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Gender Differences in Low Back Pain and Self-Reported Muscle Strengthening Activity Among U.S. Adults

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GENDER DIFFERENCES IN LOW BACK PAIN AND SELF-REPORTED MUSCLE STRENGTHENING ACTIVITY AMONG U.S. ADULTS

by

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Nomenclature

cm	centimeter
d/wk	days per week
hr/wk	hours per week
kg/m^2	kilograms per meter squared
MET/wk	MET per week
min/wk	minutes per week
mo	month
yr	year

List of Abbreviations

ADL	Activity of daily living
ATEP	Active trunk exercise protocol
BMI	Body mass index
CI	Confidence interval
CPAFLA	Canadian Physical Activity, Fitness and Lifestyle Approach
CPM	Count per minute
CSA	Cross-sectional area
DHHS	Department of Health and Human Services
DMC	Dutch population-based Musculoskeletal Complaints and Consequences Cohort study
FD	Flexion-distraction procedures
GPES	Global perceived effect scale
HUNT	Nord-Trøndelag Health Study
InCHIANTI	Clinical epidemiologic longitudinal survey
LBP	Low back pain
LSADT	Longitudinal Study of Aging Danish Twins
LTPA	Leisure-time physical activity
MEC	Mobile examination center
MET	Metabolic equivalent
MPQ	Miscellaneous pain questionnaire
MSA	Muscle strengthening activity
nH	non-Hispanic

NCHS	National Center for Health Statistics
NHANES	National Health and Nutritional Examination Survey
NHIS	National Health Interview Survey
NHLBI	National Heart, Lung, and Blood Institute
OR	Odds ratio
PA	Physical activity
PAD	Physical activity questionnaire
PSFS	Patient specific function scale
PSU	Primary sampling unit
RCT	Randomized control trail
RMQ	Roland Morris Disability Questionnaire
RR	Risk ratio
SAS	Statistical analysis software
SD	Standard deviation
SE	Standard error
SES	Socio-economic status
SNQ	Standardized Nordic Questionnaire
SUDAAN	Software for survey data analysis
VAS	Visual analog scale
WC	Waist circumference
WHA	Women's Health Australia study

Abstract

Objectives We sought to examine the gender differences between low back pain (LBP) and muscle strengthening activity (MSA) in U.S. adults (≥20 years of age).

Background Low back pain is a well-known medical condition that has been shown to impact quality of life and professional productivity. It also adds to the financial burden of our healthcare system by augmenting medical treatment costs. Muscle strengthening activity is a recognized method to prevent and treat LBP. Studies analyzing the relationship between MSA and LBP by gender have produced mixed results.

Methods The sample (n=12,721) included participants in the 1999-2004 National Health and Nutrition Examination Survey (NHANES). Three categories of reported MSA participation were created: no MSA (referent group), some MSA (≥1 to <2 d/wk), and meeting the 2008 Department of Health and Human Services (DHHS) recommendation (≥2 d/wk). The dependent variable was LBP.

Results Gender stratified analysis revealed significantly lower odds ratio of reporting LBP for women (OR 0.82; 95% CI 0.70-0.96, *P*=0.03) and men (OR 0.86; 95% CI 0.70-0.96, *P*=0.01) reporting volumes of MSA meeting the DHHS recommendation. Following adjustment for smoking, the odds ratio remained significant in women (*P*=0.03) but not in men (*P*=0.21).

Conclusions Men and women reporting volumes of MSA meeting the current DHHS recommendation were found to have lower odds of reporting LBP when

compared to those reporting no MSA prior to adjustment for smoking. After adjustment for smoking, the association between MSA and LBP continued to be significant in females but in males. These findings suggest that smoking may be an important mediating factor that should be considered in LBP research.

Chapter One: Introduction

Background

Low back pain (LBP) is a well-known multi-factorial medical condition that has various prognoses. Low back pain is very common in Western countries and it negatively impacts quality of life and attenuates productivity. It is a major cause of physical inactivity, work disability, and economic loss. Worldwide, it has been indicated that up to 80% of the general population may be affected by LBP at some point in their lives (1). In 2012, the National Center for Health Statistics (NCHS) estimated that approximately one-third of American adults reported experiencing LBP (2). In 2007, the cost of back pain in general in the United States (U.S.) was estimated to be $30.3 billion (3). There are numerous preventive and treatment approaches for LBP. Previous studies have illustrated that physical activity (PA) can play a role in reducing the prevalence of LBP (4,5). Among these activities, muscle-strengthening activity (MSA) is considered an effective treatment with preventive potential (4).

Low Back Pain

Low back pain is a health condition that is defined as pain located in the posterior aspect of the body between the 12^{th} rib and the inferior gluteal folds, with or without radiating pain (6). Low back pain is categorized into two types; non-specific and specific. Nonspecific LBP accounts for 90% of the cases, whereas only five to 10% of the cases are due to an identified cause (7). Specific causes of LBP may arise from any of the anatomical structures, including bones, intervertebral discs, joints, ligaments, muscles, neural structures, and blood vessels (8). The source of pain could be due to an underlying pathology such as degeneration, inflammation, neoplasia, metabolic bone disease, and trauma (7,9). An injury to the spinal nerves or any other soft tissue around the spinal cord causes the body to produce a local inflammatory response leading to an irritation of the nerves of the back, resulting in pain. Other causes of LBP may originate from other sources (referred pain), or may also be due to psychological conditions (7). In contrast, non-specific LBP is defined as back pain with an unknown source. Generally, LBP can be subcategorized into three levels (acute, sub-acute, and chronic) based on the onset and the duration of the pain. Acute LBP represents a condition that occurs suddenly, following a minimum of six months without the pain and lasts for less than six weeks. Sub-acute LBP occurs suddenly following a minimum period of six months without the pain and lasts between six weeks and three months. Finally, chronic LBP presents with a duration of more than three months, or occurs periodically during a six-month period (7). In many cases, individuals with activity-limiting LBP will have recurrent episodes of LBP that may be longer in duration (10,11). Consequently, the course of the pain will be viewed as chronic.

Risk Factors

There are many factors impact the onset and the course of LBP. For instance, although LBP affects men and women of all ages, it has been reported that adults of working age have a greater prevalence of LBP, then the prevalence decreases beginning in sixth decade (12). When examining gender, it has been shown that the prevalence of LBP is higher among females compared to males (13). Markers of socio-economic status (SES) have also been linked to LBP (8). Low educational status, which is a marker of SES, has been found to be associated with an increased prevalence of LBP. Additionally, low educational status is a strong predictor of pain duration and poor outcomes from LBP. The other primary marker of SES, low income, seems to be associated with LBP in the U.S. (8). The effect of body weight on LBP is controversial. While some studies have found body weight to be a weak risk factor (8,14), others have shown that higher body mass index (BMI) is associated with increased risk of LBP (15-17). Finally, psychological factors, such as stress, anxiety, depression, and pain behaviors, have been reported to be associated with LBP. Psychological factors in the workplace, such as job dissatisfaction, lack of social support, and poor work relations, have also been reported to be some of the strongest risk factors for LBP (18,19). Conversely, the precise mechanisms underlying the associations among these factors are unclear (8). These can all lead to an increased incidence of LBP.

Incidence and Prevalence of LBP

Epidemiological research has shown that 60 to 85% of Westernized adults have experienced or will experience back pain at some point in their lives (7,20). Hoy et al. (8) showed in their systematic review that the estimates of the one-year incidence of a first-ever episode of LBP range between 6.3% and 15.4%, and the estimates of the one-year incidence of any episode of LBP are between 1.5% and 36%. They also showed that the point prevalence of LBP ranged from 1.0 to 58.1%, and the one-year prevalence ranged from 0.8 to 82.5%. Variations in estimates are due to the heterogeneity across studies and study participants. Estimating the incidence of LBP is a problem as the incidence of first-ever reported episode of LBP is already high by early adulthood (21). In addition, many of these estimates were reported from studies that did not define minimum episode duration, so they could include acute, sub-acute, and chronic LBP.

In the U.S., 2012 data from the National Electronic Injury Surveillance System indicated the incidence of LBP to be 139 per 100,000 person-years (22). According to 2012 data from the Centers for Disease Control and Prevention database, 28.4% of adults over the age of 18 reported experiencing LBP (23). This pain was defined as pain that lasted a whole day or more. Low back pain incidence and prevalence estimates often have high degrees of variability due to the dynamics between multiple surveillance systems.

There are a significant number of reports illustrating age and gender-specific estimates of LBP (2,24,25). It was reported that approximately one-third of adults between the ages of 45 and 74 years reported LBP (2). A recent report from the NCHS illustrated that the prevalence of LBP in adults between the age of 18 and 44 years was 24.4% (25). This report also indicated that the prevalence of LBP was greater in females (29.9%) than males (26.8%), independent of age.

Impacts and Outcomes of LBP

Low back pain has been shown to have a significant impact on individuals, their families, professional life, communities, and health care system (8). Low back pain is one of the most common health problems causing suffering and disability (20,26), and it is a leading cause of physical inactivity (26). Based on data from the 2005 Survey of Income and Program Participation, 7.6 million adults with disabilities identified back problems as the main cause of their disability (27). Impaired PA includes limitation in activities of daily living (ADL), leisure activities and vigorous activities (7). According to the National Health and Nutrition Examination Survey (NHANES) II and data from the 2003-05 National Health Interview Surveys (NHIS), more than seven million adults reported activity limitations because of chronic back conditions (28). Individuals with LBP may become dependent and need care from others (7). As a result, a temporary or permanent work disability could occur, impacting one's career. Low back pain accounts for most of the work absenteeism, reported second after colds (29). According to data from the 1998 NHIS, 149 million workdays were lost by Americans due to back pain (30).

In addition to the physical impairments and professional detriments, LBP increases the financial burden to the healthcare system by augmenting medical treatment costs (7,8,31). In the U.S., it was estimated that direct healthcare expenditure for back pain was $30.3 billion in 2007 (3). The annual mean expenditures for back problems totaled $1,589 per person, with a total of $4.58 billion being spent on prescription medications to treat back pain problems in adults (3). Smith et al. (32) reported that the mean cost of the ambulatory care of back pain per patient increased from $1,146 between 2000 and 2001 to $1,742 between 2006 and 2007. They also reported that the estimated biennial national expenditures increased from $26.9 billion to $52.8 billion between 2000 and 2007.

It has been illustrated that use of health care services for back pain is related to the chronicity of the back pain (32). In a separate analysis of chronic and non-chronic LBP conducted in 2006-2007, researchers revealed that the mean biennial cost per patient with chronic back pain was significantly higher ($3,152 vs. $903). The national costs for patients with chronic back pain were $35.7 billion compared with $17.2 billion for patients with non-chronic back pain. Exploring methods that can help reduce expenditures from LBP are crucial. Muscle strengthening activity may be one way to favorably impact low back health. Focusing on core muscle training may provide substantial benefits in both preventing and treating LBP.

Muscle Weakness and LBP

The human spine is an unstable structure and therefore further stabilization is provided by the activity of the trunk musculature (33). Trunk muscles, which are often referred to as core muscles, also play an important role in the maintenance of normal spinal alignment (34,35). It is also believed that core muscles are crucial in protecting the spinal structures against harmful loads (36), thus preventing injuries leading to LBP (35,37,38). During the past decade, the medical profession has adopted various LBP explanatory models (39), which often list core muscle weakness as a potential confounding factor. There is a growing consensus supporting the association between core muscle weakness and LBP (5,33,36). The effect of core muscle performance on LBP is widely accepted by the medical community and MSA programs are commonly prescribed for people with LBP.

