ASSOCIATION BETWEEN LUMBAR EXTREMES OF MOTION AND MUSCULOSKELETAL INJURY OF THE LOW BACK AND HIP IN ADULT WOMEN

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To the Dean of the Graduate School:

I am submitting herewith a dissertation written by Nicole Patrice Borman entitled "Association between Lumbar Extremes of Motion and Musculoskeletal Injury of the Low Back and Hip in Adult Women". I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Physical Therapy.

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We have read this dissertation and recommend its acceptance:

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ABSTRACT

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ASSOCIATION BETWEEN LUMBAR EXTREMES OF MOTION AND MUSCULOSKELETAL INJURY OF THE LOW BACK AND HIP IN ADULT WOMEN

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The purpose of this study was to quantify the association between baseline measurements of lumbar extremes of motion, body mass index, self-reported histories of physical activity, and stiffness for musculoskeletal injuries of the low back and hip among women of different ages and racial groups.

Participants in the WIN study at the Cooper Institute in Dallas, TX completed Web-based questionnaires on demographics, orthopedic history of symptoms, injuries, and weekly minutes of moderate and/or vigorous physical activity. Data from self-reported orthopedic history of 911 women were analyzed along with measures of lumbar spine motion. The self-reported data consisted of age, race, physical activity level, history of stiffness, and history of musculoskeletal injury (MSI).

Four-hundred and sixty-three (50.8%) of 911 women reported having a history of MSI of the low back and hip. Univariate logistic regression models suggest that lumbar flexion in the middle or third quintile (OR = 0.66, 95% CI = [0.44 to .99], p = .05) and history of stiffness (OR = 5.99, 95% CI = [4.5 to 8.0], p = .001) relate to increased likelihood of MSI. Further analysis using multivariate logistic regression revealed that

although the women in the third quintile for lumbar flexion were still less likely to report an MSI (*OR* = 0.68, 95% CI = [0.43 to 1.1], $p = .11$), it did not reach statistical significance. However, women with reported history of stiffness in the low back and hip at baseline had increased likelihood of MSI regardless of baseline quintile of lumbar motion. Further, the multivariate logistic regression model for MSI controlling for lumbar flexion and extension motion, race, age, body mass index, and physical activity demonstrated that women with history of stiffness (*OR* = 6.2, 95% CI = [4.6 to 8.3], $p = .001$) have increased likelihood of MSI of the low back and hip.

Women with self-reported history of stiffness at baseline are 6 times more likely to report MSI of the low back and hip. Therapeutic interventions to address low back and hip stiffness early may aid in decreasing MSI of these regions for other women with comparable characteristics.

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CHAPTER I

INTRODUCTION

Healthy People 2020, a national health promotion and disease prevention initiative, seeks to improve public health by increasing the quality and years of life for everyone (U.S. Department of Health and Human Services [HHS], 2000). Researchers from the Centers for Disease Control and Prevention (CDC), the American College of Sports Medicine (ACSM) (Pate et al., 1995) and the U. S. Surgeon General (Haskell, et al., 2007) jointly recommend putting emphasis on regular moderate physical activity in place of vigorous exercise for health benefits. This emphasis calls attention to health-related physical fitness, the capacity to perform daily activities with vigor and prevent the onset of diseases and problems associated with physical inactivity (Franklin, 2000). At any level of physical activity, the possibility for developing musculoskeletal signs and symptoms such as pain, joint stiffness, numbness/tingling, muscle weakness is present. A musculoskeletal injury, depending on its severity, can limit movement, participation or motivation to be active (Hootman, et al., 2002b; Pate et al., 1995).

Muscular and joint pains are common complaints throughout life. Physical activity intensity may be a factor in developing musculoskeletal signs and symptoms or causing activity limitation. Collectively, women are more likely to be physically inactive when compared to men (Bassett et al., 2010). Some studies have reported a female predominance in chronic musculoskeletal pain (Wijnhoven, de Vet & Picavet, 2006) and

back impairments (Andersson, Ejlertsson & Leden, 1998). Since the mechanisms of chronic pain are poorly understood, women may be more vulnerable than men to react negatively to exposure to risk factors or pain. There might be an undiscovered connection between musculoskeletal pain, activity limitation and injuries since back impairments commonly cause activity limitation in the U. S. for the young and middle-aged. The National Health Interview Study from 1985 to 1988 (NHIS) indicated that back and spine impairments are more common in women at 70.3 versus men at 57.3 per 1000 population, correspondingly (NHIS, 1988). Women and minorities lag behind in nearly every leading health indicator and exhibit higher incidences of chronic diseases, mortality and poorer health outcomes (Owens, 2008; Goldberg, Hayes, & Huntley, 2004) when compared to white men. Most research pertaining to physical activity and musculoskeletal injury on women focuses on women in the military or in sports without exploring race as a factor (Gilchrist, Jones, Sleet, Kimsey, 2000; Jones & Knapik, 1999). Accepted research has shown clear association between the quantity of weight-bearing exercise performed and the risk of lower extremity injury (Koplan, Powell, Sikes, Shirley, & Campbell, 1982; Koplan, Rothenberg, & Jones, 1995; Koplan, Siscovick, & Goldbaum, 1985). Thus far, the association for level of physical activity for health benefits and musculoskeletal injury risk for community-dwelling women has not been determined.

Investigating the potential association between lumbar range of motion and musculoskeletal injuries in women in the general population is warranted because women may be susceptible to chronic musculoskeletal pain and back impairments. Research

designed on health-related physical fitness components such as flexibility could yield results that are reliable, relatively inexpensive and could be compared to normative data. In general, flexibility is important in everyday activities and differs based on gender and possibly race (Dvorak, Vajda, Grob, & Panjabi, 1995; McGeary, Mayer, Gatchel, Anagnostis, & Proctor, 2003; Ng, Kippers, Richardson, & Parnianpour, 2001; Sullivan, Dickinson, & Troup, 1994).

The term *range* of motion implies that two numbers are needed to define a motion such that the first number indicates where the motion starts and the second number indicates where the motion ends. This terminology is consistent with the neutral zero method of notation (Fitzgerald, Wynveen, Rheault, & Rothschild, 1983) that is widely used throughout the world and is supported by the American Academy of Orthopedic Surgeons (AAOS) and the American Medical Association (AMA) (Greene & Heckman, 1994). The term 'extremes of motion" (EOM) rather than "ranges of motion" (ROM) was used in the current study to more accurately reflect the measurement method. To minimize the influence of the participant's resting posture, the lumbar flexion angle was measured by placing the inclinometer on the participant's fully flexed spine. This measurement was defined as flexion extreme of motion (EOM). For the lumbar extension angle, the inclinometer was placed on the participant's fully extended spine. This measurement was defined as extension EOM. The use of EOM as opposed to ROM to quantify human motion has been advocated by Kondraske (1995).

Statement of the Problem

Existing research exploring measurements of the low back and hip in women primarily focus on body composition, muscular strength, and endurance in settings of athletics or occupations (Ciarapica & Giacchetta, 2009; Mattila ,Niva, Kluru & Pihlajamaki, 2007; Neely, 1998a; Neely, 1998b;Twitchet et al., 2010). However, little research gives attention to men and women in the free-living community. In addition, even less published research explores the potential association between general overall flexibility of the low back and hip in community dwelling adult women and musculoskeletal injuries (MSIs) of the low back and hip taking into consideration factors such as age, body mass index, and self-reported history of symptoms in these regions. Better understanding of these potential associations, may reveal opportunities to improve health-related physical fitness of community-dwelling women.

Purpose of the Study

The purpose of this study was to quantify the association between measurements of lumbar extremes of motion, body mass index, self-reported level of physical activity, and self-reported stiffness with musculoskeletal injuries of the low back and hip among women of different ages and racial groups.

Research Questions

The following research questions were applied to this study:

1. Will the association of musculoskeletal injury of the low back and hip differ between women with lowest or highest lumbar flexion EOM when compared with women with lowest lumbar flexion EOM?

2. Will the association of musculoskeletal injury of the low back and hip differ between women with lowest or highest lumbar extension EOM when compared with women with lowest lumbar extension EOM?
3. Will the association of musculoskeletal injury of the low back and hip differ between women with lowest or highest gross lumbar EOM (combined flexion and extension EOM) when compared with women with lowest gross lumbar EOM?
4. Will the association of musculoskeletal injury of the low back and hip differ between women in different age groups, racial groups, body mass indices, self-reported physical activity levels and self-reported symptom of stiffness?

Operational Definitions

The definitions used in this study were as follows:

1. Apparently healthy: Women who may or may not have chronic diseases or conditions such as coronary artery disease, hypertension, or diabetes but are medically stable and the disease or condition does not prevent or limit their usual daily or recreational activities.

2. Lumbar active range of motion: The amount of active movement of the participant's lumbar spine in the sagittal plane as measured in degrees. Lumbar flexion ROM measures active bending forward while lumbar extension ROM measures active arching backward of the lumbar spine.

3. Gross lumbar active range of motion: The amount of total gross lumbar ROM calculated by the sum of the measured degrees for ROM of lumbar flexion and extension ROM for the participant.

4. Extremes of motion: The two limits by which the motion of a given joint is constrained, one at each end of the range of motion, measured in degrees.

5. Body Mass Index (BMI): A relationship between weight and height associated with body fat and health risk. The BMI does not measure body fat directly. To calculate BMI: weight in kilograms is divided by height in meters squared. Available at: (http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html). Accessed: 07/18/2011.

7. Race: The concept of race as used by the Census Bureau (complies with the Office of Management and Budget's standards) reflects self-identification by people according to the race or races with which they most closely identify. These categories are sociopolitical constructs and should not be interpreted as being scientific or anthropological in nature. Furthermore, the race categories include both racial and national-origin groups. (U.S. Census Bureau, 2000 Census of Population, Public Law 94-171 Redistricting Data File. Updated every 10 years. Available at: (http://factfinder.census.gov/home/en/epss/glossary_r.html). Accessed: 07/16/2011).

8. Musculoskeletal injury: A musculoskeletal injury that caused the participant to see a health care provider or interrupted the participant's daily activities for 2 or more days.

9. Lower quarter musculoskeletal injury: Musculoskeletal injury pertaining to the low back and hip of the participant.

Assumptions

The assumptions of this study were as follows:

1. All participants performed extremes of motions to the best of their ability during testing.

2. All information provided by participants to the investigator via the orthopedic history was accurate.

3. The Women's Exercise Injury study (WIN) orthopedic testers reported and collected the orthopedic data correctly.

Limitations

The limitations of this study were as follows:

1. The study involved only women therefore generalizability may be limited to this population.

2. Participants may not have been representative of the general population because of the convenience sampling.

3. The cross-sectional design of the study will prohibit any determination of causal associations.

Significance of Study

Although the cross-sectional design of this study limits the benefit of deriving causal inferences, the characteristics studied are worthwhile to categorize and identify probable significant associations for lumbar range of motion, body composition and self-reported orthopedic signs and symptoms of the low back and hip for musculoskeletal injuries for adult women. These associations may aid in developing intervention strategies and/or recommendations to increase physical activity for adult women without incurring injury. In addition, the study results may guide rehabilitation and fitness

professionals in their assessments of adult women with comparable characteristics. Healthcare professionals, who routinely offer recommendations regarding physical activity for health, may increase their knowledge of potential associations with musculoskeletal injuries for women in different age and racial groups. Finally, this study will provide additional gender and race-specific data and possibly suggest beneficial directions for further research using other study designs.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to quantify the association between measurements of lumbar motion, body mass index, self-reported histories of physical activity and stiffness with musculoskeletal injury of the low back and hip among women of different ages and racial groups. This literature review contains information organized under the following headings:(a) physical activity (PA) and musculoskeletal injury (MSI); (b) potential risk factors contributing to MSI (c) measurement issues related to lumbar motion and self report data and (d) summary.

Physical Activity (PA) and Musculoskeletal Injury (MSI)

Chronic diseases are conditions or diseases related to or caused by inactivity or poor fitness (i.e., sedentary lifestyle) and estimates of 50% up to 70% of the US population have some type of chronic disease (Grundy et al., 2004). Millions of Americans have chronic diseases such as heart disease, hypertension, Type 2 diabetes, obesity, certain cancers, low back pain, osteoporosis, and osteoarthritis that may lead to premature mortality and could be treated or improved with regular physical activity (American Cancer Society [ACS], 2002; American Heart Association [AHA], 2001; Centers of Disease Control and Prevention [CDC], 2002; National Diabetes, 2002; U.S. Census Bureau; U.S. Department of Health and Human Services [HHS], 2001). Physical inactivity is an important public health concern. The Centers of Disease Control and Prevention (CDC) report that 60% of adults do not achieve the recommended amount of

physical activity and at least 25% of all adults are not active at all (Centers of Disease Control and Prevention, 1999). The 2008 Physical Activity Guidelines for Americans, a publication of the US Department of Health and Human Service (USDHHS), advocates regular moderate physical activity. Moderate physical activity has been shown to improve well-being and health for people of all ages (USDHHS, 2008). Yet physical inactivity is more common among women than men. A CDC report on prevalence and disability summarizes that 14.6% of men are more likely to stand compared to 12.3% of women; but both sexes are equally likely to walk, at 50.1% of men versus 49.4 % of women during their usual daily physical activities. Also, 35.4% of men are more likely to engage in regular leisure-time activity as compared to 28.5% of women. However, 21.3% of men are more likely to participate in high vigorous level of physical activity as compared to 16.9% of women. Conversely, 11.6% of women are more likely to never engage in any physical activity at all compared to 7% of men being at this level (CDC, 2009). The recommended physical activity guidelines for substantial health benefits require regular moderate physical activity. The recommended level of physical activity intensity can be measured using numerous methods such as metabolic equivalents (METs), target heart rate, Borg perceived exertion scale or the talk test. Whatever method used, a person must be able to distinguish between moderate and vigorous physical activity intensities. According to the 2008 Physical Activity Guidelines, moderate means when you perform the PA your breath and heart rate is noticeably faster but you can still carry on a conversation, such as in walking briskly at a 15 minute mile pace. Vigorous means when you perform the PA your heart rate is substantially

increased and your breathing is too fast to have a conversation, such as when jogging/running (USDHHS, 2008). The recommended frequency for adults is at least 150 minutes per week at a moderate intensity, or 75 minutes a week of vigorous intensity aerobic physical activity, or an equivalent combination of moderate and vigorous intensity aerobic activity (USDHHS, 2008). These guidelines offer the public ways to vary physical activities but still attain health benefits. For instance, loss of function such as decreased ability to climb stairs, walk long distances or lift objects, is often seen in aging adults largely due to the adoption of a lifestyle of physical inactivity. Few older women have lifestyle habits that incorporate the recommended frequency and intensity of healthy physical activity. Nevertheless, women tend to live longer so the potential positive benefits from the choice of a lifestyle of physical activity should not be overlooked (Physical Activity and Older Americans: Benefits and Strategies - Agency for Healthcare Research and Quality (http://www.ahrq.gov/ppip/activity.htm). Accessed 7/19/2010 (ARHQ, 2002).

