stress – strain relationship suggests that tissue strength increases up to a limit and injury results beyond that limit. Similarly, consistent MMH activities can exceed the adaptation limits, decrease the tissue tolerance and makes the spinal tissues susceptible to injury (Marras, 2003). The process of injury is not only associated with high loads (Fig 1.4), but also with sustained low loads for increased time duration (Fig 1.5) (McGill, 1997). Another method to produce injury in MMH workplaces is by application of sub-failure load, which causes stress over a sustained period of time and can result in LBP (McGill, 1997).

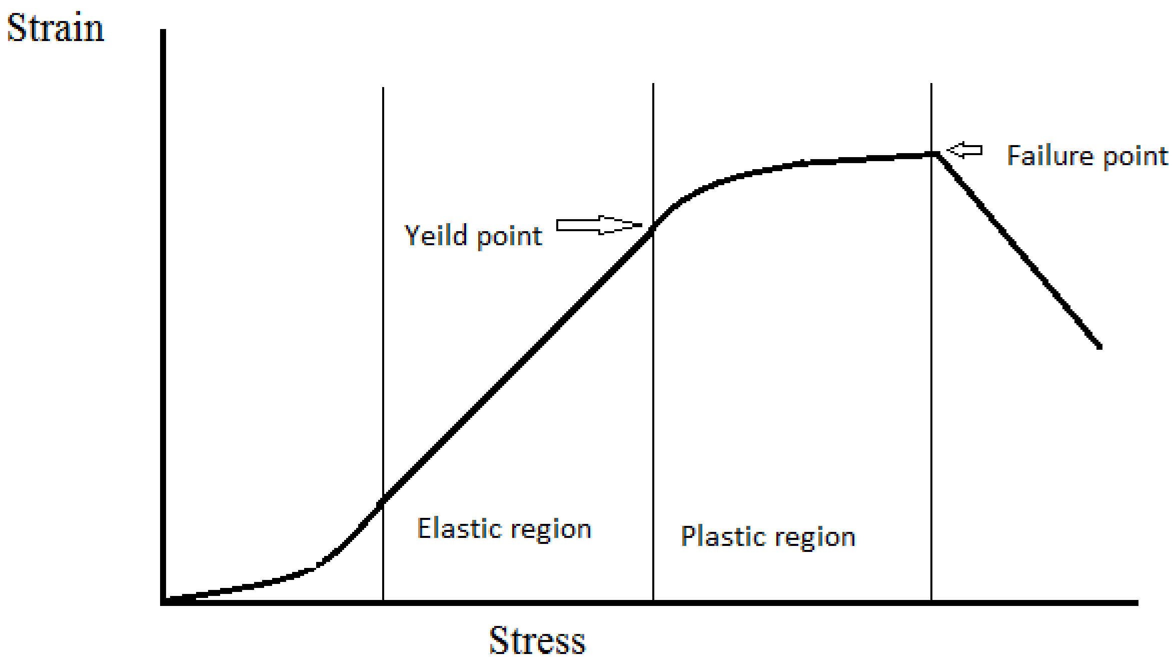

Fig1.6. Stress- strain relationship

Physical stress works as a catalytic agent to push tissues from the elastic region to the plastic region, potentially past the yield point as a threshold for tissues around the lower back. Highly repetitive MMH activities and awkward postures can potentially cause plastic deformation injury [shown in Fig. 1.6]. Degeneration of spinal tissues follows as cells respond to unfavourable mechanical and nutritional environment, leading to the development of a vicious cycle of tissue weakening and injury which leads to concentration of stress and in turn pain (Adams, 2004).

1.3.4 Spinal Creep

Spinal creep is defined as gradual deformation of spinal structures due to spinal loading. Spinal creep is important because it affects the kinetics and kinematics of spinal unit (Little & Khalsa, 2005). Prolonged flexion of the spine results in sustained loading of posterior passive tissues and this sustained loading reduces the margin of safety and leads to injury [shown in Fig. 5] (McGill, 1997). Sustained periods of spinal loading result in spinal creep which can create spasm in para-spinal muscles and leave the spine unstable due to laxity between segments (Langevin & Sherman, 2007; Little & Khalsa, 2005; Marras, 2000). Prolonged spinal creep produces laxity in viscoelastic structures around the lumbar spine which incite de-sensitization of mechanoreceptors within the spine and induces loss of reflexive stabilizing forces (Little & Khalsa, 2005; Pope et al., 2002). Loss of spinal stability and prolonged spinal creep during MMH activity can lead to acute loading in the spine, due to buckling of inter-segmental musculature (Potvin, 2008; Preuss & Fung, 2005).

1.3.5 Re-Injury

Soft tissue injuries of the back result in loss of tissue stiffness which leads to increased deformation of tissue on load application (McGill, 1997). The stiffness will recover and the injury will gradually heal but the mechanical properties of the tissue change due to scar formation (McGill, 1997). Scar tissue disrupts the fibre organization of the tissue resulting in reduced extensibility and decreased range of motion or abnormal joint motion (McGill, 1997) which can potentially cause change in -strength and -tolerance of the tissue (Valouchová & Lewit, 2008).

Change in mechanical properties of the tissues can cause a change in movement strategies causing accumulation of trauma in the lower back which can potentially make the spine unstable during load bearing situations such as in MMH activities. Repetitive spine loading causes chronic damage, and fatigue to spinal tissues which can lead to changes in co-ordination and movement strategies. These strategies can cause acute low back injuries (Holm-e al., 2002). Changed movement strategies, patterns, and degenerative processes can cause a change in proprioception of mechanoreceptors which results in prolonged muscle activation due to reflex activation of involved muscle groups, causing acute back pain (Holm et al., 2002; Moseley & Hodges, 2005). Re-injury occurs when a particular episode of LBP was not handled appropriately and the worker returns to work prematurely. Inappropriate biomechanics of the injured worker when combined with the repetition of MMH activities, especially in the absence of a potential solution that can take the load off the back, may lead to re-injury. With re-injury, both the consequences on the worker and the costs increase. Marras et al. (2007) reported LBP recurrence as a major challenge for both healthcare sector and industrial sectors. Within one year of following a first episode of LBP, e-reporting of injury occurred in 78% of the cases (Marras et al., 2007). This_recurrence ranged from 11% to 15% of the total working time. Carey and colleagues (1995) showed that "functionally disabling recurrent LBP, for 8% to 14 % of individuals lasted between 3 to 6 months, and for 20% to 35% of individuals lasting between 6 to 22 months". Brown and colleagues (1995) concluded "the prevalence of recurring LBP since joining of Royal Canadian Police Force was 49%, compared to lifetime prevalence reported for the general population" contrasting to a survey of police officers in the United States (1998).

1.4 Consequences of LBP

LBP is one of the major health problems found in the industrialized countries which accounts for approximately 38 million lost working days (Guo, Tanaka, Halperin, & Cameron, 1999; Kerr et al., 2001; Labriola et al., 2006; Marras et al., 2007). Lifetime prevalence of LBP varies from 50-84% worldwide (Werner et al., 2012) and 84 % of lifetime prevalence is reported in the Canadian population (Cassidy et al., 1998). Jones and Kumar (2001) proposed that LBP is the most expensive malady in industrialized countries. According to the Statistics Canada Canadian Community Health Survey (2000); back pain ranked second in the list of chronic conditions for example, in Alberta (1998) the cost of new LBP disability claims was found to be $28,132,411 (Jones & Kumar, 2001). Likewise, the cost of LBP care derived from Australian Adult Back pain survey (2001) was a total of $ 835,447,813 (Aus.) (Walker et al., 2003). In the Netherlands, the cost of LBP is 1.7% of the total Gross National Product (GNP) where sick leave and disability constitute 93% of the total costs of LBP (van der Giezenet al., 2000).

The economic burden associated with LBP has an enormous economic impact due to absenteeism from work, lost productivity, training costs and related worker's compensation costs. In most industrialized countries, the cost of LBP accounts for 20-30% of worker compensation costs and 50% of all direct compensation costs, affecting both the economy and the workplace (Kerr et al., 2001). The National Health Interview Survey- (NHIS) (1995), reported a total of 149 million lost workdays because of all types of back pain in the USA (Guo et al., 1999). In the Netherlands, 93% of total costs associated with back pain constituted indirect costs and 7% constituted direct costs (Van Tulder et al., 1995). Worker's compensation includes indirect compensation and direct compensation costs. Direct compensation costs are medical bills, hospital bills, rehabilitation, lost wages, medication, and loss of earning capacity. Indirect compensation costs include productivity loss, morale reduction, the continuation of employee's benefits, accident handling reports, rescheduling expense, temporary employee cost and cost of spoiled work (Kerr et al., 2001). Exacerbation of pain potential due to fear of movement causes increased movement restriction and increased loading, causing more painful episodes; progressing acute LBP to chronic LBP (Langevin & Sherman, 2007; Manchikanti, 2000; Marras, 2000).

1.4.1 Pain

Pain is a poignant sensation of substantial impudence to the biological system. The International Association for Study of Pain defines pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage" (Adams, 2004). Pain is a complex perception influenced by prior experience in which the Central Nervous System (CNS) is responsible for the development of such perception which is a cascade of changes initiated by tissue damage elicited by a collection of synaptic, neurotransmitters and re-modelling similar to learning and memory (Moseley & Hodges, 2005). Marras (2008) stated that "much of pain experience can be initiated by a physical insult to the biological system, it is possible for pain to be perceived due to a disturbance of any part of the bio-psychosocial system; we call the human experience." In MMH workplaces, loading of tissues due to biomechanical risk factors can result in a sensation of pain. This result is due to the load-tolerance relationship during any MMH activity (Marras, 2000). Pain in-turn affects the productivity and influence absenteeism as well (Fig 1.7).

Acute: Any pain that results due to sudden injury to the tissues in the lower back is acute pain. Activation level of muscles in response to rapid loading of spine springs micro trauma in the lower back. Continuation of micro trauma advances to tissue failure/Chronic injury and pain.

Chronic: Acute pain that persists for more than three months is called chronic. Chronic injury most often occurs due to insufficient warning of overload during repetitive activities. Sustained loading along with physical work factors act on workers' performance and has also been investigated as a risk factor of LBP (Murtezani et al., 2010).

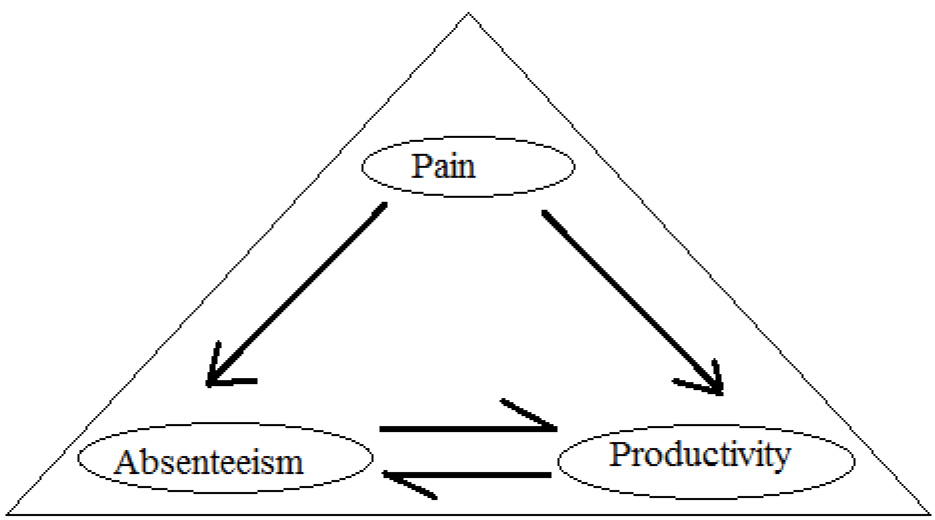

Fig 1.7. Relation between consequences of LBP

1.4.2 Productivity

Industrial performance is an essential element which relies upon worker productivity. Wieser et al. (2011) mentioned three causes of productivity loss: absenteeism (temporary absence from work), presenteeism (reduced productivity despite being present in the workplace) and permanent disability. In the Weiser study (2011), cost of productivity loss was measured using two approaches. The first is a human capital (HC) approach, which calculated a €4.1 billion ~ $4.223 billion cost and the second method is a friction cost (FC) approach which estimated €2.2 billion ~ $2.266 billion (Wieser et al., 2011). In a human capital approach, productivity loss is estimated by work-time lost multiplied by gross earnings of the individuals affected and it includes costs incurred due to above mentioned three causes of productivity losses (Wieser et al., 2011). The friction cost measured productivity loss by the cost incurred until the sick worker was replaced. The cost of presenteeism is the same as in the human capital approach but for the cost of absenteeism, the time period for friction is considered 22 weeks and the cost of permanent disability is not considered at all (Wieser et al., 2011).

Pain, productivity and absenteeism are strongly related (Fig 1.7). Decreased productivity can lead to absenteeism or absenteeism can lead to decreased productivity after return to work, as a consequence of LBP. Absenteeism from work results in production losses due to an impaired ability to work (Tymecka-Woszczerowicz et al., 2015). Presenteeism also reduces the productivity of workers and increase the chances of re-injury.

1.4.3 Absenteeism

The prevalence of absenteeism is international. Absenteeism not only drains the funds from the MMH industry, but also flows from the health industry as well. Above all, absenteeism from work due to LBP impacts the quality of life and return to work motives of the workers. Consequences of LBP vary from disability and poor quality of life to absenteeism. The span of absenteeism ranges from days to years depending upon the extent of LBP. In western societies, low back pain patients (10-25%) take long term absence from work accounting for 75% of cost due to leave and disability (Lambeek et al., 2010). Walker et al. (2003) stated that 10% of Australians suffer disability from LBP, which ranges from nuisance pain to severe affliction, in any 6-month period causing permanent disability and sickness absence. Likewise in Sweden, back pain is the leading cause of sick leave and early retirement; a huge drain on the country's economy and health system (van der Giezen et al., 2000). Ghaffari et al. (2006) state that the consequences of LBP such as recurrence, disability, productivity loss and the corresponding increase in economic cost are far reaching and associated with increased absence. Considering the above statistics, one can conclude that low back injuries have played and will continue to play a significant role in decreased efficiencies and especially increased absenteeism in the workplace (Jones & Kumar, 2001).