PA and LBP

The link between MSA and LBP continues to be explored, and as a result, MSA, is commonly recommended not only as a treatment for LBP, but also as a preventative strategy (36,40). Studies conducted to examine the relationship between PA and LBP illustrate an inverse association (5,41-44). In a study utilizing data from the 2003-3004 NHANES, Smuck et al. (5) found that PA level was negatively related to LBP. In their overall model, investigators reported that the best reducing effect on LBP were from moderate and high intensity PA (odds ratio (OR) 0.98 and 0.99 per standard deviation (SD) increase, respectively). Another population-based study by Dijken et al. (41) investigating the association between the prevalence of LBP and PA revealed that individuals reporting low PA during leisure-time were significantly more likely to report LBP when compared to those without LBP (OR 1.35; 95% CI 1.19 –1.53). In a cross-sectional study examined the associations between moderate levels of PA, health benefits and LBP among Australian women reported similar results (42). Researchers categorized the participants into three groups based on age. The PA scores were also categorized. Researchers found that women in all activity categories in all three age groups, compared to sedentary women, were less likely to report LBP. The adjusted OR for LBP by PA score in low to moderate active young (18-23 years), middle-aged (45-50 years), and older women (70-75 years) were 0.83 (95% CI 0.74–0.94), 0.89 (95% CI 0.80–0.99), and 0.91 (95% CI 0.80–1.02) respectively. In another cross-sectional study that evaluated the association between PA and chronic LBP (43), the investigators found a U-shaped relationship between PA and chronic LBP. Investigators reported that the extremes of the total PA pattern were associated with chronic LBP. A moderate increase in the odds of chronic LBP was found in participants reporting a sedentary lifestyle (OR 1.31; 95% CI 1.08–1.58) and in those reporting vigorous PA (OR 1.22; 95% CI 1.00–1.49). Finally, results from a prospective cohort study with 15 years of follow up concluded that frequent exercising decreased the risk of future sick leave associated with LBP compared to not exercising (44). This finding was among those with a previous history of LBP.

In contrast, other studies did not find association(s) between PA and LBP (45-47). Yip (45) examined the relationships between physical work activities, work stress, leisure-time physical activity (LTPA), and the occurrence of LBP among 144 nurses from Hong Kong. The study revealed that nurses who reported moderate or high levels of LTPA experienced similar LBP symptoms to those who were categorized as sedentary. Among the sedentary group, the results indicated that 35.7% of the nurses had new LBP onset, whereas 42.7% did not report any new LBP with no significant difference between the groups. Cecchi et al. (46) estimated the incidence and frequency of LBP utilizing data from the Clinic Epidemiologic Longitudinal Survey (InCHIANTI) conducted in Tuscany, Italy. Researchers did not find an association between LTPA and LBP. Kujala et al. (47) investigated muscle strength, aerobic power, and occupational and leisure-time physical loading as predictors of back pain. The study included a cohort of 456 adults who reported being free from back pain. Anthropometric measurements along with aerobic power, and upper and lower extremities muscle strength measurements were taken at baseline. Data on the levels and types of PA and occupational physical loading were also collected. Five years after baseline assessment, a questionnaire was sent to participants inquiring about back pain history. Researchers reported non-significant differences in the aerobic power, muscle strength, or LTPA between the groups with no back pain, mild back pain, and marked back pain at baseline or follow-up. Despite a few studies illustrating contrasting findings, the majority of work supports a favorable association between PA and LBP. Much of this work has been utilized in developing clinical practice guidelines for working with individuals with LBP.

Current Clinical Practice Recommendations

Core strengthening exercises are commonly utilized to treat patients with LBP (48). Based on a clinical practice guideline from the American Physical Therapy Association (48), clinicians should consider moderate to high-intensity exercise, such as jogging, running, push-ups, and weight lifting, for patients with chronic LBP without generalized pain. In patients with chronic LBP with generalized pain, progressive, low-intensity, submaximal fitness and endurance activities are recommended. The evidence-based guidelines also recommend clinicians to incorporate trunk coordination, strengthening, and endurance exercises to reduce the pain and disability in patients with chronic LBP. Thus, a number of randomized controlled trials (RCTs) have been conducted to evaluate the effectiveness of MSA in treating LBP (49-53).

Shnayderman et al. (49) assessed the effect of walking compared to MSA on the functional abilities of patients with chronic LBP. The researchers noted that both groups showed a significant improvement according to the LBP functional scale. The mean differences between pre and post intervention scores were 8.1 points (95% CI 4.4–12.6) in the exercise group and 10.1 points (95% CI 4.8–15.4) in the walking group with no significant difference between groups. Important to note, this study did not measure the difference in the pain levels between the two groups following the intervention.

Costa et al. (50) examined the effect of motor control exercises in 154 patients with chronic LBP. The intervention consisted of either specific motor control exercises directed to the multifidus and transversus abdominis or no therapy. Primary outcome measures were pain intensity (measured with a 0–10 numeric rating scale [NRS]); activity (measured with a 0–10 Patient-Specific Functional Scale [PSFS]); patient's global impression of recovery (measured with the -5 to +5 Global Perceived Effect Scale [GPES]) at six and 12 months; and activity limitation (measured by the Roland-Morris Disability Questionnaire [RMQ]) at two, six, and 12 months. Researchers demonstrated that the exercise intervention improved patient activity and the general impression of recovery. The mean effect of the exercise intervention on activity limitation was 1.1 points (95% CI 0.3 –1.8), and the mean effect on global impression of recovery was 1.5 points (95% CI 0.4 – 2.5). The effect of the exercise intervention on pain intensity was not significant at two months or six months. At 12 months, there was a statistically significant effect (*P*=0.030) on pain in favor of the exercise group (Table1).

Table 1: Effects of Exercise Intervention versus Placebo treatment

Variable	**Unadjusted Mean Outcome (SD)**		**Exercise Group Versus Placebo Group**	
	Exercise Group	**Placebo Group**	**Adjusted Treatment Effect (95% CI)**	***P***
Pain				
2 mo	4.6 (2.8)	5.6 (2.6)	-0.9 (-1.8 to 0.0)	.053
6 mo	5.0 (2.9)	5.6 (2.5)	-0.5 (-1.4 to 0.5)	.335
12 mo	5.0 (2.9)	6.3 (2.3)	-1.0 (-1.9 to -0.1)	.030
Global impression of recovery				
2 mo	1.3 (3.2)	0.0 (3.1)	1.5 (0.4 to 2.5)	.005
6 mo	1.5 (2.6)	0.3 (3.0)	1.4 (0.3 to 2.4	.010
12 mo	1.2 (2.7)	-0.3 (2.9)	1.6 (0.6 to 2.6)	.003
Activity				
2 mo	5.2 (2.4)	4.1 (2.3)	1.1 (0.3 to 1.8)	.004
6 mo	5.3 (2.7)	4.3 (2.6)	1.0 (0.3 to 1.8)	.007
12 mo	5.5 (2.6)	4.0 (2.6)	1.5 (0.7 to 2.2)	<.001
Activity limitation				
2 mo	9.6 (6.5)	11.9 (5.9)	-2.7 (-4.4 to -0.9)	.003
6 mo	10.3 (7.0)	12.2 (6.7)	-2.2 (-4.0 to -0.5)	.014
12 mo	11.4 (7.8)	12.3 (6.4)	-1.0 (-2.8 to 0.8)	.271

Note. Adapted from "Motor control exercise for chronic low back pain: a randomized placebo-controlled trial" by Costa et al. *Phys Ther* 89: 1275-1286, 2009.

Gudavalli et al. (51) compared the outcome of flexion–distraction procedures (FD) with an active trunk exercise protocol (ATEP) among chronic LBP patients. Data from a visual analogue scale (VAS) for perceived pain and the RMQ for low back function was used for the primary outcome measures. The FD group received flexion and traction applied to specific regions in the lower back performed by a Chiropractic Physician. The ATEP group received stabilizing and flexibility exercises, modalities, and cardiovascular training. Researchers reported significant differences between the pre- and post-treatment outcomes at four weeks, independent of treatment group (VAS: $P<0.01$; RMQ: $P<0.01$). Between the two groups, the FD intervention significantly reduced the pain more than the ATEP ($P=0.01$). No difference was observed for the RMQ score between the two groups.

Ferreira et al. (52) compared the effects of three different treatment programs: general exercise, motor control exercise, and manipulative therapy, in patients with chronic LBP. The general exercise program included MSA, stretching and aerobic exercises. The motor control exercise program involved specific trunk muscles retraining using ultrasound feedback. The spinal manipulative therapy included joint mobilization and manipulation. The PSFS and GPES were the primary outcome variables. This study indicated that the motor control exercise group and the spinal manipulative therapy group had slightly better outcomes than the general exercise group at eight weeks. The differences between the motor control exercise group and the general exercise group were 2.9 for the PSFS (95% CI 0.9–4.8) and 1.7 for the GPES (95% CI 0.9–2.4). The differences between the spinal manipulative therapy group and the general exercise group were 2.3 for the PSFS (95% CI 0.4–4.2) and 1.2 for the GPES (95% CI 0.4–2.0). The long-term outcomes (six and 12 months) were similar between the groups.

Mannion et al. (53) examined the effect of three different treatments for patients with LBP. Treatment groups included low-impact aerobic exercises, muscle reconditioning, and active physiotherapy that included MSA. The results of this study showed a significant (*P*=0.0001) reduction in mean pain intensity for each therapy group immediately following therapy and at one year. There were no significant differences reported between the groups regarding the extent of the changes (*P*=0.99). With regards to temporal changes in self-reported disability, the groups did differ during the 12-month study period (*P*=0.03). All groups showed a similar reduction in self-reported disability immediately following therapy (*P*=0.0001), whereas there were notable differences between groups at six-months. During the first six-months, the aerobic and muscle reconditioning groups revealed a further decline in disability, while the physiotherapy group showed regression towards pre-therapy levels. The values remained stable in all groups at 12 months, with no significant difference between the groups (*P*=0.61). The investigators suggested that the behavior in regards to disability, but not pain, could be related to the patients' perspective toward the disabling effects of the pain, or to pain adaptation during treatment. These findings indicate that the type of treatment and activity volume are important considerations when working with individuals with LBP.

Based on the 2008 PA guidelines proposed by the U.S. Department of Health and Human Services (DHHS) (54), adults should engage in a minimum of 150 min/wk of moderate intensity PA, or 75 min/wk of vigorous intensity PA. These guidelines also recommend that adults should engage in MSA two or more times per week on nonconsecutive days. The MSA should utilize all major muscle groups at moderate or high intensities. Muscle strengthening activity that targets the core muscles provides many benefits for individuals with LBP. Such benefits include pain reduction, functional improvements, and augmented core muscle strength (49-53).

Gender Differences in LBP and PA

Based on consistent evidence, the global prevalence of LBP is higher among females (13,55,56). Lawrence et al. (28) estimated the prevalence of specific rheumatic conditions based on data from the 2002 NHIS. The prevalence of LBP was 24.3% for men (95% CI 23.4–25.2) and 28.3% for women (95% CI 27.5–29.1). The 2002 NHIS report also showed that the age-adjusted prevalence estimates of LBP were 21.5, 25.7, and 19.5% for Hispanic or Latino, nH white, and nH black or African American males respectively, and 26.8, 28.9, and 27.3% for Hispanic or Latino, nH white, and nH black or African American females respectively (57). In contrast, Smuck et al. (5) utilized data from 2003-2004 NHANES and found no significant differences in the prevalence estimates between the two genders concluding that gender was not an important predictor of LBP. Despite some contrasting findings, the majority of evidence supports LBP being more prevalent among women.

There are several theoretical and experimental rationales for this difference. One of the proposed theories is that females have higher sensitivity to painful stimuli and lower pain thresholds compared to males. Several experiments have been conducted to examine if there were gender differences in pain perception using various stimuli that induce cold pain (58-62), heat pain (63-66), and pressure pain (67-70). Generally, these studies reported a non-significant pattern between gender and pain sensitivity. Regardless of the existing conclusions, there is no evidence that a gender-linked difference in pain perception applies to LBP (71). Additionally, experimental LBP studies support the lack of meaningful gender differences in low back musculature pain perception (67,72-76).