At any intensity of physical activity, the possibility of sustaining a musculoskeletal injury (MSI) exists. Musculoskeletal injuries are the most prevalent type of injury associated with PA ranging from minor general muscular aches and pains to something more severe. Researchers may be challenged when operationally defining what an injury is. One example by Thein-Nissenbaum, Rauh, Carr, Loud, and McGuine (2011) defined MSI as an injury, either from direct trauma or overuse, which was the direct result of participation in sport during the season. This definition however, is too narrow when considering daily PA. For adults whether inactive or active, physical

activity-related musculoskeletal injuries can occur during home, leisure, sports and/or work. A healthy and active lifestyle may predispose an individual to sustaining a MSI. The risk of MSI increases with greater amount and intensity of the physical activity. Adults who participate at the recommended level of physical activity for health have injury rates that do not appear to be higher than those adults who are physically inactive (Haskell et al., 2007). Musculoskeletal injuries may occur in the upper quarter such as the neck, shoulder, elbow, wrist or hand or the lower quarter such as the low back, hip, pelvis, knee, ankle or foot. Musculoskeletal injuries of the lower quarter are more likely to occur with any physical activities during leisure, sports or work (Hootman et al., 2002a; Wijnhoven, de Vet, & Picavet, 2006). Hootman et al., (2002a) studied participants who were monitored for activity-related and non-activity-related musculoskeletal injuries; 25% of the participants reported activity-related MSIs with 83% of those injuries occurring to the lower quarter. In the United States, back pain is the most common cause of activity limitation for persons younger than 45 years and the most prevalent musculoskeletal impairment for persons up to age 65 years (Praemer, Furnes & Rice, 1992). The Chartbook on Women and Disability in the United States lists musculoskeletal injuries of the back and spine as more common for 15.9% of women as compared to 15.5% of men (Jans & Stoddard, 1999). A MSI depending on its severity can limit movement as well as participation or motivation to be active (Hootman et al., 2002a; Pate et al., 1995). The effect that a musculoskeletal injury can have on participation or motivation to be active is significant because of the multiple health - related conditions associated with physical inactivity.

Although the relationships between physical activity and musculoskeletal injury are not completely understood, several studies have reported a predominance in the prevalence of chronic musculoskeletal pain in both the general and working populations, as well as a tendency for higher rates of musculoskeletal injuries for women. Meaning, women may have a vulnerability to response with a pain cascade when exposed to risk Leden, 1998; Eriksen, 2003; Guo, Chand, Yen, Chen & Guo, 2004; Brault, et al., 2009; Urwin et al, 1998; Wijnhoven, de Vet, & Picavet, 2006). Research exploring women and MSIs during athletics and work settings (Cowan, Jones & Shaffer, 2001; Darakjy, Marin, Knapik & Jones, 2006; Geary, Irvine & Croft, 2002; Trinkoff, Brady, & Nielsen, 2003) occur more frequently than research investigating women and MSIs during everyday activities.

Since 1994, disability-related costs for direct medical care and lost productivity have exceeded an estimated $300 billion annually in the United States (USDHHS, 2005). For those women who choose a lifestyle of physical inactivity, the impact of disability is most likely substantial. This impact of disability can be considered the consequence to some extent of physical inactivity since gender, genetics, biological, or psychosocial factors cannot completely account for the effects of disability on women (Verbrugge, 1989). One in five Americans has a disability and more than half of persons with disability are women (Jans & Stoddard, 1999). Research reveals that women have higher rates of chronic illnesses (e.g., rheumatoid arthritis, diabetes, osteoarthritis, low back pain, neck pain, etc.), more severe disability and higher rates of multiple disabling conditions (Santiago & Muschkin, 1996). These negative outcomes could predispose

women to experiencing an activity-related injury but also, highlight potential adverse consequences of physical inactivity for women. One in two women versus one in four men over the age of 50 years will develop a fracture due to osteoporosis; fractures due to osteoporosis lower a person's quality of life (National Osteoporosis Foundation, www.nof.org; http://www.nof.org/node/40). For both sexes as aging occurs, the incidence of disability increases with the highest risk age group being 65 years or older. On average women may live five to seven years longer than men and older women have higher rates of disability compared to men at the same age (National Health Interview Survey, 1992 http://dx.doi.org/10.3886/ICPSR06343). Older women have a higher occurrence of activity limitation due to greater longevity and for the reason that activity limitation also increases with aging (National Health Interview Survey, 1992). Women tend to have higher functional limitations that are clinically significant, for example, frequent falling, decreasing ability to perform daily tasks such as preparing meals, shopping, climbing stairs, or transferring to a car which draw attention to lessening physical fitness and increasing likelihood for a possible MSI. For women in the workplace there is the possibility of a higher rate of musculoskeletal disorders that prevent them from returning to work as compared to men (McGeary, Mayer, Gatchel, Anagnostis, & Proctor, 2003; Prather, Foye, Stiens,Wilder & Cianca, 2002). These examples call attention the need for disability-related medical and public health services for women as well as men. The lifestyle choice of physical activity is crucial for musculoskeletal health and aging to help prevent disability for women.

The report from the Survey of Income and Program Participation (SIPP), a longitudinal panel survey of household members using self-reported data conducted by the U.S. Census Bureau, summarized that 24% of women had a higher prevalence of disability compared to 19.1% of men at all ages. In addition, the three most commonly reported causes for disability were arthritis or rheumatism, back or spine problems (musculoskeletal) and heart trouble for women. For both sexes, as age increased so did the self-report of disability. This report further proposes that "modifiable lifestyle characteristics" (e.g., physical inactivity, obesity, tobacco use) are major contributors to most common causes of disability suggesting that more health promotion and education programs are necessary (Brault, Hootman, Helmick, Theis, & Armour, 2009).

Evidence shows that regular PA for health benefits can reduce chronic diseases and ensuing disability. However, we also know that the likelihood of a MSI can occur with being physically active. Certainly, evidence proposes that habitual physical activity reduces the risk of chronic diseases, including type 2 diabetes (Knowler et al., 2002), osteoporosis (Vouri, 2001), obesity (Wing, 2001), depression (Pollock, 2001), and cancer of the breast (Breslow, Ballard-Barbash, Munoz & Graubard, 2001) and colon (Slattery & Potter, 2002). The four leading causes of mortality for American women are heart disease, certain cancers (breast and colon), cardiovascular disease (hypertension and stroke) and Type 2 diabetes which can all lead to premature mortality but can be treated and improved with increased physical activity (CDC, 2000). Even though women live longer than men, most data on aging is based on epidemiological studies on men

(Newman, Arnold, Naydeck et al., 2003), therefore findings may be difficult to compare. In the Nurse's Health Study (NHS), an ongoing prospective cohort study of female registered nurses aged 30 to 55 who were free of major chronic diseases at baseline were followed up to the age of 70 or older (Sun, Townsend, Okereke, Franco, Hu, & Grodstein, 2010). Sun, et al. (2010) explored PA at midlife pertaining to surviving to 70 years or older by using two categories of survivor: successful aging survivor and usual aging survivor. The successful aging survivor was defined as having no major chronic disease, no cognitive or mental health impairments and no physical limitations for moderate PA. The usual aging survivor was defined as having a major chronic disease history, cognitive impairment, physical or mental health impairments. Results of this study provide evidence to support the importance of moderate physical activity for women with aging. Specifically, successful aging survivors were more active than usual aging survivors. They were also leaner, less likely to smoke, have slightly lower prevalence of hypertension or high cholesterol, and have a walking pace at moderate level. In addition, the results revealed that being physically active were associated with successful aging for both lean and overweight women (Sun et al., 2010). The researchers did not directly explore MSI; but, they concluded that the successful aging survivors' moderate PA or higher did provide evidence that higher levels of midlife PA are associated with exceptional health status among women who survive to older ages. In addition, the positive association between moderate PA and overall health for lean and overweight women supports physical activity not inactivity. Overall, available evidence relating to PA at the moderate activity level as recommended by the 2008 Physical

Activity Guidelines (HHDHHS, 2008) indicates that there is an acceptable risk-to-benefit ratio, despite the MSI risk.

Potential Risk Factors Contributing to Musculoskeletal Injury

Risk factors are characteristics, conditions or behaviors that increase the likelihood of a specific outcome and are typically classified as extrinsic and intrinsic. When considering a MSI, extrinsic risk factors would include the specific parameters of PA such as frequency, duration and intensity as well as the conditions associated with the environment in which the PA takes place, such as terrain, weather and equipment. Intrinsic risk factors refer to the personal and internal characteristics of the individual (Gilchrist et al., 2000). Both intrinsic and extrinsic factors can contribute to MSI for the lower quarter. Wilder and Sethi (2004), note that intrinsic factors are biomechanical abnormalities unique to a particular individual and include features such as malalignments, muscle imbalances, inflexibility, weakness and instability. Strong predictors of MSI include a previous history of injury as well as walking or running more than 20 miles per week (Hootman et al., 2002a). The following section discusses research evidence concerning selected intrinsic risk factors associated with MSI for community dwelling adult women.

Sex

Much of the published exercise research supports the finding that women have an increased risk of MSI compared to men when performing similar PA. Women continue to increase participation in athletics and enter work environments or fields of traditional male-dominance. Thus they are experiencing more diverse physical activities as well as

musculoskeletal injuries. Researchers who suggest that women have a predominance of prevalence for chronic musculoskeletal pain and a high proportion of musculoskeletal injuries (Eriksen, 2003; Guo et al., 2004; Brault et al., 2009; Urwin et al, 1998; Wijnhoven, de Vet, & Picavet, 2006) also believe that women are more susceptible to negative outcomes with the same exposure as men. Anatomical differences between men and women such as a wider pelvis, lower total muscle mass and bone, larger quadriceps angles (Q-angles) and greater degrees of genu valgum (Cowan, Jones & Shaffer, 2001) or physiological differences such as hormonal effects on connective tissues may contribute to MSI rates (McClure, Adams, & Dahm, 2005). Military studies relating to women during basic training consistently record an increased risk of injury in comparison to men in the same training program (Cowan, Jones & Schaffer, 2001; Gilchrist, Jones, Sleet, Kimsy & CDC, 2000). Conversely, other researchers have observed that civilian women runners record the same injury rate as men in similar running programs. Macera (1992) concluded that these women apparently are able to self-modulate the parameters of their running programs to better coincide with their fitness levels and/or any minor overuse injuries . Cowan et al. (2001) reported that military women upon entering basic training were noted to be less fit than male counterparts. It is possible that this initial lack of fitness contributes to the increased risk of injury among these women. In addition, Centers for Disease Control and Prevention, (1999) and Cowan et al., (2001), documented that most injuries to both military men and women were overuse injuries primarily in the lower extremities, but women had greater incidence of stress fractures (CDC, 2000; Cowan et al., 2001). For women in sports, commonly seen MSIs include

spine disorders such as muscular sprain/strain; knee disorders such as patellofemoral and anterior cruciate ligament; shoulder disorders such as rotator cuff or instability and predisposition to stress fractures of the femur, pelvis and metatarsal (McClure, Adams & Dahm, 2005). Based on these findings from military and civilian women, it is presumed that community dwelling women, without controlling for fitness level, at any fixed level of physical activity will have a greater risk for injury than men. These results further draw attention to the lack of adequate research about community dwelling women pertaining to PA and the possible risk of MSI.

Body Mass Index

Body mass index (BMI) is an alternative for body fat based on an individual's height and weight (Keys, Fidanza, Karvonen, Kimura & Taylor, 1972; World Health Organization [WHO], 1995). Body mass index is correlated to body fat but does not actually measure percent body fat. Instead BMI provides a simple numeric value that relates body weight to height to classify a relative risk for disease (Morrow, Jackson, Disch & Mood, 2011). Body mass index is calculated by dividing body weight in kilograms by height squared in meters. For individuals, the current BMI classification values are as follows: a BMI less than18.5 for underweight; a BMI of 18.5 to 24.9 for normal weight; a BMI of 25.0 to 29.9 for overweight; a BMI of greater than 30 is obese and represents an increased health risk and a BMI of greater than 40 is classified as morbid obesity (Franklin, 2000). Some, research relating to BMI and MSI indicate no relationship for individuals with BMI values of underweight and normal weight. However, for individuals with BMI values in the overweight and obese ranges, the

research suggests that this relationship changes. There is an increased risk for MSI for individuals with BMI values of overweight and obese. Cowan, Bedino, Urban, Yi and Niebuhr (2011) examined military training recruits and found that the recruits who were over body fat standards were 47% more likely to sustain an MSI and to have 49% higher utilization of health care as compared to those recruits who were weight qualified. All participants were males, 18 years or older and had passed the entrance physical fitness test prior to participation in the research. Pollock and Cheskin (2007) also observed that having a BMI value in the overweight or obese range increased the risk of traumatic workplace injury. Lastly, Finkelstein, Chen, Prabhu, Trogdon, and Corso (2007) noted a clear association between MSI and BMI. Their results documented that the odds of sustaining a MSI requiring medical attention were 15% to 48% greater for individuals with a BMI of 30 or greater. Based on these findings, individuals with BMI classifications of underweight and normal, have no increased risk for MSI. However, individuals with BMI classifications of overweight and obese, have an increased risk of MSI.

Previous Injury

In the report published by the CDC regarding exercise-related injuries in women (CDC, 2000), history of a previous MSI was shown to be a risk factor for injury in both civilian and military populations. Thacker, Stroup, Branche, Gilchrist, and Weitman (1999) reported in a systematic review of literature related to prevention of ankle sprains in sports that the most commonly identified risk factor for an ankle sprain was a previous ankle sprain. As previously mentioned the majority of musculoskeletal injuries sustained

during physical activity are classified as overuse or repetitive in nature (Gilchrist, Jones, Sleet, Kimsey, & CDC, 2000; Jones et al., 1993; Hootman, et al., 2002b).

Physical Activity/Lifestyle

The current level of physical fitness of an individual has been documented as one of the most significant risk factors for injury in military studies. Additionally, low levels of aerobic fitness and to a lesser extent low muscular endurance have been consistently associated with MSI (Jones, Shaffer & Snedecor, 1999). Alternatively, women and men with the highest aerobic fitness levels also have the lowest injury rates in the military studies (Knapik, Sharp, Canham, et al., 1999).

Participating in regular physical activity might be protective against MSI (CDC, 2002). In military studies on men that examined running before entry into the Army and Marine Corps, a protective effect was shown. For military women the association with injury risk and regular physical activity (i.e., running) was reversed. Meaning for the women, the more years of participation in running, there was an associated increased risk of injury. These researchers postulated that survivor effects on the women participants may have altered the results of the study. Because no comparable civilian studies on women could be found, no conclusions can be drawn concerning the influence of previous physical activities and MSI. Further research is needed among women (and men) in both military and civilian populations.

Age

Age has been explored as a risk factor for MSI in numerous settings but results are inconsistent. Several studies report increased risks for MSI in older persons in the

military (Jones et al., 1993). Data from military and civilian research implies that among adults aged less than 45 years, age alone is not a strong predictor of MSI. In a study of 844 recreational runners (635 women, 205 men, Taunton et al. (2003) found that age was significantly associated with injury for the women, but not the men. Using multivariate logistic regression modeling, Taunton found that being over 50 years of age significantly increased the risk injury (*OR*=1.92, CI=1.11-3.33) while being less than 31 years had a protective effect for new injuries in women (*OR*=0.57, CI=0.34-0.97). Based on the findings of Taunton et al. (2003) and Jones et al. (1993), age is not a strong predictor for MSI at age less than 31years; however, age greater than 45 years may increase the likelihood risk for MSI.