Workplace absenteeism is the first step that a worker takes to deal with LBP but this usually has an adverse effect on the workplace. Workplace injuries take a corporate financial toll because of resulting absenteeism from work (Van Nieuwenhuyse et al., 2004). "Lost workdays as a result of workplace injuries exceeded the number of lost workdays as a result of labor unrest in Canada during 1993-1996" (Van Nieuwenhuyse et al., 2004). Absenteeism due to LBP is prevalent in many major industries and high-risk industries such as millwork, construction, crude petroleum, natural gas extraction, motor vehicle equipment manufacturing, nursing, and personal care (Van Nieuwenhuyse et al., 2004). The highest prevalence of LBP is present in individuals with physically demanding jobs which include standing and lifting for the majority of the workday (Power, 2000; Chen, 2005).

Work absenteeism is a big issue that has attracted the attention of the industrialized world. Lambeek et al. (2010) reported that 10-20% of LBP patients took a long-term absence from work and were responsible for 75% of sick leave and disability costs. It is also reported that due to LBP, there is a strong association between workplace absenteeism and associated disability (Burdorf & Jansen, 2006; Murtezani et al., 2010). Workers' having less lost time from work due to injury have better functional status when compared to workers who are on disability leave for longer periods of time (Guo et al., 1999).

The prevalence of absenteeism is international. It ranges from 2% to 8% and days of absence from workdays/year ranges from 9 days in U.S, to 10 days in West Germany, to 20 days in Canada, to 25 days in Netherlands, to 30 days in Great Britain and 40 days in Sweden" (Manchikanti, 2000). The prevalence of absenteeism due to LBP is "9% in Irish health care workers and 9% in New Zealand Veterinarians" (Widanarko et al., 2012). In the Netherlands, 14% of laundry and dry-cleaning workers and 15% of Greek shipyard workers also reported absenteeism due to LBP (Widanarko et al., 2012).Considering the above statistics, one can conclude that low back injuries have played and will continue to play a significant role in decreased efficiencies and especially increased absenteeism in the workplace (Jones & Kumar, 2001).

1.5 Solution(s)

The main aim of dealing with consequences should not only be to reduce pain but also to restore function to its maximum level (Lambeek et al., 2010). Low back pain impacts not only an individual's life, but also results in immense socio-economic costs (van der Giezen et al., 2000). For decreasing both the personal and socio-economic burden, many suggest that ergonomic intervention strategies should be introduced in the workplace to promote a rapid and safe return to work (van der Giezen et al., 2000). To control risk factors which are contributing to absenteeism in the workplace, a better understanding of factors occurring beyond simple identification must occur. This can help in understanding the difference why some people are at greater risk than others despite being in the same job (Marras, 2000).

1.6.1 Ergonomics

Ergonomics is a discipline used to make work and workplaces safer for workers. According to the International Ergonomics Association (IEA): "Ergonomics (or the human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (definition adopted by IEA Council in August 2000 (http://www.iea.cc/ergonomics/)) (Niu, 2010)." Ergonomics in the workplace should be given greater importance to the development of new instruments when considering interventions of LBP (Niu, 2010). Westgaard and Winkel (1997) stated: "for prevention, workplace adjustments are prioritized because they must [sic] have a more permanent and long-term character to decrease workload for a group of workers, and they are frequently aimed at the primary cause of the problem". Jones and Kumar (2001) also reported that "ergonomic programs have recently become a major factor in proposed occupational health and safety legislation in both the United States and Canada." With the help of these programs, the labor departments of both countries hope to minimize musculoskeletal injuries such as LBP in the workforce (Jones & Kumar, 2001). Ergonomic programs utilize intervention techniques that focus on methods that achieve prevention by reducing the exposure to risk factors causing LBP (Zalk, 2001).

The aim of ergonomic workplace intervention is to reduce mechanical exposure to factors responsible for developing LBP. Decreasing the exposure of workers to risk factors can also potentially increase the efficiency and productivity of MMH workers. Marras (2000) concluded that “for an intervention to be effective, it must reduce the mechanical exposure to stressors, actively involve the worker and must affect the organizational culture”. Ergonomic interventions in the workplace which may reduce absenteeism and promote early return to work and could potentially save billions of dollars (Jones & Kumar, 2001; Arnetz et al., 2003).

1.6 Ergonomic Interventions

Ergonomic interventions for the present analysis are defined as intervention that involves education, procedural change (administrative change), equipment (engineering control) to maximize the worker efficiency and relieve the load from the lower back. Such interventions can include the application of an effective lifting technique, modifying the physical demands and adjustment of working height (lift table, tilt table) while performing MMH activities.

Application of ergonomic intervention gained momentum in developed countries as the proper application of ergonomics reduces injury in the workplace, enhance performance and results in fewer compensation claims and more financial benefit to the economy (Jaromi et al. , 2012). The major problems that cause LBP that affect MMH workers performance both directly and indirectly, encompass improper workplace designs, ill-structured jobs, the mismatch between worker’s abilities and demands, poor human machine interface and inappropriate management (Shikdar & Sawaqed, 2004). May et al. (2004) stated that a preventative method for improving employees' health is ergonomic job redesign of the physical work environment as it helps in achieving an adequate balance between worker characteristics, work activities and task demands. MMH is moving from the point where load used to be a risk factor to present day where repetition and awkward motion under time pressure are more important risk factors (Marras, 2000).

1.5.2 Risk factors

Professions which involve mainly MMH including tasks such as standing, lifting and bending postures such as: nursing, carpentry, construction, oil field workers, labourers, etc. increase the risk of LBP. When such jobs combine with risk factors of awkward postures, repetition, and spinal loading, they increase the frequency of low back pain leading to absenteeism (Al-Obaidi et al., , 2000; Loisel et al., 2001; Moseley & Hodges, 2005). MMH activities modulate LBP risk in any MMH workplace. Designing ergonomic interventions can potentially minimize the risk factors associated with LBP and subsequent absenteeism in MMH industry.

The physical environment in the workplace and ergonomics in the workplace provide a subjective assessment of the risk factors contributing to occupational LBP. Lariviere et al. (2000) suggested the use of lifting strategies that reduce L5/S1 loading. They further reported that there is a decrease in load on the lower spine by improving bio-mechanics of workers with the help of different lifting and lowering techniques. Jaromi et al. (2012) indicated that different lifting and lowering postures and movements may reduce the pressure on the spine, which could produce positive long-term results such as decreased intensity of pain, less recurrent LBP episodes and improved spinal functions (). Jaromi et al. (2012 that the "learning of appropriate body posture helps in working safer and avoids spinal overloading, thus significantly decreasing the risk of formation and relapse of LBP."

1.6.2 Types of ergonomic interventions

Ergonomic interventions include engineering and administration controls. It also involves the worker's participation. Ergonomics necessitates the involvement of worker participation with design control or admin control as and when needed to cease the growth of risk factors. Engineering controls are the mechanisms which lessen the physical exertion of a job with the help of assistive technologies such as equipment, tools, and workplace design, etc. to allow safe and efficient performance of jobs (Worksafe, 2010). Administrative controls such as job rotation or change in the type and design of work is another factor known to reduce the risk factors causing or contributing to LBP (Frazer et al., 2003).

Administrative control intervention is preferred by the employer as it is the cheapest manner of minimizing the impact of risk factors on workers according to them. Job rotation or alternate work after injury could lessen the pain sensation in a particular worker but as soon as the workers is placed on the old job, the interaction with risk factors of LBP again starts and brings the workers closer to re-injury and decreased productivity. Engineering control interventions are the second choice of employers. Engineering interventions are utilized when administrative controls do not produce effective results in terms of controlling the risk of LBP. On the contrary, if engineering interventions control the effect of risk factors during MMH activities. Engineering intervention needs to be the first choice of employers as engineering designs take the load off the low back and maintains the productivity of workers along with maintaining the quality of life of workers. Engineering controls seem costly at first but when weighed with the long term benefits for workers and cost associated (after failure of administrative controls), engineering control still stands on the cheaper side.

Ergonomics programs mainly focus on engineering controls, such as tool and workstation dimensions, heavy lifting, awkward postures, and repetitive tasks (Alperovitch-Najenson et al., 2010). Workplace design can decrease the load on the spine by utilizing the six main engineering factors as follows:

- “Design – Interface, height at workplace, load securing base
- Load characteristic – type and size of load, weight, shape/symmetry of load object
- Workers' performance – forces required, load capacity, safety
- Workers’ characteristic – age, sex, strength, motivation, training and task knowledge
- Workplace conditions – terrain, slopes/steps, maintenance, obstacles
- Work requirements – frequency and duration, speed, work pressure” (Worksafe, 2010)

Engineering Controls: Engineering controls can helps workers achieve a balance between worker characteristics and task demands and mainly deals with the concern of poor human-machine system design (Shikdar & Sawaqed, 2004). Engineering controls reduce mechanical equipment injuries and improve worker productivity along with decreasing overall cost of workplace injuries (Shikdar & Sawaqed, 2004). Engineering controls can assist in eliminating the risk factors associated with acute and chronic LBP via aligning the work rates according to human pace and ergonomic standards (Worksafe, 2010).

Administrative Controls: Administrative controls have two approaches; one is identifying workers who are likely to suffer LBP at work, and the other is controlling the length of exposure to the risk factors. These approaches can be attained with the help of job rotation in which the cumulative risk exposure is monitored on a rotating basis. Job rotation spreads the risk exposure over a larger population which minimizes the exposure of a particular worker. The tricky part that still needs to be analyzed is "how much exposure is too much exposure?". Training should be provided to the workers to understand and minimize the distance between load and spine which results in the reduction of spinal loading moment exposure and; worker selection which depends on the type of work and strength level of the operator/employee.

Engineering ergonomic solutions for MMH workers is a primary means of reducing LBP risk. In MMH workplaces, the mismatch between a person's ability to perform MMH task and the demands of handling MMH task could result in injury due to workpiece positioning, equipment orientation and workstation layout. Frazer et al. (2003) emphasized the importance of engineering controls to reduce peak forces and cumulative forces arising from repetition and long duration of work. Administrative control/management plays an important role in controlling and accelerating recovery from low back injury. Management's understanding for ergonomic intervention to prevent low back pain and its associated consequences could prevent the incidences of injury. Ergonomic approaches for redesigning MMH workplaces can also help in decreasing low back injuries by considering increasing workers capability and ensuring long term productivity.

Vand der Molen et al., (2010) performed a study to evaluate the use of ergonomic measures such as mechanical material transport and use of mechanized multifunctional machines on low back complaints among construction workers. The study failed to find a statistically significant relationship of ergonomics on LBP. Warming et al., (2008) tried to study the effect of transfer technique for reducing LBP but the study was weakened due to a lack of outcomes and high withdrawal rate, and the author suggested the need for future studies in the same direction. Alternatively, Latza et al. (2000) reviewed if an ergonomic evaluation favoured a causal relation between LBP and MMH jobs. Ergonomic evaluation helped in guiding effective interventions of using a device for lifting and moving heavy loads (Latza et al., 2000). The major contributing factor to LBP is biomechanical strain during repeated lifting and transferring activities. Yip (2001) performed a study among Hong Kong nurses and identified a relation between LBP risk and patient handling. It was suggested that the main route to prevent LBP risk is ergonomics. D'Arcy et al. (2012) reported that among nurses, there was a decreased potential of developing a back injury with the help of lifting devices and proper training among nurses.

The likelihood of developing LBP is lowered following regular ergonomic interventions when adjusting working height (Marras, 2000; Van der Molen et al., 2009; Vander Molen et al., 2004). Kerr et al. (2001) modified physical demands to determine risk factors of LBP at work and concluded that physical demands at the work place act as independent risk factors of LBP. There is an unclear relation between CLI (Composite Lift Index) and LBP for predicting the risk of LBP associated with manual lifting (Lu et al., 2013). For multiple lifting tasks, the lifting index (LI) is used for safe lifting. LI is calculated = load weight/ recommended weight limit (Waters, Putz-Anderson, Garg, Safety, & Health, 1994). The composite lifting index represents the collective demands of the job. The CLI is the sum of single task LI and the incremental increases in the CLI as each subsequent task is added and the incremental increase in the CLI for a specific task is defined as the difference between the LI for that task at cumulative frequency and LI for that task at its actual frequency (Waters, Putz-Anderson, Garg, Safety, & Health, 1994). Lariviere et al. (2002) performed a study on a biomechanical comparison of lifting techniques during free style lifting and lowering tasks and suggested the need for a more detailed biomechanical analysis. To minimize the adoption of awkward postures causing LBP among MMH workers, there is a need for increased ergonomic intervention and initiatives (Andersen et al., 2012; Widanarko et al., 2012) along with increased awareness about the causal factors of LBP causing sickness absence (Alexopoulos et al., 2008). Manual handling also increases the likelihood of low back pain – sick leave (LBP-SL) and multi-dimensional intervention programs are needed that are effective in decreasing LBP-SL (Dawson et al., 2011).