Another factor discussed in the literature is the dissimilarities in the anatomical and physiological characteristics of males and females. However, there is very limited research in this area (39,77). Nourbakhsh and Arab (39) investigated the association between 17 mechanical factors and the incidence of LBP. Researchers reported significant gender differences in abdominal muscle strength among the asymptomatic participants ($P<0.05$). Hides et al. (77) conducted a study to compare the multifidus size and symmetry in asymptomatic individuals with chronic LBP. This study found that asymptomatic male subjects had significantly larger multifidus cross sectional areas (CSA) compared to asymptomatic females. These differences were seen at levels L2–L4 (P=0.001) but not at L5 level (P= 0.22). Due to the paucity of data, the findings from the aforementioned studies do not provide enough evidence to link a specific anatomical factor to the estimated prevalence differences between genders.

A potential factor that could explain the differences in the prevalence estimates of LBP between genders is the physiological differences that are relative to exercise performance (78). Females have lower blood volume, fewer red blood cells, and lower amounts of hemoglobin. This results in a lower oxygen carrying capability in their blood leading to a lower capacity to increase their arterial-venous O^2 difference (79). Females also have smaller hearts, which results in higher resting and submaximal heart rates, lower stroke volumes, and an attenuated oxygen pulse. Females also have fewer and smaller muscle fibers, although the distribution of muscle fiber types is similar between the genders. Theoretically speaking, these differences may modify the benefits of preventive and treatment exercise regimes. Nevertheless, even with these dissimilarities, studies have failed to show any gender differences with regard to MSA performance improvements (78). Finally, the potential gender disparity in LBP may reflect the differences in PA participation, primarily MSA. Several studies have shown that males participate in greater levels of PA in compare to females (80-82). This difference in PA participation may offer men greater protection from LBP.

In summary, the evidence is unclear when examining gender and LBP. Gender stratified studies are needed to examine all the possible risk factors for LBP.

Research Purpose and Questions of the study

Currently, there are few studies that have examined the association between LBP and meeting U.S. PA guidelines. Therefore, this study was designed to examine the associations between self-reported MSA and LBP in a nationally representative sample of U.S. adults utilizing the1999-2004 NHANES. Emphasis was placed on determining whether meeting the 2008 MSA recommendation, which includes engaging in MSA ≥ 2 d/wk, is associated with significantly lower odds of reporting LBP. It is important to elucidate the potential benefits of various levels of MSA when examining LBP. The specific research questions for this study were:

1. Is there an association between meeting the current DHHS recommendation for MSA and self-reported LBP?
2. If a relationship does exist, does this relationship vary by gender?

To the extent of our knowledge, this is the first study to examine the potential associations between MSA and LBP and the potential gender differences in the prevalence of LBP by MSA volume in adults aged ≥ 20 years in NHANES 1999-2004.

Project Description

The sample in this study was limited to adults (≥ 20 years of age) who attended the mobile examination center (MEC) in the 1999-2004 NHANES. The participants included in the analyses had complete data on all the variables of interest. Finally, pregnant women were excluded from the analyses. The University of North Florida Institutional Review Board approved the use of the NHANES data. The present study has some limitations due to its design. These limitations include:

1. The most recent NHANES MSA data were collected from 1999-2004. Therefore, the analyzed data may not be reflective of the current U.S. adult population.
2. Due to the nature of the cross-sectional study design, causality cannot be inferred.
3. The LBP data were self-reported over the previous three months and the MSA data over the past 30 days. As a result, the frequency of LBP and MSA are subject to recall bias and possible social desirability effect.

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Chapter Two: Review of Literature

Specialists have described the frequency of LBP experienced by modern society as an “epidemic,” and reports in the literature consistently support this opinion (1). Global reports showed that LBP is the leading cause of activity limitation and work absenteeism (2-4). Beside the physical consequences, the financial costs of LBP are considerable and are associated with a huge economic burden (3,5-8). While it is common that individuals in all societies are likely to experience LBP, its prevalence seems to vary based on several factors. These factors include age, gender, socio-economic status, and occupation. As a person gets older, the risk of LBP increases (6,9). The overall prevalence of LBP increases until 50 to 60 years of age, and then gradually declines (6). In a recent review study by Hoy et al. (10), it has been reported that females tend to have greater prevalence estimates of LBP. Low educational status (6,11) and low income (6) have also been shown to be associated with an increased prevalence of LBP. The relationship between these risk factors and LBP are not well understood.

Physical activity may provoke LBP or play a role in preventing LBP (12). The most frequently reported risk factors for LBP are physical work, including frequent bending, twisting, lifting, pulling, pushing, repetitive work, static postures, and vibrations. Several risk factors related to immobilization or inactivity have also been linked to LBP. Lack of PA may attenuate the strength of the back, abdominal, and thigh musculature, and reduce the endurance of the muscles. The theoretical explanation for this concept is that PA may induce acute and repetitive subclinical, or even more severe, injuries to the structures of the back. It has been suggested that strong core muscles can protect the spine from injuries or minimize the damages from an injury (12). Greater levels of muscular endurance of the core musculature can help to maintain spinal motor control, thus reducing fatigue from various functional tasks and decreasing the risk of high loading on the spine. Additionally, greater levels of cardiorespiratory fitness have been shown to reduce the risk of low back injury due to improved circulation.

This literature review briefly summarizes 1) physical inactivity as a risk factor for LBP; 2) PA as a protective factor for LBP; 3) heavy PA and LBP; 4) muscle weakness and LBP; 5) MSA and LBP; and 6) gender differences in LBP and PA.

Physical Inactivity and LBP

When examining the effects of sedentary lifestyles on the health of the spine, studies have shown mixed results (13-19). While some studies concluded that physical inactivity is not a risk factor of LBP (13,14), the majority reported an association between being inactive and LBP (15-19). Yip (13) examined the relationships between physical work activities, work stress, leisure-time physical activity (LTPA), and the occurrence of LBP in 144 nurses from Hong Kong. Participants completed a face-to-face baseline interview, which was followed-up by a telephone interview one year later. The results revealed that being inactive did not significantly increase the odds of LBP incidence (P=0.35). The findings also revealed that among the nurses with new onset LBP, 35.7% were sedentary (defined as no sport, exercise, or activity that caused breathlessness/sweating in the past week), 51.8% were underactive (defined as three or more sessions per week, lasting at least 20 minutes per session, of any PA that resulted in at least some sweating or increase in breathlessness), and 12.5% were active (defined as either three or more sessions per week, for at least 20 minutes per session, of PA resulting in a medium to large sweat or increase in breathlessness, or five or more sessions per week, for at least 30 minutes per session, of any PA that resulted in at least some sweating or increased breathlessness). Among the nurses without new onset LBP, 42.7% were sedentary, 40.9% were underactive, and 11.4% were active.

Similar findings were reported by Picavet et al. (14) when analyzed data from a population-based cohort. The aim of the study was to identify whether physical inactivity predicts future LBP. Baseline information about LBP history and PA were collected between 1993 and 1997 using a questionnaire. In 1998, a follow-up questionnaire was mailed to each participant. The authors concluded that LBP at baseline was the best determinant of future LBP and that physical inactivity was not a strong predictor for LBP. Among those who spent less than 0.5 hr/wk being physically active, including work and LTPA, the ORs of LBP after one to four years were 1.11 (95% CI 0.94–1.32) among those who did not have LBP at baseline and 0.91 (95% CI 0.72–1.15) among those who reported baseline LBP.

A cross-sectional study evaluating the prevalence of LBP and related factors in a representative Italian cohort reported contrasting findings (15). Researchers used data from the Italian Clinic Epidemiologic Longitudinal Survey. Participants were categorized based on their back pain status during the previous 12 months. They were asked if they had any back pain and how often they had back pain during the previous 12 months. Those who reported frequent LBP were asked specific questions concerning pain severity, pain location, activities that triggered the pain, and their functional limitations due to the pain. Lower extremity muscle strength was assessed bilaterally using a dynamometer. Upper extremity muscle strength was assessed by a standard handgrip test. The findings illustrated that self-reported PA during the previous year was significantly lower (*P*<0.001) in participants with frequent back pain. Additionally, there was no association between history of LTPA and frequent back pain.

Dijken et al. (16) assessed the prevalence of LBP in relation to physical work demands and LTPA in 5,798 participants aged 25–79 years. Participants were asked to provide information regarding the duration and frequency of their LBP. Data on workplace physical demands one year prior to the baseline assessment was collected. Based on these data, four physical working categories were created: sedentary work (paperwork, mostly sitting work); light physical work (office work, teaching, shop assistant, and walking a lot but no heavy lifting); moderate heavy work (carpentry, plumbing, healthcare, and lift quite a lot); and heavy work (forestry work, farming, fishing, construction work, lift a lot of heavy objects, and a lot of physical strain). Leisure-time physical activity was also estimated for the previous year and six subcategories were created: no PA, walking sometimes, light PA, moderate PA, high PA, and practicing in sports at a competitive level several times a week. The researchers found that 41% of the sample reported having LBP. The prevalence of LBP was 44.1% in females and 37.8% in males. Among those with LBP, the greatest prevalence was found in the 55–64 year age group in both men and women. The study also revealed that individuals with LBP were less physically active during leisure time (OR 1.35; 95% CI 1.19–1.53).

Venseth (17) investigated the associations between chronic LBP and time spent sitting, LTPA, and occupational activity. The sample consisted of 22,445 participants from the Nord-Trøndelag Health (HUNT) study, which is a population-based health survey conducted in Nord-Trøndelag County, Norway. Information regarding LBP status, LTPA and work activity were collected using a questionnaire. Researchers created four categories of PA, based on hours; inactivity (none), low activity (< 3 hours light activity, and no hard activity), moderate activity (≥ 3 hours of light activity and/or < 1 hour of hard activity) and hard activity (any hours of light activity and > 1 hour of hard activity). The results showed that performing more than three hours of light LTPA per week trended toward protection, reducing the odds of LBP by 20% (OR 0.80; 95% CI 0.62–1.04). In contrast, performing a high level of LTPA significantly decreased the odds of LBP (OR 0.79; 95% CI 0.64–0.96) and a similar statistically significant association for high LTPA was observed among the participants who sat less than six hours per day (OR 0.69; 95% CI 0.52–0.90). Interestingly, a combined analysis of the time spent sitting per day and total LTPA showed that an increased amount of sitting time was associated with lower odds of LBP across all categories. Inactive individuals who sat more than 11 hours a day had lower odds of LBP (OR 0.61; 95% CI 0.32–1.14) compared to individuals who sat less than six hours per day, but the difference was not statistically significant. Additionally, independent of the time spent sitting per day, increased levels of LTPA attenuated the odds of LBP.

Brown et al. (18) examined the associations between moderate levels of PA, health benefits, and back pain among Australian women. The sample was randomly selected from the Women's Health Australia (WHA) study. Participants were categorized into three groups based on age; young (age 18-23), middle-aged (age 45-50 years), and old (age 70-75 years) women. The PA scores were categorized as follows: < 5 (none or very low, equivalent to no PA or moderate PA once per week); 5≤15 (low to moderate, moderate PA two to four times, or vigorous PA one to two times per week, or equivalent combination); 15≤25 (moderate to high; moderate PA five to eight times, or vigorous PA three to five times per week, or equivalent combination); 25≤40 (high; moderate PA eight to13 times, or vigorous five to eight times per week, or equivalent combination); and 40 (very high; vigorous activity more than eight times per week). The study revealed that women in all activity categories in all three cohorts were less likely to report back pain. The adjusted OR for LBP by PA score in low to moderately active young (18-23 years), middle-aged (45-50 years), and old (70-75 years) women were 0.83 (95% CI 0.74–0.94), 0.89 (95% CI 0.80–0.99), and 0.91 (95% CI 0.80–1.02) respectively, compared to sedentary women.

