A REVIEW OF THE POSSIBLE EFFECTS OF PHYSICAL ACTIVITY ON LOW-BACK PAIN

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ABSTRACT

Objective: Low back pain (LBP) and injury represents the most prevalent and costly repercussion from musculoskeletal injury in the work place. This review examines the earlier and current research reported on the significance of physical activity on musculoskeletal injuries and LBP, the benefits and limitations of therapeutic exercise, and the potential features of various exercise modalities that may contribute to the secondary and tertiary prevention of low-back pain.

Methods: A search was performed using MEDLINE to identify original studies published in English from January 1990 to December 2013. Physical activity in the form of aerobic, muscle strengthening, flexibility, and occupational (labor) activities among working adults (18 – 65 years of age) alone and with other non-surgical therapies were selected. A hand-searched collection from a personal literature library also was used.

Results: Fifteen studies met the inclusion criteria, addressing aerobic exercise (n=4), muscle strengthening exercise (n=3), combination of aerobic, muscle strengthening, and flexibility exercises (n=5), and occupational labor/exercise (n=3). The investigations generally supported the benefits of programmed and structured exercise alone and with other therapies for the treatment of LBP.

Conclusions: Given the physical and financial burden to treat LBP, this issue remains a great public health importance. With the burden on society from LBP and the prevalence of the disorder among populations, research from physical activity on LBP has produced varied results without a specific type of exercise that results in resolved LBP better than most. Most agree that some activity is better than none, but no one activity is better than the others when the multifactorial etiology of LBP remains inconsistent. Isolating the vertebrae that causes the LBP would be beneficial for participant selection with future research. Different forms of pathological evidence or combinations of pathological measurements may help to establish proof of beneficial exercise or a combination of exercise therapies.

Key words: low back pain, physical activity, rehabilitation, therapeutic exercise

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The significant and generous contribution by colleagues at the University of Pittsburgh were responsible for the successful completion of this effort. Dr. Russell Rycheck and Dean Mary Derkach were generous administrators for providing support, positive reinforcement, and removing hurdles that may have prevented success. Drs. Andrea Kriska and Kristi Storti provided many years of support and academic guidance. Drs. Nancy Glynn, Elizabeth Nagle, and Christina Wassel were pivotal for guiding me to the end.

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1.0 INTRODUCTION

1.1 Overview of Occupational Musculoskeletal Injuries

Occupational musculoskeletal injuries are a major cause of disability and worker absenteeism [1]. Most musculoskeletal injuries in the work place are sprains & strains, dislocations, and fractures [2]; in addition to inflamed joints [3]. The most frequent cause of musculoskeletal injuries involve overexertions [3, 4] and bodily reactions [3]. Overexertions more commonly involve lifting or pushing/pulling of objects [4]. The most numerous body part affected by sprains/strains is the back [2]; in addition to all bodily joints, which included the back [3, 5].

The incidence of work-related musculoskeletal injuries increases with age up to the 21-30 age range (approximately 2000 injuries/100,000 workers), then the incidence declines steadily to retirement age [3]. The 41-50 age range contains the largest proportion (51%) of musculoskeletal injuries among all work-related disorders [3]. Kelsey suggests that excessive force is responsible for trauma in the younger age groups, where physiologic changes to the body concomitant with aging are the major factors in the etiology of injury and trauma in the older age groups [2]. The changes in the work-related musculoskeletal injury types across age groups are concomitant with the changes in injury causes, i.e. as overexertions decrease with age so do the frequency of sprains/strains [6]. These trends are the same for males and females [6]. Nationally, females are more likely to report musculoskeletal problems, but physician-reported contacts are approximately equal between the sexes [5]. When work-related reporting mechanisms are observed, males are more likely to encounter a work-related musculoskeletal injury [6, 7]; and males have a higher risk of having activity restriction, changing jobs, or losing days from work [5]. This observation among men increases with increasing age. For example, the proportion of fractures increases with age [6], however, the increase is greater in females than in males [2]. A proportional examination of the work-related injury data implies that females do not encounter more fractures but they suffer from fractures at an age range approximately 10 years earlier than males [6]. Kelsey suggests the disproportionate numbers of fractures to older females are associated with moderate trauma in postmenopausal women [2]. The most frequent occupations that report musculoskeletal injuries in males adjusted for age are truck drivers, laborers, and janitors; for females, the occupations are nursing aides, registered nurses, and assemblers [6].

The occurrence of work-related musculoskeletal injuries has been associated with socioeconomic status. Occupational musculoskeletal injuries are more prevalent among individuals who have lower income, lower levels of education, and widowed persons [5]. The time of employment is associated with the susceptibility of a work-related musculoskeletal injury. Sinkule et al. reported 52% of all musculoskeletal injuries in the work place during 1980 occurred within one year of employment or less [3]. Further examination revealed that 37% of the injuries occurred in less than 12 months of employment [6]. The number of incident cases of occupational musculoskeletal injuries decreases as the years of service increases [6, 8].

The health risks from leisure-time physical activity also are shared by occupational activity. The etiology of occupational musculoskeletal injuries has been implied to be similar to the principles of muscle strength training [9]. The uncontrollable factors that contribute to the possible etiology of musculoskeletal injuries in the work place include the following: repetitive motions at abnormal speeds [10]; static muscle work [10]; abnormal work positions [10]; repetitive lifting [10]; position transfers [10]; required apparel [10]; monetary incentives [4]; and social or family pressure [4]. When work is performed according to production expectations, the increase in metabolism potentially could exacerbate complications from underlying cardiovascular disease. Results from studies which examined the heart rate response of workers performing tasks, *ad libitum*, responded within an acceptable limit for eight hours of work, however, some of the subjects had heart rates higher than expected for the same tasks [4].

1.2 Occupational Low-Back Pain (LBP) and Musculoskeletal Injuries

The most common cause of work-related LBP is from an overexertion which resulted in a sprain or strain to the back [2, 11-13]. The most frequent sources of overexertions which led to LBP were lifting, bending bodily motions, and falls [14]. Combined bodily motions such as lifting loads in bended or twisted positions also contributed to the frequency of claims due to LBP [12]. "Lifting" was the cause of most work-days lost due to LBP [11]. The weight of loads lifted also correlated positively with absenteeism due to LBP [8].