Plenty of research has been conducted on how to decrease the length of absenteeism among MMH workers due to LBP (Arnetz et al., 2003; IJzelenberg, Molenaar, & Burdorf, 2004; Burdorf & Jansen, 2006; Alexopoulos et al., 2008; Werner & Côté, 2009; Andersen et al., 2012; Widanarko et al., 2012). The effectiveness of ergonomic interventions in preventing absenteeism due to LBP has been difficult to prove. Numerous studies have been conducted scrutinizing the relationship between LBP and absenteeism. For instance, studies have been conducted to determine the association between ergonomic interventions and LBP (Marras, 2000; Vander Molen et al., 2004; Lu et al., 2013); and LBP and absenteeism (Andersen et al., 2012; Widanarko et al., 2012). Occupational LBP has a high level of economic consequence and results in a high rate of absenteeism (Marras, 2000). The majority of studies have focused on ergonomics and LBP, but the available studies for the effectiveness of ergonomics run on small data sets with few participants. The effectiveness of ergonomics has been so far proven via small studies (less numbers of participants), on individual MMH working populations, and certain industries performing manual handling tasks. Along with ergonomics, job monitoring is an essential component of ergonomics which provides information about the risk factors causing sickness absence and helps in determining strategies for reducing sick leave (Alexopoulos et al., 2008). Millions of dollars have been spent on research studies to find the effectiveness of ergonomics in reducing LBP, yet there is no pooled effect of available research studies which call for a meta-analysis to determine if ergonomics is helpful in decreasing LBP and sequential absenteeism. A meta-analysis can summarize the results of available studies in determining the usefulness of ergonomics in MMH industry as it overcomes the small sample size of individual studies and detects the effects of the intervention.

1.7 Dealing with individual risk factors

Individual factors are influenced mostly by attitudes and beliefs of workers. Knowledge of factors affecting the health of workers in the workplace is necessary. Education sessions that provide information about healthy habits and fostering healthy adoption of bio-mechanics are influential in changing the health and behaviour pattern of employees. Yip (2001) suggested designing LBP prevention programmes focusing on improved ergonomics via education and such programmes should focus on proper techniques that minimize the load on lower back while either performing a manual task or using mechanical devices for performing the MMH tasks. Education and training to MMH workers is not a replacement, but a complement to ergonomic interventions. Educational information should be imparted to MMH workers for improving body mechanics and decreasing the risk of LBP. Workers adjust to maximum workload without undue strain/discomfort, and without becoming unusually tired or weakened, but the proper knowledge of working patterns via proper training can prevent many workplace injuries (Yip, 2001, 2004). Understanding the causes of low back injury can help workers understand their own care and to help demonstrate techniques for decreasing workplace injuries.

Education and counseling should be enforced periodically by management. Participation by workers is invaluable for the creation of safer and friendlier work systems. Education with worker participation generates appropriate ergonomic solutions to modify work demands to match physical capacities and demands of workers for a quicker and safer return to work (Loisel et al., 2001). Active participation of workers and management for identifying risk factors in the workplace and for finding the most appropriate solution for those risk factors has proven beneficial (Arnetz et al., 2003). Wilson and Haines (2002) stated that "the involvement of workers[sic] in planning and controlling a significant amount of their own work, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals" are widely recognized and utilized in improving ergonomic aspects at work. Nagamachi 1995, stated "Participatory ergonomics consist in the workers' active involvement in implementing ergonomic knowledge and procedures in their workplace, supported by their supervisors and managers, in order to improve their working conditions". Participatory ergonomics interventions include a diverse set of skills and knowledge which increase the likelihood of ergonomic implementation and decrease absenteeism. When participatory ergonomics is included in the workplace, workers who are involved return to regular work 1.9 times faster than workers who have not been involved, indicating a greater need for ergonomics programs to decrease work absenteeism caused by LBP (Jones & Kumar, 2001).

1.8 Meta-analysis as a means of measuring the effectiveness of ergonomic interventions

This study employs both a quantitative and qualitative literature review methodology, known as a meta-analysis. A meta-analysis illustrates the importance of replication, is a process of summing up research findings, and is used for synthesizing effect sizes. A meta-analysis is a powerful tool which overcomes the issues of small sample size of individual studies and increases the precision for estimating effects (Walker et al., 2008). It provides a solid foundation for the next generation of research on any given topic by pointing out the gaps in the literature and summarizing or combining results across studies thereby providing an empirical answer to the research questions (Ellis, 2010; Walker et al., 2008). Meta-analysis brings into focus the direction and magnitude of the effects across the studies. Supporting the narrative review Steve Goodman (1991) wrote, “The best meta-analyses knit clinical insight with quantitative results in a way that enhances both of them and; the clinical insight and quantitative results should combine the careful thought and synthesis of a good review with the scientific rigor of a good experiment”.

Meta-analysis gives weight to studies based on their size and stability. It allows us to critically evaluate and statistically combine the results of comparable studies to improve the estimate of an effect size of an intervention. On the other hand, meta-analysis is always performed for quantitative studies and the qualitative aspect is always neglected by the researchers. Also, the conclusions of a meta-analysis differs when different studies are sampled for different reasons. So, a meta-analysis when done properly and cautiously, it brings new and useful information that helps health professionals and others who are looking for the answer to a specific question.

Heterogeneity is another word used for diversity in the studies. Two sources that explain variability in a meta-analysis are within-study variability and between-study variability. Within-study variability is always present in a meta-analysis due to sampling error in the included studies (Huedo-Medina et al., 2006). Between-study variability is present when there is heterogeneity in the study and it occurs due to different type of interventions, designs and samples (Huedo-Medina et al., 2006). This meta-analysis will have within-study as well as between-study variability. The random effects model assumes that the treatment effect is not the same across all the studies (variation among the studies), and the goal is to estimate the average effect in studies. Whereas, in fixed effects model, the difference between effect sizes of studies is due to sampling error (Borenstein et al.a, 2009). "The random effects model is based on the mean of the distribution of effects" (Borenstein et al., 2009). Each study is weighted equally in a random effects model. The random effects model yields wide confidence intervals which indicate that the distribution will likely be heterogeneous.

The problem of publication bias can be overcome with a more accurate synthesis method which can analyze the effect size of completed studies in the field of ergonomic intervention rather than mention just a summary effect. A meta-analysis includes both published and unpublished studies, as well as, significant and non-significant results. Many studies have been conducted using a small sample size (Marras, 2000 (n=6); Larivière, Gagnon, & Loisel, 2002 (n=12)) suggesting that ergonomic interventions are an effective measure for preventing absenteeism caused because of LBP; however, few studies have been conducted using a large sample size (van der Molen, Sluiter, & Frings-Dresen, 2009 (n=1921). This justifies the need for a meta-analysis because this type of analysis maximized the sample sizes of smaller studies in combination. The meta-analysis provides complimentary information that is valuable to researchers, clinicians, ergonomists, employers and MMH workers.

1.9 Rationale

In the wake of all the research done for finding a solution to decrease LBP, ergonomics is often presented as a viable alternative to other possible solutions such as medical treatments and changing jobs. Ergonomics deals with what is thought to be the cause of occupational LBP – it is, therefore, logical to introduce ergonomics into MMH jobs. Since ergonomics is related to the creation of an ergonomic friendly environment, available research verifies that an ergonomically friendly workplace could lay the groundwork for an LBP free workplace.

The majority of available research supports the use of ergonomics for LBP. While the available quality studies, when considered individually, support the use of ergonomics, the question remains, if they are re-grouped for more power, by a meta-analysis, will the outcome still support ergonomics as a viable solution to occupational injury. Meta-analysis controls the quality, power and number in the studies. The goal of the present study was to identify whether ergonomics has the potential to reduce LBP in MMH workplaces and eliminate the consequence of absenteeism resulting due to LBP.

1.10 Purpose

The goal of this quantitative study is to analyze the effect of ergonomics on LBP in workers performing MMH jobs in developed countries. The significance of the relationship is that it may provide an understanding of how ergonomics can help in the reduction of LBP in MMH workers. Likewise the study examined whether absenteeism is a consequence of LBP. The data collection process incorporated an in-depth search of studies that ascertain the effects of different ergonomic interventions on LBP and in turn, absenteeism.

1.11 Hypothesis

The purpose for the present study is to determine whether ergonomic interventions for the risk factor of posture in the workplace improves LBP outcome such as absenteeism among MMH workers in developed nations. The hypothesis is separated in two parts as it is difficult to analyze the effect of ergonomics on LBP resulting in absenteeism in one meta-analysis. For ergonomic intervention analysis, the null hypothesis, **(H_0)** Ergonomic intervention has no effect on LBP in MMH workers and the alternate hypothesis is **(H_A)** Ergonomic intervention improves LBP in MMH workers. For absenteeism analysis, the null hypothesis **(H_0)** LBP has no effect on absenteeism in MMH workers and the alternate hypothesis is **(H_A)** LBP increases absenteeism in MMH workers.

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Chapter 2

Methodology

This meta-analysis follows the combination research design suggested by Cooper and Hedges (1994) (Hedges, 1994). He proposed four stages for meta-analysis: "(1) the problem formulation stage, (2) the data collection stage, (3) the data evaluation stage, (4) the analysis and interpretation stage." At the problem formulation stage, the studies are judged by the concept investigated and methodologies involved in the original research (Hedges, 1994). For this study, a literature search was completed on the effectiveness of ergonomic interventions and absenteeism due to LBP. The data collection stage involves a search of literature meeting the inclusion criteria (Hedges, 1994). The data evaluation stage mainly deals with data extraction and results of selected studies along with an assessment of study quality (Hedges, 1994). The analysis and interpretation stage uses statistical procedures to evaluate the homogeneity of studies and the process of combining the study results (Hedges, 1994).

2.1 Meta-Analysis- I: Ergonomic Intervention Analysis (Effect of ergonomic intervention on LBP in MMH workers)

An electronic search was performed for the identification of studies. A systematic review of the literature was done in NLM (National Library of medicine), PubMed/MEDLINE, Google Scholar, Embase/Science Direct and the Cochrane database. The terms "low back pain + ergonomic intervention + manual material handling + workers + posture + meta-analysis + occupational + absenteeism + posture + consequence" were used for the literature search. The terms were also used in combination with ‘and’ and ‘or’ between each term. The selection of studies was done on the basis of several inclusion and exclusion criteria.

2.1.1 The inclusion criteria

- Studies published in English
- Related to LBP
- Related to occupational exposure
- Related to etiology (workplace, biomechanical factors)
- Related to workplace manual material handling
- Related to ergonomic intervention in the workplace (Studies including ergonomic intervention targeting physical loading/LBP are considered)
- The publication year 2000-2014
- Type: Random Control Trials, Case-control studies, cohort studies and clinical trials

2.1.2 The exclusion criteria

- No specific population
- No particular outcome
- Pathological back pain
- Non-specific back pain, whole spine pain
- Health services research
- Absence of statistical measures (mean and standard deviation)

The search resulted in the selection of a total of 427 studies:

- 78 reviews were deleted due to duplication whereby obtaining the same study occurred between the different search engines
- 291 studies were excluded on the basis of inclusion criteria
- 28 left for detailed study
- 22 excluded due to irrelevancy (Studies that fit in the inclusion criteria but have only reported results without mentioning mean and standard deviation values or the studies mentioned an unclear ergonomic intervention)
- 6 included in the meta-analysis

2.1.3 Null Hypothesis

Meta-analysis I

H_0: Ergonomic intervention has no effect on LBP in MMH workers

H_A: Ergonomic intervention improves LBP in MMH workers

Meta-analysis –I has continuous outcomes which the forest plot will illustrate while using raw data as means, standard deviation, sample sizes and confidence intervals as blocks and lines. The participants are divided into experimental and control groups. Three heterogeneity statistics are used: Tau^2 for among-study variance (random effects meta-analyses), chi^2 test and I^2 statistic.

2.1.4 Participants and Methods Description

Van der Molen (2004)

The study conducted by Van der Molen et al. (2004) was on ten bricklayers and ten bricklayers' assistants;. The authors calculated the effect of mechanization (crane) for bricklayers and assistants. Scaffolding consoles were used as a low back intervention for bricklayers at T1(start time of observation period) to T4 (end of observation period over a repeated 4.5h observation period) over a 4.5 hour period including breaks. In the analysis, experimental mean and the standard deviation was calculated by adding the parameters at T4 for ten bricklayers and assistants and the control parameters are calculated at T1. The start time of intervention was taken as a control because at that point there had been no effect of the intervention on the participants in the study. T1 includes the mean (S.D) for 31-cm elevation for bricklayers [0.9 (1.4)] and mechanization for bricklayers' assistants [0.9 (1.9)]. T4 includes mean and S.D for 31-cm elevation for bricklayers [1.6 (2.5] and mechanization for assistants [1.1 (2.1)]. The combination of mean and S.D is calculated with the help of mini calculator available in Rev Man 5.3.

Van Der Molen et al. (2009)

Van Der Molen et al. (2009) performed another type of design on construction workers (pavers and carpenters), taking four ergonomic measures for activities (lifting, pulling, carrying and bending) while performing MMH tasks at work over a period of 4.5 years. The four ergonomic measures are more or less the same as risk factors or biomechanical factors involved in other included studies which could be modified with the ergonomic interventions. The authors did a baseline study in 2000 on 1322 carpenters and 907 pavers; and a follow-up study in 2005 including 600 carpenters and 314 pavers. In the analysis, the control participants included are 1036, i.e., mechanical materials transport (386), mechanical placing of window frames (324), paving stones (158) and mechanical setting of kerb stones (168); and experimental ones are 885, i.e., aids for handling heavy loads (357), height adjustable working platform (356) and working with a multifunctional machine (172). The calculation is based on several groups and is done with the help of the RevMan 5.3 calculator. Mean and standard deviation were calculated by putting some respective participants (as per category) and confidence interval in RevMan 5.3. The mini calculator in Revman 5.3 helped in calculating the mean of means, which is then included in meta-analysis I.

Lariviere et al. (2001)

Lifting techniques as compared to freestyle lifting have also been analyzed by Lariviere et al. (2001), evaluating L5/S1 loading and posture of segments. The study appears twice in the meta-analysis as it was the same subjects that have been assessed for different variables. The ones included in the study are M_R: resultant moment and F_C: compression estimate. Each variable is included individually in the meta-analysis I. The mean (S.D) for experimental M_R: 164 (23) and F_C: 3657 (763); Control M_R: 177 (25) and F_C: 4096 (995).

Marras et al. (2000)

Marras et al. (2000) also evaluated low back disorder risk in MMH jobs using a variety of tools. The authors analyzed LBD by high, medium and low-risk category. The present analysis includes high LBD risk category for pre-intervention and post-intervention groups. The pre-intervention group is taken as a control group, and the mean (S.D) for the control group is 81.2 (11). The post-intervention group is considered as an experimental group, and the mean (S.D) is 78 (6). The standard deviation for both groups is calculated with the help of values given for mean, C.I by inputting them in RevMan 5.3 calculator.