Measurement Issues Related to Lumbar Motion

Lumbar range of motion can be considered an overall measure of the low back and hip flexibility which incorporates the joints of the lumbar spine and hip, ligaments, and muscles. Normative databases for measurements of lumbar motion can be difficult to compare because of the variety of measurement instruments used, the wide variability in individuals in the databases, and the lack of standard measuring techniques when performing lumbar motion. Some instruments measure lumbar ROM in degrees while other instruments measure the same phenomena in centimeters. For example, Moll and Wright (1971) reported lumbar ROM values in centimeters based on 237 participants who were 15 to 75 years of age, while Dopf, Mandel, Geiger and Mayer (1994) reported lumbar ROM values in degrees based on 30 participants who were 20 to 35 years of age. These normative data are incompatible so they cannot be used for comparison. Lumbar

ROM can be measured using different instruments such as a radiograph, a tape measure, a goniometer, or an inclinometer. Radiographic methods are the gold standard for spinal range of motion measurements. Researchers have reported that radiographs are accurate and reliable for measuring total lumbar ROM in symptomatic and asymptomatic individuals with intraclass coefficients (ICC) ranging from .72 to .94 (Weiner et al., 1994). Radiographs however, are not clinically practical for measuring lumbar ROM due to the radiation exposure, excessive time involved, limited accessibility, and expense (Mayer, Tencer, Kristoferson, & Mooney, 1984). Consequently, lumbar ROM measuring methods using a tape measure, goniometer, or inclinometer have been considered.

Tape Measure Techniques

A tape measure method of measuring lumbar ROM such as fingertip-floor or skin distraction is easy to use and inexpensive. Brief descriptions of the fingertip-to-floor and skin distraction techniques follow. The fingertip-to-floor method requires the participant to slowly bend forward as far as possible and attempt to touch the floor with the fingers while keeping the knees straight and feet together. At the end of the motion, the examiner measures the distance between the tip of the participant's middle finger and the floor with either a centimeter ruler or a tape measure. The skin distraction method requires the examiner to locate and mark two landmarks on the back of participant while standing and then the participant tries to touch his toes. The examiner notes the difference between the landmarks from the initial position and the fully bent forward position at the end position. The difference in the starting position and the end position

recorded in cms, is the flexion range of motion (Norkin & White, 2009). Tape measure methods cannot accurately measure true lumbar ROM. That is, tape measure methods assess the combined flexion movements for the hip, lumbar and thoracic spine. In addition, researchers have reported wide variability in reliability when using tape measure methods based on inconsistency in palpation (Alaranta, Hurri, Heliovaara, Soukka, & Harju, 1994; Mellin, 1987; Williams, Binkley, Bloch, Goldsmith, & Minuk, 1993). In particular, Williams et al. (1993) reported intraclass correlation coefficients for interrater reliability for the tape measure method as $ICC_{3,1} = .72$ for flexion and $ICC_{3,1} = .76$ for extension. For the purpose of describing reliability, these *ICC* values would signify a moderately reliable method for measuring lumbar flexion and extension (Portney & Watkins, 2000).

Goniometric Measurements

Lumbar ROM measurement using a universal goniometer (UG) can also be inexpensive and easy to use but true lumbar motion cannot be isolated from hip motion. The UG is an instrument commonly used to measure joint position and range of motion in the clinical setting. Typically, the UG is made of plastic or metal, has a body shaped like a protractor with two arms (stationery and moving) attached to the center point of the body (Norkin & White, 2009). Several researchers have determined the interrater and intrarater reliability using a UG for measuring spinal ROM. Nitschke, Nattrass, Disler, Chou, and Ooi, (1999) compared lumbar spine ROM in 34 males and females with low back pain using an UG and double inclinometers. The UG measured all ranges of lumbar motion with intrarater reliability ICC values ranging from .92 for flexion to .76 for right

lateral flexion. However, interrater reliability ICC values ranged from .52 for flexion and .84 for extension. Fitzgerald, Wynveen, Rheault and Rothschild (1983) compared measurements of the thoracolumbar spine for motions of lateral flexion and extension using the UG, but intertester reliability coefficients were calculated based on the paired results of two testers who were student physical therapists. Intertester Pearson reliability coefficients were reported as .88, .76 and .91 for extension, right lateral flexion and left lateral flexion, respectively.

Inclinometry Measurements

An inclinometer is an instrument used to measure the angle or range of motion in a simple joint such as the elbow or complex joints such as the spine, and is calibrated or referenced based on gravity or an angle sensor. There are two major types of inclinometers, mechanical or electronic, and several different styles. Mechanical inclinometers usually consist of a protractor with either a weighted pendulum or a fluid indicator that must be aligned before measurement. Electronic inclinometers usually are self-contained portable units designed to accurately measure angular changes and may be non-computerized or computerized. Currently, lumbar ROM measurements using an inclinometer may offer the best method for quantifying complex lumbar motion. The American Medical Association (1993) recommends use of the dual inclinometry method to measure spinal ROM even though some inconsistencies in reliability and validity exist. The dual inclinometry method requires two inclinometers. The examiner locates two primary landmarks or bony structures at the middle of the back (i.e., anatomically named, T12 and S1 for lumbar measurement). One inclinometer is placed on each landmark

(e.g., upper and lower inclinometer positions). For flexion, the participant bends forward to the maximum flexion, then the examiner reads and records both inclinometers values. The upper inclinometer (i.e., anatomically named T12 angle) value represents combined lumbar and pelvic motion, and the lower inclinometer (i.e. anatomically named S1 angle) value represents the pelvic angle value. True lumbar motion is the difference between the two inclinometer values.

Variability in measures of interrater and intrarater reliability for dual inclinometry does occur. For instance, Beattie, Rothstein, and Lamb (1987) reported clinically acceptable values of intrarater reliability when measuring lumbar ROM using dual inclinometry method for both symptomatic and asymptomatic individuals: $ICC_{3,1} = .93$ (symptomatic) and $ICC_{3,1} = .90$ (asymptomatic), and $ICC_{3,1} = .94$ for interrater reliability. Mayer et al. (1984) compared dual and single inclinometry methods with radiographic measurement of lumbar sagittal motion. The normal group was comprised of 13 volunteers ($M_{age} = 31.1$ years) and the chronic low back pain group was comprised of 38 patients. The investigators documented mean inclinometric measurements for lumbar flexion as 60.5° ($SD = 16.7°$) and mean radiographic measurement as 58.5° ($SD = 21.6°$) thus, signifying no significant difference ($p < .001$) between the two methods for measuring lumbar flexion. Subsequently, Mayer et al. (1984) reported that clinicians could expect dual inclinometry to be accurate within 10% of lumbar radiograph. Likewise, Gill, Krag, Johnson, Haugh, and Pope (1988) compared measurements of lumbar ROM using the methods of dual inclinometry, modified Schober tape measure technique, fingertip-to-floor, and photometry. The dual inclinometry and modified

Schober methods were deemed repeatable methods. The fingertip-to-floor and photometry methods produced the greatest variability in measurements and exhibited poor repeatability compared to the other methods. The modified Schober technique, according to Gill et al. was the most reliable of the four techniques. Yet the modified Schober technique is limited for clinical application because the linear measurements attained are not easily compared to methods using degrees for measuring lumbar ROM.

Electronic Inclinometry

Electronic inclinometry possibly can provide a more reliable method of measurement for lumbar ROM than using a tape measure, universal goniometer or dual inclinometers. Although, few researchers have examined interrater and intrarater reliability of the non-computerized APM I portable electronic inclinometer, more research has been done using the non-computerized Cybex Electronic Digital Inclinometer (EDI-320), the predecessor of the APM I. Mulry (1999) examined the intra-examiner reliability of measuring lumbar motion using the APM I and the EDI-320. The research consisted of 72 participants performing one of 10 randomly assigned motions. The 10 possible motions were lumbar flexion, lumbar extension, right/left lumbar lateral flexions, right/left thoracolumbar rotations, right/left cervical rotations and elbow flexion and extension of the participants' dominant arm. The test measurements for each motion were grouped into two distinct data sets for the EDI-320 and APM I with statistical analysis was conducted separately on each data set. The $ICC_{3,1}$ for each method were reported as.97 for the EDI-320 and as .99 for the APM I. Borman, Jackson-Trudelle, and Smith (2011) examined intra-examiner reliability using the APM I to measure sagittal

lumbar ROM for 85 participants and reported excellent reliability with $ICC_{3,2}$ values of .99 for flexion and .97 for extension. Chiarello and Savidge (1993) reported interrater reliability of the EDI-320 compared with dual inclinometry. Their research consisted of 12 participants with no history of low back pain (M_{age} = 25 years) and 6 symptomatic participants (M_{age} = 32.7 years). The testers were three physical therapists (one with 10 years experience, one with 12 years experience, and one with 1 year of experience). The participants performed standing flexion, standing extension, and prone extension. For all participants lumbar ROM in the three positions was computed and descriptive statistics calculated. Intrarater reliabilities were reported as degrees of variability for each therapist's measurements for the three positions and for asymptomatic and symptomatic participants. Each of the therapist's measurements did not differ by greater than 5 degrees for all measurements between the EDI-320 and dual inclinometers. No significant difference was found between the EDI-320 and the dual inclinometers in measuring lumbar sagittal motion when used for asymptomatic and symptomatic participants regardless of position. Thus both devices measured lumbar ROM comparably. The researchers stated that using either tool in the clinical setting to document lumbar ROM represents improvement over observational methods. However, differences in the interrater reliabilities were apparent and took into account manipulation and operation of the instruments. The researchers reported interrater reliability for dual inclinometry as $ICC_{3,1}$ values ranging from .57 for flexion and .86 for standing lumbar extension in the asymptomatic participants. The interrater reliability for the EDI-320 was reported as $ICC_{3,1}$ values ranging from .64 for standing flexion and .85 for prone

extension in asymptomatic participants. The dual inclinometry method was reliable for measuring patients in all positions and interrater reliability improved with device familiarity suggesting a learning or practice effect. The EDI-320 was reliable when measuring in prone for asymptomatic participants and extension for symptomatic participants. There did not appear to be a consistent pattern for improving, interrater reliability for the EDI-320.

In summary, the gold standard for measuring lumbar ROM is radiography. However, for routine clinical use, radiographs are expensive, invasive, time-consuming and impractical. Thus, other measuring methods are compared to radiography. In particular, tape measurement methods exhibit variable reliability and do not adequately isolate true lumbar ROM. In addition, the linear measurements are not easily converted to degrees. Goniometric methods also have limited usefulness for measurements of spinal motion and exhibit variable reliability. Inclinometeric methods are more comparable to radiography. Inclinometric measurements are usually considered 10% less accurate than radiologic measurements (Mayer et al., 1984), but exhibit far less variability in interrater and intratester reliability compared to tape measure and goniometer measurements. Finally, electronic inclinometry shows promise as a clinical tool due based on its capabilities for referencing motion, accuracy, reliability, and usefulness. To date little research exists that explores the relationship between lumbar motion and MSI risk for community dwelling women of the low back and hip.

Measurement Issues Related to Self-Report

Self-report is a term used to describe subjective or personal data collected directly from the individual participant (Fleming, 2011). Research pertaining to interest in participants' subjective experiences, their thoughts or behaviors determines the selection of self-report methods for data collection. Self report data collection often combines subjective and objective measures for completeness and accuracy. Self-report methods commonly used allow participants to respond to questionnaires. Usually, questionnaires are relatively low cost, easy to administer and potentially can be developed so that they can assess a wide range of dimensions (Meyer, Deck, & Raspe, 2006). A large variety of self-report questionnaires exist for use in rehabilitation research and clinical practice for assessing a participant's level of pain such as the Brief Pain Inventory (BPI) or Numeric Rating Scale (NRS) (Krebs, Carey & Weinberger, 2007) or for assessing quality of life such as the Medical Outcomes Short Form Health Survey (SF-36) (http://www.sf-36.org/tools/sf36.shtml). Self report physical activity (PA) questionnaires have been validated and widely used (Welk, 2002). Examples of PA assessment questionnaires include the U.S. Centers for Disease Control and Prevention (CDC) Behavioral Risk Factor Surveillance System (BRFSS) (Kilmer et al., 2008), the Youth Risk Behavior Surveillance System (YRBSS), and the National Health and Nutrition Examination Survey (NCHS, 2007). Each of these tools uses participants' self reported responses to assess behaviors pertaining to PA in large populations using a questionnaire. Other advantages to using a questionnaire are that data can be delivered and collected in a variety of ways such as in-person, individually, by group, through mailings, interviews or

Internet and they provide a standardized means of accessing individuals' subjective factors. The most significant disadvantage when using a questionnaire is related to reliability and validity issues. Researchers have identified two important factors concerning validity of self-report data: issues about cognition and situation. A cognitive issue addresses whether the participant understands the question or has the knowledge or memory to answer accurately. A situational issue deals with any influences the setting such as being at home or at the clinic when answering the questionnaire (Brener, Billy, & Grady, 2003). Furthermore, participants can falsely or inattentively report via overinflating or under-inflating their responses, have bias unrelated to the content, have cognitive or memory limits, tend to agree with whatever the researcher expects or even be affected by the way the questions are asked (Tourangeau & Yan, 2007). In a study, reliance of self report data for measurement of both dependent and independent variables may raise concerns about validity of relationships of variables. For the current study, MSI was viewed as a self report variable. The previously discussed data collection process is relevant and reliable. As one researcher quoted, "No questionnaire is perfect and there is always a certain margin of error. However, overall the results provide us with an accurate indication of what is occurring" (Brener, Billy, & Grady, 2003).

Summary

This literature review briefly summarizes research relevant to general physical activity (PA) and musculoskeletal injury (MSI), selected potential risk factors, and measurement issues related to lumbar motion, and self report relating to MSI in community dwelling women of the low back and hip.

CHAPTER III

METHODS

Existing basic knowledge to classify potential significant associations relating to musculoskeletal injuries for the low back and hip in community dwelling women is inadequate. The purpose of this study is to quantify the association between lumbar extremes of motion and musculoskeletal injuries in the low back and hip among women of different age and racial groups. This study is a subset of a 5- year observational investigation, the Women's Injury Study (WIN) funded by the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS). This chapter includes the following sections: (a) Women's Injury Study, (b) participants, (c) examiners and researcher assistants, (f) instrumentation, (d) The WIN study procedures, (e) brief overview of WIN orthopedic examination procedures, (f) data analysis, (g) validity substudy and (h) reliability substudy.