Heneweer et al. (19) utilized data from the Dutch population-based Musculoskeletal Complaints and Consequences Cohort study (DMC) to investigate the relationship(s) between specific activities and LBP. Researchers stratified 8,000 participants by age and gender. Information regarding musculoskeletal pain, health consequences of the pain, and the intensity and time spent partaking in the following: ADL's, LTPA, and sport activities were collected. Investigators reported that approximately 21% of the participants reported chronic LBP. Results also indicated that being sedentary and not meeting the Dutch PA guidelines was associated with increased odds of chronic LBP (OR 1.41; 95% CI 1.11–1.80) and (OR 1.23; 95% CI 1.05–1.45), respectively, compared to not being sedentary and those who met the Dutch PA guidelines. The Dutch guidelines require a minimum of 30 minutes of moderate PA per day for at least 5 days a week for a healthy level of PA (19). The researchers also showed that the ADL's and LTPA were not associated with LBP.

Physical Activity and LBP

Experts have reviewed the associations between PA and LBP from two different perspectives. The first perspective considers PA protective for LBP, while the second considers PA a potential risk factor. This section focuses on the protective effect of PA on LBP. Theoretically, it has been proposed that 30 or more cumulative minutes of moderate PA on most days of the week (three to five days) may prevent or ameliorate LBP by improving the blood supply to the end-plates of vertebral discs, thus, eliminating accumulated irritating interstitial tissue fluids and reducing inflammation (20). It has also been shown that LTPA enhances spinal mobility by stretching and relaxing spinal musculature.

Similar to the influences of a sedentary lifestyle and inactivity on LBP, equivocal evidence exists regarding the effect of PA on LBP. Some studies showed that engaging in PA may protect people from LBP (19,22-26), while others have shown no difference between those who are physically active and those who are not (13,15,21). Heneweer et al. (19) reported that performing sport activities for 1–2.5 hr/wk was associated with lower odds of LBP (OR 0.72; 95% CI 0.58–0.90) independent of PA intensity. When sport activities were classified into specific types of back loading forces, researchers found that the majority of the participants (93%) were performing dynamic loading exercises, which made it difficult to determine what type of sport activities had the greatest effect(s). Paradoxically, when participants were classified according to their total PA volume, both extremes of low and high PA levels were associated with greater odds of chronic LBP in females [1.44 (95% CI 1.10–1.83) and 1.36 (95% CI 1.04–1.78)], respectively. No comparable findings were provided for men from the researchers.

Müller et al. (22) examined the risk indicators for self-reported sick leave due to LBP. The sample consisted of all Glostrup residents in Denmark who were born in 1918, 1928, 1938, and 1948. Subjects participated in a health survey in 1977 and 1978, which included interviews and physical assessments focused on cardiovascular diseases and LBP. In 1993, the participants were sent a questionnaire inquiring about LBP and sick leave due to LBP. Researchers concluded that frequent exercising decreased the risk of future sick leave from LBP. They also reported that among those with a previous history of LBP, frequent exercising decreased the risk of work absenteeism from LBP compared to those who reported not exercising (P=0.006).

Hurwitz et al. (23) examined the effects of recreational PA and back exercises on LBP, related disability, and psychological stress in 681 LBP patients. The researchers collected data on recreational PA and back exercises, LBP, related disability, and psychological stress at baseline, six weeks, and six, 12, and 18 months. A numerical rating scale from 0 (no pain) to 10 (unbearable pain) was used to assess the average and the most severe pain intensity during the week prior to the assessments. Participants who rated their pain intensities of 2 or higher were considered to have clinically meaningful levels of pain, yet, a clear meaning of “average pain” was not defined in the study. Participants were asked at baseline and at each follow-up appointment about the total weekly hours spent in recreational PA. This allowed for the assignment of an activity-specific metabolic equivalent (MET) and the calculation of a MET score for each participant. The associations between PA and back exercises with coexisting and subsequent pain, disability, and psychological distress were estimated using multivariable logistic regression modeling. At baseline, the researchers found that seven-in-10 participants reported engaging in recreational sport or PA. After 18 months, the researchers found that the ORs of severe LBP were 0.78 (95% CI 0.55–1.09) among participants in the low quartile of recreational PA (0.1– 10.49 METs/wk) and 0.62 (95% CI 0.44–0.87) in those in the top quartile (≥ 26 METs/wk) compared to participants reporting no PA. Additionally, the ORs of average LBP were 0.83 (95% CI 0.60–1.13) among participants in the low quartile of recreational PA and 0.72 (95% CI 0.52–0.99) in those in the top quartile. The authors did not report the statistical difference between quartiles.

Hartvigsen et al. (24) examined the associations between PA, physical function, and the incidence of LBP in a cohort of elderly twins. The sample included all Danish twins aged 70 and older who participated in the Longitudinal Study of Aging Danish Twins (LSADT) and who were free from LBP at baseline (no LBP one month prior to the study). The baseline (2001) and the follow-up (2003) variables included LBP status, PA level, and overall physical function. Low back pain status was assessed using a modified version of the Standardized Nordic Questionnaire (SNQ) on musculoskeletal disorders. Physical activity was assessed by asking the participants if at the time of the study, they were engaging in light or strenuous PA. Anyone answering “yes” was then queried on the frequency of the reported activities. The associations between PA levels and LBP were estimated using a logistic regression analysis. Researchers found that engaging in strenuous PA at baseline was protective for any LBP (OR 0.21; 95% CI 0.12–0.37) and previous LBP lasting more than 30 days during the past year (OR 0.08; 95% CI 0.03–0.18). The odds of LBP were lower in those who performed a greater frequency of the strenuous PA, which revealed a significant dose-response association between the frequency of strenuous PA and LBP (P=0.03).

Nilsen et al. (25) investigated the relationship between physical exercise, BMI, and the risk of chronic LBP in adults. The data were obtained from 30,000 adults who participated in the HUNT study. All participants reported no pain or physical impairments at baseline. Baseline variables included total hours spent in physical exercise per week, musculoskeletal pain, and body weight. Information on LBP status was obtained from the SNQ. Participants also completed a questionnaire inquiring about the frequency, duration, and intensity of weekly LTPA. The study findings illustrated total weekly LTPA was inversely associated with the risk of chronic LBP (P-trend = 0.02 in females and < 0.001 in males). When compared to inactive individuals, the adjusted risk ratio (RR) for LBP in females who were exercising for 1.0–1.9 hr/wk was 0.84 (95% CI 0.74–0.95). In males with the same activity level, the RR was 0.88 (95% CI 0.77–1.00). The RR was further reduced in males who were exercising for ≥ 2.0 hr/wk (RR 0.75; 95% CI 0.64–0.88). Corresponding RR in females were not as strong as in males (RR 0.92; 95% CI 0.74–0.95) but remained significant. Investigators also noted that the inverse effect of exercise intensity on the risk of LBP was similar among those who reported moderate or vigorous intensities when compared to those who reported lower intensities.

Payne et al. (26) examined the association between LBP history, PA participation, and measurements of health-related fitness level in 520 Canadians between 15 and 69 years old. Each participant reported the history of LBP, the frequency and intensity of their PA, and their fitness level. Physical activity participation was assessed using the

Health Physical Activity Participation Questionnaire used by the Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA). A final score was calculated to create a total PA participation level for each participant. The researchers also conducted a baseline assessment including partial curl-ups, trunk flexion, and grip strength based on the CPAFLA. Back extensor endurance was assessed using a modified Sorensen back extension test. Participants were stratified by gender into either a no history of LBP (188 males, 220 females) or with history of LBP (45 males, 67 females) group. Researchers reported that females with no history of LBP had significantly higher scores for trunk flexion ($P<0.02$), partial curl-ups ($P<0.04$), back extensor endurance ($P<0.01$), and PA participation ($P<0.01$) compared to those with LBP history. Results also indicated that males with no history of LBP had significantly higher scores for trunk flexion ($P<0.001$), back extensor endurance ($P<0.0003$), and PA participation ($P<0.007$) compared to those with LBP history, however, no significant difference ($P\geq0.05$) in partial curl-ups was found.

In contrast, Yip (13) examined the relationship between physical work activities, work stress, LTPA, and the incidence of LBP among 144 Korean nurses. Baseline data regarding work physical demands, work stress, and LTPA were obtained from the participants via an interview. In the 12-month follow-up interview, participants were asked about the incidence of LBP. Investigators reported that nurses reporting engaging in moderate or high levels of LTPA experienced similar LBP symptoms compared to sedentary controls ($P=0.35$). Among the sedentary nurses, the 12-month incidence of LBP was 36%, whereas the majority (48%) did not experience LBP.

Cecchi et al. (15) reported similar findings to those reported by Yip (13) by utilizing cross-sectional data from the clinical epidemiologic longitudinal survey (InCHIANTI) conducted in Italy. The initial data was collected between 1998 and 2000, which included an interview, general medical examination, and physical performance assessment. Status of LBP during the previous 12 months was obtained from 1,299 participants. Those who reported having a history of LBP were asked additional questions regarding the intensity, frequency, location, and affected functional activities. Participants also responded to questions related to their work physical demands. Leisure and recreational PA during the younger and middle years was assessed during ages 20 to 60 years. Physical activity for the last 12 months was classified as: hardly any PA; mostly sitting; light exercise (no sweat); moderate exercise 1–2 hours/wk; moderate exercise 3 hours/wk; intense exercise 3 hours/wk or more. Investigators reported no association between the history of LTPA and LBP (P=0.325). The reported estimated prevalence of PA one year prior to the initial assessment was significantly lower in participants with back pain (P<0.001).

Kujala et al. (21) investigated muscle strength, aerobic power, occupational and leisure-time physical loading as predictors of back pain. The researchers followed 456 adults who were free from back pain at baseline. Physical activity level and type, in addition to occupational physical loading, were determined using a questionnaire. Based on the participant responses, activities were classified to the following: ADL's, walking only, typical aerobic training (such as swimming, cycling, and running), and mixed training that included different types of exercise (such as volleyball, tennis, and squash). Data on anthropometrics, aerobic power, and muscle strength were also collected by the researchers themselves. Participants were contacted by mail after five years and were asked to complete a follow-up questionnaire inquiring about their back pain during the previous five years. Researchers reported no differences between the groups with no back pain, mild back pain, and marked back pain in baseline aerobic power (P=0.31), trunk flexors strength (P=0.66), trunk extensors strength (P=0.33), or LTPA (P value was not reported). These findings suggested that aerobic power, muscle strength and LTPA may not associated with future LBP.

Heavy Physical Activity and LBP

There is a growing consensus that heavy PA and some extreme sporting activities increase the risk of LBP. Some research areas focusing on work-related risk factors and LBP have reported that force, repetition, and abnormal and static postures may increase the risk of LBP (27). The mechanical explanation for this association is that some postures increase the flexion of the spine, induce disc damage or rupture, and produce changes similar to those seen in natural disc degeneration. However, studies examining the association between heavy PA, work-related activities, and LBP have revealed inconsistent findings (13,15-17,21,23).

A prospective study examined the relationships between physical work activities, work stress, LTPA, and the existence of LBP among 144 nurses from different Hong Kong district hospitals (13). Baseline data provided information regarding demographics, work-related activities and stress, PA both at work and during leisure time, and any history of LBP. Low back pain was defined as discomfort in the lower spinal area for at least one day during the past 12 months. Three categories of LTPA were created:

sedentary, underactive, and active. Researchers reported that the incidence of new onset LBP increased with longer hours spent in one posture, performing heavy work activities such as ambulating patients more frequently (P=0.05), and with more spinal dynamics such as bending to lift an item from the floor (P=0.01).

Cecchi et al. (15) evaluated the prevalence of LBP and its associated factors in a sample of 1,008 Italian adults. Data from the InCHIANTI was utilized. Participants were inquired about their LBP during the previous 12 months. Those who reported recurrent LBP provided details regarding their pain severity, location, activities that triggered the pain, and functional limitations caused by the back pain one month prior to the assessment. The findings illustrated that high work physical demand was significantly greater (P<0.005) in participants with recurrent back pain. One primary weakness of this study was the age of the participants (65 years of age and older), which limits the external validity of the findings.