Kerr et al. (2001)

Modifications of physical demands at work with the help of work sampling techniques for posture and detailed kinematic posture data and their impact on LBP is also studied by Kerr et al. (2001) for the continuous variable of back pain disability on 137 experimental [mean, S.D; 11.7 (7.0)] and 179 control [mean, S.D; 2.5 (5.0)] participants.

Lu et al. (2013)

For predicting the risk of LBP, Lu et al. (2013) evaluated the efficacy of Revised National Institute for Occupational Safety and Health (NIOSH). Among all the variables, the maximum load is considered for analysis with the help of multiple lifting techniques. All subjects (N= 78) are taken as control variable with mean (S.D) [9.0 (6.8)]; and LBP (N= 25) is taken as experimental variable with mean (S.D) [8.5 (5.0)].

2.2 Meta-analysis II: Absenteeism Analysis (Effect of LBP on absenteeism in MMH workers)

An electronic search is performed for the identification of studies such as, in Meta-analysis I. A systematic review of literature is done in NLM, PubMed/MEDLINE, Google Scholar, Embase/Science Direct and the Cochrane database. The terms "low back pain + ergonomic intervention + manual material handling + workers + posture + meta-analysis + occupational + absenteeism + consequence + baseline + result" are used for the search of literature. All the terms are also used in combination of and/or. Selection of studies is done on the basis of inclusion and exclusion criteria.

2.2.1 The inclusion criteria

- Studies published in English
- Related to LBP
- Related to occupational exposure
- Related to etiology (workplace, mechanical factors)
- Related to LBP as a cause of absenteeism
- Related to studies having baseline and follow-up studies
- The Publication year 1995-2014
- Type: RCT, Case-control studies, cohort studies and clinical trials

2.2.2 The exclusion criteria for meta-analysis II

- No specific population
- No particular outcome
- No Pathological back pain
- Non-specific back pain, whole spine pain
- Health services research
- Absence of statistical measure (odds ratio)

The search resulted in selection of total 191 studies-

- 31 studies got deleted due to duplication (obtaining the same study from different search engines)
- 160 studies were excluded by inclusion criteria
- 17 left for detailed study
- 14 excluded due to irrelevancy (studies that fit in the inclusion criteria have mentioned the total number of subjects but did not mention the subjects in a specific category)
- 3 included in the meta-analysis

2.2.3 Null Hypothesis

Met-analysis II

H_0 : LBP has no effect on absenteeism in MMH workers

H_A : LBP increases absenteeism in MMH workers

Meta-analyses II has dichotomous outcomes which the forest plot will illustrate raw data with the help of 2 x 2 tables and confidence interval as blocks and lines. Participants were added to a contingency table including events and non-events for both control intervention and experimental intervention groups. Three heterogeneity statistics were used: Tau^2 for among-study variance (random effects meta-analyses), chi^2 test and I^2 statistic.

2.2.4 Participants and Methods Description

Meta-analysis II involves analysis of 3 studies to find the relationship between LBP and its absenteeism consequence in MMH workers. Given the strict inclusion criteria, only three studies were considered and included in meta-analysis II. Most of the studies searched analyzed LBP and absenteeism, but they lacked the consideration of ergonomic intervention and/or MMH workers. Revman 5.3 calculates the odds ratio based on events and a total number of participants for experimental variable and control variable.

Anderson et al. (2012)

Anderson et al. (2012) performed a cohort study on 8,952 healthcare workers using the Standardized Nordic Questionnaire. LBP is given in percentage for no LBP at all (31.7%), LBP for 1-30 days (45.5%) and LBP for more than 30 days (22.7%). The control variable included in this analysis is no LBP (31.7 % of 8, 952) and the experimental variable in this study is the total of 1-30 days and more than 30 days [(45.5 + 22.7) % of 8, 952].

Alexopoulos et al. (2008)

Alexopoulos et al. (2008) performed a longitudinal study to determine the LBP risk factors causing absenteeism among 853 shipyard workers. The study included white-collar workers (N = 229) which are taken as control subjects; and the rest of the workers as experimental subjects (N = 853 – 229). The risk factor for sick leave for LBP in past 12 months is considered in the analysis i.e. control (14.8%) and experimental (15.4%).

Widanarko et al. (2012)

Widanarko et al. (2012) performed the study to know about the consequences of LBP risk factors on 3003 participants. The total number of participants in the control group was 2698 and for experimental group were 305. The events reported for the occurrence of LBP among the experimental group were 276 and among control group were 2146.

2.3 Data Analysis and Synthesis

Data analysis and synthesis were done by categorizing the subjects into experimental and control group. For meta-analysis I, the experimental group is the group that has gone under ergonomic intervention in the workplace for managing LBP and control group is the group that has not gone under any ergonomic intervention. For meta-analysis II, experimental group is the group that has reported absenteeism due to LBP and control group is the group that has not reported LBP due to absenteeism. The Effect size reflects the magnitude and impact of the ergonomic intervention on LBP in MMH workers. The effect size is calculated for each study and will be represented by the square in the graph. The square will represent the magnitude and direction of ergonomic intervention in the blue collar population.

Data management and extraction are done with the help of Review Manager (RevMan) 5.3. RevMan stores all the searched studies. The studies were imported into RevMan using .ris format. Imported studies were placed into the category of studies awaiting classification. According to the inclusion criteria, the studies were moved to the category of included studies.

The RevMan software calculates the effect size with the given values and performs the three statistical tests for heterogeneity as well. The results are determined with the help of forest plots.

2.3.1 Effect Size

The effect size for Meta-analysis I is calculated with the help of mean, standard deviation and a number of participants. The Effect size is calculated on the basis of standardized mean difference, Random effect, 95% CI. Heterogeneity is measured by Tau square and Goodness of fit is calculated by Chi square.

For meta-analysis II, the results are obtained by categorizing the subjects (MMH workers) into experimental and control groups. The experimental group is the group that resulted in absenteeism because of LBP. The control group is the group that has not resulted in absenteeism because of LBP. The effect size is calculated with the help of odds ratio (inverse variance), random effect, 95% CI.

2.3.2 Test of Heterogeneity

Heterogeneity is measured by Tau square and Goodness of fit is calculated by Chi square. The precision of the studies depends on the confidence interval (C.I). Narrow C.I studies will have greater accuracy and wider C.I studies will have lower accuracy. The size of the square in the graph will also tell us about the precision. The more weight of the square, the better precision it has.

There are three statistical tests for heterogeneity that are used in both the meta-analyses. These are Chi square (Cochrane Q), I square and Tau square tests. For chi square the rule of thumb is, if chi sqaure value is greater than the degree of freedom, then heterogeneity is present. The degree of freedom is always one less than the number of studies found in the meta-analysis. I square is an index that represents total variation across studies due to heterogeneity. I square is calculated as I square = 100x(Q – df)/Q. I square values range from 0% to 100%, with 0% values indicating no heterogeneity and values proceeding towards 100% showing considerable heterogeneity. For the last and accurate estimate of heterogeneity, Tau square is an estimate of the between-study variance in the random-effects meta-analysis. There is the presence of substantial statistical heterogeneity if the value of Tau sqaure is more than 1.

The next step calls for the computation of the statistical significance of the mean/overall effect size by either converting the result to a z-score to determine whether the probability of obtaining a score of this size is less than 0.05 or by calculating the 95% confidence interval and seeing whether the interval excludes the null value of zero. As these meta-analyses will include small sample size, significance testing can be misleading, indicating no need for significance testing ("Effect Size | Research Rundowns," n.d.). The data analysis will be done with the help of RevMan 5.3 from the Cochrane collaboration (Review Manager (RevMan) [Computer program]. Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012). The RevMan 5.3 is the latest and is trusted for the accuracy of the results provided. It is free for academic use.

2.3.3 Random Effects Model

The random effects model assumes that the treatment effect is not same across all the studies (variation among the studies), and the goal is to estimate the average effect in studies. The difference between effect sizes of studies is assumed to be due to sampling error (Borenstein, Hedges, Higgins, & Rothstein, 2009). The random effects model is based on the mean of the distribution of the results (Borenstein et al., 2009). Each study is weighted equally in a random effects model. The random effects model yields wide confidence intervals which indicate that the distribution is likely to be heterogeneous.

2.3.4 Missing Data

Missing data were dealt by emailing the authors and cross-checking the references. The wait time was two weeks for the contacted authors to reply and in the case of no response the articles were eliminated from included studies. The cross-checking of the references was also done to find the raw data as and when needed to calculate the mean, standard deviation and odds ratio for the estimate of effect size.

2.3.5 Bias

As the meta-analysis possesses a greater probability of bias, we employed the funnel plots technique to detect the possibility of bias or systematic heterogeneity in selection phase (Walker et al., 2008). In the funnel plots, each estimate is placed on the graph where the X-axis corresponds to the effect size and the Y-axis corresponds to the sample size. The logic behind the funnel plot technique is that the precision of estimates will increase with the size of studies (Walker et al., 2008). Imprecise estimates from small samples will be scattered at the bottom of the graph and the estimates obtained from large samples will be clustered at the top of the figure. In the absence of bias, the dispersion of results will have a symmetrical funnel shape and in the presence of bias, the graph will be skewed and show a lack of symmetry (Walker et al., 2008). To investigate the relationships between variables this study used weighted multiple regression analysis. It was used to ascertain the causal effect of one variable upon another i.e. the effect of an ergonomic intervention on LBP and the effect of physical activity on LBP or we can say regression analysis is used to estimate the effect of causal variables upon the variables they influence.

2.3.6 Sensitivity Analysis

In the meta-analysis, sensitivity analysis needs to be done to determine the ‘robustness' of the results we get after doing the regression analysis (Walker et al., 2008). The sensitivity analysis was done by presenting the results after removal of some studies from the analysis e.g. some studies appear to be an outlier in a meta-analysis, then their influence on a meta-analysis should be assessed by excluding it from the meta-analysis (Walker et al., 2008).

In the case of inconclusive results, there will be qualitative literature support added to the measured effect. The results from the quantitative research are synthesized with the assistance of qualitative literature having a pool of available evidence and the same topic of interest.

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Chapter-3

Results

3.1 Meta-analysis I: Ergonomic Intervention Analysis

3.1.1. Null Hypothesis

The null hypothesis, **(H_0)** Ergonomic intervention has no effect on LBP in MMH workers and the alternate hypothesis is **(H_A)** Ergonomic intervention improves LBP in MMH workers.

We failed to reject the null hypothesis as there is a lack of statistical evidence to accept the alternate hypothesis.

3.1.2 Type of studies for Ergonomic Intervention Analysis

For the ergonomic intervention analysis, any studies which used ergonomic interventions for the participants were considered. A total of six studies were used (Table 3.1) two of which were follow-up studies (Van der Molen et al., 2009) – 1yr follow-up and (Lu et al., 2013) – 4.5 yr. follow up; using self-reported LBP. An experimental study (Marras, 2000) for ergonomic intervention, another a comparative study measure design (Larivière et al., 2002), one within subjects control study (Vander Molen et al., 2004) and a case – control study (Kerr et al., 2001).

Study	Type of Study Design	Participants	Intervention	Outcome
(Larivière et al., 2002)	Comparative study with a repeated measure design	Experimental-15 Control – 18	Lifting techniques	Detailed biomechanical analysis is needed
(Vander Molen et al., 2004)	Controlled field study	Experimental – 10 Control-10	Adjustment of working height of the storage of materials	Significant less LBP in ergonomic conditions
(Van der Molen et al., 2009)	Controlled field study	Experimental-885 Control- 1036	Ergonomic measures	Regular use lowered the likelihood of LBP
(Kerr et al., 2001)	Case-control study	Experimental – 137 Control – 179	Modification of physical demands	Physical demands at workplace act as independent risk factor for LBP

(Lu et al., 2013)	Questionnaire study	Experimental – 25 Control- 78	Multiple lifting techniques	Relationship between Chronic lifting Index (CLI) and LBP is unclear
(Marras, 2000)	Experimental study	Experimental – 6 Control – 6	Workplace Ergonomic Intervention S	Ergonomic Interventions reduce likelihood of LBP

Table 3.1 Brief description of the included studies in Ergonomic Intervention Analysis

3.1.3 Measure of treatment effect: Effect Size

For Ergonomic intervention Analysis, the effect size is calculated with the help of mean, standard deviation and no. of participants. The required values have been taken out of the articles and put into the Revman 5.3 software.