1.3 LBP From Acute Injury

As data bases of worker injuries provide information regarding the reported type of action associated with a low-back injury, the evidence that a chronic health problem such as LBP developed from an acute injury is relatively weak [15, 16]. A major question that arises when examining the association of LBP to an injury is whether the change in pathology was acquired because of the acute injury or was a cumulative injury (also known as, repeated trauma). Symptomatically, muscular strength and flexibility are compromised in the presence of LBP.

With LBP, studies have reported reduced strength and flexibility in the back [17-19], the hamstring area of the legs [20], and the quadriceps muscle group [21]. Researchers have attempted to ascertain a single etiology to occupational LBP, others have provided convincing evidence that the complex nature of the back in an aging body of different genders has alluded to a multi-factorial etiology. From the medical prospective, LBP has been given an assortment of diagnoses that has added to the confusion by those investigating this health problem [16, 22].

Much of the research investigating the etiology of LBP has examined the relationship of the load handling requirements, or physical requirements, of the task with the occurrence of LBP. Several reports cite the significant association of the amount of load handled with the severity and frequency of LBP [2, 4, 23-28]. Gross [23] and Jensen [24] reported a significant association of the number of patient lifts with LBP among nursing personnel. Andersson [29] attributed the performance of physical work, frequency of lifting, and posture while load handling as risk factors to LBP. Contrary to these studies, Magora failed to associate the frequency of bending as a cause for LBP [30]. In a retrospective analysis of LBP among active garbage collectors and sedentary teachers, Onishi and Nomura compared the musculoskeletal attributes of those who experienced LBP to those who were apparently healthy [27]. The study reported similar physical attributes and muscle strengths among healthy garbage collectors and the garbage collectors who suffered from LBP. This study, as well as others [31], concluded that the sedentary nature of urbanistic life and industrialization have contributed to weakened trunk muscles, which significantly increases the risk of LBP [27].

1.4 Physical Activity and LBP

The previous research regarding the effects of exercise on LBP typically was an approach for secondary and tertiary prevention, i.e. exercise (programmed and structured aerobic, muscle strengthening, or joint flexibility activities with defined outcomes, e.g. improved oxygen consumption, muscular strength, or joint integrity and stability) was used as a therapeutic treatment to strength the back or abdominal muscles when back pain was present or to rehabilitate those recovering from LBP. Non-weight bearing activities, such as swimming or bicycling, were prescribed to maintain cardiovascular endurance [32]. The role of exercise for LBP patients was cumbersome to evaluate due to the complexity of the back injury and the wide variation of LBP between LBP patients [16]. Therefore, exercise has a therapeutic role for patients with LBP, but the inter-variation characteristics of LBP between patients prevented an aggressive approach from this type of therapy.

Physical activity has been used as a form of primary prevention for musculoskeletal injuries from exercise. Therefore, it follows that physical activity may be a potential factor in treatment or prevention of low-back pain and injury in the work place as well. With the increased awareness in health promotion and injury/illness prevention, the increased importance of physical activity has been recognized in the public health literature as a crucial element for optimal health. The health benefits of physical activity can be categorized as physical (e.g., cardiovascular, orthopaedic, flexibility, and musculoskeletal), psychological, and perhaps, economical.

The beneficial effects from aerobic exercise are produced when exercise has been performed with adequate intensity, duration, and frequency. The exercise requires dynamic use of large muscle groups, performed most days each week at an intensity relative to an individual's aerobic capacity. The type of exercises performed determined the relative gains in physical fitness.

1.5 Occupational Physical Activity and LBP

Many studies have been unable to accurately assess occupational physical activity or associated leisure physical activity. Controlling for self-selection to various occupations or job transfers has had the tendency to contribute to the dilemma of assessing risk indicators for low back injuries [33]. Whether the risk from the occupation is related to the type of activity or to the increased metabolism from the task itself represents a sample of the issues that investigators have been trying to assess.

The type of occupation has been found to be related to energy expenditure. The caloric expenditure from manual labor is the largest of all occupational groups [34, 35]. When lifting and carrying are involved in the task, the weight of the load, the rate of work and the distances involved contributed to work capacity [35]. Lifting techniques also affected metabolism, i.e. the bent leg technique involved a greater oxygen consumption compared to the cantilever method when the weight of the load and lifting rate were held constant [36]. The proper amount of work performed in an eight hour shift also has been studied. About 21-33% of the maximum aerobic capacity has been accepted as a safe metabolic rate for an eight hour shift of varying tasks [4]. Variability for the actual metabolic rate changes little except when heavier workloads were encountered [4]. The National Institute for Occupational Safety and Health (NIOSH) has classified the factors which affect the metabolic rate of manual work, which are as follows: (1) body posture -- different muscle groups are used with varying postures and biomechanics of lifting; (2) weight of the load -- linear relationship exists between the weight of the object and metabolic rate; (3) frequency of lifting -- linear relationship exists between work pace and metabolism; (4) vertical traveling distance of the lift -- raising and lowering the body with the load affects efficiency, total weight moved and metabolism ; and (5) vertical location -- lifting the same net vertical distance from two different vertical heights involved varying body mechanics and metabolism [36]. NIOSH also recommended the following physiological guidance: (1) for occasional lifting (1 hour), metabolic energy expenditure should not exceed 9 kilocalories/minute for fit males or 6.5 kilocalories/minute for fit females; (2) continuous occupational activity should not exceed 33% of aerobic capacity; (3) work capacity for individuals cannot be predicted from attributes of age, gender, body weight, etc; and (4) the metabolic rate of lifting is influenced by the load handled, the vertical level of the object to be lifted, the vertical travel distance and the frequency of the lift [36].

When examining the muscular strength of workers, Kamon attempted to assess this variable in a cross-sectional exam of 602 workers at a paper factory [37]. The investigators showed that women were 60% as strong as men, strength was inversely related to age and strength was similar between workers with different strength demanding jobs [37]. The last finding was unexpected, assuming that workers employed for many years at the heavy jobs would be stronger than those working many years at the light to moderate jobs. NIOSH has determined that anthropometric measurements also are not adequate indicators of strength [36].