The Women's Injury Study

The Women's Injury study (WIN) is a Web-based surveillance study of physical activity habits and musculoskeletal injuries in women. The objective of the WIN study is to determine the incidence and predictors of musculoskeletal injuries in free-living women. This information gained will be used to assess the public health burden of musculoskeletal injuries and to identify risk factors for these injuries. To qualify for the WIN study, women had to be at least 20 years of age and have access to a computer with Internet capabilities. Women were excluded if they had a disease or condition that

limited or interfered with their usual daily or recreational activities or used an assistive device to ambulate. Qualified women who voluntarily agreed to participate in the WIN study signed an informed consent in compliance with the Cooper Institute's Review Board and underwent a baseline orthopedic examination by a licensed physical therapist. The aforementioned substudy presents WIN study data obtained from the questionnaires (baseline and orthopedic history) and orthopedic examination.

Participants

Participants were a cohort of free-living women who were recruited for the WIN study at the Cooper Institute in Dallas, Texas. The diverse sample (918 adult women, (M_{age} = 52 years, age range: 20-83 years) provided demographic information and medical history during an orientation session. Next the participants completed a 2-week practice phase where they entered weekly physical activity data into the Web-based system. Participants who successfully met the requirements for the practice phase then completed an orthopedic online symptom and injury questionnaire and underwent an orthopedic examination. Completion of the orthopedic examination provided entry into the study for the remaining observational period. During this observational period participants continued to report injuries and physical activities via the Web-based data collection system on a weekly basis for as long as 3 years. Approximately 75% of the participants were recruited from Caucasian ancestry and the remaining 25% from minority groups primarily African-American and Hispanic women.

Examiners and Research Assistants

The orthopedic examiners were three licensed physical therapists who were also doctoral level students from the School of Physical Therapy at Texas Woman's University. All examiners were trained and practiced the standard procedures used to assess low back and lower extremity static biomechanical measures, muscle flexibility, joint mobility and stability, and muscle strength. Two additional persons were trained as research assistants to assist with data entry during the orthopedic examination. Detailed procedures for the WIN orthopedic examination follow.

Instrumentation

For anthropometric data the following instruments were used to measure height, weight and body composition: a digital scale (Tanita™ Model BWB-800), a stadiometer (Perspective Enterprise™ Easy Glide Bearing Stadiometer) and skin fold calipers (Lange ™). The digital scale (Tanita™ Model BWB-800) was selected to measure body weights in kilograms (kg) to the nearest 0.1 kg. Published literature about digital scales has reported appropriate precision, reliability and validity for use in the research and clinical settings (Hacker, 1991). The wall-mounted stadiometer (Perspective Enterprise™ Easy Glide Bearing Stadiometer) was used to measure height in centimeters (cm) to the nearest 0.1 cm (www.cdc.gov/nchs/data/nhanes/bm.pdf). Research has demonstrated that significant errors in calculations may result if based on self-reported values for heights and weights rather than measured values (Kuczmarski, Kuczmarski, Najjar 2001). The measured heights and body weight values were used to calculate body mass index (BMI). The Lange® skin fold caliper was used to measure subcutaneous fat at three skinfold

sites (triceps, suprailiac, and thigh) and calculate body fat percentage. For women, the skinfolds equations used to calculate body fat percentage correlates with results from hydrostatically determined body fat percentages as .815 to .820 with standard errors from 3.7 to 4.0% (Jackson & Pollock, 1985; Jackson, Pollock, & Ward, 1980).

The Human Performance Measurement (HPM) system (Human Performance Measurement, Inc®., Arlington, TX) is a computer-automated system that integrates a battery of tests used to evaluate a wide range of sensorimotor functions. The BEP for Windows ™ software manufactured by Human Performance Measurement, Inc®., in Arlington, TX was the operating system for BEP III and BEP VIIa HPM components and allowed recording and storing data on an IBM compatible notebook computer. The BEP VIIa and BEP III components were used in this study to assess joint angles and isometric strength, respectively. The BEP VIIa, a portable, computerized, self-contained electronic inclinometer that measures joint angles of the extremities and trunk, was used to measure hamstring and gastrocnemius muscle lengths as well as lumbar flexion and extension motions in degrees. These measurements were based on extremes of motion (EOM) rather than ranges of motion (ROM). Purposely, the BEP VIIa references measurements after the participants have reached their extreme motion, and relative to an anatomical neutral segment that is independent of the segment being measured. By referencing to an independent anatomical segment, the BEP VIIa can measure the results of movement after the participants have reached their end of motion position. This may help alleviate a potential source of error, which exists between trials because the reference is dependent on whether the participant returns to the same starting position after each trial. A neutral

starting position can vary between trials and between sessions. When the starting position varies, the result will vary accordingly regardless of the accuracy of the device. By referencing the device after the participants have reached their extreme position, this potential source of error is removed from the measurement method. Although, few researchers have examined the interrater and intrarater reliability of the BEP VIIa, more research has been done exploring the predecessor design model, the EDI-320. Researchers examined intra-examiner reliability of the BEP VIIa and its corresponding measurement procedure compared with intra-examiner reliability of the EDI- 320 for measuring lumbar extremes of motions. The comparison of two distinct data sets for EDI-320 and BEP VIIa were reported as $ICC_{3,1}$ values for each method. The ICC values were reported as .97 for the EDI-320 and as .99 for the BEP VIIa (Mulry, 1999).

The BEP III, a computerized, hand-held dynamometer, (Human Performance Measurement, Inc®., Arlington, TX), was used to measure isometric muscle strength in Newton-meters (N-m) of selected lower extremity muscles. The BEP III measured maximal isometric force produced by the muscle. The BEP for Windows ™ software estimated moment arm lengths based on the participants' heights. The standard error associated with estimated segment lengths based on stature has previously been shown to be approximately 1.0 cm compared to measured segments (Webb Associates, 1978). In addition to isometric muscle strength of selected lower extremity muscles, hand grip force was assessed. The Jamar® Hydraulic Hand Dynamometer was used to measure peak isometric hand grip force on a scale of 0 to 200 pounds (lbs) (0 to 91kgs) at the 3rd position of 5 adjustable grip positions. Standard positioning and instructions were used

to improve reliability and validity of strength measures as suggested by Mathiowetz, Weber, Volland, and Kashman (1985). Mathiowetz et al. (1985) also reported that use of Jamar dynamometer provided more accurate measures of grip strength than another soft handle dynamometer.

The biomechanical measurements for navicular height, leg length discrepancy and knee ligament laxity required using a plastic ruler, a leveling caliper, graduated foot lifts, a tape measure and a MEDmetric® KT 1000, respectively. The 15.2 cm (6") plastic ruler was used to measure navicular height in subtalar neutral and relaxed standing positions in millimeters (mm) based on the methods of Sell, Verity, Worrell, Pease and Wigglesworth (1994). These researchers reported moderate reliability for measurement of navicular drop with intraclass coefficients ranging from .33 to .76 and standard error of the measurement at 95% confidence intervals ranging between ±1.5 mm and ±3.5 mm. The leveling caliper, graduated foot lifts and tape measure were used to assess equality of the landmarks of the anterior superior iliac spine (ASIS) heights between legs to determine the presence in standing of a functional leg length discrepancy and/or in supine for a true leg length discrepancy. Woerman and Binder-MacLeod (1984) compared five clinical assessments for measuring leg length discrepancy, comparing each to on another and the radiography. The indirect method of measuring leg length equality, which employed using lift blocks under a foot with a subject in the standing position from their research was showed to be the most accurate and precise method of any the other five measuring techniques tested. For the direct method the most accurate and precise method used a tape measure between various anatomical landmarks, specifically, the landmarks of the

anterior superior iliac spine and the lateral malleolus of the fibula. Laxity of the knee ligaments, anterior and posterior cruciate ligaments was assessed using the MEDmetric® KT 1000, an instrument that provides an objective measure for anterior and posterior displacement of the tibia relative to the femur. Brosky (1999) used the KT-1000 for testing anterior and posterior translation of the tibia during rehabilitation of patients post anterior cruciate reconstruction. He compared intrarater reliability of the KT 1000, Biodex isokinetic dynamometer and three functional hop tests. His research found no significant differences and good reliability in ICCs results for the Biodex dynamometer at .82 for involved and .97 for uninvolved and for the 3 functional tests at .88 involved and .97 for the uninvolved except the KT-1000 results were higher at .91to .93 for the involved compared with ICCs of .69 and .72 for the uninvolved which was attributed to inability of the patient with ACL reconstruction to relax with testing or altered physiological changes post injury.

The WIN Study Procedures

Participants who met the inclusion and exclusion criteria previously described were scheduled for an orientation session. During this orientation session, the WIN study was described, Institutional Review Board consent forms signed, and the baseline questionnaire that included demographic and medical conditions history information was completed. Next the participants completed a 2-week practice phase where they entered weekly physical activity data into the Web-based system. Participants who successfully met the requirements (i.e., women who wore the WIN pedometer and logged in to the website twice during the 2-week practice phase) in this phase advanced

to the WIN orthopedic testing. The WIN orthopedic testing started with the participants completing the written informed consents, Protected Health Information (PHI) forms (see Appendix B), and Web-based orthopedic history questionnaires (see Appendix C). Next, unique participant identification (PID) numbers were assigned. The PID numbers were used to refer to all the WIN data regarding the participants for research purposes. Following completion of the questionnaire and verification by the physical therapist, the WIN orthopedic examination proceeded.

Brief Overview of the WIN Orthopedic Examination Procedures

For the WIN orthopedic examination, the participant wore a sports bra and shorts or loose fitting pants that allowed free movement and accessibility to the anatomical landmarks. Examiners used standard instructions to the participants to ensure correct and consistent performance of the various tests. The WIN orthopedic examination protocol consisted of standard clinical assessments for the lower quarter and provided quantitative data on anthropometrics, static alignment, muscle flexibility, joint mobility and stability, and muscle strength. Anthropometric data included height, weight and skinfold measurement. For the height measurement, the participant removed her shoes but socks could be worn. The participant was positioned in front of a ruled vertical board (stadiometer) with her weight equally distributed. If possible, her heels, buttocks, scapulae, and posterior aspect of the cranium were in contact with the vertical board. In some participants this was not possible, and in these cases, the heels and buttocks or the cranium were in contact with the vertical board. The head was positioned in the neutral position (neither flexed nor extended) and the participant was asked to look straight

ahead. The examiner stood to the side, viewing the participant from the sagittal plane. The participant was instructed to "take a deep breath and hold" as the headboard was lowered to the most superior point on the head with only enough pressure to compress the hair and this position of the headboard was secured by tightening the wing nut. The examiner read and recorded the measurement by standing in front of the vertical board and making sure their dominant eye was level with the "Read here" mark. Height was recorded to the nearest 0.1 cm.

For the body weight measurement a digital scale was used. The participant removed her shoes, but socks could be worn. The participant stood motionless with her body weight evenly distributed and centered on the scale platform. Light indoor clothing (shorts, t-shirt, or hospital gown) could be worn during the measurement. The examiner stood to the side of the participant, facing the digital scale. The examiner waited until the digital readings of the scale stabilized then recorded the weight measurement to the nearest 0.1 kg.

For body composition assessment two measures were considered body fat percentage and body mass index (BMI). Three skinfold sites (triceps, superiliac, thigh), were measured using Lange ® skin calipers and results were used in formulas based on age and gender to calculate body fat percentage per the recommendations of Jackson and Pollock (1985). Body mass index is a based on an equation which relates weight and height to health risk. On the other hand, skinfolds can reliably measure body

composition change over a period of time if measurements are taken by a skilled person using the same technique and equipment.

Muscle flexibility assessment examined lumbar flexion and extension motions as well as hamstring and gastrocnemius muscle lengths. Lumbar measurements using the computerized BEP VIIa electronic inclinometer resulted in extremes of motion rather than range of motion values. The BEP VIIa purposely employs references for measurements after the participants have reached their extreme motion, and to an anatomical neutral segment that is independent of the segment being measured. By referencing to an independent anatomical segment, the BEP VIIa can measure the results of movement after the participants have reached their end of motion position. This may help alleviate a potential source of error, which exists between trials because the reference is dependent on whether the participant returns to the same starting position after each trial. A neutral starting position can vary between trials and between sessions. When the starting position varies, the result will vary accordingly regardless of the accuracy of the device. By referencing the device after the participants have reached their extreme position this potential source of error is removed from the measurement method. The BEP VIIa was calibrated according to manufacturer instructions each day prior to any data collection. The participant was instructed to stand in an upright, relaxed posture with her feet 10 - 15 cm apart, head erect and eyes focused directly ahead with weight evenly distributed. The examiner marked the first sacral vertebra at S1 and the 12^{th} thoracic vertebra at T12 for use in isolating the lumbar spine movement. The examiner established a reference point for the lumbar flexion extreme of motion

measurement by aligning the BEP VIIa vertically with the center of the participant's lateral thigh and clicked once. The examiner then instructed the participant to bend forward as far as possible keeping her knees straight as she tried to touch the floor with her hands. When the participant had achieved maximum flexion extreme of motion, the examiner placed the BEP VIIa at the participant's S1 vertebrae and clicked once to continue measuring the lumbar flexion extreme of motion. Next, the examiner placed the BEP VIIa at the participant's T12 vertebrae and clicked once to end the measuring of the lumbar flexion extreme of motion. Finally, the examiner moved the BEP VIIa in the direction of the motion and clicked one more time to assign the correct direction for flexion lumbar extreme of motion measurement. The procedure was repeated two more trials to total three lumbar flexion extreme of motion trials and the mean was calculated. For extension, the same procedures stated were applied but the examiner instructed the participant to lean back as far as possible while keeping her knees straight. The gastrocnemius and hamstring muscle flexibility, the measurements were also assessed with the BEP VIIa in a supine position.

Biomechanical alignment at the leg, knee and foot were assessed. The static foot alignment for subtalar pronation was assessed by measuring the navicular drop distance in mm on the 15.2 cm plastic ruler during subtalar neutral and and in relaxed standing positions. Next, leg length discrepancy was assessed. The leveling caliper and graduated foot lifts were used to assess equality of the landmarks of the anterior superior iliac spine (ASIS) heights between legs to determine the presence in standing of a functional leg length discrepancy. A tape measure was used to measure the distance in

cms between ASIS and lateral malleolus of each leg in supine for a true leg length discrepancy.

Joint mobility and stability were assessed at the ankle for ligament laxity by conducting an Anterior Drawer test and recording results as either positive or negative for the presence of excessive mobility of the ankle. For the ligament laxity of the knee, measurements of anterior and posterior translations of the tibia were taken. Laxity of the knee ligaments, anterior and posterior cruciate ligaments was assessed using the MEDmetric® KT 1000, an instrument that provides an objective measure for anterior and posterior displacement of the tibia relative to the femur.

Lastly, muscle strength for hand grip was measured in kgs using the Jamar grip dynamometer while strength of the hamstrings, quadriceps, hip abductors, and hip external rotators was measured in units of Newton-meters (N-m) using the BEP III. For all muscle strength tests, standard test positions and procedures were used. Stabilization procedures were used as needed as the participant was instructed to push as hard as possible against the dynamometer.

Completion of the orthopedic examination provided entry into the study for the remaining observational period. During this observational period participants continued to report injuries and physical activities via the Web-based data collection system on a weekly basis for up to 3 years. The focus of the current study; however, is the history of injury and symptoms provided by participants in the Orthopedic History questionnaire at baseline, prior to the longer observational period.