	Experimental			Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
LariviÃ¨re 2002	164	23	15	177	25	18	13.8%	-0.53 [-1.22, 0.17]
LariviÃ¨re 2002	3,657	763	15	4,096	995	18	13.8%	-0.48 [-1.17, 0.22]
Marras 2000	78	6	6	81.2	11	6	11.0%	-0.33 [-1.48, 0.81]
Lu 2013	8.5	5	25	9	6.8	78	15.1%	-0.08 [-0.53, 0.37]
van der Molen 2009a	0.83	2.35	885	0.96	3.08	1036	16.2%	-0.05 [-0.14, 0.04]
VAN DER MOLEN 2004	1.35	2.2617	20	0.9	1.6243	20	14.2%	0.22 [-0.40, 0.85]
Kerr 2001	11.7	7	137	2.5	5	179	15.9%	1.54 [1.29, 1.80]
Total (95% CI)			**1103**			**1355**	**100.0%**	**0.08 [-0.59, 0.75]**

Heterogeneity: Tau² = 0.72; Chi² = 141.95, df = 6 (P < 0.00001); I² = 96%
Test for overall effect: Z = 0.24 (P = 0.81)

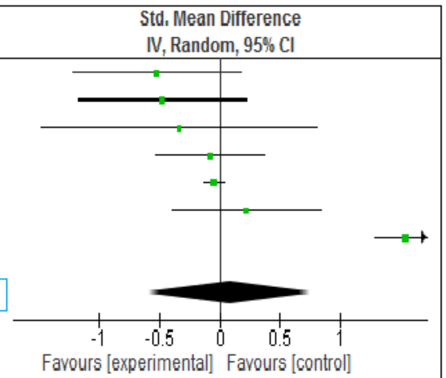
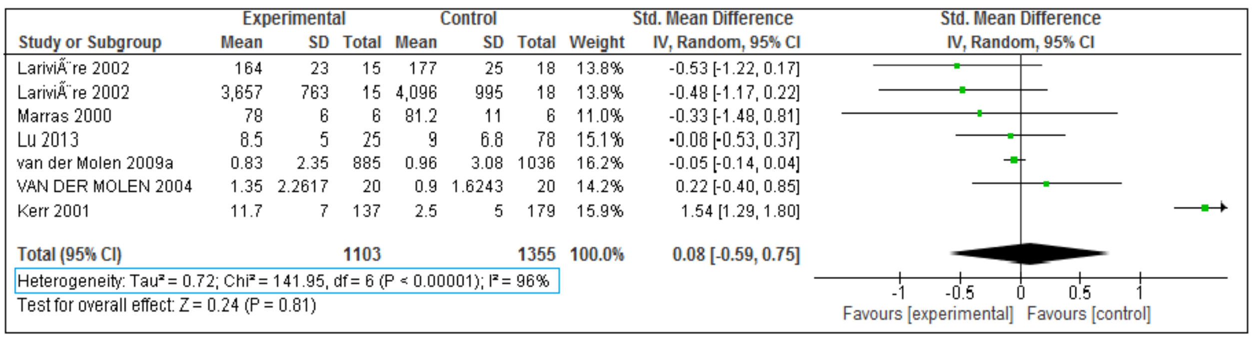


Fig 3.1: Forest Plot for Ergonomic Intervention Analysis

The effect size describes how much the ergonomic intervention affects LBP. The effect size for meta-analysis I is 0.08 (-0.59, 0.75) as per the analysis (Fig 3.1). The effect size of 0.08 implies that risk of having LBP is lower for the control group than the experimental group, and the impact falls in the range of [-0.59, 0.75]. For continuous outcomes, Cohen classified effect sizes as small (0.2), medium (0.5), and large (0.8) (Sullivan & Feinn, 2012). The effect size of 0.08 is noticeably smaller.

3.1.4 Heterogeneity



Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
LariviÃ¨re 2002	164	23	15	177	25	18	13.8%	-0.53 [-1.22, 0.17]
LariviÃ¨re 2002	3,657	763	15	4,096	995	18	13.8%	-0.48 [-1.17, 0.22]
Marras 2000	78	6	6	81.2	11	6	11.0%	-0.33 [-1.48, 0.81]
Lu 2013	8.5	5	25	9	6.8	78	15.1%	-0.08 [-0.53, 0.37]
van der Molen 2009a	0.83	2.35	885	0.96	3.08	1036	16.2%	-0.05 [-0.14, 0.04]
VAN DER MOLEN 2004	1.35	2.2617	20	0.9	1.6243	20	14.2%	0.22 [-0.40, 0.85]
Kerr 2001	11.7	7	137	2.5	5	179	15.9%	1.54 [1.29, 1.80]
Total (95% CI)			**1103**			**1355**	**100.0%**	**0.08 [-0.59, 0.75]**

Heterogeneity: $Tau^2 = 0.72$; $Chi^2 = 141.95$, df = 6 ($P < 0.00001$); $I^2 = 96\%$

Test for overall effect: Z = 0.24 (P = 0.81)

Fig 3.2: Heterogeneity for Ergonomic Intervention Analysis

In the case of Chi square values, following the rule of thumb, the value for heterogeneity is 141.95, df = 6 (P<0.00001) shows heterogeneity is present in the studies. I^2 is an index that represents total variation across studies due to heterogeneity. In this case, the I^2 value is 96% indicating considerable heterogeneity. True heterogeneity in between studies cause 96% of the total heterogeneity and not by sampling error. I^2 = 96% also implies high heterogeneity among studies. Moving forward to the last and accurate estimate of heterogeneity, Tau square gives an estimate of the between-study variance in a random-effects meta-analysis. A value of Tau square more than 1 indicates the presence of substantial statistical heterogeneity. In meta-analysis I, the value Tau square is 0.72 (less than 1) implying that there is less chance of significant statistical heterogeneity. The remaining two estimates chi^2 ($P<0.00001$) value and $I^2=96\%$ values indicate a high likelihood of heterogeneity among included studies.

3.1.5 Assessment of risk of bias in included studies

The table below (Table 3.2) describes the type of bias present in each of the studies included in Ergonomic Intervention Analysis. The detection of bias was done on the basis of information present in the studies.

Type of Bias **Study**	**Selection bias**	**Performance bias**	**Detection bias**	**Attrition bias**	**Reporting bias**
(Larivière et al., 2002)	**None**	**None**	**None**	**None**	**Present**
(Vander Molen et al., 2004)	**Present**	**None**	**None**	**Present**	**None**

(van der Molen et al., 2009)	**Present**	**None**	**None**	**None**	**None**
(Kerr et al., 2001)	**Present**	**Present**	**None**	**None**	**Present**
(Lu et al., 2013)	**Present**	**Present**	**Present**	**Present**	**Present**
(Marras, 2000)	**None**	**Present**	**Present**	**None**	**None**

Table 3.2: Bias Summary for Ergonomic Intervention Analysis

In the absence of bias, the dispersion of results will have a symmetrical funnel shape but in the presence of bias, the graph will be skewed and show a lack of symmetry (Walker et al., 2008).

3.1.6 Funnel Plot

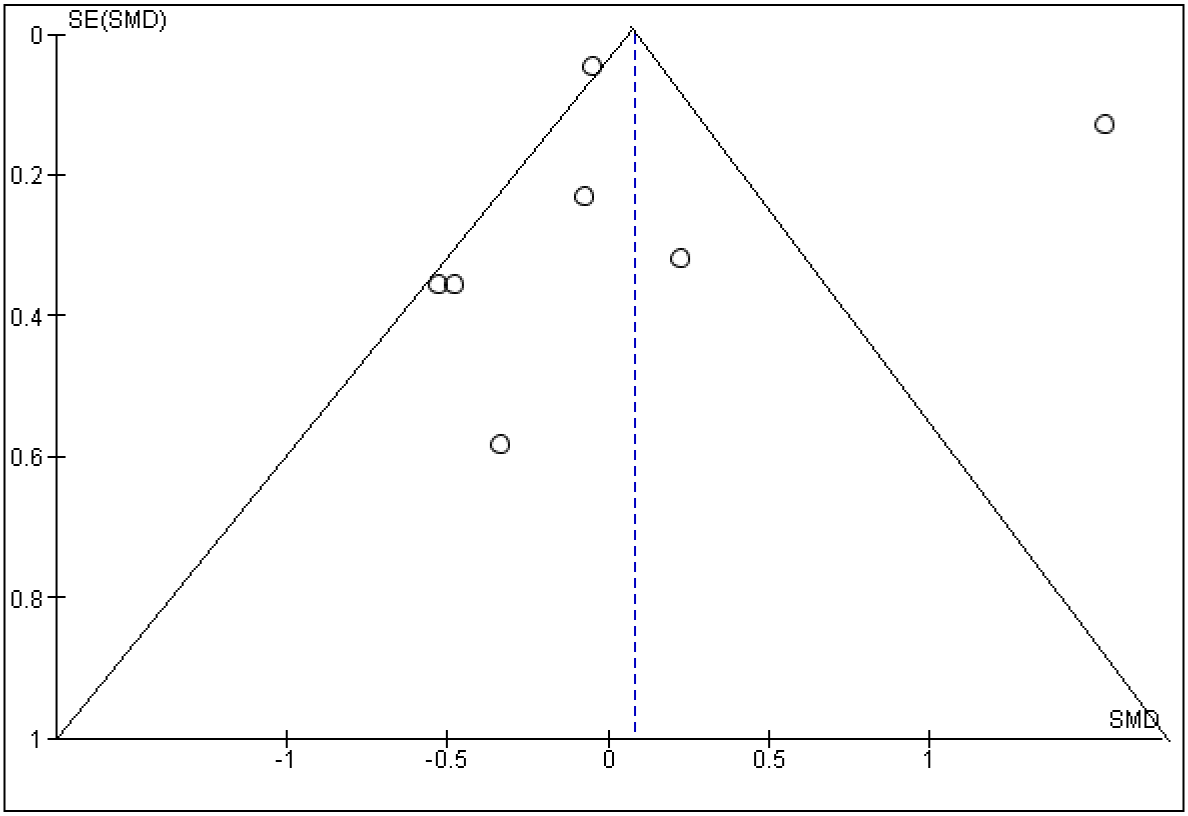


Fig 3.3: Funnel Plot of current data indicating the bias for Ergonomic Intervention Analysis. The top right estimate represents the study done by Kerr et al. The estimate lies far as an outlier possibly because of Type I error present in that study.

The funnel plot from Ergonomic Intervention Analysis (Fig 3.3) suggests that all the estimates from the studies are precise as they are scattered toward the top. Also, the graph shows a small degree of skewness which implies that it is less likely the data are biased.

3.1.7 Sensitivity Analysis

Sensitivity analysis checks the robustness of the studies and their results. It involves the process of removing any single study from the analysis and checking if the result remains the same or if any single single study skews the results significantly.

	Experimental			Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
LariviÃ¨re 2002	164	23	15	177	25	18	16.6%	-0.53 [-1.22, 0.17]
LariviÃ¨re 2002	3,657	763	15	4,096	995	18	16.6%	-0.48 [-1.17, 0.22]
Marras 2000	78	6	6	81.2	11	6	14.1%	-0.33 [-1.48, 0.81]
Lu 2013	8.5	5	25	9	6.8	78	17.6%	-0.08 [-0.53, 0.37]
van der Molen 2009a	0.83	2.35	885	0.96	3.08	1036	0.0%	-0.05 [-0.14, 0.04]
VAN DER MOLEN 2004	1.35	2.2617	20	0.9	1.6243	20	16.9%	0.22 [-0.40, 0.85]
Kerr 2001	11.7	7	137	2.5	5	179	18.2%	1.54 [1.29, 1.80]
Total (95% CI)			**218**			**319**	**100.0%**	**0.09 [-0.80, 0.98]**

Heterogeneity: Tau² = 1.11; Chi² = 81.41, df = 5 (P < 0.00001); I² = 94%
Test for overall effect: Z = 0.20 (P = 0.84)

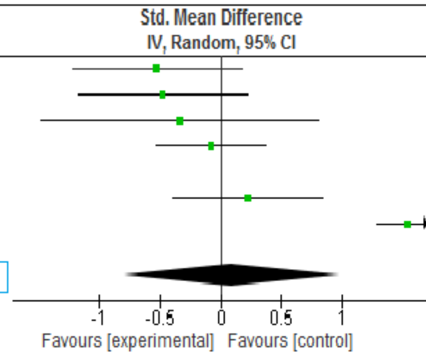
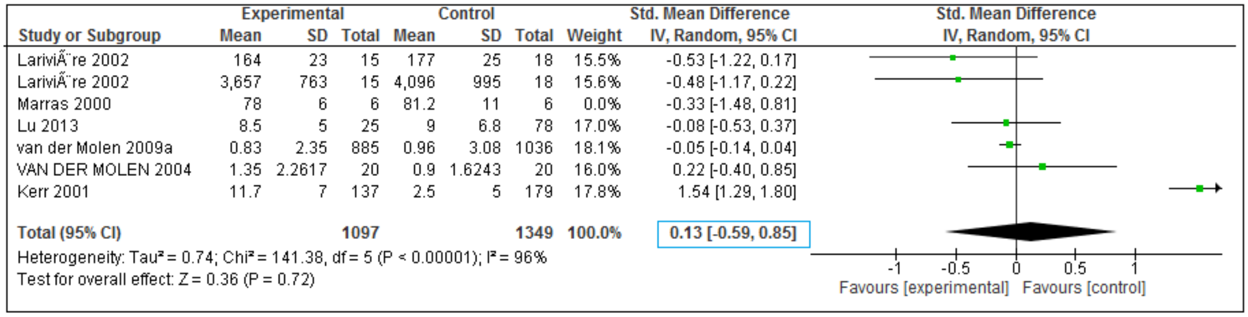


Fig 3.4: Ergonomic Intervention Analysis results – Sensitivity I

Sensitivity I involves removing the Van der Molen et al., 2009 study from the analysis (Fig 3.4). The table shows us the same results after removing this particular study from the analysis.



Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
LariviÃ¨re 2002	164	23	15	177	25	18	15.5%	-0.53 [-1.22, 0.17]
LariviÃ¨re 2002	3,657	763	15	4,096	995	18	15.6%	-0.48 [-1.17, 0.22]
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van der Molen 2009a	0.83	2.35	885	0.96	3.08	1036	18.1%	-0.05 [-0.14, 0.04]
VAN DER MOLEN 2004	1.35	2.2617	20	0.9	1.6243	20	16.0%	0.22 [-0.40, 0.85]
Kerr 2001	11.7	7	137	2.5	5	179	17.8%	1.54 [1.29, 1.80]
Total (95% CI)			**1097**			**1349**	**100.0%**	**0.13 [-0.59, 0.85]**

Heterogeneity: Tau² = 0.74; Chi² = 141.38, df = 5 (P < 0.00001); I² = 96%
Test for overall effect: Z = 0.36 (P = 0.72)

Fig 3.5: Ergonomic Intervention Analysis results – sensitivity IISensitivity II involves removing of Marras, 2000 study from the analysis (Fig 3.5). Sensitivity II also shows us the same results as sensitivity I or as the original analysis.