1.6 Cardiovascular Risk Factors and LBP

Svensson et.al. reported a cross-sectional evaluation of a random sample of men (age range: 40-47 years) to compare cardiovascular risk factors in those participants with and without LBP [38]. The investigators classified the subjects into four groups, which are as follows: A--back pain or back problems at some time during their life; B--back pain or back problems which occurred at least once a month; C--ongoing back pain or back problems, at least two times a week; and, D--never had back pain (which served as controls) [38]. In groups A, B, and C, calf muscle pain was more common as well as dyspnea on exertion, when compared to controls [38]. These subjects were more physically active at work, but less physically active during their leisure time [38]. Contrary to previous reports [12, 39], there were no differences between men with or without LBP with respect to height [38]. There also were no differences between men with or without LBP with regard to systolic and diastolic blood pressure, resting heart rate, serum cholesterol, or electrocardiographic changes [38]. The authors also reported a statistically significant association between the presence of LBP and psychological stress [38]. The perception of psychological stress at work was statistically significant only in group C. These results are informative but should be interpreted with caution. For example, without a standardized measure of the intensity, duration, or frequency of occupational physical activity, the amount of physical activity at work remains a relative term. The same ambiguity applies to leisure time activity as well. Previous reports have established a substantial number of workers which change jobs as a result of LBP [20]. However, in the report by Svensson et.al., no adjustment was made for changes in job status prior to or during the study, therefore, the reports of job-related attributes may be somewhat unreproducible [38].

1.7 Improving Musculoskeletal Health Through Physical Activity

The primary, longitudinal purpose of physical activity has been to improve physical health. For the 2020 Healthy People objectives, the target uses an increase in adults engaged in regular moderate (unknown metabolic equivalent) physical activity above 43.7% (the base year of 2008) and an increase in adolescents engaged in federal-recommended regular physical activity above 18.4% (the base year of 2009) [40, 41].

Theoretically, those with a higher physical work capacity (PWC) can perform submaximal exercise, including activities of daily living, with a reduced effort thereby reducing fatigue [42]. The gains from physical activity also have included increases in muscular strength for different ages and gender [43]. How the level of activity can effect occupational performance has received attention of health experts in the United States. This attention is based on the theoretical principles of exercise physiology and psychology: if functional capacity can be improved, then the capacity to work at one's chosen occupation also can be improved.

1.8 Screening LBP with Muscular Strength

Whether muscle strengthening exercise can be effective in prevention and/or treatment of low back pain from injury is unclear. Currently, it is known that those who suffer from LBP have reduced strength in the trunk extensor muscles; low muscle endurance contributes to LBP; and minimal trunk strength is necessary to return to normal function [44]. It is not certain whether exercise contributes to function or to reduction of pain or both [44]. Conditioning exercises have been used to decrease the degree of incapacity accompanying low back dysfunction [44].

The assessment of muscular strength as a pre-employment parameter is based on the rationale that weaker employees incur more injuries. For trained athletes, inconclusive research exists relating the use of strength training and its role in the prevention of injuries. In a study of 20 occupations within a tire & rubber plant that examined the effects of pre-employment strength tests on the employee's physical capacity to qualify for jobs, investigators reported a 3-fold greater incidence of medical visits by control groups over the experimental group [45]. In addition, the experimental group did not incur any visits to treat musculoskeletal injuries of sprains or strains. The investigators did not examine the effect of job transfers as a way of bypassing the screening.

1.9 Physical Activity and Joint Flexibility

The use of physical activity to improve joint flexibility is vague. Buskirk reviewed reports that supported the use of chronic physical activity toward the improvement of flexibility within elderly males and females [46]. A historical research report by Panush [47] and a prospective study by Rhodes [48] were inconclusive when tests were applied to exercise and control groups in an effort to detect a significant difference in flexibility between groups.

1.10 Public Health Significance

The financial and human capital costs from occupational LBP are burdensome. Among all occupational injuries, injuries to the back remain as the leading affected body part at 19.9% in 2011 [49]. Only injuries to the head exceed the costs per claim ($82,382) from occupational injuries compared to the back ($73,555), of which the greater portion were low-back injuries, or $39,643 per claim.

For those less than 45 years of age, LBP is the most frequent cause of disability [2, 50]. Annually, approximately 3% of Americans are temporary disabled and 1% are totally disabled due to LBP [5]. Approximately 80% of all Americans will experience an injury resulting in LBP during their lifetime and the chances are likely that the site of the injury will be reinjured at least once [51].

1.11 Objective

This essay will concentrate on the most prevalent and costly repercussion from musculoskeletal injury in the work place, i.e. low-back pain (LBP) and injury. The following review will examine the earlier and current research reported on the significance of physical activity on musculoskeletal injuries and LBP, the benefits and limitations of physical activity, and the potential features of physical activity that may contribute to the secondary and tertiary prevention of low-back pain.

2.0 METHODS

Two sources were used to identify articles published for this review. First, a bibliographic database by the United States Library of Medicine, MEDLINE. The MEDLINE was used to search for literature from 1990 to 2013 in English on the relationship of exercise and low-back pain. Abstracts were used to preview relevant, original articles with a search of key words: “exercise”, “musculoskeletal training”, “physical activity”, “physical work capacity”, “flexibility”, “occupational”, “low-back pain”, and “low-back injuries”. Second, a 35-year personal collection of literature on low-back pain and injuries was hand-searched.

The availability of relevant manuscripts from personal archives provided information that was collected before and after the inception of the world-wide web, when the author was an epidemiologist for the National Institute for Occupational Safety & Health (NIOSH) followed by significant clinical experience in a physical therapy tertiary care facility. Many of the available sources were used as primary sources from related literature (also known as cross-references). Experts agree not much has changed in the study of the effects from physical activity and exercise for the primary, secondary, and tertiary prevention of low-pain pain and disability [52].

3.0 RESULTS

3.1 Aerobic Exercise

As a form of physical activity, chronic aerobic exercise has been used for the strength improvement of the ligament-bone integrity at the joint. Tipton examined the morphologic ligamentous connection in rats and dogs treated with physical activity and immobilization [53]. This research further cited a strong correlation between junction strength with body weight and a weak correlation with ligament mass; thereby suggesting different mechanisms representing the effects of physical activity on junction strength and on ligament mass. Similar results with repaired ligaments have been reported. Human studies have cited a reduction in joint stiffness, maintenance of muscle tone and proper posture with aerobic exercise [54]. Effects of physical activity on improved levels of subjective low back pain from injury have been reported [21]. From this activity, strong tendons, ligaments, joint cartilage, connective tissue sheaths, tendon-to-bone and ligament-to-bone junction strength, and bone mineral content augment injury prevention. Physical activity, in one form or another, has been advised for prophylaxis from sport injuries and occupational trauma [55].