Dijken et al. (16) estimated the prevalence of LBP in relation to PA during both work and leisure activities. The researchers randomly selected 5,798 participants between the ages of 25 and 79 from northern Sweden. Participants provided information regarding the duration and frequency of LBP and workplace PA one year prior to the study. Four categories of work activities were created: sedentary work; light physical work; moderate heavy work; and heavy work. The results of this study revealed that 41% of the participants (55% female and 45% male) reported a history of LBP. Individuals reporting LBP were found to engage in physically demanding work more frequently (OR 1.97; 95% CI 1.59–2.45), with significantly greater intensities of physical work activity (OR 1.44; 95% CI 1.09–1.90).

Similarly, Venseth (17) investigated the potential association(s) between chronic LBP, sitting time, LTPA, and occupational activity among 22,445 participants from the second HUNT study. Low back pain and occupation information were collected from the SNQ, which was inclusive to the primary study. The findings illustrate that hard physical labor increased the odds of chronic LBP (OR 1.19; 95% CI 1.02–1.40) when compared to occupations involving primarily sitting. A combined analysis of LTPA and physical work demands illustrated that high levels of LTPA decreased the odds of chronic LBP independent of work demands. A high volume of LTPA was defined as “any hours of light activity and > one hour of hard activity.” Findings also indicated that the lowest odds of LBP were observed in those reporting more frequent sitting at work but also reporting higher levels of LTPA (OR 0.62; 95% CI 0.45–0.85).

Kujala et al. (21) investigated the effect of muscle strength, aerobic power, occupational and leisure time physical loading as potential predictors of LBP. The study sample included 450 adults free from LBP who were followed for five years. Anthropometric measurements, aerobic power, and upper and lower extremities muscle strength were evaluated at baseline. Data on PA level, PA type, and occupational physical loading was also collected. Five-year follow-up assessments showed that high occupational physical demands at baseline predicted LBP (P=0.036). A significant association was also found between occupational musculoskeletal loading and future LBP (P=0.005).

Oliveira et al. (28) investigated the perception of contributing factors in the development of LBP in a cohort of twins. This study was a follow-up to a study that investigated the prevalence of LBP among Australian twins. Authors estimated the prevalence of LBP in the original study and invited those who met the new study criteria to participate. Each twin was interviewed to collect detailed information on LBP and potential risk factors. The findings revealed that the majority of the twins (96%) considered heavy physical workloads, such as lifting, manual tasks, awkward postures, and gardening the possible causes for their LBP. Although it is important to consider the patient's perception regarding pain, valid assessments need to be applied in such studies.

Muscle Weakness and LBP

Many LBP studies often list core muscle weakness as a potential confounding factor. In fact, a number of high quality studies support that core muscle weakness is associated with LBP (29,30). Core musculature includes the abdominals in the front, paraspinal muscles (multifidus and erector spinae) and gluteal muscles in the back, the diaphragm as the roof, and the pelvic floor and hip girdle musculature as the bottom (31).

Several studies have examined the relationship between core muscle weakness and LBP (30,32-34). Lee et al. (30) conducted a prospective study to investigate if core muscle weakness was a risk factor for LBP. This study included 67 participants (30 males and 37 female) with no history of LBP. The isokinetic muscle strength of back extensors and flexors was initially evaluated using back extension, flexion, and torso rotation units. After five years, the participants were classified into two groups based on the LBP status; a group with no LBP and a group with LBP. Researchers reported that the initial extension to flexion ratio of the LBP group was significantly ($P<0.05$) lower than the group with no LBP. Investigators concluded that strength imbalance in the core musculature may be a risk factor for LBP.

Cho et al. (32) investigated the effects of back muscle weakness and spinal deformities on LBP. The researchers recruited 60 healthy individuals without LBP and measured their trunk flexor and extensor strength using a dynamometer. After two years, researchers divided the participants into two groups according to the incidence of LBP. Twenty-nine participants reported having LBP during the previous two years (23 females and six males) and 19 reported not having LBP (eight females and 11 males). Researchers reported that females had significantly (P<0.01) higher LBP incidence. A significant positive association (P<0.05) was found between age and LBP in both genders. Crude findings also illustrated that trunk flexor and extensor strength were both significantly different between the two groups (lower in the LBP group). Following adjustments for gender and age, trunk flexor and extensor strength remained significantly associated with LBP (P<0.05).

A cross-sectional study by Nourbakhsh and Arab (33) investigated the association between 17 mechanical factors and the incidence of LBP. Researchers recruited 600 participants from five different hospitals in Iran. Participants were categorized into four groups: asymptomatic men (n=150); asymptomatic women (n=150); men with LBP (n=150); and women with LBP (n=150). The length and strength of several muscles, including the abdominal muscles, were measured. The prone press-up maneuver was used to estimate the length of the abdominal muscles, and a pressure meter was used to measure the abdominal muscle strength. The result revealed that sex by health status was significant for back extensor muscle length, back extensor muscle endurance, and abdominal muscle strength at α<0.05. As a result, separate logistic regression analyses were conducted to evaluate the degree of association between LBP and these factors for men and women. The analysis showed that among all factors, endurance of the back extensor muscles had the greatest association with LBP in both men and women ($P<0.01$). For instance, the logistic regression value was 54.3 for men and 62.93 for women. The higher the value of the logistic regression, the higher the likelihood of that factor being associated with LBP. Abdominal muscle strength was also found to be associated with LBP in men ($P=0.01$) and women ($P<0.001$) with logistic regression values as 6.36 for men and 20.2 for women. Investigators concluded that abdominal muscle strength may be a factor related to LBP.

Al-Obaidi et al. (34) examined the differences in muscle strength between smokers and nonsmokers with and without LBP. The study included 76 men between the ages of 30 and 50 who provided information related to their smoking history, back pain, and PA. Participants were divided into four groups: a control group of nonsmokers without LBP; nonsmokers with LBP; smokers with LBP; and a group of smokers without LBP. Isometric muscle strength of the back extensors was measured at multiple angles using a lumbar extension machine. Findings revealed that the mean isometric strength of the lumbar extensors was significantly different across the four groups ($P<0.001$). The mean strength of the nonsmokers without LBP was higher than the other three groups ($P<0.001$). The mean strength of the nonsmokers with LBP was greater than the smokers without LBP ($P=0.05$) and smokers with LBP ($P<0.001$). However, the mean strength of the smokers with LBP was not lower than the smokers without LBP ($P=0.46$), indicating that smoking is an important factor that should be considered in LBP research.

Muscle Strengthening Activity and LBP

Several studies have shown that strong core muscles may reduce the risk of LBP (32-34). Core strengthening exercises are commonly used as a treatment for patients with LBP (1). Evidence-based guidelines recommend clinicians utilize trunk coordination, strengthening, and endurance exercises to reduce pain and disability in patients with sub-acute and chronic LBP. However, clinical studies have reported inconsistence findings in this area (23,35-40).

Shnayderman et al. (35) conducted an RCT to assess the effects of walking and MSA on functional abilities in patients with chronic LBP. Fifty-two sedentary participants ages 18-65 were recruited from a physiotherapy department. Six-minute walk distance and trunk flexor and extensor endurance were the primary outcomes. The Oswestry LBP Disability Questionnaire and the Fear-Avoidance Beliefs Questionnaire were completed by all participants. The pre- and post-treatment assessments were done utilizing a blinded design. Following baseline assessments, participants were randomly assigned to either a walking group or an MSA group. A physical therapist was responsible for the exercise sessions in both groups. The intervention in the walking group consisted of walking on a treadmill with a specific protocol. The MSA group performed strengthening exercises for the trunk and the upper and lower extremities. Each session started with warm-up and ended with cool-down exercises. The core exercise session started with low-intensity exercise and progressed by increasing the number of exercise repetitions and loading positions. Following a six-week intervention, researchers found that changes in the primary measures were not significantly different between the two groups. For instance, the Low Back Pain Functional Scale showed an increase by a mean of 8.1 points (95% CI 4.4–12.6) in the exercise group and 10.1 points (95% CI 4.8–15.4) in the walking group with non-significant difference between groups of 0.48 (95% CI -5.9–6.9). The trunk flexor endurance test also showed significant improvements in both groups, increasing by a mean of 0.6 points (95% CI 0.0–1.1) in the walking group and 1.1 points (95% CI 0.3–1.8) in the exercise group with non-significant difference between groups of 0.4 (95% CI -0.4–1.3). One important shortcoming in this study was that the authors did not measure the changes in pain level following the intervention, which is one of the primary reasons that LBP patients seek medical consultation.

Another RCT conducted by Gudavalli et al. (36) revealed similar findings to the aforementioned study. The study was designed to compare the outcome of FD with an ATEP among 235 patients with chronic LBP. Participants were randomly assigned into two groups; 123 in the FD group and 112 in the ATEP group. A visual analog scale and the RMQ were used to obtain the primary outcome measures for perceived pain and low back function. The FD group received flexion and traction maneuvers, which were applied to specific regions of the lower back by a Chiropractic Physician, while the ATEP group received stabilization and flexibility exercises, modalities application, and cardiovascular training. At four weeks, researchers observed significant differences between the pre- and post-treatment across all outcomes, independent of treatment group (VAS: $P<0.01$; RMQ: $P<0.01$). Between the two groups, the FD intervention reduced pain significantly ($P=0.01$) compared to the ATEP group. No difference was seen in the RM scores between the two groups. Further subgroup analysis indicated that chronic LBP patients with moderate to severe symptoms improved more with the FD protocol and patients with recurrent pain and moderate to severe symptom improved more with ATEP.

Ferreira et al. (37) compared the effects of three different treatment programs: general exercise, motor control exercise, and manipulative therapy, in patients with chronic LBP. The sample consisted of 240 adults with chronic LBP who were seeking treatment from physical therapy departments at three hospitals in Sydney, Australia. Baseline measures included PSFS and GPES at eight weeks, and six and 12 months. Following the baseline assessment, participants were randomly allocated to either a general exercise group, a spinal manipulative therapy group, or a motor control exercise group. The general exercise program included strengthening, stretching and aerobic exercises. The motor control exercise program involved training specific trunk muscles using ultrasound feedback. Spinal manipulative therapy program involved joint mobilization and manipulation of the spine. Each intervention group received 12 treatment sessions. The findings illustrated that the motor control exercise group and the spinal manipulative therapy group had slightly better outcomes than the general exercise group at eight weeks. The between-group differences of the motor control exercise group and the general exercise group for PSFS and GPES were 2.9 (95% CI 0.9–4.8) and 1.7 (95% CI 0.9–2.4) respectively. The between-group differences of the spinal manipulative therapy group and the general exercise group for PSFS and GPES were 2.3 (95% CI 0.4–4.2) and 1.2 (95% CI 0.4–2.0) respectively. The long-term outcomes (six and 12 months) were similar between the groups. Although the motor control exercise program and the spinal manipulative therapy program had better short-term outcomes, the long-term effects were similar in all three programs.