Data Analysis

The study design was a cross-sectional observational study consisting of two parts. Part 1 dealt with reliability and validity in Chapter IV. The reliability substudy was conducted to assess the intra-rater and inter-rater reliability when measuring lumbar EOM (flexion and extension) in women using the BEP VIIa inclinometer. The validity substudy was conducted to investigate the concurrent validity of the BEP VIIa inclinometer and the single bubble inclinometer when measuring lumbar EOM for flexion and extension in women. Part 2 is described in Chapter V and dealt with quantifying the association between lumbar EOM and a number of predictor variables with MSI of the lower quarter. All statistical analyses used SPSS version 15 (SPSS Inc, Chicago, IL). The subsequent Chapters IV and V address the details for the aforementioned substudies with pertinent data descriptions as needed.

CHAPTER IV

VALIDITY AND RELIABILITY OF ACTIVE LUMBAR RANGE OF MOTION MEASUREMENTS IN COMMUNITY WOMEN USING THE EXTREMES OF MOTION METHOD

Lumbar range of motion measurements are necessary to document outcomes for fitness clients or patients with back pain in research and clinical settings. Although visual methods can be used to estimate ROM, these methods provide no objective record, make comparisons between different sessions difficult, and have a high degree of variability (Waddell & Venner, 1984; Watkins, Riddle, Lamb, & Personius, 1991; Youdas, Carey, & Garret, 1991). Thus, the demand for an objective method of measurement and a practical measuring instrument is high.

Accurate measurement of compound and complex motions of the spine is nearly impossible with a traditional universal goniometer that has one stationary arm and one adjustable arm. Some researchers have reported variance as high as 53% with the use of goniometric measurement for the spine (Gill, Krag, Johnson, Haugh & Pope, 1988). Active lumbar ROM is commonly measured as an objective outcome of lumbar spine mobility in persons with or without symptoms. These ROM measurements may be of use in determining disability or impairment ratings, interpreting functional capacity data, or quantifying mobility changes as a result of an intervention (Nitschke, Nattrass, Disler, Chou, & Ooi, 1999; Roussel et al., 2006).

Radiography is the gold standard for spinal ROM measurement (Mayer, Chen, Lavender, Trafimow and Andersson, 1995). Radiographic measurements however, are impractical for routine lumbar ROM assessments due to factors such as radiation exposure, time intensiveness, limited availability, inadequate accessibility and excessive cost for clinicians/researchers. Currently, in the clinical setting, spinal motion is commonly measured using goniometers, tape measures, or fluid inclinometers with each of the measuring methods having its own set of limitations, and the resultant measurements are not interchangeable. A fluid inclinometer uses a dial scale and the fluid meniscus indicates the degrees of motion moved, and the dial scale must be manually aligned properly before and after each measurement. Such measuring issues may affect accuracy when the participant is unable to maintain the initial or final positions or complicate determining the degrees of motion when using two inclinometers. These measurement issues highlight the need to upgrade the measuring method and instrument for lumbar range of motion measurements. An electronic inclinometer could reduce these issues by recording the initial and final spinal motion automatically as the device rests on the person's back.

Other measurement issues have been associated with documentation of lumbar spine motion. The term *range* of motion implies that two numbers are needed to define a motion such that the first number indicates where the motion starts and the second number indicates where the motion ends. This terminology is consistent with the neutral zero method of notation (Fitzgerald, Wynveen, Rheault, & Rothschild, 1983) that is widely used throughout the world and is supported by the American Academy of

Orthopedic Surgeons (AAOS) and the American Medical Association (AMA). In contrast, lumbar *range* of motion is most often recorded as a single number that represents only the end point of motion. This practice assumes that the start position is zero, yet several researchers have identified this practice as problematic (Coates, McGregor, Beith, & Hughes, 2001; Sullivan, Dickinson, & Troop, 1994). The double inclinometer measurement for lumbar flexion and extension advocated by the AMA Guides uses initial resting posture as the zero reference from which flexion and extension are measured (AMA, 2001) but initial resting posture varies for individuals. For example, one study found that the mean amount of lordosis in the resting posture for women was 31.7° and 24.3° for men when using the *y*-tangent method originally described by Loebl (1967) and measured by Sahrmann, Norton, and Van Dillen (2004). Other sources have reported similar values of resting lordotic posture and similar differences between men and women (Bergenudd, Nilsson, Uden, & Willner, 1989). The difficulty in using initial resting posture as the zero reference is that as a person flexes forward, the lordosis must first be reversed. Because this reversal of lordosis is added to the lumbar range of motion measurement when using the double inclinometer technique, excessive lordosis will artificially increase the flexion range of motion value (Coates et al., 2001). For lumbar extension measurements, an excessive amount of lordosis artificially decreases the extension range of motion measurement since the underlying vertebrae are already in a position of extension (Loebl, 1967; Kondraske, 1995). Sullivan et al. (1984) argued that the true measure of lumbar range of motion in the sagittal plane should not be dependent on the amount of lumbar lordosis present at rest.

Typically, for lumbar range of motion reliability is reported more often than validity, responsiveness, or agreement in studies. Many studies have been performed to determine the reliability of different instruments that measure lumbar ROM. For example, good intra-rater reliability was found by Ng, Richardson, Kippers, & Parnianpour (2001) when using an inclinometer to measure lumbar flexion and extension range of motion reporting $ICC_{3,1}$ values of .87 and .92 respectively. Saur, Ensink, Frese, Seeger, & Hildebrandt (1996) found that although the inclinometer is a valid and reliable instrument to use when measuring lumbar ROM, the inclinometer is more reliable when measuring flexion, $r = .98$, $p < .001$ than extension, $r = .75$, $p < .001$. Few studies on women have investigated the reliability of an electronic inclinometer when measuring lumbar flexion and extension ROM. Additionally, the concurrent validity of an electronic inclinometer with a single bubble inclinometer has not been explored.

The purposes of this methodological study were (a) to determine the intra- and inter-rater reliability of lumbar flexion and extension range of motion measurements taken with an electronic inclinometer and using a method that does not use lumbar lordosis as the zero reference point, and (b) to assess concurrent validity of the electronic inclinometer measurements when compared to measurements taken with a single bubble inclinometer for measuring lumbar flexion and extension range of motion measurements using the same method in women without symptoms.

Women's Injury Study

The Women's Injury study (WIN) is a Web-based surveillance study of physical activity habits and musculoskeletal injuries in women. The objective of the WIN study is

to determine the incidence and predictors of musculoskeletal injuries in free-living women. This information will be used to assess the public health burden of musculoskeletal injuries and to identify risk factors for these injuries. To qualify for the WIN study, women had to be at least 20 years of age and have access to a computer with Internet capabilities. Women were excluded if they had a disease or condition that limited or interfered with their usual daily or recreational activities. Qualified women who voluntarily agreed to participate in the WIN study signed an informed consent in compliance with the Cooper Institute's Review Board and underwent a baseline orthopedic examination by a licensed physical therapist. A methodological study was conducted as part of the larger WIN study that was funded by the National Institute of Arthritis and Musculoskeletal and Skin Diseases. The following describes the methods used in the methodological substudy.

Methods

This methodological substudy was designed to investigate the reliability and validity of the computerized electronic inclinometer BEP VIIa that could be used to quantify lumbar range of motion in research or the clinic.

Participants and Examiners

Participants were a cohort of free-living women who were recruited for the WIN study at the Cooper Institute and Texas Woman's University in Dallas, Texas. Two samples were recruited from the participants who met the inclusion and exclusion criteria for the WIN study. To investigate in the validity study, a sample (39 adult women, M_{age}

= 37.7 years, age range: 21-75 years) and to investigate in the reliability study, a sample (40 adult women, M_{age} = 35.9, age range: 20-75 years) were recruited. All participants provided demographic information and signed informed consents approved by the Institute Review Boards at the Cooper Institute and Texas Woman's University.

Four students from the School of Physical Therapy at Texas Woman's University acted as examiners. Examiner 1 was an experienced licensed physical therapist with several years of clinical experience using the electronic inclinometer to measure spinal ROM. Examiners 2, 3 and 4 were novices (professional entry-level physical therapy students) with no experience using the electronic inclinometer. Before data collection, the novice examiners received approximately 10 hours of training on the use of the electronic and bubble inclinometers using standard test procedures, after which they measured lumbar spinal ROM on 10 volunteers.

Instruments

Height and body weight of each participant were taken using a wall-mounted stadiometer and digital scale, and recorded to the nearest 0.1 cm or kg, respectively. Research has demonstrated that significant errors in calculations may result if based on self-reported values for heights and weights rather than measured values (Kuczmarski, Kuczmarski, Najjar, 2001).

The BEP VIIa, a portable, self-contained electronic inclinometer was used to measure lumbar flexion and extension motions in degrees. The BEP VIIa is a part of the Human Performance Measurement (HPM) system manufactured by Human Performance Measurement, Inc®, Arlington, TX, and is a computer-automated system that integrates a

battery of tests used to evaluate a wide range of sensorimotor functions. The Basic Elements of Performance (BEP) software for Windows ™ (Human Performance Measurement, Inc. ® Arlington, TX) was the operating system for the HPM and allowed recording and storage of the electronic inclinometer data on an IBM compatible notebook computer. Limited research about intra-rater and inter-rater reliability of the BEP VIIa exists. Some researchers have compared the computerized BEP VIIa with its predecessor design model, the non-computerized Cybex Electronic Digital Inclinometer 320 (EDI-320). Mulry's (1999) unpublished research compares intra-rater reliability of the BEP VIIa at $ICC_{3,1}$ = .99 and the EDI-320 at $ICC_{3,1}$ = .97 using a method of lumbar range of motion measurement which does not use lumbar lordosis as the zero reference point, and both devices showed excellent reliability.

The Baseline ™ bubble inclinometer manufactured by Fabrication Enterprise Inc., White Plains, NY, is a portable protractor with a fluid-level indicator, and was used to assess lumbar flexion and extension motion in degrees. The bubble inclinometer's dial scale and fluid meniscus indicate the degrees of motion moved, and the dial scale must be manually aligned properly before and after each measurement. Research by Chiarello and Savidge (1993) comparing the accuracy of the EDI-320 and a fluid-level inclinometer showed no significant differences in measuring spinal motions; however, differences in inter-rater reliability for the devices was noted. Specifically, the fluid inclinometer showed poor reliability for flexion with $ICC_{3,1}$ = .57 in persons without symptoms and moderate reliability for flexion, $ICC_{3,1}$ = .82 and extension, $ICC_{3,1}$ = .86 in persons with symptoms. While the EDI-320 showed moderate reliability for flexion,

$ICC_{3,1}$ = .74 and extension, $ICC_{3,1}$ = .65 in persons without symptoms, it showed moderate reliability for flexion, $ICC_{3,1}$ = .74 and high reliability for extension, $ICC_{3,1}$ = .83 in persons with symptoms. In addition, Chiarello and Savidge (1993) observed that the inter-rater reliability of the fluid goniometer improved with increased tester familiarity with the device. Thus learning and practice effects were postulated.

Measurement Procedures

Height and Weight

For height, weight, and lumbar range of motion measurements, each participant removed her shoes; however, socks could be worn. For the height measurement, the participant stood in front of a ruled vertical board (stadiometer) with her weight equally distributed over both feet. Ideally, the participant's heels, buttocks, scapulae, and posterior aspect of her cranium were in contact with the stadiometer. If the participant was unable to attain this position, she stood with only her heels and buttocks in contact with the stadiometer. Her head was positioned in neutral (neither flexed nor extended) and the participant was asked to look straight ahead. The examiner stood to the side, viewing the participant in the sagittal plane. The participant was instructed to "take a deep breath and hold" as the headboard of the stadiometer was lowered to the most superior point on the head with only enough pressure to compress her hair, then the examiner read and recorded the measurement.

For the body weight measurement, the participant stood motionless with her body weight evenly distributed and centered on the scale platform and was asked to look

straight ahead. Light indoor clothing such as shorts, t-shirt, or hospital gown could be worn during the measurement. The examiner read and recorded the measurement. The measured heights and body weights were used to calculate body mass index , BMI = weight/height^2 for each participant.

Lumbar Extremes of Motion (EOM) Method

The term "extremes of motion" (EOM) rather than "ranges of motion" (ROM) was used to more accurately reflect the measurement method. To minimize the influence of the participant's resting posture, the lumbar flexion angle was measured by placing the device either the electronic or bubble inclinometer on the participant's fully flexed spine. This measurement was defined as flexion extreme of motion (EOM). For the lumbar extension angle, the device was placed on the participant's fully extended spine. This measurement was defined as extension EOM. The use of EOM as opposed to ROM to quantify human motion has been advocated by Kondraske (1995).

The BEP VIIa was calibrated according to manufacturer instructions each day before measuring. The participant was instructed to stand in an upright, relaxed posture with her heels 10 - 15 cm apart, head erect, and eyes focused directly ahead with weight evenly distributed over both feet. Each examiner independently palpated and marked the T12 and S2 spinous processes. The lumbar EOM measurement required four data points which were determined by clicking the BEP VIIa. Sequentially, the examiner aligned the BEP VIIa vertically with the center of the participant's lateral thigh and clicking once established the reference point for the lumbar flexion EOM measurement. Next, the

participant bent forward as far as possible keeping her knees straight as she tried to touch the floor with her hands. When the participant had achieved maximum flexion EOM, the examiner placed the BEP VIIa at the participant's S2 vertebrae and clicked once to continue measuring the lumbar flexion EOM. After that, the examiner placed the BEP VIIa at the participant's T12 vertebrae and clicked once for the end the measurement of the lumbar flexion EOM. Finally, the examiner moved the BEP VIIa in the direction of the motion and clicked one more time to assign the correct direction for flexion lumbar EOM measurement. This procedure was repeated two more trials, and the BEP for Windows software determined the mean of the three measurements. For lumbar extension EOM measurement, the same procedures were used but the examiner instructed the participant to lean back as far as possible while keeping her knees straight.

The specific measurement procedures for the lumbar flexion and extension EOM measurements using the single bubble inclinometer corresponded to measurement procedures used for the BEP VIIa with the following exceptions. The single bubble inclinometer measurement required no calibration before testing and no assignment for the direction of motion at the end of measurement. The values for the initial reference point for the lumbar flexion EOM, point of maximum lumbar flexion EOM at S2 and point of maximum lumbar flexion EOM at T12 were reading from the dial scale of the inclinometer, verbalizing to the recorder who also calculated manually the results. The same procedures were repeated for lumbar extension EOM measurement.

Validity and reliability were assessed by measuring lumbar flexion and extension EOM in women using the BEP VIIa electronic inclinometer and the Baseline™ bubble

inclinometer with the previously described procedures. For validity, two novice student physical therapists acted as examiners and measured both lumbar flexion and extension EOM with both instruments. Each examiner measured each participant with the BEP VIIa first followed by the bubble inclinometer according to the previously described procedures. Between each instrument testing, the participants were given a break of approximately one minute. In addition, when measuring with the bubble inclinometer, each examiner was responsible for reading the device and verbalizing the degrees of lumbar motion which was documented manually by a second person, the recorder. For reliability, two examiners, an experienced physical therapist, Examiner 1 and a novice student physical therapist, Examiner 2, measured both lumbar flexion and extension EOM using only the BEP VIIa electronic inclinometer. To establish intra-reliability, Examiner 1 tested each motion twice, and for inter-rater reliability, Examiner 2 tested each motion once. The Examiners' testing order was randomized. Three tests of three trials of flexion and extension EOM were assessed for each participant per previously described procedures. Between each test, the participants were given a break of approximately one minute.