Physical activity can reverse joint stiffness across various age groups. Chapman et al. (1972) examined the effects of physical activity on joint stiffness in two groups of males, 15-19 years and 63-88 years of age [56]. The results demonstrated that joint stiffness, in both young and old individuals, is a reversible phenomenon. In a study of active (treatment) and inactive (control) employees, Chenoweth used an aerobic exercise program to examine effects on volunteer participants [57]. The exercise program met for 45-60 minutes twice each week for 12 weeks. The description of exercise intensity was light calisthenics and stretching to strenuous jumping, hopping, and modified running activities. Of the significant results for the 12-week program, increased back flexibility and decreased absenteeism was reported for the treatment group, in addition to modest decreases in resting heart rate (2.5 beats per minute), systolic blood pressure (2.3 mmHg), diastolic blood pressure (2.6 mmHg), body weight (1.6 pounds), and body composition (2.1% body fat).

Harkcom et al. (1985) reported favorable results after examining levels of joint stiffness in rheumatoid arthritis patients in exercise programs of varying levels [54]. Participant volunteers consisted of a cohort of selected 20 women with rheumatoid arthritis of various severity and treatments but consistent with stable treatment regimens stable drug therapies and no steroid injections received before or during the study. The intervention included three groups of increasing durations each session (Group-A, 2.5 to 13 minutes (n=4); Group-B, 7.5 to 24 minutes (n=3); and Group-C, 15 to 35 minutes (n=4)), during the 12-week program of bicycle ergometry compared to sedentary controls (n=6) selected among the initial volunteers. Pre- and post-treatment evaluations included self-perception of exertion for activities of daily living and joint pain, grip strength, a walking test, muscle strength measured at the knee, and a graded exercise test of aerobic capacity using a bicycle ergometer. Significant improvements included aerobic capacity (for each treatment group, versus baseline), exercise test time (for each treatment group, versus baseline), joint pain (for each treatment group, versus baseline), and muscle strength

(Group-B only, versus baseline). The exercising group also reported a decrease in the scores for pain and swelling, morning stiffness and improved sleep patterns.

Chan et al. [58] studied the effects of aerobic exercise in addition to conventional physiotherapy for patients with LBP. Their cohort consisted of 46 men and women selected for treatment or control by randomization. Treatment patients engaged in aerobic exercise (treadmill walking, cycling, or stepping) for eight weeks under the supervision of a physical therapist at an intensity of 40-60% of heart rate reserve for 20 minutes, three meetings each week of which one was unsupervised home-based exercise. Outcome variables included pain, functional disability, and physical fitness using aerobic capacity, back extensor muscle endurance, low-back and hamstring flexibility, and body composition (% body fat). After eight weeks, the treatment group improved for all outcome variables where the control group only improved for body composition and back flexibility. At 12 weeks, both groups improved both pain and disability scores when compared to baseline.

Sculco et al. [59] examined the effects of aerobic exercise alone for the treatment of LBP of various pathologies. Participants included 35 patients from a neurosurgical practice at a tertiary care teaching hospital and were not receiving treatment for cardiovascular disease, current acute severe LBP, or low-back surgery within six months. The intervention included a 10-week home-based exercise program of walking or cycling, four days each week at 60% of their age-predicted maximum heart rate, beginning at 20 minutes and progressively increasing exercise duration to 45 minutes/period. Outcomes (pain and mood state inventories) were measured at 10-weeks and 30-months. At 10-weeks, the active group reported, fewer injuries, less depression, anger, and total mood disturbance compared to controls. At 30-months, the physically active group filled fewer pain prescriptions, needed fewer physical therapy referrals, and improved their work status compared to controls.

Indirect benefits from fitness programs include fewer medical claims filed and reduced costs from the medical claims [60-63]. One report which reviewed an aerobic fitness program over a four year period for men (age range = 35-55 years) cited no difference in the number of claims filed between compliers and noncompliers or those who dropped out of the program [64]. However, the average cost per claim for the nonexercisers was two times the cost of the claims submitted by those who participated in the exercise program [64]. In an evaluation of a corporate fitness program comparing short term participation (18-30 months) and long term participation (>30 months) to those who did not participate, a lower charge rate in hospital costs was reported by both exercise groups compared to the nonexercising controls; age was associated with increased medical costs and utilization; gender was related to medical costs, i.e. women incurred higher costs and more utilization than men; and salaried workers incurred lower medical costs and utilization rates compared to wage earners [65]. The reports by Chan and Sculco also present the indirect benefits from aerobic activity, such as improved mood states, reduced pain, less pain medication and return to work [58, 59].

Table 1: Summary of studies investigating the relationship between aerobic activity with LBP and injury

Authors	Participants	Mean Age± SD (years)	Design	Physical Activity	Findings
SUPERVISED					
Chenoweth 1983 [57]	25 healthy treatment group & 25 control group	N/A	Cross-sectional prospective	12 weeks of calisthenics and supervised aerobic exercise 2 times/week	↑ back flexibility and ↓ absenteeism
Harkom et al. 1985 [54]	20 rheumatoid arthritis outpatient women	52±12	Cross-sectional prospective	12 weeks of supervised aerobic activity @ 70% HRmax 3x/week	↓ perceived exertion, morning stiffness, and back pain; ↑ aerobic capacity and muscular strength; ↓ joint pain
Chan et al. 2011 [58]	24 LBP patients with standard care + exercise & 22 LBP patients with standard care alone (controls)	Exercise: 47±8.3 Controls: 46±11.5	Cross-sectional prospective case-control	8 weeks of supervised aerobic activity @40-60% HRreserve 20 min/day, 2x/week, plus 1 day home-based exercise/week	8 weeks: ↓ body weight, BMI, % body fat; ↑ aerobic capacity, muscle endurance, and back flexibility 12 months: No difference in pain or disability between groups.
UNSUPERVISED					
Sculco et al. 2001 [59]	17 LBP patients with exercise & 18 LBP patient controls	Exercise: 47.2±9.0 Controls: 48.1±7.3	Cross-sectional prospective case-control	10 weeks of home-based walk/cycling at 60% HRmax; 20-45 min/day; 4 days/week	10 weeks: ↓injuries by exercise group; ↓ depression, mood state and anger by exercise group 30 months: ↓pain Rx and physical therapy referrals; ↑ work status among exercisers compared to controls