Cairns et al. (38) evaluated the effect of adding spinal stabilization exercises to a conventional physiotherapy program for patients with LBP. A total of 97 adults with LBP were recruited following a referral from a general practitioner, spine consultant, or physical therapy clinic. Self-reported questionnaires were completed at baseline, completion of treatment, and at six and 12 months. Researchers used the Roland Morris Disability Questionnaire (RMQ) to measure back-related functional disability. Following initial assessments, participants were randomized into two groups; a conventional physiotherapy treatment group or a conventional physiotherapy plus specific spinal stabilization exercise group. Patients in both programs received a maximum of 12 treatment sessions over 12 weeks. The conventional treatment consisted of exercises utilizing low loads and high repetitions for the multifidus and transversus abdominis. The spinal stabilization exercise group received endurance training for the deep abdominal and back extensor muscles in addition to the conventional treatment. The study revealed that both groups improved over time in pain intensity and the physical components of quality of life. The mean change in pain measured by numerical rating scale was -2.1 (95% CI -2.9– -1.4) for the specific spinal stabilization exercise group and -2.2 (95% CI -3.0– -1.5) for the conventional physiotherapy group. There was no statistically significant difference between the groups (P=0.84). The mean change in physical functioning measured by the RMQ was -5.1 (95% CI -6.3– -3.9) for the specific spinal stabilization exercises group and -5.4 (95% CI -6.5– -4.2) for the conventional physiotherapy group, with no statistically or clinically significance between groups (P=0.67). Investigators concluded that both interventions significantly improved LBP to a similar degree.

Mannion et al. (39) examined the effect of three different treatments in 148 patients with LBP. Participants were randomly assigned to one of three treatment groups; low impact aerobics, muscle reconditioning on training devices, or active physiotherapy, which involved core strengthening exercises. A questionnaire was used to collect data on pain intensity, frequency, and existing disability at the baseline, six and 12 months. Findings revealed that all treatment protocols reduced pain intensity significantly with no significant difference between the groups (P=0.99). There was also a significant reduction in pain frequency across all groups with no significant difference between the groups (P=0.82). Further analysis showed a significant reduction in self-rated disability immediately following the intervention and at the 12-month follow-up. Between groups analysis revealed a significant difference between the physiotherapy group and the low impact aerobics and muscle reconditioning groups (P=0.03). The primary advantage of this study was investigators used established cut points for the clinical changes in pain intensity.

Costa et al. (40) compared the effects of motor control exercises with no intervention in 154 patients with chronic LBP. Patients were randomly assigned to either a motor control exercise group or a placebo group. The motor control exercise program involved activation of the deep trunk muscles, including transversus abdominis and multifidus, and inhibition of the over activated superficial muscles. The placebo group received 20 minutes of detuned shortwave diathermy and five minutes of detuned ultrasound. Each group received 12 half-hour treatments over eight weeks. Researchers reported that the exercise intervention improved patient activity and the general impression of recovery. The mean effect of the exercise intervention on functional activity, which was measure by the PSFS, was 1.1 points (95% CI 0.3–1.8) and the mean effect on global impression of recovery was 1.5 points (95% CI 0.4– 2.5). Researchers also reported that the effect of the exercise intervention on pain intensity was not significant at two months (P=0.053) or six months (P=0.335). However, there was a statistically significant effect at 12 months (P=0.030) with 22% pain recovery in the exercise group and 9% in the placebo group compared to baseline.

In contrast to the previous studies, Hurwitz et al. (23) estimated the effect of recreational PA and back exercises on LBP, related disability, and psychological stress in 681 LBP patients and reported different findings. Measurements were taken at baseline, six weeks, and six, 12, and 18 months. A numerical rating scale (zero = no pain and 10 = intolerable pain) was used to assess the average and the most severe pain intensity during the week prior to the trial. Participants also reported total weekly hours spent in recreational PA. Metabolic equivalents were then assigned to each activity, and a total MET score was calculated for each participant. The associations of PA and back exercises with coexisting and subsequent pain, disability, and psychological distress were analyzed using multivariable logistic regression modeling. At baseline, researchers found seven in 10 participants reported engaging in recreational sport or PA. After an18-month follow-up, researchers found that back exercises were positively associated with LBP and related disability. The OR for the most severe LBP among those who rarely (< 1 day/week) participated in back exercise were1.48 (95% CI 1.09–2.00) compared to 2.12 (95% CI 1.57–2.85) among those who participated more often (4–7 days/week). The OR for average pain were similar among those who rarely participated (OR 1.49; 95% CI 1.14–1.94) and among those who participated more often (1.56; 95% CI 1.18–2.06).

Gender Differences in LBP and PA

Several studies and systematic reviews have revealed gender differences in the estimated prevalence of LBP (10,41,42). Lawrence et al. (43) measured prevalence estimates of various musculoskeletal conditions in the U.S population using published studies. The authors reported that the prevalence of LBP was 24.3% in men (95% CI 23.4–25.2) and 28.3% in women (95% CI 27.5–29.1). Utilizing data from the 2002 NHIS, Lethbridge-Çejku et al. (44) reported that the age-adjusted prevalence estimates of LBP were 21.5%, 25.7%, and 19.5% among Hispanic or Latino, nH white, and nH African American males, respectively. The report also illustrated the age-adjusted prevalence estimates of LBP among females were 26.8%, 28.9%, and 27.3% among Hispanic, nH White, and nH African American females, respectively. In contrast, findings from Smuck et al. (45) did not show any differences between genders when examining prevalence estimates of LBP. The study aims were two-fold: 1) to determine if obesity is a potential risk factor for LBP in U.S. adults; and 2) to examine the potential role of PA in modulating this association. The sample included 6,796 adult males and females (≥ 20 year) that were divided into four groups based on their BMI: normal weight, < 25 kg/m^2; overweight, 25–30 kg/m^2; obese, 31–35 kg/m^2; and morbidly obese, ≥ 36 kg/m^2. Physical activity estimations were calculated from the objectively measured accelerometer data collected by the NHANES. The accelerometer data provided information on the frequency, intensity, and duration of PA. Low back pain status was obtained from a self-reported questionnaire. Investigators reported no difference in the prevalence estimates of LBP between genders, suggesting that gender may not be an important predictor of LBP.

There are several theoretical and experimental rationales for these potential gender differences. One of the proposed theories is that females have greater sensitivity to painful stimuli and lower pain thresholds compared to males. Several laboratory studies were conducted to examine the gender differences in pain perception using various stimuli (46-58). The majority of these studies noted a non-significant distinctive pattern of gender and pain sensitivity. According to the current literature, there is no evidence that a gender-linked difference in pain perception is relevant to the perception of LBP (59). When viewing LBP as muscular pain, the majority of experimental studies on muscular pain sensitivity did not reveal a difference between genders (55,60-64).

Anatomical and Physiological Characteristics and LBP

Another area discussed in the literature is the variations in the anatomical and physiological characteristics between males and females; however, there is a paucity of data in this area (33,65). Most of these findings were secondary observations from studies designed with different primary aims. Nourbakhsh and Arab (33) investigated the association between 17 mechanical factors and the incidence of LBP. The researchers recruited 600 participants between 20 and 65 years of age from five different hospitals in Iran. Subjects were divided into four groups: asymptomatic men (n=150), asymptomatic women (n=150), men with LBP (n=150), and women with LBP (n=150). Seventeen different measurements were collected including the length and strength of the back and abdominal muscles. The researchers reported that gender by health status was significant for back extensor muscle length and endurance, as well as abdominal muscle strength (P <0.05), as a result, separate analyses for men and women were conducted. Researchers reported a significant difference between asymptomatic subjects and those with LBP for back extensor endurance (*P*<0.001 for men and women), back extensor length (*P*=0.008 for men, *P*=0.007 for women), and the strength of the abdominal muscles (*P*=0.01 for men, *P*<0.001 for women).

In addition to the difference in muscle strength, differences in the size of spinal musculature between genders have also been reported. Hides et al. (65) conducted a study to compare multifidus size and symmetry in asymptomatic individuals and patients with chronic LBP. Between 1998 and 2002, data from 50 patients with chronic LBP were collected. Participants, along with 40 asymptomatic controls, were recruited from a clinical setting. The primary outcome variable was the CSA of the multifidus muscle measured using an ultrasound imaging for each vertebral segment from L2 to L5. Low back pain patients underwent a physical examination. Data on pain level, disability status, duration of symptoms, pain side, and vertebral level of the pain were collected. The findings illustrated that in asymptomatic participants, males had significantly larger multifidus CSA than females at the levels of L2–L4 (*P*=0.001) but not at L5 level (*P*= 0.22). The study also revealed that in both genders, the multifidus CSA at L4 and L5 vertebral levels were significantly larger in asymptomatic participants compared with LBP patients (*P*=0.001).

Another prospective factor that could explain potential gender differences when examining LBP are the morphological and physiological dissimilarities between men and women that are relative to exercise performance (66). Females possess fewer red blood cells and smaller amounts of hemoglobin, leading to lower oxygen levels in their blood, thus a slightly attenuated capability to increase their arterial-venous O^2 difference (67).

Females also have smaller hearts, which results in higher resting and submaximal heart rates, lower stroke volumes, and a higher oxygen pulse. Though the distribution of muscle fiber types is similar between the genders, females have fewer and smaller muscle fibers (67). Although females and males have different characteristics of muscle fibers, studies have not shown any gender differences in improvements with endurance and MSA (66). There is no current evidence linking these factors to LBP, however, future investigations may include these factors as potential contributory variables.

Gender Variation in PA Level and LBP

The potential gender specific differences in LBP could also be attributed to the dissimilarities in PA participation. Several studies have shown that males participate in greater levels of PA (68). Harreby et al. (68) investigated the potential associations between LTPA and LBP, education, work, social class and smoking in a cohort of 640 school children. In 1965, all 14 year-old students in Helsingor County underwent a radiological examination of the thoracic and lumbar spine. Data on LBP was collected for each participant. In 1990, participants were asked to complete a self-administered LBP questionnaire, which was based on the SNQ for analyzing musculoskeletal symptoms. The questionnaire also queried information regarding anthropometric measures, education, working conditions, social conditions, PA at work, LTPA, and smoking. Four hundred and eighty-one participants (222 males and 259 females) returned the questionnaires. The findings revealed that 25% of females were physically inactive during their leisure time and 15% were physically active for more than three hr/wk. In contrast, 18% of the males were physically inactive and 31% were physically active for more than three hr/wk. The study showed a significant gender difference (*P*<0.0001) in relation to the frequency of sport activities; 51% of women were participating in sport activities at least three hr/wk compared to 76% of men. This study did not show a correlation between LBP and PA in adulthood.

Hartvigsen et al. (24) conducted a prospective cohort study of twins to investigate the associations between PA, physical function, and the incidence of LBP in the elderly. The sample included all Danish twins aged 70 an older who participated in the LSADT. Study participants were free of LBP at baseline. Low back pain was assessed during using a modified SNQ of musculoskeletal disorders. Physical activity was assessed by asking participants if they, at the time of the study, engaged in light or strenuous PA. If participants answered "yes," the frequency of the activity was also determined. Logistic regression analysis was used to estimate the associations between PA levels and LBP. Baseline descriptive data illustrated that 13% of males and 19% of females were not physically active, while 86% of males and 80% of females reported engaging in light PA weekly. It was also shown that 42% of males and 35% of females reported engaging in strenuous PA at least weekly, while 55% of males and 36% of females reported performing no strenuous PA. The authors did not report if the differences are statistically significant between the groups.

Nilsen et al. (25) investigated the relationship between physical exercises, BMI, and the risk of chronic LBP among 30,000 females and males from the HUNT study. The analysis revealed that among the females, 12,323 were inactive at baseline compared to 3,795 who were exercising for two or more hours per week. Among male participants, 12,666 reported being inactive compared to 4,592 who reported exercising for two or more hours per week. Overall, 63% of females and 62% of males were inactive.

Payne et al. (26) examined the association between self-reported history of LBP and health-related measurements, fitness level, and PA participation in a sample of Canadian adults. The study sample included 233 males and 287 females between 15 and 69 years of age. Baseline assessments included measuring abdominal and back muscle strength and back extensor endurance. Abdominal muscle strength was assessed via partial curl-up, according to the CPAFLA protocol, and trunk flexion was assessed using a flexometer. Back extensor endurance was assessed using a modified Sorensen back extension test. Physical activity participation was assessed using the Health Physical Activity Participation Questionnaire. Each participant reported the frequency and intensity of their PA. A final score was then calculated to create a total PA participation level for each participant. Participants were stratified by gender into two groups; no history of LBP (188 males, 220 females) and with history of LBP (45 males, 67 females). Females with no history of LBP had significantly higher scores of PA participation ($P<0.01$). Similarly, males with no history of LBP were found to have significantly higher scores of PA participation ($P<0.007$).