Data Analysis

Data were analyzed using SPSS version 15 (SPSS Inc, Chicago, IL). Data analysis consisted of appropriate descriptive statistics including but not limited to means and standard deviations (SDs) for the samples. Concurrent validity was assessed using paired t-tests to compare differences in lumbar measurements obtained with the electronic inclinometer and those obtained with the single bubble inclinometer. A

Pearson's (r) correlation coefficient was also calculated. Intra- and inter-rater reliability was assessed using intraclass correlation coefficients (ICCs), standard error of the measurement (*SEM*), confidence intervals (*CI*s). Minimum detectable change ($MDC_{95\%}$ =2.77 x SEM)) were also calculated. For the purpose of describing reliability, ICCs above .75 were considered good reliability; .50 to .75 indicated moderate reliability; and below .50 indicated poor reliability (Portney & Watkins, 2000). All statistical tests of significance were conducted with an alpha level of .05.

Results

Thirty-nine women (M_{age} = 37.7 years, age range: 21-75 years) with mean body mass index of 24.1 participated in the validity study. The mean and standard deviation values for lumbar flexion and extension EOM measurements obtained with the BEP VIIa electronic inclinometer and the single bubble inclinometer are shown in Table 4.1. The results indicate good to excellent associations for lumbar flexion EOM (r = .95, p = .000) and lumbar EOM extension (r = .84, p < .01) measurements obtained with the BEP VIIa electronic inclinometer and those results obtained with the single bubble inclinometer. Furthermore, the results of the paired t-tests revealed no significant differences for lumbar flexion (t = .393, p = .697) and extension (t = -.367, p = .716) EOM measurements for the two instruments. All p-values calculated were greater than .05, indicating no significant differences.

Table 4.1

Lumbar Extremes of Motion (°) (EOM)

	Lumbar Flexion EOM(°) M ± SD	Lumbar Extension EOM(°) M ± SD
Electronic Inclinometer	23.0 ± 9.5	58.0 ± 10.7
Single Bubble Inclinometer	22.8 ± 9.2	58.4 ± 12.4

Note. $n = 39$

Forty women (M_{age} = 35 years, age range: 21-75 years) with mean body mass index of 24.1 participated in the reliability study. Means and standard deviations were calculated for lumbar flexion and extension EOM measurements acquired by each of the two examiners using the BEP VIIa inclinometer and are shown in Table 4.2. The experienced physical therapist was labeled Examiner 1, and the novice student physical therapist was labeled Examiner 2. Intra- and inter-rater reliability, 95 % confidence intervals, *SEM* and $MDC_{95\%}$ values for lumbar flexion and extension EOM measurements were calculated and are shown in Table 4.3.

Table 4.2

Lumbar Extremes of Motion (°) (EOM) using BEP VIIa Electronic Inclinometer

Examiner	Flexion EOM (°) ($M \pm SD$)	Extension EOM (°) ($M \pm SD$)
Examiner1 Trial 1	19.87 ± 7.92	52.52 ± 12.14
Examiner1 Trial 2	19.88 ± 8.22	53.09 ± 11.29
Examiner2 Trial 1	19.46 ± 7.79	55.37 ± 13.49

Note. $n = 40$
Examiner 1 = experienced physical therapist; Examiner 2 = novice student physical therapist

Table 4.3

Intra-rater Reliability and Minimal Detectable Change ($MDC_{95\%}$) for Lumbar Extremes of Motion (EOM) Measurements Using an Electronic Inclinometer

	$ICC_{3,3}$	95% *CI*	*SEM* (°)	$MDC_{95\%}$
Flexion	.97	(.95 - .99)	2.23	6.18
Extension	.94	(.88 - .97)	3.45	9.56

Note. n = 40
CI = confidence interval, *ICC* = intraclass correlation coefficient, *SEM* = standard error of the measurement, *MDC* = minimal detectable change,

Table 4.4

Inter-rater Reliability and Minimal Detectable Change ($MDC_{95\%}$) for Lumbar Extremes of Motion (EOM) using an Electronic Inclinometer

	$ICC_{2,3}$	95% CI	SEM(°)	$MDC_{95\%}$
Flexion	.90	(.81 - .95)	6.46	17.89
Extension	.80	(.58 - .88)	10.09	27.94

Note. $n = 40$
CI = confidence interval, *ICC* = intraclass correlation coefficient, *SEM* = standard error of the measurement, *MDC* = minimal detectable change,

Discussion

This methodological study investigated reliability and validity for an electronic inclinometer (BEP VIIa) that could potentially be used to quantify lumbar motion. The use of the "extremes of motion" (EOM) method while measuring with an inclinometer attempted to minimize the influence of the participant's resting posture during lumbar motion measurement. The type of inclinometer either electronic or mechanical did not have any negative impact on the ability to obtain reliable lumbar motion measurements. This outcome agrees with Chiarello and Savidge (1993) concerning the accuracy of mechanical and electrical inclinometers when measuring lumbar ROM. The results also demonstrate excellent association between lumbar flexion and extension EOM measurements obtained with the electronic inclinometer BEP VIIa and those measurements obtained with the single Baseline™ bubble inclinometer. Thus when using the EOM method, these two instruments may be used interchangeably to assess lumbar flexion and extension EOM measurements.

The intra-rater and inter-rater reliability results for the BEP VIIa demonstrate that this instrument is adequate for clinical measurements using the EOM measurement protocol. Overall, reliability was better when measuring lumbar flexion EOM measurements than extension EOM measurements. The reported intra-rater reliability was excellent (*ICC* > .90) for both lumbar flexion and extension EOM measurements and those same measurements taken by two different examiners resulted in inter-rater reliability that was good (*ICC* > .75). The measurement for lumbar extension EOM had the greatest amount of variability in this study. In addition, the confidence intervals (*CI*) for both intra- and inter-rater reliability lumbar extension EOM measurements are wider than those of the lumbar flexion EOM measurements. These results are similar to those of Saur, Ensink, Frese, Seeger and Hildebrandt (1996) who also determined that the reliability of an inclinometer when measuring lumbar sagittal range of motion was better when measuring flexion than extension.

Not surprisingly, the reported *SEM* values were approximately 30% higher for measurements of lumbar extension than lumbar flexion EOM measurements. The calculated $MDC_{95\%}$ values based on the *SEM* values were 6.18 degrees when measurements were taken by one tester and 9.56 degrees when measurements were taken by different testers for lumbar flexion EOM and 17.8 degrees when measurements were taken by one tester and 27.94 degrees when measurements were taken by different testers for lumbar extension EOM measurements (seeTable 4.4). Thus to be confident that the measured change between two measurements taken by a single tester represents "real" change for lumbar EOM measurements, the amount of change needs to be 6.18 degrees

for lumbar flexion EOM measurement and 17.8 degrees for lumbar extension EOM measurement.. Respectively, for measurements taken between 2 testers, the amount of change would need to be 17.9 degrees for lumbar flexion EOM measurement and 27.94 degrees for lumbar extension EOM measurement to represent "real" change. For extension, this amount of change represents a significant percentage of the range of motion and may be too stringent a threshold to note "real" change. In the current study, the *MDC* was calculated using the traditionally used 95% confidence limits. Therefore these estimates of *MDC* are somewhat conservative and might be considered too large to use as a threshold for deciding that "real" change has occurred. Many researchers have suggested using a value of 1.5 to 2.0 times the *SEM* rather than 2.77 times the *SEM* as a threshold for "real" change (Hopkins, 2000). Several sources of errors may have lead to variability when measuring lumbar motion in this study. Possible sources of error similar to the sources of error discussed by Mayer, Kondraske, Beals, and Gatchel (1997) such as differences in the variability of participants' performance (e.g. endurance, ligament laxity, posture, strength, spinal range of motion, etc) may have affected the measurements. In addition, even though the novice examiners received 10 hours of instruction and measured 10 volunteers, they lacked clinical experience (3 out of 4 examiners were novice in this study) and had limited familiarity with the instruments or with examining participants. These factors might affect the measurements. The lumbar extension EOM measurement exhibited the largest degree of variability and lower reliability which agrees with other spinal ROM research (Mayer et al., 1997; Nitschke et al., 1999). Possibly, more investigation is necessary to determine the factors associated

with this variability such as allowing abnormal substitution with lumbar extension or inconsistent placement of the inclinometer on the sacrum.

The effect of learning must also be taken into account when considering potential test errors. Each participant performed lumbar flexion and extension at least nine times. Participants were able to practice the motions, and their limits of motion may have changed. In addition, as the participants repeated the same movements at least nine times during testing, ligaments and muscles were possibly lengthen as measuring proceeded. This repetition could influence the consistency of measurements.

During the current study, participants with many different body types were measured and women with body mass indices ranging from 11.08 (underweight) to 58.92 (morbid obesity) were included. Measurements may have been inaccurate and inconsistent due to palpation errors since identification of body landmarks on participants with high body mass indices may be inexact (Chakraverty, Pynsent, Westwood, & Chakraverty, 2007).

Conclusions

For adult women, use of EOM instead ROM measurement procedures to assess lumbar flexion and extension motions demonstrated good concurrent validity between the BEP VIIa electronic inclinometer and the single Baseline™ bubble inclinometer. In addition, the BEP VIIa demonstrated acceptable intra-rater and inter-rater reliability for use in clinical or research use. However, detailed measurement procedures when using the inclinometer are necessary to ensure accurate results.

CHAPTER V

ASSOCIATION BETWEEN LUMBAR EXTREMES OF MOTION AND MUSCULOSKELETAL INJURIES IN THE LOW BACK AND HIP IN WOMEN

Physical inactivity is a major health problem in the United States. People of all ages, men or women, can derive health benefits from increased physical activity. Yet, collectively, women are more likely to be physically inactive. Women are less physically active at all ages compared to men (Centers of Disease Control and Prevention [CDC], 1999; Hawkins et al., 2009; O'Sullivan, Campbell & Straker, 2010;Seefeldt, Malina & Clark, 2002; Smith, Whitt, Kumanyika & Bellamy, 2003). Sixty percent of women do not perform the recommended level of physical activity for health benefits and 25% of women are not active at all. Likewise, women are most likely to have more chronic diseases, lower mortality rates, and poorer health outcomes than men (CDC, 1999: Owens, 2008; Gerend & Pai, 2008; Goldberg, Hayes & Huntley, 2004).

The role of health-related physical fitness components such as cardiovascular endurance, muscular strength/endurance, flexibility, and body composition as well as participation in physical activity as potential predictors of musculoskeletal pain and/or injuries requires more scrutiny. Studies of relationships between physical activity, musculoskeletal pain and/or injuries in women are especially needed. Several research studies explore the strength of the relationship between lumbar range of motion and functional disability in workers and persons with chronic low back pain, but these studies

demonstrate conflicting results or weak association (Nattrass, Nitschke, Disler, Chou & Ooi, 1999; Parks, Crichton, Goldford & McGill, 2003; Troke, Moore, Maillardet, Hough & Cheek, 2001). These studies imply limited usefulness for lumbar range of motion measurements in determining disability and/or functional abilities. However, research using evidence-based approaches may uncover relationships between low back motion, self-reported signs, symptoms, and self-reported musculoskeletal pain or injury. Additionally, other researchers have alluded to probable gender-related differences for treatment outcomes (McGeary, Mayer, Gatchel, Anagnostis & Proctor, 2003). Differences in documented injury rates between men and women may be attributable to how the symptoms are reported (Albert, Wingley, McLean & Sleivert, 2006; Bruce, Sims, Miller, Elliot & Ladipo, 2007; Chou et al., 2007; Jindal, Ryan, Sajjad, Murthy & Baines, 2005; McClure, Adams & Dahm, 2005). Specifically, evidence exists of gender differences in pain perception which might help clarify rehabilitation outcome variations (Almeida, Trone, Leone, Shaffer, Patheal, & Long 1999; Unruh, 1996). Furthermore, research indicating that women may be more likely to experience back impairments as well as chronic musculoskeletal pain (Wijnhoven, Vet & Picavet, 2006) draws attention to the need for broader studies on relationships between impairments, physical activity, musculoskeletal pain and/or injury in women.

Much of the current research examines women in athletic or occupational activities rather than focusing on community-dwelling women in health-related physical activities (Franklin, 2000; Larsson, Karlqvist, & Gard, 2008; McClure, Adams, & Dahm, 2005; McGeary et al., 2003). As a result, overall understanding of the potential

connection between back motion and self-reported musculoskeletal injuries in community-dwelling women is limited. The purpose of this study was to quantify the association between measurements of lumbar motion, body mass index, self-reported physical activity, and self-reported history of stiffness with musculoskeletal injuries of the low back and hip among community-dwelling women of different ages and racial groups.

Methods

Participants

Participants were a cohort of 918 community-dwelling women who were recruited for the Women's Injury Study (WIN) in Dallas, Texas at the Cooper Institute in Dallas and the Cooper Institute in Oak Cliff. The women who volunteered and met the inclusion criteria were further assessed for exclusion criteria for the study via telephone. To qualify for the WIN study, women had to be at least 20 years of age and have access to a computer with Internet capabilities. Women were excluded if they needed an assistive device to walk or if they had a disease or condition that limited or interfered with their usual daily or recreational activities. Qualified women who chose to participate signed an informed consent in compliance with the institutional review board at The Cooper Institute and Texas Woman's University and underwent a baseline orthopedic examination by a licensed physical therapist.

Testers were licensed physical therapists who were PhD students from the School of Physical Therapy at Texas Woman's University. Before data collection, the testers

received approximately 8 hours of training and practiced with the electronic inclinometer using standard test procedures.

Measurements

Anthropometric Assessment

Height and body weight of each participant were measured using a wall-mounted stadiometer and digital scale and recorded to the nearest 0.1 cm or kg, respectively. Studies have shown that significant errors in body mass index (BMI) calculations may occur if based on self-reported values for height and weight rather than measured values (Kuczmarski, Kuczmarski & Najjar, 2001). The measured height and body weight were used to calculate body mass index, BMI = weight/height^2 for each participant (Franklin et al., 2000).

Self-Reported Assessment

Self-reported data for musculoskeletal injury (MSI), pain (pain) and stiffness (Stiff) were obtained from the participants' responses on The WIN Orthopedic History Questionnaire (Appendix C) pertaining to symptoms and injury of the low back and hip areas. Operational definitions for the self-reported variables follow. For this study, a *self-reported injury* was operationally defined as an injury which disrupted the participant's usual activities at home, at work or during leisure for at least 2 days or that required medical intervention. For MSI, the participants reported history of musculoskeletal injury relating to onset. A *self-reported history of onset* was defined with three response alternatives: presently have, within the last year, or more than one year. For pain and stiff, a *reported physical symptom* was defined as a symptom which the participant

presently or previously had for at least 14 days with four response alternatives: not applicable, presently have, within the last year or more than a year ago.