3.2 Muscular Strength and Endurance

Hemborg et al. (1983) investigated the involvement of the abdominal muscles and back muscles during lifting in healthy young men [66]. The subjects were tested using a standardized testing protocol before and after a five week exercise program specifically aimed at improving the strength of the abdominal and back muscles by isometric exercise. The results included improving the strength of the abdominal and back muscles, however, the investigators discovered that intraabdominal pressure had not changed during the lifting tasks. In addition, the activity of the back muscles during lifting had not changed as a result of the training. In an investigation by Chapman and Troup (1969), a 14 day exercise program for developing the erector spinae muscles in 13 young adult males proved a significant linear relationship between electrical activity by the muscles and the force produced by lumbar musculature [67].

The strength of the trunk flexors is inversely related to backache and back pain associated with bending forward and lifting [1]. Weak leg flexors have been related directly to lost workdays from back pain [1]. Aerobic exercise in the form of walking and running has been related to improved back flexibility [57]. Lack of adequate exercise to maintain flexibility is thought to have a direct risk of falls in the elderly.

Insufficient activity that strengthens abdominal muscles is associated with an increased risk of low back pain. The musculoskeletal integrity of intraabdominal, intrathoracic and trunk muscles influences the maintenance of posture during various lifting and carrying tasks [16]. Increasing intraabdominal and intrathoracic pressure in order to relieve the load from the lumbar spine is the rationale for improving muscular strength of the abdominal and trunk muscles with isometric abdominal muscle exercises. Conversely, Nachemson reported a study of isometric

Table 2: Summary of studies investigating the relationship between muscle strengthening activity with LBP and health

Authors	Participants	Mean Age± SD (years)	Design	Physical Activity	Findings
Chapman & Troup 1969 [67]	13 healthy men	19.8±1.99	Cross-sectional prospective	14 days of static isometric pulling at ≤30% max voluntary contraction with 2 days pulling at 80% max voluntary contraction	↑ lumbar muscle strength with ↑ motor fiber recruitment not hypertrophy
Hemborg et al. 1983 [66]	20 healthy men	28 (23-33 years)	Cross-sectional prospective	5 weeks of isometric training of abdominal muscles	↑ trunk flexor and back muscle strength
Granhed et al. 1987 [68]	8 competitive power lifters	28±5.9	Cross-sectional observational (bone mineral content (BMC) on L3)	Long-term muscle strengthening	↑ in BMC at L3 as training intensity ↑ Changes in BMC with training intensity was not a linear relationship with amount of weight lifted.

testing of normals and low back injured from chronic over use; no significant differences were noticed in abdominal strength between the groups for males and females [69].

Bone mineral content (BMC) of the axial skeleton improves from physical activity. As levels of physical work capacity increase, there appears to be an associated increase in the BMC of the lumbar spine. In a study examining activities of daily living in postmenopausal females and muscle strengthening exercise in world class power lifters, the positive correlation between activity and lumbar BMC was intact [68]. An additional point by the power lifter study suggested limitations in the linear relationship between the bone mineral of the lumbar spine and the compressive strength, i.e. when BMC exceeds a certain level, compressive strength does not increase concomitantly.

3.3 Combinations of Aerobic, Joint Flexibility, and Muscle Strengthening Activities

Probably the most cited report where physical activity was used to prevent occupational low back injuries was a prospective study to evaluate strength and fitness measurements and the subsequent incidence of back injuries in 1,652 firefighters (ages 20-55) from 1971-1974 [70, 71]. Prospective measurements included flexibility, muscle strength, and physical work capacity as measured on a bicycle ergometer. Subsequent incident cases of low back injuries were tabulated for different categories of fitness. Results included a higher percentage of injuries in the least fit group. The most costly injuries were in the most fit group, however, this result was skewed by a low number of incident cases in the group (two), one of which cost $130,000.

Kohles et al. [72] examined two groups of patients with chronic LBP with a pretreatment program lasting 1-2 weeks (Group 1) and another that lasted 2-6 weeks, including aerobic exercise and muscle strength training (Group 2). Group 2 not only exhibited greater isokinetic trunk strength compared to Group 1, they also exhibited trunk strength similar to normal, unaffected controls. The differences also were seen for improved range of motion of the back and hip joints. The combined greater education, aerobic, muscle strength and flexibility activities proved to decrease inhibitory factors (e.g., pain or reinjury) and increased physical capacity.

Van der Velde and Mierau [73] determined the effects of aerobic, muscle strengthening, and flexibility exercise on measures of pain and disability in patients with LBP. The exercise program (aerobic exercise, muscle strengthening, and joint flexibility) lasted 10 months with data collected through chart reviews of patient changes. Patients with pain of the cervical and thoracic regions were included. In addition to improvements in aerobic capacity above the normal range for a similar cohort of healthy participants, pain levels were lowered significantly and disability scores were lower in the exercise group compared to pre-treatment measurements.