Venseth (17) conducted a study investigating the associations between chronic LBP and time spent sitting, LTPA, and occupational activity. The data utilized was from a population-based health survey (N=22,445) administered in Nord-Trøndelag County, Norway. The research team established four PA categories based on total hours reported by the participants; "inactivity" (none), "low activity" (<3 hours of light activity, and no hard activity), "moderate activity" (≥ 3 hours of light activity and/or <1 hour of hard activity) and “hard activity” (any hours of light activity and >1 hour of hard activity). The results illustrated that 5.4% of the men and 3.3% of reported being inactive, with no further details provided regarding other PA levels.

Carlson et al. (69) examined the trends of meeting the 2008 Physical Activity Guidelines for Americans. The study sample came from the 1998 – 2008 National Health Interview Surveys (NHIS). Participants were asked about the frequency, intensity, and duration of their aerobic activity, and then they were classified as aerobically active or inactive. Participants were also asked about their participation in MSA. The findings illustrated that 43.5% of the U.S. adults were aerobically active and 21.9% met the MSA recommendation. This study also revealed that men were more aerobically active than women. The estimated prevalence of being highly active in men was 33% (95% CI 31.8–34.3) compared to 24.2% (95% CI 23.2–25.2) in women. Similarly, a greater percentage of men reported participating in MSA. The estimated prevalence of males who met the MSA guidelines was 25.7% (95% CI 24.6–26.8) compared to 18.3% (95% CI 17.4–19.3) of females. The author did not report any *P* values for these differences.

Summary

It is well documented that engaging in regular PA provides significant benefits for general health. Physical activity has been shown to improve circulation, strengthen muscles, and improve flexibility. Physical activity is also believed to enhance blood and nutrient delivery to the intervertebral discs, which helps maintain spinal health. In addition, MSA has been postulated to reduce the risk of LBP and reduce complications. Some study findings indicate that the inclusion of MSA in the treatment plans of patients with LBP may attenuate pain and improve overall symptoms. Furthermore, there is a paucity of research linking physical inactivity to the incidence of LBP and more research in this area is needed.

The prevalence estimates of LBP and PA participation seem to vary between males and females. There are multiple rationales for these differences. Based on the 2008 PA guidelines for Americans (70), adults should engage in MSA two times or more per week. It is essential to examine the potential associations between MSA and LBP among men and women. The reviewed studies employed various methodologies and populations. Therefore, external validity is limited for many of these findings. The present study examines the associations between LBP and MSA utilizing a nationally representative sample from the 1999-2004 NAHNES.

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Chapter Three: Methodology

The primary aim of this study was to examine the potential gender differences between self-reported MSA and LBP in a nationally representative sample of U.S. adults who participated in the 1999-2004 NHANES.

Data Collection

This study included six years of data from the 1999-2004 NHANES. The NHANES is an ongoing survey conducted by the National Center for Health Statistics and the Centers for Disease Control and Prevention (1). The NHANES was designed to estimate the health and nutrition status of the non-institutionalized U.S. civilians over the age of two months. The selected participants completed household interviews and provided data on anthropometric measurements and biomarkers, which were collected in one of several mobile examination centers (MEC) utilized by the NHANES.

Sampling Design

The NHANES is conducted using a complex, multistage probability sampling design. In stage one, the primary sampling units (PSUs) are selected. These PSUs are mostly single counties or small groups of adjacent counties. In stage two, the PSUs are divided into segments made up of city blocks or their equivalent. In stage three, households within each segment are listed and a sample is randomly selected. Finally, individuals within these households are chosen to participate in the household interview section of the NHANES from a list of all eligible persons residing in selected households. Individuals are drawn randomly from designated age, sex, and race/ethnicity screening subdomains. A subset of individuals who participated in household interviews also attended the MEC for the provision of other measurements and examinations.

The design and weighting methods utilized in NHANES have been consistent over the history of the survey. In order to produce nationally representative data, the NHANES creates sample weights. The sampling weights are used to account for the selection probability, non-response rates, and oversampling of certain population subgroups such as African Americans, Mexican Americans, persons with low income, adolescents aged 12-19 years, and persons aged ≥ 60 years. Oversampling is applied to increase the reliability and precision of health status indicator estimates for these groups.

Sampling weights were used in the analyses for this study to account for the complex survey design, including survey nonresponse, oversampling, and post-stratification adjustments to match the population control totals for each sampling subdomain. This last adjustment makes the weight counts the same as an independent count of the U.S. 2000 Census. In this study, a six-year weight was created for the sub-sample. Creating the necessary six-year weight (WTMEC6YR) was done while merging the six years of survey data collected from 1999-2004 using the Statistical Analysis Software (SAS) (2). The SAS coding used to create the sample weight is as follows:

```
If sddsrvyr in (1,2) then MEC6YR = 2/3 *WTMEC4YR; ***1999-2002***;
If sddsrvyr=3 then MEC6YR = 1/3 *WTMEC2YR; ***2003-2004***;
```

Note, whenever utilizing the survey cycle variable (SDDSRVYR), 1=1999-2000, 2=2001-2002, and 3=2003-2004.

Subjects

The total 1999-2004 NHANES sample size was 31,126 participants, ages two months and above. For this study, the final sample consisted of 12,721 U.S. adults ≥ 20 years of age who met the following criterion: 1) had provided complete data on all variables of interest in the interview 2) attended the MEC 3) if female, not pregnant. The total number of males was 6,396 and the total number of females was 6,325.

Study Measures

Dependent measure(s): low back pain (LBP)

The dependent variable in this study was self-reported LBP. The presence or absence of self-reported LBP was determined from the NHANES questionnaire. Low back pain was defined by affirmative response to the following item from the miscellaneous pain questionnaire file item MPQ070: *During the past 3 months, did {you/SP} have low back pain?*

Primary Independent Measure(s): Muscle Strengthening Activity (MSA)

The primary independent variable in this study was calculated from 'self-reported' MSA patterns. The final sample provided responses to the following items from the physical activity questionnaire file item PAD440: *Over the past 30 days, did {you/SP} do any physical activities specifically designed to strengthen {your/his/her} muscles such as lifting weights, push-ups or sit-ups? Include all such activities even if you have mentioned them before in the past 12 months*. The sample also provided responses to physical activity questionnaire file item PAD460: *Over the past 30 days, how often did you do* *these activities? [Activities designed to strengthen {your/his/her} muscles such as lifting weights, push-ups or sit-ups.]*. The MSA variable was created with three categories: no MSA, some MSA, and meeting the DHHS MSA PA recommendation. No MSA was categorized as 0 d/wk, some MSA as ≥ 1 to < 2 d/wk, and meeting the recommendation as ≥ 2 d/wk.

Other Independent Measures

The potential confounding variables that were controlled for in this study included the following:

Age

Age was categorized into three categories: 20–39 (referent group), 40–59, and ≥ 60 years.

Race/Ethnicity

Participants were classified into one of four race/ethnic groups: non-Hispanic white (referent group), non-Hispanic black, Mexican American, and Other.

Waist Circumference

Waist circumference (WC) was dichotomized according to the recommended gender specific cut points by the National Institutes of Health, National Heart, Lung, and Blood Institute (NHLBI) (3). These categories for males included unhealthy (WC ≥ 102 centimeter (cm); referent group) and healthy (WC < 102 cm). Categories for females included unhealthy (WC ≥ 88 cm; referent group) and healthy (WC < 88 cm).

Smoking

Smoking was categorized into three categories: current smoker (referent group), former smoker, and never smoked.

Data Analysis

The data in this study were initially managed using SAS 9.2 (3). The statistical software SAS was used to conduct both complex variable recodes and data coding validation. SAS-callable SUDAAN (4) was then used to conduct the analysis, incorporating sampling weights within the context of the correlated multi-stage complex sampling design inherent to the NHANES. Participants who responded ‘don’t know/not sure,’ refused to answer, or had missing responses for any of the questions or measures were excluded from the analyses. Logistic regression models were stratified by gender and adjusted for age, race, WC, and smoking. Best-fit models were created using a forward selection method based on the presence or absence of significant Wald f-test results. The resultant ORs were used to illustrate the associations between LBP and each of the remaining independent variables. These variables are age, race, augmented WC, and smoking in men. In women, the remaining variables are augmented WC and smoking.

Limitations

The present study is not without limitations. Due to the cross-sectional nature of the study, causality cannot be inferred. The NHANES data in our analyses was collected between 1999 and 2004, therefore, the analyzed data may not reflect the current U.S.

adult population. The LBP data was self-reported during the previous three months and MSA data was self-reported during the previous 30 days. Recall bias is possible as a result of the data being self-reported. To the extent of this author's knowledge, this is the first study to examine the potential gender differences in LBP and volumes of MSA in a nationally representative sample of U.S. adults. This study adds to the evidence evaluating the relationship between MSA and LBP.

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Chapter Four: Results

The age-adjusted prevalence estimates of LBP in U.S. adult was significantly higher (*P*=0.0005) in women than men; 40.7% and 37.1% respectively (Table 1). In men, the prevalence of LBP was lower in those who met the current MSA recommendation (34.4%) compared to those who perform some (35.4%), or no MSA (37.9%). In women, the prevalence of LBP was lower in those who perform some MSA (34.3%) compared to those who met the current MSA recommendation (36.5%), or who did not perform any MSA (42.3%). These findings suggest a potential dose-response relationship between MSA and LBP in men, but not in women. Low back pain was found to be dose-dependent with age in women, however, the highest prevalence of LBP in men was in the age group between 40 and 59 years old. When examining race, the highest prevalence of LBP was in nH White men (38.6%) and nH White women (41.2%). Mexican American adults were found to have the lowest prevalence of LBP, 31% among men and 36.6% among women. There was a positive linear association between LBP and smoking status in both genders with the highest prevalence in the current smokers; 43.6% in men and 47.1% in women. The age-adjusted prevalence of LBP was also greater in men and women with an augmented WC, 40.2% and 43.9%, respectively.

Table 1. Prevalence of LBP by Sample Characteristics: 1999-2004 NHANES

Covariates	Men		Women		
	N	*Weighted % (SE %)*	*N*	*Weighted % (SE %)*	*P* Value for Gender Difference
Total	6396	37.1 (0.85)	6325	40.7 (0.66)	0.0005
MSA					
None	4665	37.9 (0.98)	5027	42.3 (0.81)	<0.0001
Some Activity (<2 d/wk)	413	35.4 (3.23)	336	34.3 (3.43)	0.151
Meets Recommendation (≥2d/wk)	1318	34.4 (1.55)	962	36.5 (1.40)	<0.0001
Age					
20-39	2133	35.6 (1.10)	1994	38.9 (1.24)	<0.0001
40-59	1989	39.9 (1.58)	2006	41.7 (1.38)	0.969
≥ 60	2274	35.1 (1.37)	2325	42.2 (1.14)	<0.0001
Race					
nH white	3267	38.6 (0.97)	3173	41.2 (0.82)	0.34
nH black	1224	32.7 (1.23)	1269	40.0 (1.67)	0.003
Mexican American	1459	31.0 (1.37)	1406	36.6 (1.33)	<0.0001
Other	446	36.8 (2.70)	477	40.1 (2.60)	0.097
Smoking Status					
Current Smoker	1696	43.6 (1.89)	1194	47.1 (1.84)	<0.0001
Former Smoker	2092	39.3 (1.62)	1326	44.6 (2.25)	<0.0001
Never Smoked	2608	31.8 (1.15)	3805	37.5 (0.87)	<0.0001
Augmented WC					
Yes	2562	40.2 (1.34)	4069	43.9 (0.96)	<0.0001
No	3834	35.2 (1.13)	2256	36.1 (1.27)	<0.0001

Independent variables included muscle strengthening activity (MSA), age (years), race, smoking status, and augmented waist circumference (WC) Men (yes: ≥ 102 cm, no: < 102 cm), Women (yes: ≥ 88 cm, no < 88 cm).
Abbreviation: SE, standard error; nH, non-Hispanic

Tables 2 and 3 illustrate the results of the logistic regression analyses examining the associations between LBP and MSA controlling for demographic and lifestyle factors.