Physical Activity Assessment

During the physical activity assessment via phone interview, participants were asked the following questions based on the Behavioral Risk Factor Surveillance System for physical activity to assess moderate and/or vigorous activity: "During the past month, other than your regular job, did you participate in any physical activities or exercise such as running, calisthenics, golf, gardening or walking for exercise?" Answering "yes" to this question resulted in follow-up questions concerning vigorous and moderate physical activities. The follow-up question consisted of the following: "Now, thinking about vigorous physical activities you do in a usual week, do you do *vigorous activities* for at least 10 minutes at a time, such as running, aerobics, heavy yard work, or anything else that causes large increases in breathing or heart rate and would eventually make you strain?"And with equivalent language for *moderate activities* for at least 10 minutes at a time such as brisk walking, bicycling, vacuuming, gardening, or anything else that causes small increases in breathing or heart rate and would not make you strain?" Answering "yes" to either of these questions resulted in a follow-up question requesting the days per week and minutes per day the activity was performed. Consistent with the 2008 Physical Activity (PA) Guidelines for Americans, the accumulated self-reported total minutes of moderate and/or vigorous activity minutes were totaled. Specifically, vigorous minutes were multiplied by 2 and added to moderate minutes for moderate to vigorous PA (MVPA) values (United States Department of Health and Human Services [USDHHS],

2008). Participants accumulating 150+ minutes of MVPA were assigned a value of zero for meeting the recommended PA guideline and those participants who did not meet the recommended PA guideline were assigned value of one.

Lumbar Motion Assessment

For lumbar motion measurements of flexion and extension, an electronic inclinometer was used. The Human Performance Measurement (HPM) system (Human Performance Measurement, Inc®., Arlington, TX), a computer-automated system with an integrated battery of tests was used. The Basic Elements of Performance (BEP) software for Windows ™ (Human Performance Measurement, Inc®., Arlington, TX) was the operating system for the HPM and allowed recording and storage of the electronic inclinometer data on an IBM compatible notebook computer. The BEP VIIa, a portable, computerized, electronic inclinometer that measures joint angles was used to measure lumbar flexion and extension motions in degrees. In our previous methodological sub-study, reliability of the BEP VIIa was established with the same test procedures used in the current study. Intra-rater reliability was calculated for flexion, $ICC_{3,3} = 0.97$ and for extension, $ICC_{3,3} = 0.93$. Inter-rater reliability for flexion, $ICC_{2,3} = 0.90$ and for extension, $ICC_{2,3} = 0.78$ was also determined. A previous chapter in this document describes more details regarding the reliability and validity of the BEP VIIa electronic inclinometer.

Measurement Procedures

Height and Weight

Height and weight measurements were taken first. Each participant removed her shoes; however, socks could be worn. For the height measurement, the participant stood in front of a ruled vertical board (stadiometer) with her weight equally distributed over both feet. If possible, her heels, buttocks, scapulae, and posterior aspect of the cranium were in contact with the vertical board. If the participant was unable to attain this position, she stood with only her heels and buttocks or her cranium in contact with the vertical board. The head was positioned in neutral (neither flexed nor extended) and the participant was asked to look straight ahead. The rater stood to the side, viewing the participant in the sagittal plane. The participant was instructed to "take a deep breath and hold" as the headboard was lowered to the most superior point on the head with only enough pressure to compress the hair, then the rater read and recorded the measurement. For the body weight measurement, the participant stood motionless with her body weight evenly distributed and centered on the scale platform and she was asked to look straight ahead. Light indoor clothing such as shorts, t-shirt, or hospital gown could be worn during the measurement. The rater read and recorded the measurement.

Lumbar Extremes of Motion (EOM) Method

The terms "extremes of motion" (EOM) were used rather than "ranges of motion" (ROM) to more accurately reflect our measurement method. To minimize the influence of the participant's initial resting posture, the lumbar flexion angle was measured by

placing the electronic inclinometer on the participant's fully flexed spine. This measurement was defined as flexion extreme of motion (EOM). For the lumbar extension angle, the inclinometer was placed on the participant's fully extended spine and this measurement was defined as extension EOM. The use of EOM as opposed to ROM to quantify human motion has been advocated by Kondraske (1995).

The BEP VIIa was calibrated according to manufacturer instructions each day before testing. The participant was positioned with her feet 10 - 15 cm apart and instructed to stand with weight evenly distributed in an upright, relaxed posture with eyes focused directly ahead. The rater marked the first sacral vertebra (S1) and the 12th thoracic vertebra (T12) for use in isolating lumbar spine movement. The rater established a reference point for the lumbar flexion EOM measurement by aligning the BEP VIIa vertically with the center of the participant's lateral thigh and clicked once. The rater then instructe the participant to bend forward as far as possible keeping her knees straight as she tried to touch the floor with her hands. When the participant had achieved maximum flexion EOM, the rater placed the BEP VIIa at her S1 vertebrae and clicked once. Next, the examiner placed the BEP VIIa at the participant's T12 vertebrae and clicked once to end the measuring of the lumbar flexion extreme of motion. Finally, the rater moved the BEP VIIa in the direction of the motion and clicked one more time to assign the correct direction for flexion lumbar EOM measurement. The procedure was repeated two more trials and the BEP for Windows software calculated and displayed the mean of the three measurements. The described procedures for measuring lumbar flexion EOM resulted in a compound measurement for gross lumbar flexion EOM, pelvis (hip)

contribution, and true lumbar flexion EOM. For lumbar extension EOM, the same procedures stated above were used; however, the rater instructed the participant to lean back as far as possible keeping her knees straight.

Data Analysis

Data analysis consisted of appropriate descriptive statistics including means and standard deviations (SDs) for the sample. Correlation analysis was performed to insure that the selected variables were independent of each other for the logistic regression analysis. After descriptive and correlational statistics were produced, univariate logistic regression followed by multivariate analyses were performed to estimate the crude and adjusted odds ratio (*OR*) with 95% confidence intervals (CI) for risk of self-reported MSI using the predictor variables - age, race, lumbar flexion (in quintiles), lumbar extension (in quintiles), body mass index, moderate to vigorous physical activity and history of stiffness. All statistical tests of significance were conducted at an alpha level of 0.05. Data were analyzed using SPSS version 15 (SPSS Inc, Chicago, IL).

Results

A total of 918 community dwelling adult women were tested. Of these women, seven participants' had incomplete data so were excluded from analysis. Our final cohort of 911 women (707 Caucasian, 162 African-American, 12 Asian, six Native-American, one Native-Hawaiian, 23 Other Race, M_{age} = 53.1 years, age range: 20-82 years, M_{BMI} = 27.6, BMI range: 16.72-67.15). The baseline characteristics of participants are presented in Table 5.1 by M and SD, frequencies and stratified by with or without musculoskeletal injury (MSI) at baseline. Although, race was considered a predictor variable, our sample

was primarily representative of White/Caucasians and Black/African-Americans; the other racial groups were too small to be able to draw inferences. Lumbar flexion and extension EOM measurements were divided into five equal parts creating quintiles. Each quintile represents $1/5^{th}$ or 20% of the measurements. The first quintile (Q1) represents the 20% of women with the lowest amount of lumbar flexion and extension motion while the fifth quintile (Q5) represents the 20% of women with the highest amount of lumbar flexion and extension motion. Forty percent of the participants were categorized as having normal BMI at 18.5 to 24.9 or underweight BMI at less than 18.5 while 59% were categorized as having overweight BMI at 24.9 to 29.9 or obese BMI at greater than or equal to 30. For moderate to vigorous physical activity (MVPA) values, these were calculated for the participants by using the formula two multiplied by the number of vigorous minutes of PA then adding the number of moderate minutes of PA where meeting recommended PA guidelines meaning MVPA was equal to or greater than 150 minutes; otherwise, MVPA was less than 150 minutes meaning not meeting recommend PA guidelines. Results for MVPA based on the total participants, 33% of the women were categorized as meeting the recommended PA guidelines while 67% of the women did not meet the recommended PA guidelines. Additionally, for those participants who met the recommended PA guidelines, 52 % of these women reported having a history of MSI and 48% of the remaining women reported having no history of MSI. In contrast, for those participants who did not meet the recommended PA guidelines, 50% reported having a history of MSI and 50% of the remaining women reported having no history of

MSI. Lastly, 74% of the participants reported having a history of stiffness and MSI and 26% of the participants reported having no history of stiffness and MSI.

Table 5.1

Participants Descriptives ($M \pm SD$) and Frequencies Stratified by Musculoskeletal Injury (MSI) at Baseline

Variable	$M \pm SD$ $n = 911$	Number of Cases No MSI n=448 (%)	Number of cases MSI n=463 (%)
Age (yr)	53.05 ± 12.3	NA	NA
Race	**White/Caucasian**	340(76)	367(79)
	Black/African-American	88(20)	74(16)
	Other	20(4)	22(5)
Lumbar Flexion (°)	15.65 ± 10.63		
Q1		81(18)	100(22)
Q2		88(20)	94(20)
Q3		101(22)	82(17)
Q4		85(19)	98(22)
Q5		93(21)	89(19)
Lumbar Extension(°)	53.07 ± 12.93		
Q1		93(21)	88(19)
Q2		84(19)	99(22)
Q3		89(20)	94(20)
Q4		90(20)	92(20)
Q5		92(20)	90(19)

(continued)

Table 5.1

Participants Descriptives (M ± SD) and Frequencies Stratified by Musculoskeletal Injury (MSI) at Baseline (continued)

Variable	*M* ± *SD* *n* = 911	Number of Cases No MSI n=448 (%)	Number of cases MSI n=463 (%)
BMI (kg/m^2)	27.60 ± 6.20		
Normal BMI 18.5 – 24.9		171(37)	178(38)
Underweight BMI <18.5		7(1)	6(1)
Overweight BMI 25 – 29.9		148(35)	146(32)
Obese BMI > 30		122(27)	133(19)
MVPA			
Met (≥ 150 minutes of MVPA/week)	0	144(32)	155(33)
Did not meet (<150 minutes of MVPA/week)	1	304(68)	308(67)
Stiffness			
No stiff	0	342(76)	162(35)
Stiff	1	106(24)	301(65)

Note. Reference group **boldface,** Q=quintile, Q1 = lowest lumbar motion, Q5 = highest lumbar motion, BMI = body mass index, MVPA = moderate to vigorous physical activity, MVPA = minutes of moderate PA + 2 * minutes of vigorous PA, Stiffness = self-reported history of stiffness.

Table 5.2 shows the intercorrelation matrix for the outcome and predictor variables and provides an overview of the data. The outcome variable, musculoskeletal injury, MSI (variable 1), and the predictor variables (variables 2-8) are listed. Initial results of the correlation analysis revealed that several predictor variables had high

degree of association, meaning, $r = .5$ or higher. A high degree of association was found between the self-reported symptoms variables for pain, duration and recurrence; therefore, they were removed from consideration for the logistic regression analysis. Similarly, the variable, Gross Lumbar Flexion + Extension (i.e., a variable created by adding the lumbar EOM of flexion and extension) was removed based on a high degree of association with the variables, lumbar flexion and extension. The correlation coefficients for all the pairs of variables (variables 1-8) vary from absolute values of .007 to .416, indicating little or no relationship to a fair degree of relationship (Portney & Wakins, 2000). The variable MVPA shows the weakest association and the variable Stiff shows the strongest association with MSI.

Table 5.2

Intercorrelations of Associated Factors for Self-Reported Musculoskeletal Injury (MSI)

Variable	1	2	3	4	5	6	7	8
1 MSI	1.000	.06	-.029	.016	-.085**	-.025**	-.014	.416**
2 Age		1.000	-.201**	.019	-.304**	-.336**	-.146**	.067*
3 Race			1.000	.177**	.005	.144**	.012	-.069*
4 BMI				1.000	-.295**	.181**	-.183**	.063
5 Lumbar Flexion					1.000	.043	.159**	-.044
6 Lumbar Extension						1.000	.045	-.008
7 MVPA							1.000	-.007
8 Stiff								1.000

Note. MSI = self-reported musculoskeletal injury; BMI = body mass index; MVPA = moderate to vigorous physical activity; Stiff = self-reported history of stiffness
*Correlation significant at the 0.05 level (2-tailed).
**Correlation significant at the 0.01 level (2-tailed).

Univariate logistic regression models were used to analyze the association between the predictor variables, age, race, quintiles of lumbar flexion and extension EOM, BMI, MVPA and Stiff and the outcome variable, MSI. Results demonstrated that the only significant univariate predictor variables that related to increased likelihood of MSI was the third quintile (Q3) of lumbar flexion EOM (OR = 0.66, 95% CI = [0.44 - .99], p = .05) and Stiff (OR = 5.9, 95% CI = [4.5 - 8.0], p =.001). That is, women in the 3rd quintile (middle quintile for medium amount of lumbar flexion EOM) for lumbar

flexion EOM were 34% less likely than women in the 1st quintile (lowest quintile for least amount of lumbar flexion EOM) to report a MSI. In addition, women who self-reported stiffness were nearly 6 times more likely to have had a MSI than women who did not self-report stiffness.

Further analysis of the predictor variables and MSI based on lumbar quintiles of EOM while controlling for race, age, BMI and physical activity are presented in Table 5.3. The multivariate logistic regression showed that once multiple factors are controlled for, having less or more lumbar flexion EOM did not significantly reduce the likelihood of having a MSI (*OR* = 0.68, 95% *CI* [0.43 – 1.1]). Although the women in the 3rd quintile for lumbar flexion EOM were still less likely to have reported a MSI than women in the 1st quintile when controlling for multiple factors, the reduced likelihood did not meet statistical significance. Conversely, stiffness was still a significant predictor of MSI even after controlling for other factors.

Table 5.3

Multivariate Logistic Regression Model Predicting Self-Reported Musculoskeletal Injury (MSI)

		95% CI for Odds Ratio		
Variable Name	Odds Ratio	Lower	Upper	P value*
Age	1.1	0.99	1.0	.37
Race	1.1	0.79	1.4	.74
Lumbar Flexion				
Q1	Referent			.41
Q2	1.0	0.63	1.6	.98
Q3	0.68	0.43	1.1	.11
Q4	0.93	0.58	1.5	.77
Q5	0.79	0.48	1.3	.36
Lumbar Extension				
Q1	Referent			.37
Q2	1.6	1.0	2.4	.05
Q3	1.1	.69	1.7	.70
Q4	1.3	.78	2.0	.35
Q5	1.2	.75	2.0	.82
BMI	1.0	.98	1.0	.58
MVPA	0.96	0.67	1.3	.79
Stiff	6.2	4.6	8.3	.001*

Note. Q = Quintile, Q1= lowest lumbar motion, Q5 = highest lumbar motion, BMI = body mass index, MVPA = moderate to vigorous physical activity, Stiff = history of stiffness

*$p < .05$

Discussion

This study investigated the association between lumbar extremes of motion (EOM), body mass index (BMI), self-reported histories of physical activity (MVPA), and stiffness (Stiff) with musculoskeletal injury (MSI) of the low back and hip in community-dwelling women of different ages and racial groups. Overall, univariate analyses

revealed that the majority of the predictor variables were not significantly associated with MSI. The univariate analyses showed that only two of seven predictor variables were significantly associated with MSI, i.e., the third quintile (Q3) for lumbar flexion EOM and stiffness (Stiff). Furthermore, for the variable Stiff, this outcome is strongly supported by its fair correlation coefficient of $r = .416$, $p = .01$.with MSI.