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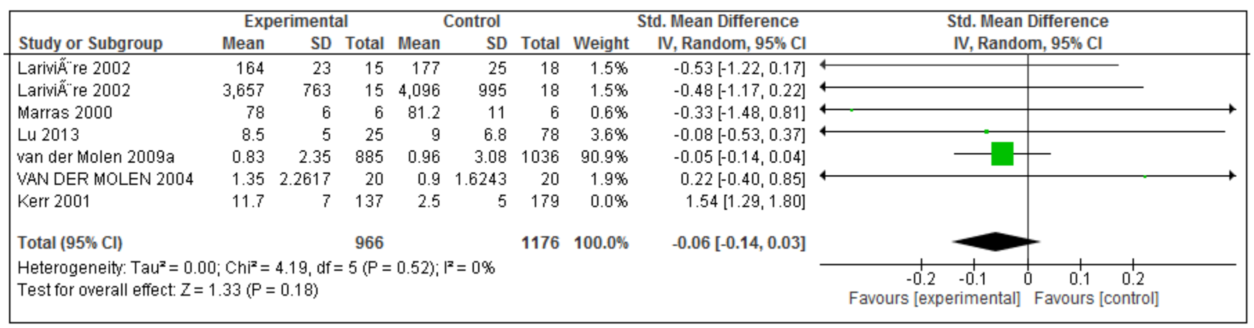

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
LariviÃ¨re 2002	164	23	15	177	25	18	1.5%	-0.53 [-1.22, 0.17]
LariviÃ¨re 2002	3,657	763	15	4,096	995	18	1.5%	-0.48 [-1.17, 0.22]
Marras 2000	78	6	6	81.2	11	6	0.6%	-0.33 [-1.48, 0.81]
Lu 2013	8.5	5	25	9	6.8	78	3.6%	-0.08 [-0.53, 0.37]
van der Molen 2009a	0.83	2.35	885	0.96	3.08	1036	90.9%	-0.05 [-0.14, 0.04]
VAN DER MOLEN 2004	1.35	2.2617	20	0.9	1.6243	20	1.9%	0.22 [-0.40, 0.85]
Kerr 2001	11.7	7	137	2.5	5	179	0.0%	1.54 [1.29, 1.80]
Total (95% CI)			**966**			**1176**	**100.0%**	**-0.06 [-0.14, 0.03]**

Heterogeneity: Tau² = 0.00; Chi² = 4.19, df = 5 (P = 0.52); I² = 0%
Test for overall effect: Z = 1.33 (P = 0.18)

Fig 3.6: Ergonomic Intervention Analysis results – sensitivity IIIRemoval of a study done by Kerr et al., (2001) changed the results (Fig 3.6). The analysis favoring control subjects is now favoring experimental subjects i.e. suggesting that ergonomic interventions are favorable for decreasing LBP in MMH workers. The forest plot for meta-analysis I (Fig 3.1) also showed that the study was done by Kerr et al., (2001) is the outlier in the analysis. The outlier could be due to Type I error present in the study.

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Both, sensitivity analysis I and sensitivity analysis II (Fig 3.4 and Fig 3.5) shows the same results as the initial analysis but sensitivity analysis III (Fig 3.6) showed opposite results proving the presence of an outlier in the study. The studies removed from the actual data to perform sensitivity analysis were randomly selected. There were no criteria involved with removing those particular studies. There is a possibility that any study could be removed to perform a sensitivity analysis to find the outlier or for checking the robustness of results.

3.2 Meta-analysis II: Absenteeism Analysis

3.2.1. Null Hypothesis

The null hypothesis **(H_0)** LBP has no effect on absenteeism in MMH workers and the alternate hypothesis is (**H_A)** LBP increases absenteeism in MMH workers

We accepted the null hypothesis and rejected the alternate hypothesis.

3.2.2 Type of studies for Absenteeism Analysis

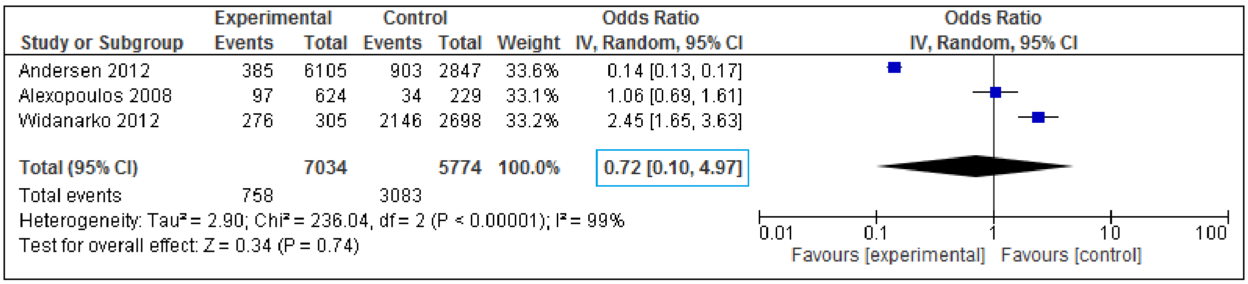
The three studies have dichotomous data which allows us to compare the subjects before and after the effect of the intervention on LBP for absenteeism (Table 3.3).

Study	**Type of study design**	**Participants Included**	**Follow – up Period**	**Method of Data Collection**	**Outcome**
(Alexopoulos et al., 2008)	Longitudinal Cohort study	853 shipyard workers	One year follow-up	Self - administered questionnaire	Increased awareness about the causal factors
(Andersen et al., 2012)	Prospective cohort study	8952 Healthcare workers	One year follow up	Questionnaire Survey	Introduction of Ergonomic initiatives
(Widanarko et al., 2012)	Survey study	3003 (Random selection**)**	12-month prevalence period	Telephone interview about self-reported LBP absenteeism	Interventions aiming to reduce awkward positions

Table 3.3: Brief description of included studies in Absenteeism Analysis

3.2.3 Measure of treatment effect: Effect Size

For Absenteeism Analysis, the effect size is calculated (Fig 3. 7) with the help of dichotomous data (odds ratio) and no. of participants. The values have been taken out of the articles and put into the Revman 5.3 software. Revman 5.3 calculated overall effect and P-value as well.



	Experimental		Control			Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	IV, Random, 95% CI
Andersen 2012	385	6105	903	2847	33.6%	0.14 [0.13, 0.17]
Alexopoulos 2008	97	624	34	229	33.1%	1.06 [0.69, 1.61]
Widanarko 2012	276	305	2146	2698	33.2%	2.45 [1.65, 3.63]
Total (95% CI)		**7034**		**5774**	**100.0%**	**0.72 [0.10, 4.97]**
Total events	758		3083			

Heterogeneity: Tau² = 2.90; Chi² = 236.04, df = 2 (P < 0.00001); I² = 99%
Test for overall effect: Z = 0.34 (P = 0.74)

Fig 3.7: Forest Plot for Absenteeism Analysis

The effect size describes how much effect LBP has on absenteeism. For binary outcomes, Cohen classified effect sizes as small (1.5), medium (2), and large (3). The effect size is 0.72 (0.10, 4.97) as per the analysis (fig 3.7). The effect size of 0.72 implies that risk absenteeism is 28% lower for experimental group than the control group. There is 95% probability that the impact will fall between 0.10 and 4.97. The center of the diamond in the forest plot is showing results in favor of the experimental group.

3.2.4 Heterogeneity

	Experimental		Control			Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	IV, Random, 95% CI
Andersen 2012	385	6105	903	2847	33.6%	0.14 [0.13, 0.17]
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Heterogeneity: Tau² = 2.90; Chi² = 236.04, df = 2 (P < 0.00001); I² = 99%

Test for overall effect: Z = 0.34 (P = 0.74)

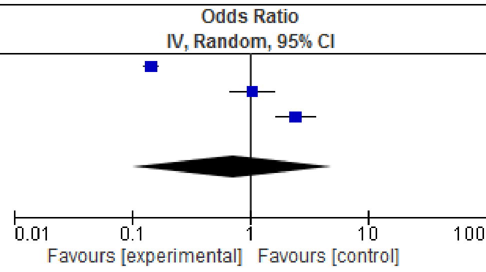

Fig: 3.8: Heterogeneity for Absenteeism Analysis

The value of all three tests Tau squared, chi squared and I^2 are similar and in support of each other. The Chi square value of 236.04 is very high with df = 2 and implies considerable heterogeneity among the studies. I^2 values range from 0% to 100%. The closer towards 100%, the greater is the heterogeneity in the study. In meta-analysis II, the value of heterogeneity is 99%. The value is quite high and supports the random effects model for meta-analysis II. The last measure to calculate heterogeneity is Tau square. As stated in meta-analysis I, if the value of Tau square> 1, substantial heterogeneity is present. In meta-analysis II, the value results to 2.90 (more than 1). All the three tests indicate high levels of heterogeneity.

3.2.5 Assessment of risk of bias in included studies

The table below (Table 3.4) describes the type of bias present in each of the studies included in Absenteeism Analysis. The detection of bias was done on the basis of information present in the studies.

Type of Bias **Study**	**Selection Bias**	**Performance Bias**	**Detection Bias**	**Attrition Bias**	**Reporting Bias**
(Alexopoulos et al., 2008)	**Present**	**Present**	**None**	**None**	**None**
(Andersen et al., 2012)	**Present**	**None**	**Present**	**None**	**None**
(Widanarko et al., 2012)	**Present**	**Present**	**Present**	**None**	**None**

Table 3.4: Bias Summary for Absenteeism Analysis

3.2.6 Funnel plot

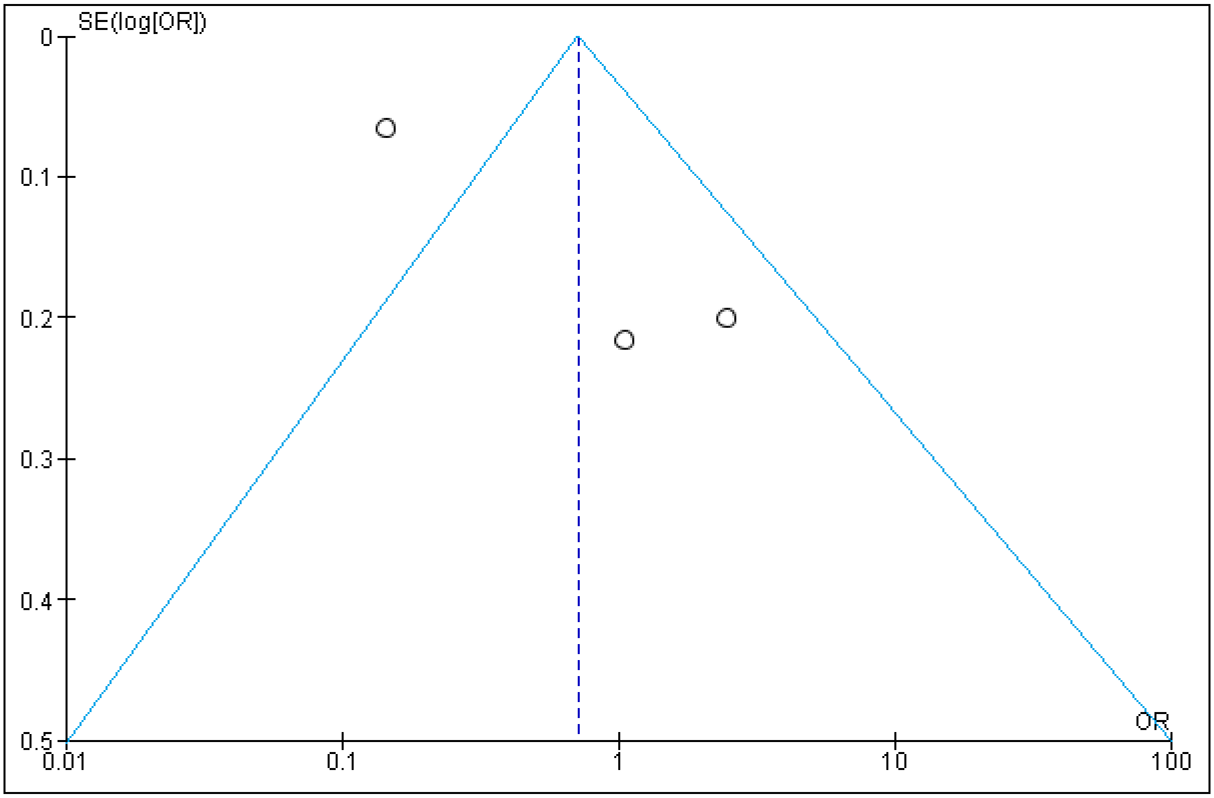

Fig: 3.9: Funnel Plot for Absenteeism Analysis

The funnel plot is the technique used by RevMan 5.3 to detect the bias present in the studies. The plot (Fig 3.9) shows that all the reviews are scattered towards the top which indicates that estimates of the data are precise, but the plot lacks symmetry, showing bias. The bias in the analysis could be present due to selection bias present in the studies, or all the subjects had a different probability of being selected due to the interest of outcome and exposure; which in turn created a biased measure called odds ratio (OR).

3.2.7 Sensitivity Analysis

Sensitivity analysis as described in ergonomic intervention analysis illustrates the robustness of the results via the process of eliminating any study from the analysis and cross-checking the results for their similarity with the original results (Fig 3.7).

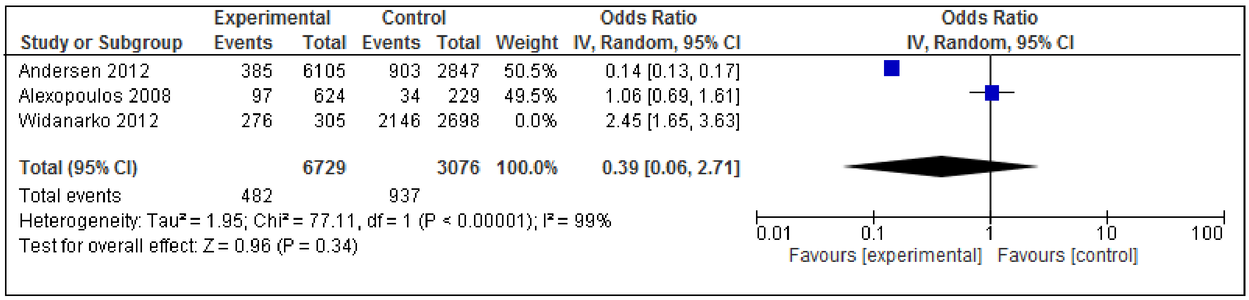

Fig 3.10: Absenteeism Analysis results – sensitivity I

The forest plot below shows (Fig 3.10) the results after removing the study done by Widanarko et al. , 2012. The forest plot shows similar results.