Table 3: Summary of studies investigating the relationship between combinations of aerobic activity, joint flexibility activity, and muscle strengthening with LBP and health

Authors	Participants	Mean Age± SD (years)	Design	Physical Activity	Findings
Cady et al. 1985 [70, 71]	998 healthy fire fighters	44±5	Cross-sectional prospective	14 years of bicycle ergometry plus calisthenics	↑ spine flexibility and those >50 years old tested with highest gains
Kohles et al. 1990 [72]	45 Group 1 LBP patients 57 Group 2 LBP patients	Grp 1: 38.2±11 Grp 2: 37.1±9	Cross-sectional prospective	3 weeks of separate LBP behavior mod for 1-2 weeks (Grp1) and 2-6 weeks (Grp2) with supervised aerobic exercise and strength training	↑ isokinetic trunk strength and flexibility of the back and hips in both groups but more so in Group 2
Van der Velde et al. 2000 [73]	137 LBP of 10-months average duration 1001 healthy controls	LBP: 34.2±8.1 Controls: 29.1±10.0	Retrospective chart review	6 weeks of aerobic exercise (60% HRmax), muscle strengthening, and flexibility training	LBP group ↑ aerobic fitness and ↓ pain and disability scores.
Vad et al. 2007 [74]	23 LBP with standard care + exercise 21 LBP with standard care alone (control)	Exercise: 31.4 Control: 30.9	Cross-sectional prospective age- and sex-match case-control	12 months of 15 min/day, 3 days/week, home-based physical therapy, yoga, and Pilates	70% of exercise group favorable scores for disability, pain, flexibility, and satisfaction compared to 33% of controls. 31% more controls had recurrent symptoms compared to exercise
Olivier et al. 2013 [75]	24 LBP patients 24 healthy controls	LBP: 32.2±7.1 Controls: 29.3±9.3	Cross-sectional prospective case-control	28 days of 5 hours/day 5days/week strengthening isotonics, aerobic conditioning, stretching, and global reconditioning	Of LBP, erector spinae back muscle ↑ reoxygenation and blood volume during lifting compared to baseline. Greater maximal loads lifted, total power, and total work compared to baseline.

Vad et al. [74] used LBP patients with a consistent pathology (disk degeneration) with leg pain which lasted 3+ months as the study cohort. The intervention included a specialized treatment program of muscle strengthening and endurance (physical therapy and Pilates), joint flexibility (yoga), and prophylactic body positioning that avoids intradiskal pressure with medical therapy and cryogenic bracing (Group I) compared to medical therapy and cryogenic bracing alone (Group II). The outcome variables include a disability inventory, a pain rating, patient satisfaction score, hip flexion, amount of medical therapy used, occupational absenteeism, and symptom recurrence. At a 12-month follow-up period, 70% of Group I exhibited a 50% reduction of pain and good patient satisfaction or better compared to Group II. In addition, Group I participants used less medical therapy each day, reported less absenteeism at work, and less symptom recurrence for the 12-month period.

In a very well-controlled study of concentrated and focused physical activities on LBP and oxygenation of back muscles and blood volume was conducted by Olivier et al. [75]. Participants included 24 cases and controls, each included 12 men and 12 women. Potential participants with any other pathologic disorders were excluded from participation. The exercise intervention lasted for 5 hours of treatment each day for 5 days/week and 4 weeks. Activities were strengthening isotonics, aerobic conditioning, and global reconditioning. Improvements for the treatment group included greater oxygenation and blood volume of the erector spinae muscles during a progressive isoinertial lifting evaluation. Greater maximal loads lifted, total power, and total work were exhibited by the treatment group at the end of the 4-week treatment compared to baseline.

3.4 Occupational Activity and LBP

Several investigators have examined the relationship of occupational activity patterns and the activity patterns associated with non-occupational activity. A considerably higher proportion of average activity occurred at work compared to after work activity or off day activity, and work activity represented as much as 69% of the total daily activity [76]. A direct relationship existed between activity patterns at work and activity patterns after work [76]. After work activity was not related to off day activity [76]. Results from the 1985 National Health Interview Survey suggests that those who work in moderately active occupations made more attempts to be active during leisure time; however, those who worked light occupations had the greatest proportion of leisure physical activity that could be classified as regularly active with appropriate amounts of physical activity [77]. Rose and Cohen attempted to determine how aging affects the patterns of occupational and leisure physical activity by examining the interviews from survivors of 500 white males who died in the Boston area [78]. Occupational and leisure activity measures decreased as age increased. Leisure activity patterns were lower than occupational activity, the greatest differences occurred in the middle decades of life. Across the age strata, leisure activity has the tendency to decrease at an earlier age compared to occupational activity. The rationale for sustained occupational activity with increasing age was dependent on the demands of the job, where leisure activity was subject to changes with aging and life styles. The occupational activity patterns with aging were unrelated to the aging patterns of leisure activity.

LaRivieve and Simonson examined the speed of handwriting as it varied with age and occupation [79]. The investigation showed a systematic decrease in handwriting speed with increasing age in those occupations where handwriting was not a major part of the job; therefore, there was no slowing in the responses associated with occupations which had repetitive demands.

Sick leave, or absenteeism, was found to be unrelated to leisure activity. Magora reported that the amount of sick days reported by workers who were physically active after work were not statistically different from the amount of sick days reported by workers who were sedentary after work [80].

The effects from variations of the occupational demands have been shown to be associated with increased risk of low back injury. Conversely, studies exist which have shown no relationship between physically heavy work and low back injury and pain [29]. Suggestions of resistance to injuries, like resistance to infection, exist as natural or acquired [81]. The response of tissues to repeated exposure of stress or strain has not been assessed adequately [82]. When sick leave was examined, no statistically significant relationship existed between absenteeism and the employee's perception of the occupational requirements or absenteeism and the employee's opinion that the low back injury was caused by the occupation [80].

When Wells et al. [83] examined the incidence of musculoskeletal injuries by letter carriers (load carrying & walking), meter readers (walking), and postal clerks (sedentary), they reported a direct relationship between musculoskeletal injuries and the more active occupations. The report also suggests a direct relationship between the intensity of occupational activity with the frequency of musculoskeletal injuries [83]. Chaffin attributes the load-frequency association with the following: increased exposure to physical insult that may increase "wear and tear" on connective tissues; muscle fatigue; and uncoordinated movements [4].