Table 2. Odds of LBP in Men reporting Muscle Strengthening Activity

Variable	*Model 1* *OR (95% CI)*	*Model 2* *OR (95% CI)*	*Model 3* *OR (95% CI)*
MSA			
None	1.00	1.00	1.00
Some Activity	0.97 (0.74-1.26)	0.98 (0.75-1.28)	0.99 (0.76-1.30)
Meets Recommendation	0.85 (0.74-0.97)*	0.86 (0.74-0.99)*	0.92 (0.80-1.05)
Age			
20-39		1.00	1.00
40-59		1.12 (0.94-1.32)	1.11 (0.93-1.31)
≥ 60		0.87 (0.73-1.04)	0.87 (0.72-1.05)
Race			
nH white		1.00	1.00
nH black		0.78 (0.67-0.90)*	0.78 (0.67-0.90)*
Mexican American		0.70 (0.59-0.82)*	0.69 (0.59-0.81)*
Other		0.92 (0.73-1.17)	0.93 (0.74-1.16)
Augmented WC			
Yes		1.00	1.00
No		0.84 (0.72-0.97)*	0.82 (0.71-0.95)*
Smoking Status			
Current Smoker			1.00
Former Smoker			0.79 (0.64-0.96)*
Never Smoked			0.59 (0.48-0.72)*

Independent variable(s) included in Model 1: muscle strengthening activity; Model 2: muscle strengthening activity, age, race, and augmented waist circumference; Model 3: included all variables from Model 2 and smoking status.
*Significant predictors (*P*<0.05).
Abbreviations: OR, odds ratio; CI, confidence interval; MSA, muscle strengthening activity; nH, non-Hispanic; WC, waist circumference

Table 3. Odds of LBP in Women reporting Muscle Strengthening Activity

Variable	*Model 1* *OR (95% CI)*	*Model 2* *OR (95% CI)*	*Model 3* *OR (95% CI)*
MSA			
None	1.00	1.00	1.00
Some Activity	0.72 (0.52-1.00)*	0.77 (0.55-1.07)	0.78 (0.56-1.08)
Meets Recommendation	0.77 (0.66-0.89)*	0.82 (0.70-0.96)*	0.83 (0.71-0.98)*
Augmented WC			
Yes		1.00	1.00
No		0.74 (0.63-0.88)*	0.74 (0.63-0.87)*
Smoking Status			
Current Smoker			1.00
Former Smoker			0.97 (0.72-1.17)
Never Smoked			0.71 (0.60-0.84)*

Independent variable(s) included in Model 1: muscle strengthening activity; Model 2: muscle strengthening activity and augmented waist circumference; Model 3: included muscle strengthening activity, augmented waist circumference, and smoking status.
*Significant predictors (*P*<0.05).
Abbreviations: OR, odds ratio; CI, confidence interval; MSA, muscle strengthening activity; WC, waist circumference

Crude analysis (model 1) revealed significantly lower odds of reporting LBP in male participants reporting volumes of MSA meeting the DHHS MSA PA recommendation (OR 0.85; 95% CI 0.74-0.97, *P*=0.02) when compared to a referent group reporting no MSA (Table 2). Crude analysis also revealed significantly lower odds of reporting LBP in female participants reporting some MSA (OR 0.72; 95% CI 0.52-1.00, *P*=0.04), or volumes meeting the DHHS recommendation (OR 0.77; 95% CI 0.66-0.89, *P*=0.0006) when compared to a referent group reporting no MSA (Table 3). Following adjustment for age, race, and WC for men and WC for women, these gender stratified analyses revealed that the odds of having LBP were 14% and 18% lower (*P*<0.05) in males (OR 0.86; 95% CI 0.74-0.99) and females (OR 0.82; 95% CI 0.70-0.96) respectively, who met the DHHS MSA PA recommendation (Tables 2 and 3, model 2). Lower odds of having LBP for men (OR 0.98; 95% CI 0.75-1.28, *P*=0.86) and women

(OR 0.77; 95% CI 0.55-1.07, *P*=0.10) participants reporting some MSA was not statistically significant when compared to the referent groups (Tables 2 and 3, model 2). Following adjustment for smoking, the association between volumes of MSA meeting the DHHS MSA PA recommendation and LBP in male participants was no longer statistically significant (OR 0.92; 95% CI 0.80-1.05, *P*=0.21) (Table 2, model 3). In contrast, the attenuated OR of LBP remained statistically significant in females reporting volumes of MSA meeting the DHHS MSA PA recommendation (OR 0.83; 95% CI 0.71-0.98, *P*=0.03) (Table 3, model 3). When examining race, significantly lower odds for LBP was found in nH black males (*P*<0.01, all models) and Mexican American males (*P*<0.01, all models). Compared to their respective referent groups with an unhealthy WC, men and women with desirable WC values were found to have significantly lower odds of LBP (P<0.05, all models). Our findings also revealed a significant association between smoking and LBP in male participants. Compared to the referent group (current smokers), male participants who never smoked had 41% lower odds of LBP (OR 0.59; 95% CI 0.48-0.72, *P*<0.0001), and former male smokers had 21% lower odds of LBP (OR 79; 95% CI 0.64-0.96; *P*=0.02). Significantly lower odds of LBP were seen in female participants who never smoked (OR 0.71; 95% CI 0.60-0.84; *P*=0.0001) but not in former female smokers (*P*=0.13). Lastly, our study revealed a non-significant association between age and LBP in male participants in all models. Based on Wald F-test results, age and race were not included in the female stratified analysis.

Chapter Five: Discussion

Several studies have shown that participating in MSA is beneficial in reducing LBP and its complications (1-3). One of the aims of our study was to determine if there was an association between volumes of MSA meeting the current DHHS PA recommendation and self-reported LBP. Our findings suggest that meeting the current DHHS PA recommendation for MSA is associated with significantly lower odds of self-reported LBP in U.S. adults. This finding is consistent with other studies illustrating the potential efficacy of MSA in reducing the odds of LBP (4-6).

Heneweer et al. (4) examined the relationship between meeting the current Dutch PA recommendation and self-reported LBP utilizing a sample of 3,364 participants from the Dutch population-based Musculoskeletal Complains and Consequences Cohort study (DMC). Data collected to estimate LBP prevalence and PA were self-reported. Physical activity was categorized into: daily routine activities (such as commuter traffic, occupational and school related PA, and domestic activities), LTPA, and sport activities. Participants reported the frequency, and duration for each activity during the previous 12 months. The intensity of each activity was expressed in METS. The researchers found that engaging in sport activities for 1–2.5 hr/wk was associated with significant lower odds of LBP (OR 0.72; 95% CI 0.58–0.90; $P \leq 0.05$). Comparing these study findings with the current study is not without limitations. Heneweer et al. (4) classified sport activities into specific types of back loading forces and our study (NHANES) identified MSA as activities designed to strengthen muscles such as lifting weights, push-ups or sit-ups, which makes it difficult to identify the activities that may have the greatest effect(s) on LBP.

Utilizing a similar design, Harada et al. (5) studied the associations between MSA and LBP in 1,351 Japanese adults between 65 and 74 years of age. The researchers selected MSA type and volume based on the U.S. DHHS PA guidelines. They also provided information on types of MSA (i.e., equipment, body weight). Participants were asked to report the frequency and intensity for each type of activity during a typical week. Low back pain was assessed by asking participants whether they had experienced LBP during the previous month. Researchers found that individuals who participated in MSA for ≥ 2d/wk using equipment (OR 0.79; 95% CI 0.54–1.47) or body weight (OR 0.81; 95% CI 0.63–1.04) were less likely to have LBP. Similar to our study, these findings support lower odds of LBP being associated with MSA, however, these associations did not reach statistical significance.

Contrasting our analysis, both aforementioned studies (4,5) did not conduct gender-stratified analyses. We found that engaging in MSA for ≥ 2d/wk was associated with significantly lower odds of self-reported LBP in men ($P<0.005$) and women ($P<0.05$). These data suggest that engaging in the recommended volumes of MSA may reduce LBP in both gender. Payne et al. (6) conducted a gender-stratified analysis to examine the associations between LBP, MSA participation, and measurements of health-related fitness in 520 Canadians adults. Each participant reported their history of LBP, the frequency and intensity of their PA, which included MSA, and their fitness level. Participants were stratified by gender into either no history of LBP (188 males, 220 females) or with history of LBP (45 males, 67 females). Researchers reported that participants with no history of LBP had significantly higher scores for PA participation, compared to those with LBP history ($P=0.01$ for females and $P=0.007$ for males).

There are many potential confounding factors that may mediate the associations between MSA and LBP. Our study also showed an association between smoking status and LBP. Our fully adjusted analysis (model three) was used to evaluate if smoking confounded the relationship between MSA and LBP. The relationship between meeting the current DHHS PA recommendation for MSA and LBP among the male participants was attenuated (P=0.21), however, this association remained significance in females (P=0.03). This finding suggests that smoking may be an important mediating factor that should be considered in LBP research. Our finding is in line with several previous studies reporting strong associations between smoking and LBP (7-9). A review of the literature indicates that some studies have become more specific in determining the effect of smoking on LBP as it relates to gender (8,9). Karahan et al. (7) investigated the prevalence and risk factors of LBP and illustrated that smoking was a statistically significant risk factor (P<0.05). Among smokers, the prevalence of LBP was 70.1% compared to 63.2% among nonsmokers (P<0.05).

Our associations were similar to Karahan et al. (7), however, we conducted gender-stratified analyses. Our results illustrated greater prevalence estimates of LBP among current smokers (43.6% for males and 47.1% for females). Similar to our findings, a study by Schneider et al. (8) investigated the gender disparity often reported in LBP research and showed that female smokers have higher odds of LBP compared to male smokers (OR 1.48; 95% CI 1.32-1.66). In a study by Dijken et al. (9), LBP was found to occur more often in regular smokers. More specifically, 17.6% of participants with LBP were regular smokers compared to 14.8% nonsmokers. This study provides more evidence illustrating that women and smokers are more likely to experience LBP.

The findings of this study are comparable to those found in the current study. We found women to have a higher prevalence of LBP in every category observed in the study. We also indicated a higher prevalence of LBP among smokers than non-smokers.

To the best of our knowledge this is the first study evaluating the relationship between self-reported MSA only and LBP in a nationally representative sample of U.S. adults. Our findings indicate that the relationship between MSA and LBP may be dose dependent. Our findings also illustrate that smoking could mediate the association between MSA and LBP. The primary strength of our study was the use of the NHANES data. The NHANES provides a representative sample of the U.S adult population, which provides strong external validity. Our study is not without limitations. Due to the data for these analyses being collected between 1999 and 2004, it may not reflect the current U.S. adult population. Other limitations include potential recall bias due to the LBP and MSA data being self-reported. Lastly, due to the nature of the cross-sectional study design, cause and effect of relationships cannot be determined.

Conclusions

Our findings suggest that in U.S. adults, a statistically significant relationship may exist between meeting the current DHHS PA recommendation of MSA ($\geq$ 2d/wk) and LBP. Smoking may mediate the relationship between MSA and LBP and gender may be an effect modifier. Based on our findings, healthcare professionals should discuss the potential benefits of MSA in regards to preventing LBP. Furthermore, all healthcare professionals should continue educating the public on the benefits of not smoking. Future studies should examine the associations examined in this study utilizing objectively measured MSA and LBP.

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Vita

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