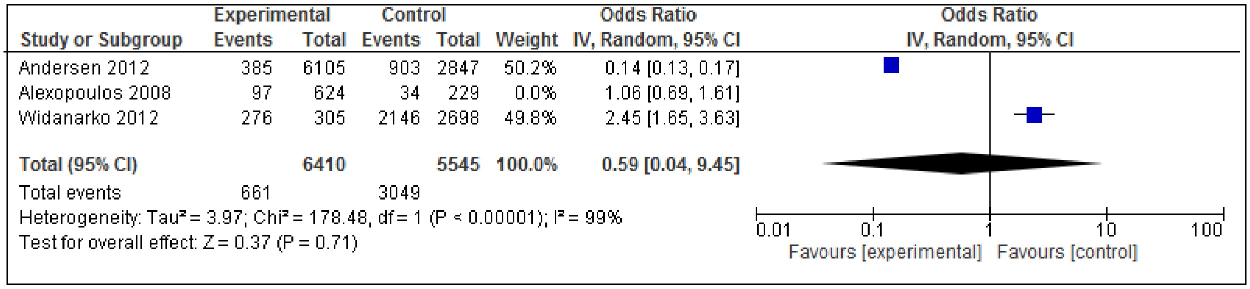

Fig 3.11: Absenteeism Analysis results – sensitivity II

Similarly, we removed the study done by Alexopoulos et al., 2008 (Fig 3.11) and analyzed the forest plot. Again, we got the same results as Sensitivity I (Table 3.10)

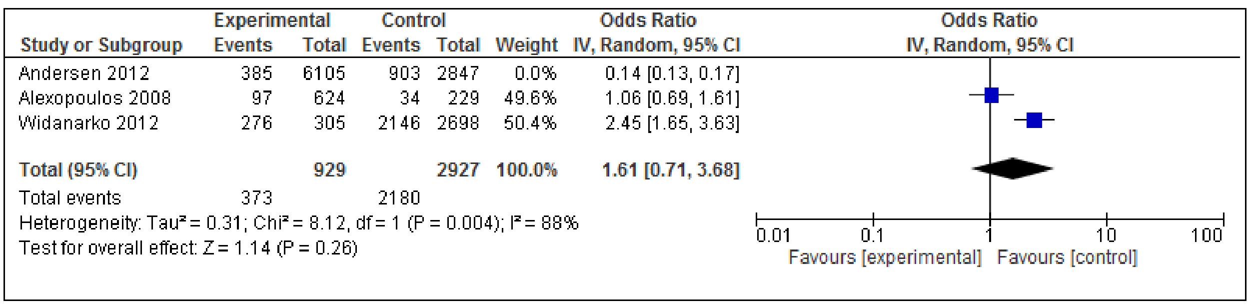

Fig 3.12: Absenteeism Analysis results – sensitivity III

Removal of Anderson et al. 2012 from the analysis, shows us (Fig 3.12) the complete opposite results from the analysis. Where the results favors the control group rather than the experimental group. The forest plot for Absenteeism Analysis also implied that this particular study is the outlier among the included studies.

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van der Molen, H. F., Sluiter, J. K., & Frings-Dresen, M. H. (2009a). The use of ergonomic measures and musculoskeletal complaints among carpenters and pavers in a 4.5-year follow-up study. *Ergonomics*, *52*(8), 954–963.

van der Molen, H. F., Sluiter, J. K., & Frings-Dresen, M. H. (2009b). The use of ergonomic measures and musculoskeletal complaints among carpenters and pavers in a 4.5-year follow-up study. *Ergonomics*, *52*(8), 954–963.

Vander Molen, H. F., Grouwstra, R., Kuijer, P. P. F., Sluiter, J. K., & Frings-Dresen, M. H. (2004). Efficacy of adjusting working height and mechanizing of transport on physical work demands and local discomfort in construction work. *Ergonomics*, *47*(7), 772–783.

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Chapter – 4

Discussion

"Industrialization has led to an explosion in back injuries and thus compensation dollars awarded" (Jones & Kumar, 2001). Jones and Kumar (2001) reported nearly 2700% increase in social security disability awards for back pain in 1956 to 1976. Some studies suggest that ergonomic interventions have the potential to decrease LBP (Kerr et al., 2001; Marras, 2000; van der Molen, Sluiter, & Frings-Dresen, 2009), but the results of the present ergonomic intervention does not support this. Null hypothesis for ergonomic intervention analysis stating ergonomic intervention has no effect on LBP in MMH workers failed to be rejected due to lack of statistical evidence against the alternate hypothesis: ergonomic intervention improves LBP in MMH workers. Most of the available literature also agrees that LBP can potentially cause absenteeism (Andersen et al., 2012; Widanarko et al., 2012) and the results of the present absenteeism analysis also support the fact that LBP causes absenteeism in MMH workers. Null hypothesis for absenteeism analysis is accepted: LBP has no effect on absenteeism in MMH workers. . However, the smaller number of included studies in the analysis could be one of the strong limitations in absenteeism analysis. Despite the availability of plenty of qualitative and quantitative literature supporting that LBP causes absenteeism, it is important to note that there is still a lack of high quality controlled and unbiased studies scrutinizing the consequences of LBP, especially in MMH workers.

4.1 Ergonomics as solution for LBP

Ergonomics is often suggested as an intervention for LBP because it has the potential to deal with the cause of LBP in MMH workers. Ergonomic measures, -strategies and -interventions include three primary approaches. The first approach is engineer control and the second approach is administrative controls, the third being personal protective equipment. These interventions can include any technique designed to protect from injury, such as; modification of lifting and lowering tasks, workplace adjustments modifying the bio-mechanics to prevent back injury or any other technique that helps the kinematics of body to function properly. Ergonomics could be a potential solution for these problems but, the findings of the present study suggests that ergonomics does not decrease the incidence of LBP.

Posture is one of the several risk factors associated with injury in the workplace. While performing occupational activities, the positions adopted by workers are thought to contribute to loading and associated damage. Awkward postures pose physical demands which lead to increased loading. However, the mechanism to perform a particular task is different for an individual worker. The study by Kerr et al. (2001) used a biomechanical analysis on 137 experimental and 179 controls from the automobile industry and assessed physical demands with direct workplace assessment. The authors suggested that direct workplace efforts to modify biomechanical factors might eliminate loading due to shear force and compression to reduce LBP. Compression and shear force act as independent risk factors for LBP in MMH workplaces.

A conventional ergonomic intervention involves placing a limit on weight being manually lifted, limiting the horizontal distance at which the weight is lifted, or restricting work duration and lifting frequencies to prevent injuries due to lifting (Hsiang et al., 1997; “Low Back Pain Fact Sheet,” n.d.; Worksafe, 2010). A standard tool used to establish these limits is the NIOSH lifting equation. The National Institute for Occupational Safety and Health (NIOSH) revised the equation in 1993, i.e., Revised NIOSH Lifting Equation (RNLE) for evaluating physical demands involved in manual lifting (Lu et al., 2013). For multiple lifting tasks, the lifting index (LI) is used for safe lifting. LI is calculated = load weight/ recommended weight limit (Waters, Putz-Anderson, Garg, Safety, & Health, 1994). One of the studies included in this ergonomic intervention analysis, done by Lu et al. (2013) used the composite lifting index for analyzing multiple lifting tasks to determine LBP risk exposures in 25 experimental and 78 control subjects over the period of a year. The study failed to demonstrate a significant relationship between LI (Lifting Index) and LBP but the author "reported the trend in the relation between LI and LBP was positive” (Lu et al., 2013).

4.2 Ergonomic Intervention Analysis

The ergonomic intervention analysis done here included a total of 6 retained studies out of 427. Three of the studies included in the ergonomic intervention analysis (Marras, 2000; van der Molen et al., 2009; Vander Molen et al., 2004) concluded that ergonomic measures do have an impact on decreasing LBP in MMH workers. Van der Molen et al., (2004) used a scaffolding console to adjust the working height as an ergonomic intervention and found that frequency of trunk flexion (>60^0) was reduced by 94% and duration of trunk flexion (>60^0) by 92%, as compared to manual handling. As a result, they reported significantly less LBP due to repeated trunk flexion. Van der Molen et al. (2009) found a similar result, and the authors stated that the construction industry needs more effective ergonomic measures and interventions.

Marras et al. (2000) included 142 participants, 36 jobs performing MMH activities; of which 32 underwent ergonomic intervention. All jobs demonstrated significant job satisfaction. One of the goals of this study was to determine the impact of an intervention on LBD. Work done by Marras et al. (2000) concluded that reducing the load on lower back results in fewer injuries in MMH workers. Another study performed by Lariviere et al. (2002), evaluated the effectiveness of using a change in lifting techniques (techniques that alter the compression and loading on the lower lumbar spine) and the results stated that “there is more loading in lifting than lowering while performing MMH jobs” (Larivière et al., 2002). They state that postural impairment or improper lifting and bending while lifting hinders the full potential of participants due to a break in the kinematic chain. However, they also suggest that a more detailed analysis is needed for determining the association between different postures and their effect on lower back (Larivière et al., 2002).

Three of the studies we used did not draw strong conclusions either in favor of or opposed to ergonomic intervention effectiveness. The three studies were (Kerr et al., 2001; Larivière et al., 2002; Lu et al., 2013). Kerr et al. (2001) suggested that biomechanical factors should be more the robust for injuries in MMH workers and insisted on assessing more physical demands in the workplace so that the risk factors associated with those physical demands could be identified and dealt with. The present ergonomic intervention analysis included studies that have examined the association of risk factors with LBP (Kerr et al., 2001; Lu et al., 2013); and studies that have analyzed the effect of ergonomic intervention and concluded that an intervention such as mechanization designed to help lower loads (van der Molen et al., 2009) could be used as a possible solution to decrease loading in MMH jobs. Though the results of the present ergonomic intervention analysis state the opposite, ergonomic interventions are often thought to be an effective solution for decreasing the loading in the lower back due to repeated MMH activities (Lu et al., 2013; Marras, 2000; van der Molen et al., 2009; Vander Molen et al., 2004). Further research (case-control study, individual study etc.) to determine the effectiveness of ergonomics in controlling the risk factors causing LBP will contribute more to future meta-analyses. The ability to replicate such results for ergonomic intervention analysis might produce results in favor of "ergonomics effectiveness in decreasing LBP".

The above speculation on the consequences of loading in the lower back suggest that different work habits adopted by individual workers in a particular MMH workplace might reduce injury risk. Ergonomics with the help of engineering solution/interventions can introduce multiple ways change the loading patterns which occur as a result of interaction between human factors and biomechanical factors. The continuing research for the relationship between ergonomics and LBP as presented above needs consideration with a broad horizon in the aspect of assessing the pathways leading to low back pain.

Ergonomics interventions can potentially reduce the incidences of LBP by taking the load off of the lower back.(van der Molen et al., 2009; Vander Molen et al., 2004). The studies included in this ergonomic intervention analysis have obtained results using different types of ergonomic intervention such as; raising platforms, mechanization, etc.. When small and varying types of interventions are grouped together and seen as a combined entity of ergonomic interventions, they appear to be ineffective in impacting LBP. This study included ergonomic intervention tested for mechanization for lifting loads, raising platforms instead of flexing or bending, lift tables, lifting aides, and redesigning of the workstation. Individually all the studies have supported the use of ergonomics but when the studies are combined to find a collective effect size, the results suggest that ergonomics has no effect on LBP.

Previous systematic reviews have mainly focused on MMH and LBP/Back (Bakker et al., 2009; Roffey et al., 2010). The results of the systematic review on causal assessment between workplace manual handling or assisting patients and LBP concluded: "it is unlikely that workplace manual handling or assisting patients is independently causative of LBP in the populations of workers studied" (Roffey et al., 2010). Another systematic review done by Kuiper et al. (1999) concluded that additional research is needed to determine if MMH as a risk factor for back disorders. Also, to provide conclusive evidence for the causal relationship between MMH and back disorders, the authors suggested a need for high-quality studies (Kuiper et al., 1999). A high-quality study is one that has a well-defined research topic, clear hypothesis, well-designed experiment and the conclusions and recommendations of which are logical and consistent with findings. The ergonomic intervention analysis done here is one of the first reviews which have focused on ergonomic intervention in MMH workers for LBP which has included only "high quality" studies.

Even with results obtained in the current meta-analysis combined with the results presented in each of studies included, there still exists the possibility of Type II error. Type II error occurs when we fail to reject the null hypothesis and the effect of a particular intervention is present but it is failed to be detected (Sullivan & Feinn, 2012). The results obtained from meta-analysis I could be the false negative result because ergonomic interventions are designed to decrease LBP in MMH workers but the result of the analysis stands opposite (Fig 3.2). Type II error indicates that the analysis is failing to detect the effect that is present i.e. ergonomic intervention is effective in decreasing LBP in MMH workers but the analysis is failing to detect it. Also, individual study results from the included studies support the fact that ergonomics is effective for LBP. On the contrary, pooled results in meta-analysis demonstrated that interventions were not helpful in decreasing LBP rather they showed that control participants are at low risk of having LBP. Since meta-analysis has enough power, the risk of type-II error is very minimal (Sullivan & Feinn, 2012) but this error could also be a result of outlier study in the analysis. The outlier study identified in ergonomic intervention analysis is a study done by Kerr et al., (2001). Funnel plot graph (Fig 3.3) and sensitivity analysis (Fig 3.6) also reported the change of results in favor of ergonomics intervention after removal of this particular study from the analysis. The author mentioned the presence of type-I error in the study and “to limit this error the author used a reduced set of biomechanical variables which was based on expert consensus” (Kerr et al., 2001). Type – I error is an incorrect rejection of true null hypothesis in a particular study or presence of false positive results. It detects an effect that is not present which implies that the there was a possibility that no biomechanical effect was present in the outlier study but was detected.