In a study of airline transport workers by Undeutsch et al. [12, 39], musculoskeletal injuries were related to the type of activity, the frequency of activity, and body weight. Back pain was prevalent in 66% of the workers, followed by knee complaints (41%). While all

Table 4: Summary of studies investigating the relationship between occupational activity with LBP and health

Authors	Participants	Mean Age± SD (years)	Design	Physical Activity	Findings
Wells et al. 1983 [83]	Letter carriers (196) Meter readers (76) Postal clerks (127)	Range, 20-60	Cross-sectional phone interview	Occupational	LBP ↑ as activity ↑ within each group. LBP rated highest of all joint pain. Letter carriers (highest weight-bearing activity) reported highest frequency of LBP
Undeutsch et al. 1984 [39]	Male airport baggage handlers (336)	36±8	Cross-sectional interview and muscle strength exam	Occupational	No relationship between muscle strength and LB injuries.
Svensson et al. 1989 [84]	Female residents, Goteborg, Sweden (1,746)	Range, 38-64	Retrospective interview	Occupational	No differences of reported LBP and education, employment type, hours worked/week, work type, breaks taken, or posture changes. Significant activities for LBP include forward bending and lifting.

musculoskeletal complaints increased with age, knee complaints increased with the increase in body weight. In the study by Wells et al. [83], letter-carriers experienced more shoulder problems when the letter carrying weight was increased. Wells et al. [83] also reported a similar rate of complaints in the lower extremities between letter-carriers and meter-readers. Luopajarvi et al. [85] compared the prevalence of musculoskeletal injuries of female assembly-line packers in a food packing plant to female shop assistants who had variable tasks. Shop assistants significantly had fewer musculoskeletal complaints than packers. In addition, packers significantly had more musculoskeletal injuries and experienced injuries more frequently than shop assistants. Most musculoskeletal injuries in the food packing project were variations of strains, sprains, and inflamed joints.

4.0 DISCUSSION

Most agree with the benefits of habitual physical activity on physical and psychological health. The funding and attention to the prevention and treatment of LBP with physical activity has been an understudied area compared to other health threats. In the 2008 Physical Activity Guidelines Advisory Committee Report from the U.S. Department of Health & Human Services, the words “low back” or “low back pain” were found at two locations – multiple sclerosis and an adverse event [52]. The word “lumbar” was found four times, once for adolescent health.

The role of randomized clinical trials in the study of exercise for the treatment of low-back pain and injury is the standard by which other studies are compared [86]. From studies that use research designs that were different from randomized clinical trial, much information can be learned and used as a framework that can be further studied by the randomized clinical trial. Challenges of the randomized clinical trial for exercise intervention with those with LBP may include sample size, selection criteria, and cost. Occupational and leisure-time LBP may contain subject characteristics that may be low-incident and difficult to recruit, or match with controls. The ethical issues with complete randomization also may be difficult to manage since the treatment for some subjects may be beneficial and the movement of subjects could include challenges for the institutional review board reviewing the study. Lastly, the costs associated with clinical trials that may include over-night accommodations or travel with the reimbursement of participants may be strenuous for the projects budgets.

The overlap of diagnoses and the separation of LBP between the type (occupational, leisure, accidental, etc.) and sub-type (acute or over-use) and location (thoracic, lumbar, sacral, etc.) further complicates the study of this disability with physical activity. Recruitment challenges, confidentiality of medical information used for harmonizing study groups, and intervention modalities are several factors that are influenced by consistent and homogeneous (disability type, gender, age, occupation, socioeconomic status, etc.) study groups.

The benefits reported by the reviewed therapeutic exercise studies were challenged by the research designs. The modest benefits by studies using aerobic exercise may have been resolved with improvements in the selection of participants and the design of exercise treatments. For the study by Chenoweth [57], a selection bias was an important factor that could have affected results, where the only group of employees used was the (first) daytime shift, the selection of participant volunteers used for the treatment group included employees that responded to the recruitment notice, and the only randomized group were controls (from a computerized list of employees). Ages for the participants and controls also were not reported. No systematic determination of sufficient sample size was reported. Since the exercise intensity was not measured then the amount of activity may not have been of sufficient intensity to produce a larger training effect, which was documented in the modest benefits in the treatment group between the first week and the twelfth week while withholding results by the control group [57]. Results from the Harkom study [54] may have been more significant if a larger sample size was selected for each group which would have improved power. The participants were selected and did not include volunteer participants which infers a systematic selection process by the investigators. The determination of subjects for each treatment group was not randomized and the distribution of gender across the groups was not reported [54]. An insufficient sample size for adequate power and significant differences between groups (such as gender) were complications also for the studies by Chan et al. [58] and Sculco et al. [59]. Outcome variables were not measured at a sufficient duration (e.g., 12 weeks) where fitness changes may have been measureable in the Chan study.

Studies that used therapeutic muscular strength and endurance may have been improved with modifications to the outcome variables. The report by Hemborg et al. [66] contained results that implied the exercise programs designed to increase muscular strength of abdominal and back muscles of workers may not have directly affected the injury rate if the lifting loads did not change. Since the pre- and post-standardized testing protocol used the same weight for lifting, it was not determined if the training program affected lifting capacity of the subjects. The research by Chapman and Troup [67] suggested the increased strength measured was attributed to gains in motor unit activity instead of hypertrophy of the muscle fibers. Nachemson [69] showed that abdominal muscle strength may not be important for prevention of low back pain.

When different variations of exercise were the intervention (combinations of aerobic, muscle strengthening, and flexibility exercise), the potential changes varied depending on the intervention combinations. Cady et al. [70, 71] reported improvements in spine flexibility and concluded that the most fit employees experienced fewer injuries and incurred injuries which cost less to treat, however several changes may have affected the outcomes. First, the amount of flexibility, muscular strength, or physical work capacity was not stratified between the different categories of fitness. Second, the results were not adjusted for age, gender, body mass (height or weight), or man-hours of work (exposure). This lack of adjustment could suggest that the most fit could be lean, nonsmoking, healthy, young men who were at reduced risk of injury and the least fit included more obese, smoking, older men who had increased risk of an injury. No mention of difference between gender for fitness or low back injury incidence was made. In addition, the authors cited the least fit group of firefighters were older, therefore, the increased incidence of low back injuries in that group may not be due to fitness level but due to other factors such as age, longer smoking history, and longer man-hours of work (lifetime exposure). For the study by Kohles et al. [72] significant power may have been achieved if the terms for establishing an adequate sample size were included. A longer preprogram treatment period produced improved results with additional aerobic exercise and muscle strengthening but it remains uncertain if the activity, the educational component, or both, were responsible for the improved results; and, would a longer (optimal) preprogram treatment period achieve even better results should have been examined closer. Van der Velde and Mierau [73] could have included measures of physical activity more specific than the language offered in the patient's medical chart. Though not pathological benefits, the study by Vad et al. [74] reported indirect benefits that may provide sustained success of various forms of exercise as supplemental therapy and may be improved if the investigators instituted a narrow case definition of subject characteristics and coupled the activity with other successful therapies. As the affected vertebral disks ascend or descend the spine between participants, the moment arms of stress may vary from the additional load of trunk weight on the affected disk area. The narrowed definition of cases may help to reduce the scope from the varied moment arms of stress placed on the low back. By far the best organized and balanced study reviewed, the investigation by Oliver et al. [75] provided informative results for the pathologies possible from various exercise. Their results suggest increased angiogenesis and muscle perfusion as a result of the treatment. Concomitant training effects may include reduced sympathetic stimulation and increased cardiac output. Other variables worth measurement for explaining the effects on participants would include oxygen consumption and blood lactate measurements. Hagberg [87] has reviewed the pathophysiology of an occupational musculoskeletal injury. In the musculature, changes include ruptured Z-discs, an outflow of metabolites from the muscle fibers, and edema which activates pain receptors. Ischemia also contributes to muscle pain, which contributes further to the accumulation of metabolic by-products, such as lactate. The production of lactate lowers the muscle pH and decreases the functional capacity of muscle enzymes, in addition to inhibiting the production of the muscle's energy source, adenosine triphosphate (ATP). If work tasks are 10-20% of the maximal voluntary contraction and are performed too frequently, the result could produce enough ischemia to traumatize the muscle cells. This trauma could affect muscle cell morphology and energy metabolism. Hagberg suggested that proper strength training could avoid such changes.

The effects from occupational labor on metabolism and residual injuries were limited and not substantially productive for reducing further LBP. Previous research efforts have been unsuccessful in establishing a clear link between occupational physical activity and the occurrence of low back pain.

4.1 Study Limitations

Probably the most significant limitation is the limited scope of a narrative review instead of the electronic literature search for a systematic review. A comprehensive approach to examining evidence-based published literature should contain elements of the following: specific literature search containing criteria defining the scope of the population (occupational or accidental LBP), subject headings of past and present exercise therapies (e.g., the rebirth of Pilates as a form of exercise therapy in the late 20th century) and therapeutic combinations (e.g., back schools), definitions of functional disabilities (pathologies involved, acute or chronic injury, extent of the disability, limitations of ambulation, etc.), specific characteristics of the research design (inclusion criteria, outcome measurement, interview type, single-subject versus group intervention, and criteria for exclusion), and cohort characteristics (age and gender specification, education, socioeconomic status, occupational class, ethnicity, religion (some limit the extent of therapeutic intervention), race, and marital status).

A recent clinical review of the state-of-the-science for LBP was published in the website Medscape [91]. The review was authored by five clinical specialists and described the epidemiology, pathophysiology, therapeutic treatments and outcomes for low-back pain and sciatica. In addition to the recent reviews by others [88], within the past 15-20 years the role of exercise in the treatment of LBP has not changed significantly, the effects of exercise therapy on LBP has not changed, and the incidence of LBP has remained relatively stable – LBP remains the most common cause of physical disability in Americans less than 45 years of age. Lumbar stabilization exercise was more therapeutic beneficial than lumbar strengthening exercise, and lumbar strengthening exercise may not have produced measureable benefits for LBP.

4.2 Future Research

Since the level of a low back injury affects the trunk above the injury and the innervated segments below the injury, isolating the vertebrae that causes the LBP would be beneficial for subject selection for future research. Head and trunk movements are determined by the level where the injury or inflammation has occurred. The lower the damage on the spinal column the greater the flexion and weight of the moment arm that must be maintained by the injured back to maintain position of the upper trunk. The location of the injured vertebrae also determines the function of the lower trunk below the injury. If the injury location is different between study participants, then the ability for physical motion also will vary between participants. Future studies then should focus with selection of participants with the same location of back impairment.

The review by Granhed et al. [68] that discussed the effects of exercise to increase muscle strength and its effects on BMC presented evidence that has not been studied further. So far, no clinical or epidemiological investigation has been conducted to examine the relationship between bone mineral content and the increased frequency of musculoskeletal sprains of the back. Perhaps the addition of pathological evidence may help to establish proof of beneficial exercise, for example, angiogenesis and increased muscle perfusion documented by Oliver et al. [75]. It would seem reasonable that a combination of measurements would be necessary to document the changes produced by a combination of exercise therapies.

4.3 Conclusions

The public health significance of physical activity on LBP has been financial as well as therapeutic. The estimated direct costs due to occupational musculoskeletal disorders (lost wages) are approximately $1.5 billion annually in 2007 [89]. The indirect costs of these disorders were estimated to be $1.1 billion [89]. In terms of workers' compensation costs, musculoskeletal conditions were ranked first by Workers' Compensation [90] with an estimated direct cost from workers compensation of $20 billion annually and indirect costs of $100 billion annually.

The frequency of LBP has been sufficiently high in scope for many years, and several statistics now are common knowledge. LBP and disability has been a multifactorial disorder (31 muscles and tendons connected to 24 bones and ligaments containing nerves from the peripheral and central nervous systems that depend on a healthy circulatory system and adversely responds to gravity) with many possible etiologies. At least 80% of all populations will be affected with

LBP at some point in their life. Once a person suffers from an injury that results in LBP, the chances are likely the same area of the back will be reinjured in the future regardless of treatment.

Given the physical and financial burden to treat LBP, this issue remains a great public health importance. The risk factors for occupational LBP have been cumbersome to identify because the mechanisms of causation are not well-defined, the injury etiology may be puzzling, and the available research provide variable results. The indirect difficulties from occupational LBP (e.g., personal and familial financial burdens, psychological harm, social and legal problems, etc.) significantly influence LBP and disability. Inconsistent research findings from research with therapeutic and occupational exercise (labor) provide confusing results for the high-risk elements [91].

With the burden on society from LBP and the prevalence of the disorder among populations, research from physical activity on LBP has produced varied results without a specific type of exercise that results in resolved LBP better than most. Most agree that some activity is better than none, but no one activity is better than the rest when the multifactorial etiology remains inconsistent. Scientists have yet to discover a method of focusing on a specific pathology to a specific region of the spine that has been affected by the same muscles, tendons, bones, ligaments, and nerves and treat that pathology with a beneficial type of physical activity with consistent positive results.

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