4.4 Absenteeism Analysis

Most of the studies have focused on causal factors of LBP, but there are some who have focus, on the consequences such as Alexopoulos et al. (2008), Anderson et al. (2012) and Widanarko et al. (2012). The study was done by Anderson et al. (2012) which is part of absenteeism analysis provided weak evidence of a relation between long-term sickness absence (LTSA) and LBP. Widanarko et al. (2012), another of the included studies of Absenteeism Analysis suggested that interventions in the workplace should focus on reducing the impact of causal factors such as awkward position, lifting, and the cold-damp environment. In other words, Widanarko et al. (2012) suggested dealing with the causes of a problem instead of dealing with the consequences.

The results of our absenteeism analysis remain positive for LBP causing absenteeism. Also, the results of the included studies support that absenteeism results from LBP. The annual incidence of 14% sickness absence due to LBP is shown by Alexopoulos et al. (2008). In support of this, Widarnarko et al. performed a study on 3003 participants over a 12 month period and found that increased risk of absenteeism in workers with awkward working positions.

The consequences of LBP include long-term sickness absence (LTSA), re-injury and reduced the productivity of MMH workers. LTSA can facilitate re-injury and in-turn reduced productivity, similarly, reduced productivity can decrease the efficiency of human factors in a particular worker which when combined with MMH workplace demands, can cause re-injury and LBP. Alexopoulos et al. (2008) emphasized factors such as previous LBP and association of physical load in workplace causing re-injury and re-injury causes LTSA, and LTSA is the reason for the increased incidences of LBP. They also reported that sickness absence is the single most important reason for the annual incidence of LBP which has gone up to 41% (from 14%) with re-injury. Anderson et al. (2012) also supported LBP to be the risk factor for LTSA among health care workers. The study also supported the fact that "one type of pain can lead to another kind of pain." For example, lower back pain disrupting the whole kinematic chain of the body and leading to strain on knees; the consequence of such pain among workers brings LTSA, decreased productivity, and economic burden on the industry (Andersen et al., 2012).

Implementation of ergonomic interventions can potentially produce positive trends in decreasing LBP and resulting absenteeism with the help of administrative control and participatory ergonomics. Lynch and Freund (2000) implemented a program consisting of patient-transferring devices (walking belts, transfer boards, and hoists), admin controls and use of proper body mechanics while moving patients in an acute care hospital. They found 30% decrease in lost-time injuries and 73% reduction in an average number of lost workdays per back injury. Likewise, "Implementation of ergonomics in seven nursing facilities with participatory ergonomics and patient-handling devices were successful in reducing the number of injuries, lost workdays, modified-duty days, and workers' compensation costs associated with patient handling activities" (Garg & Kapellusch, 2012). The available literature supports that ergonomics helps in reducing the length of absenteeism due to LBP. The results of present absenteeism analysis state that LBP results in absenteeism. In addition to this, the current study suggests that ergonomics does not help in decreasing LBP.

Absenteeism analysis of present systematic review favours LBP resulting in absenteeism. Limited availability of data is the main reason for obtaining a small effect size. The replication of similar absenteeism analyses with inclusion of more studies having the same focus could produce results with a large effect size. But it is difficult to find studies which have analyzed the effect of LBP on absenteeism in MMH workers. More research that has focused on absenteeism in MMH workers as a consequence of LBP is needed so that such absenteeism analysis might lead to conclusive results.

This absenteeism analysis should be considered biased due to the outlier in the sensitivity analysis. It is highly likely that the outlier study could be due to a large number of participants it contains compared to other studies. Also, there is the possibility of the presence of experimental error in the outlier study. Experimental error is an erroneous difference between two measured values. The outlier study by Anderson et al. (2012) linked two data sets one being sickness absence data obtained from Danish Register for Evaluation of Marginalization (DREAM) register, the second being their own health questionnaire survey data. The linking of the data may have led to the experimental error.

4.6 Ergonomic Interventions

Ergonomic interventions are typically divided into three types: engineering control, administrative control and protective equipment. The ergonomic intervention can alter the biomechanics while performing MMH activities and decreased susceptibility to LBP. Engineering control interventions such as lift tables, overhead pulley, and workstation adjustments to lessen the impact of LBP have been investigated by Marras et al. (2000). They found that ergonomic interventions have the potential to reduce the incidence of LBP in MMH workers. The study supported the fact that ergonomic interventions lessen the impact of LBP but due to the inclusion of less number of participants, the potential of ergonomic impact on LBP is not actively supported. In support of the above fact, Marras et al. (2000) also stated that we need more quality control studies to find a strong relation between engineering intervention and LBP.

Administrative control is another critical intervention which can control the re-injury factors and the length of sickness absence. Administrative control is mostly performed with the help of managers and supervisors and in combination with the other intervention type i.e. Engineering control. Change in the design of work to reduce the risk factors associated with low back pain is achieved via the administrative control in MMH jobs. Job rotation is a factor which should be monitored by the administration. Job rotation may help to alleviate the physical stress and fatigue on a particular set of muscles, ligaments, and tendons and the rotation could be set to 4 hours in a day or between days (Frazer, Norman, Wells, & Neumann, 2003). There are many supposed benefits associated with job rotation including a cross-trained workforce, reduced monotony, reduced stress, reduced absenteeism, increased ability to handle change by the workers and reduced cumulative trauma disorders" (Frazer et al., 2003).

Workers who are absent from work for a long period of time will have decreased productivity and also, there are increased chances of re-injury in such workers in absence of ergonomic intervention. Engineering controls, if provided initially after the absenteeism period can potentially increase/maintain the productivity of the worker. However, workers who are given a modified job after return to work result in “presenteeism”. Such workers when included in the future studies can give erroneous results. Future research with the implementation of an intervention involving engineering and administrative control is needed and the combination of present and future research could produce more conclusive results. This future research can also help in eliminating the risk factors causing LBP from MMH industry.

Despite the results of the ergonomic intervention analysis being negative, all the included studies still favor the fact that ergonomics can prevent the workplace injuries. The negative results could be due to outliers or effect size of the individual studies. The study will help practising ergonomists in knowing that training in ergonomic practices can reduce the chances of occupational low back injuries and also, improving the work efficiencies in workers. Ergonomic interventions need to be designed by an independent ergonomist.

The ergonomist can help in making injury prevention a top priority by monitoring the safety trends in the workplace. More practising ergonomists are needed in occupational settings to measure the effect of applied interventions. Practising ergonomists design ergonomic intervention as per the needs of the job and biomechanics of worker. They need to do a better job in reporting the effectiveness of ergonomic interventions.

4.7 Limitations

The major limitation for ergonomic intervention analysis and absenteeism analysis is the limited number of studies which met the inclusion criteria. Available research has focused mostly on ergonomic changes affecting absenteeism and LBP. The majority of the studies have dealt with both LBP and absenteeism in the same testing groups for MMH workers. Very few of the studies have differentiated the ergonomic impact on LBP and thus, LBP influencing the rate of absenteeism in workers. Most of the available research has focused on relating ergonomics and absenteeism with LBP. The three affecting factors i.e. ergonomic interventions, LBP and absenteeism appear as a triangle linking to each other. In this triangle, the three possibilities that arise are 1) ergonomic intervention impacts LBP and absenteeism, 2) LBP impacts absenteeism and is affected by ergonomic interventions, 3) absenteeism can be reduced with the help of ergonomic intervention by decreasing LBP impact on MMH workers. If LBP episode has already taken place then it can help in reducing the resulting absenteeism. So, this thesis focused on three factors individually and found the link via 1) effect of ergonomic interventions on LBP and 2) effect of LBP on absenteeism. To find the studies considering the above two situations for the thesis was a difficult task, which led us to a limited number of studies.

A second limitation of the argument is the unavailability of sufficiently detailed statistical description within the published papers. Third, most of the studies have included all available types of workers. Separating the blue collar workers or the MMH workers from the group is a challenging task especially when the data needed is not provided in the statistical testing of that particular study and; the article fits the inclusion criteria. A fourth limitation is a variability in the intervention effects due to the presence of methodological diversity in the available studies.

Fifth, publication bias, also referred to as the file and drawer problem. The biased publication of statistically significant results versus the under-representation of non-significant results. The published record may be biased toward the studies where ergonomic intervention is found to be statistically significant. This likely occurs mostly in the studies which fail to reject the null hypothesis. Such biases always exist in the literature. Meta-analysis has the potential to alternate the results, such as; Ergonomic Intervention Analysis of the thesis presented that ergonomic interventions have no impact on LBP despite every included study supported the fact that ergonomic intervention helps in decreasing LBP in MMH workers. If there is the availability of more research regardless of significant or non-significant results, there is a possibility of getting stronger and conclusive results.

Study	Pros	Cons
(Larivière et al., 2002)	Control of lumbar lordosis to modulate internal tissue loading	Choosing only healthy subjects for lifting and lowering
(Vander Molen et al., 2004)	Randomly assigned bricklaying conditions	
	Workers' extent of exposure to physical work demands is undetermined	Leaving one worker for practical reasons (not mentioned in study)
	Intervention focused on decreasing trunk flexion	Intervention caused increased trunk rotation
(van der Molen et al., 2009)		Ergonomic measures did not reduce physically demanding activities for carpenters and pavers
		Construction workers did not use ergonomic measures due to lack of team work
		Longer follow-up period
(Marras, 2000	Absence of external varying factor for the risk observed due to workplace interventions	Interventions were designed by companies and not by professional ergonomists
(Lu et al., 2013)		Physical risk exposure data for lifting task is not collected for each subject
		Large subject drop-out rate
(Kerr et al., 2001)		Type I error
		Over-stated reporting of physical demands of work

(Widanarko et al., 2012)	Size of study	Over or under estimation of prevalence of absenteeism
		No indication of sequence of events
(Alexopoulos et al., 2008)	Employees absent due to another LBP episode before the termination of follow-up	Sickness absence information
	Subjects worked in same company	Education level of workers
(Andersen et al., 2012)	Large sample size	All type of musculoskeletal pain included in the study
		Lack of information from Danish register on LTSA

Table 4.1: Pros and cons of the studies included in meta-analyses

Lastly, included studies have also influenced the results. Marras (2000) mentioned the most important limitation in his study that the ergonomic interventions were designed by companies and not by ergonomists. The interventions designed by companies are not likely to be as effective as one designed by ergonomists. Companies/workplaces will typically choose the cheapest option and the cost associated with the intervention is may not be offset by the benefit gained by it. For example, the cost of redesigning a workstation may be more expensive (in the short term) than what might be saved in insurance premiums or worker's compensation costs. An ergonomist would have the interest of the worker in mind while the workplace would have to consider its short term expenditures. Over/under reporting of physical demands at work is also mentioned by Lu et al. (2013) in their study. Similarly, over or under estimation of absenteeism prevalence is mentioned by Widanarko et al. (2012). Reliable sickness absence information is also an issue for not getting effective results (Alexopoulos et al., 2008; Andersen et al., 2012).

4.8 Strengths

The major power of the study is combined results. This study presented the pooled effect that ergonomic intervention does not play a role in decreasing the LBP. Also, the results for Absenteeism Analysis were inconclusive due to a low number of included studies. However, the performance obtained included a larger set of the population which increased the accuracy and precision of both Ergonomic Intervention Analysis and Absenteeism Analysis.

4.9 Conclusion

The included studies individually mention that ergonomic intervention produces favorable results to workers by decreasing the impact of LBP. However, pooling the results of several studies together in the ergonomic intervention analysis suggests the opposite i.e. ergonomics is not likely to reduce LBP in MMH workers. No such conclusion was possible with the absenteeism analysis for the effect of LBP on absenteeism. Availability of a limited number of studies as per the inclusion criteria made the results of absenteeism analysis inconclusive. Limited research could be due to publication bias or could be due to lack of quality studies focusing the target factors of

LBP and absenteeism. highly likely that inclusion of more studies could produce conclusive results stating that LBP causes absenteeism.

There is a need for meta-analyses that involve both qualitative and quantitative studies. Qualitative studies provides a comprehensive description of a particular intervention and also the assessment of investigation method on the findings of the study whereas quantitative meta-analysis synthesize the data quantitatively. The probability of erroneous conclusions in a qualitative review increases proportionally with the number of studies. The literature can over-come such limitations with the help of a combined review. The qualitative studies can summarize the accumulated knowledge with the help of significant data results obtained by quantitative analysis. The results obtained with the help of systematic approach to obtain the primary data set and described with the help of subjective judgement can not only improve the quality of meta-analysis but also, helps us obtain the significant results.

4.10 Future Directions

Ergonomic measures reduced the mechanical exposure of workers to the risk factors for some activities (Van der Molen et al., 2009). The MMH industry and its related tasks are differentiated and divided into many sub-types such as; lifting the materials, placing materials without mechanical help on their proper places while construction, that we need various ergonomic solutions for reducing the exposure of workers to such risks. Ergonomists now have a good understanding of the building blocks for the causal pathways of LBP in MMH jobs, such as;

eliminating awkward movements, correcting posture and reducing repetitive motion etc. However implementation of ergonomic solutions modifying these building blocks is not always effective. Clearly some contributing factors are being overlooked.

Another reason for conflicting results in the literature could be the inclusion criteria of the studies. Studies typically include all types of workers to increase the number of participants or because that is the available structure of the workplace. In order to find the effect of ergonomic intervention, the inclusion criteria needs to be strict and include only the type of workers it is designed for. Presenteeism is also another factor that effects that can affect the results. If there is no active participation from the worker, then the worker can become an outlier in the intervention study and will affect the results.

Future Research also needs to focus on qualitative studies as these studies can change the face of the industrial world in improving the quality of life of MMH workers by bringing forward the ergonomic interventions that decreasing the loading and in-turn LBP. Also, saving the world from the consequences of absenteeism which could lead to drainage of economic and financial resources of many industries. Also, the research in the field of ergonomic interventions should focus on including the three parameters; the engineering control, the administrative control and the worker participation.

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