The values for lumbar range of motion (i.e., EOM) measurements were reliable and comparable to values attained in the study by Troke et al. (2001) who also used a computerized electronic goniometer (i.e., modified CA6000 Spine Motion Analyzer) but a different protocol to determine range of motion measurements of the lumbar spine based on age and gender. The univariate and multivariate results of the current study showed no significant association between lumbar EOM and physical activity with MSI which supports other research studies concluding weak or little to no association between lumbar range of motion measurements and functional abilities or impairments for persons with or without disease (Parks et al., 2003; Nattrass et al., 1999). However, neither of these studies, specifically, explored the association between lumbar motion and musculoskeletal injury as we attempted.

In the current study, a significant association was found between self-reported stiffness (Stiff) and MSI even after controlling for multiple factors. Although not statistically significant, women in the 3rd quintile of lumbar flexion (more flexion) were 32% less likely to self-report an MSI than those women in the 1st quintile of lumbar flexion. These results would suggest that stiffness is predictive for MSI but lumbar EOM is not predictive for MSI. These muscle characteristics, stiffness and range of motion, are

clinically important and can be measured in either, objective and subjective terms. For this research, stiffness was measured subjectively by self-reported measures in general terms while EOM was measured objectively by direct measure with specific protocols. Several researchers have explored these muscle characteristics of stiffness and range of motion (Chesworth & Vandervoot, 1995; Hoge et al., 2010; Lineker, Badley, Charles, Hart, & Streiner, 1999; Ryan et al., 2008). For instance, Chesworth & Vandervoort (1995) examined passive stiffness in ankles to quantify joint stiffness using a strain gauge and potentiometer. These researchers were able to objectively and even graph the joint function and stiffness and note energy losses with motion. While Lineker et al, (1999) uses a classification system for morning stiffness for rheumatoid arthritis patients with the goal to become more patient-centered. The current research may have benefitted from the results of either of these studies because the researchers made efforts to differentiate their "stiffness". In the current study, the classification or description of stiff should have be more precise of stiffness from the participant and researcher viewpoints. In addition, Hoge et al., (2010) implies that gender differences may affectd how women respond to ovement or stiffness. . Therefore, this factor might be a concern in the current study.

In the preliminary correlation analysis, self-reported pain and self-reported stiffness data were highly correlated implying potential redundancy in the data as reported, so only one of these self-reported variables could be used in the logistic regression models. Possibly the participants had different perceptions of what stiffness meant. This study had participants with high lumbar motion with history of stiffness as

well as participants with low lumbar motion with history of stiffness. For our study, the two phenomenons were not associated. Stiffness can be defined as "slowness or difficulty moving joints..." (Lineker et al., 1999) and may possibly may hint at an underlying basis of the link between pain and/or stiffness for these participants.

This study has several limitations. First, the study design was cross-sectional and observational; therefore no cause and effect conclusions can be made. However, if the same associations between stiffness and MSI are consistently observed in future studies then stiffness may be considered an associated factor for a woman to have a self-reported MSI. Second, in this study the participants were volunteers in the WIN study and could have been different than other women with similar characteristics. Third, some of the key predictor variables were determined solely on self-reported data such as physical activity (MVPA), history of stiffness (Stiff) and the outcome variable, self-reported musculoskeletal injury (MSI). Research on self-reported measures make known that persons tend to report what they believe the researcher expects to see and reflect positively on their own abilities such as over-reporting (Cook & Campbell, 1979). Using questionnaires may have been the only feasible method to assess the key predictor variables in this large population. The physical activity questionnaire used in our study was based the Behavioral Risk Factor Surveillance System with proven psychometric properties; but more often, questionnaires such as the WIN Ortho questionnaire do not have well established psychometric properties. The study results can only be generalized to populations of similar demographics and baseline characteristics.

Despite these limitations, the results show a positive association between Stiff and MSI. Specifically, a woman with a history of stiffness is 6 times more likely to self-report a musculoskeletal injury of the low back and hip regardless of her baseline lumbar extremes of motion. Future research should explore potential parameters of stiffness, causal relationships between these parameters of stiffness and musculoskeletal injury in longitudinal studies. Additionally, the objective to develop early stiffness interventions may potentially decrease the occurrence of musculoskeletal injury for these women.

Conclusion

Women with history of stiffness are 6 times more likely to self-report a musculoskeletal injury of the low back and hip. This finding is clinically significant because the results of the study suggest that in the absence of reduced lumbar range of motion women with the symptom of stiffness will more likely report a musculoskeletal injury. Therapeutic interventions designed to address stiffness early may aid in decreasing or potentially preventing the occurrence of MSI of the low back and hip for women of comparable characteristics.

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APPENDIX A

Institutional Review Board (IRB) Approval Letters

The Cooper Institute
12330 Preston Road, Dallas, Texas 75230
972.341.3200 • www.cooperinst.org

KENNETH H. COOPER, M.D., M.P.H.
Chairman of the Board

STEVEN N. BLAIR, P.E.D.
President and Chief Executive Officer

TERRY E. ADDIS, DrPH
Vice President and Chief Operating Officer

June 7, 2006

Michael LaMonte
Steven Blair
The Cooper Institute

Re: Women's Exercise Injuries: Incidence and Risk Factors
Approval # 06-15

Dear Mike / Steve:

This letter serves to certify that the IRB gave approval to the above referenced study. Staff are cautioned to ensure participants are aware of the extended dates (5 yrs) on the Health Record Release form. Questions were asked about the medical history length—should take no more than 60 min to complete, and about the internet access—about 70% across all cultures. Staff are asked to reconsider the requirement that participants not move from Dallas during the study; since reporting via internet, could it not be done from any location?

If there are changes from the approved materials, any surveys, recruitment materials, and other study materials must be presented to the IRB for final approval when finalized.

Please remember that you must obtain consent from all participants, provide the participants with a copy of the consent form, and notify the IRB immediately if the protocol changes in any way.

This study will be due for annual review before June 6, 2007.

Please contact me at sfarrell@cooperinst.org or 972 341 3275 or Melba Morrow, Vice President, Research Administration at mmorrow@cooperinst.org or 972 341 3247 if there are questions.

Sincerely,

Stephen Farrell, PhD
Chair, Institutional Review Board

The Cooper Institute
501(c)(3)

KENNETH H. COOPER, M.D., M.P.H.
Chairman of the Board

April 7, 2009

James Morrow
The Cooper Institute and the University of North Texas

Re: WIN: Women Exercise Injuries: Incidence and Risk Factors
Approval # 09-04

Dear Dr. Morrow:

This letter certifies that the above-referenced study was granted continued approval at the IRB meeting of April 06, 2009. The IRB applauds the completion of the recruitment and the excellent adherence rate (>750 women actively participating). You are also commended for the many presentations and papers that have been submitted.

Please remember this study will be due for the next annual review by April 06, 2010, and that any changes to the protocol must be submitted to the IRB for review before implementation.

Please contact me at sfarrell@cooperinst.org or Melba Morrow at mmorrow@cooperinst.org or 972 341 3247 if there are questions.

Sincerely,

Steve Farrell

Stephen Farrell, PhD
Chair, Institutional Review Board

12330 Preston Road, Dallas, Texas 75230
800-635-7050/972-341-3200 Oak Cliff Center 214-330-9165 www.cooperinstitute.org

APPENDIX B

The Win Study Protected Health Information Form

THE WIN STUDY

Authorization to Release Protected Health Information (PHI) for Research

Participant Name _____
Print Name

Date of Birth _____ WIN ID: _____

From today until the end of this study in 2011, I authorize the release of my medical records (as indicated below) to the Women's Injury Study (WIN) at the Cooper Institute in Dallas, Texas. These records are for **research purposes,** and will remain strictly confidential. I authorize a **photocopy or facsimile** of this release form to be acceptable and valid. I understand that I may revoke this authorization at any time by providing a written request to The Cooper Institute. I understand that once this information is disclosed, it may be redisclosed by the recipient and the information may not be protected by federal privacy laws or regulations. My request to release these records to THE WIN STUDY will have no impact on the releasing facility's provision of care to me.

Completed By WIN Study Staff

The records to be released are for the date _____to _____ for the diagnosis or treatment of _____.

____Face Sheet/Attestation with ICD codes
____Admitting History & Physical Exam
____Emergency Room Report
____Radiology Reports (including CT, MRI)
____Discharge Summary
____Consult (specify _____)
____Operative Reports
____Other _____

This information is to be **obtained from** (specific name and organization):_____
Address*:_____
Fax number:_____ Phone number:_____
For the purpose of: _THE WIN STUDY_____

_____
Signature of Participant or Legally Authorized Representative Date

_____
Signature of Participant's Witness Date

Health Information Department: Mail records to:

THE WIN STUDY
c/o Dr. James R. Morrow, Jr. (Principal Investigator)
The Cooper Institute
Division of Epidemiology
12330 Preston Road
Dallas, TX 75230

Please contact Tiffany Gearhart, Assistant Project Manager at 972-716-7041 or email THEWINSTUDY@cooperinst.org with any questions about this request.

APPENDIX C

The WIN Study Orthopedic History Questionnaire

47628

Subject Name _____

Today's date ☐☐ / ☐☐ / ☐☐☐☐

Orthopedic History Questionnaire

Part I: HISTORY OF SYMPTOMS: Please select from the list below any body part(s) for which you presently have or have previously had any physical symptoms that lasted for at least 14 days:

a. Head

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

b. Jaw

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

c. Neck

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

d. Shoulder

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

QC	DE	Verification

Participant ID ☐☐☐☐☐☐☐☐ **staff code** ☐☐☐

47628

e. Upper Arm

O Pain	O Presently have	O Within the last year	O More than a year ago
O Joint Stiffness	O Presently have	O Within the last year	O More than a year ago
O Numbness/Tingling	O Presently have	O Within the last year	O More than a year ago
O Weakness	O Presently have	O Within the last year	O More than a year ago

f. Elbow

O Pain	O Presently have	O Within the last year	O More than a year ago
O Joint Stiffness	O Presently have	O Within the last year	O More than a year ago
O Numbness/Tingling	O Presently have	O Within the last year	O More than a year ago
O Weakness	O Presently have	O Within the last year	O More than a year ago

g. Lower Arm

O Pain	O Presently have	O Within the last year	O More than a year ago
O Joint Stiffness	O Presently have	O Within the last year	O More than a year ago
O Numbness/Tingling	O Presently have	O Within the last year	O More than a year ago
O Weakness	O Presently have	O Within the last year	O More than a year ago

h. Wrist

O Pain	O Presently have	O Within the last year	O More than a year ago
O Joint Stiffness	O Presently have	O Within the last year	O More than a year ago
O Numbness/Tingling	O Presently have	O Within the last year	O More than a year ago
O Weakness	O Presently have	O Within the last year	O More than a year ago

i. Hand/Fingers

O Pain	O Presently have	O Within the last year	O More than a year ago
O Joint Stiffness	O Presently have	O Within the last year	O More than a year ago
O Numbness/Tingling	O Presently have	O Within the last year	O More than a year ago
O Weakness	O Presently have	O Within the last year	O More than a year ago

j. Abdomen

O Pain	O Presently have	O Within the last year	O More than a year ago
O Joint Stiffness	O Presently have	O Within the last year	O More than a year ago
O Numbness/Tingling	O Presently have	O Within the last year	O More than a year ago
O Weakness	O Presently have	O Within the last year	O More than a year ago

k. Low Back

O Pain	O Presently have	O Within the last year	O More than a year ago
O Joint Stiffness	O Presently have	O Within the last year	O More than a year ago
O Numbness/Tingling	O Presently have	O Within the last year	O More than a year ago
O Weakness	O Presently have	O Within the last year	O More than a year ago

Participant ID | | | | | | | | |

47628

l. Hip Pelvis

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

m. Upper Leg

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

n. Knee

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

o. Lower Leg

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

p. Ankle

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

q. Foot/Toes

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

r. Other

○ Pain	○ Presently have	○ Within the last year	○ More than a year ago
○ Joint Stiffness	○ Presently have	○ Within the last year	○ More than a year ago
○ Numbness/Tingling	○ Presently have	○ Within the last year	○ More than a year ago
○ Weakness	○ Presently have	○ Within the last year	○ More than a year ago

Participant ID | | | | | | | | | |

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Part II: INJURY HISTORY: Injured body part where the injury disrupted your usual activities at home, at work, or during leisure-time for at least 2 days or required medical intervention. For each injured body part , please mark the onset, duration, and injury recurrence.

a. Head Injury

a1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

a2. Duration ○ Less than or equal to 3 months ○ More than 3 months

a3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

b. Jaw Injury

b1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

b2. Duration ○ Less than or equal to 3 months ○ More than 3 months

b3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

c. Neck Injury

c1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

c2. Duration ○ Less than or equal to 3 months ○ More than 3 months

c3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

d. Shoulder Injury

d1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

d2. Duration ○ Less than or equal to 3 months ○ More than 3 months

d3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

e. Upper Arm Injury

e1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

e2. Duration ○ Less than or equal to 3 months ○ More than 3 months

e3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

f. Elbow Injury

f1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

f2. Duration ○ Less than or equal to 3 months ○ More than 3 months

f3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

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g. Lower Arm Injury

g1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

g2. Duration ○ Less than or equal to 3 months ○ More than 3 months

g3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

h. Wrist Injury

h1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

h2. Duration ○ Less than or equal to 3 months ○ More than 3 months

h3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

i. Hand/Fingers Injury

i1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

i2. Duration ○ Less than or equal to 3 months ○ More than 3 months

i3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

j. Abdomen Injury

j1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

j2. Duration ○ Less than or equal to 3 months ○ More than 3 months

j3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

k. Low Back Injury

k1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

k2. Duration ○ Less than or equal to 3 months ○ More than 3 months

k3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

l. Hip Pelvis Injury

l1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

l2. Duration ○ Less than or equal to 3 months ○ More than 3 months

l3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

m. Upper Leg Injury

m1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

m2. Duration ○ Less than or equal to 3 months ○ More than 3 months

m3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

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n. **Knee Injury**

n1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

n2. Duration ○ Less than or equal to 3 months ○ More than 3 months

n3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

o. **Lower Leg Injury**

o1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

o2. Duration ○ Less than or equal to 3 months ○ More than 3 months

o3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

p. **Ankle Injury**

p1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

p2. Duration ○ Less than or equal to 3 months ○ More than 3 months

p3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

q. **Foot/Toes Injury**

q1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

q2. Duration ○ Less than or equal to 3 months ○ More than 3 months

q3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

r. **Other Injury**

r1. Onset ○ Presently have ○ Within the last year ○ More than a year ago

r2. Duration ○ Less than or equal to 3 months ○ More than 3 months

r3. how many times the injury recurred

○ 0 ○ 1 ○ 2 ○ More than 2 times

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Part III: INJURY TREATMENT and DIAGNOSIS

Did you seek medical treatment for any of the above injuries?

○ Yes ○ No

If yes, what did the healthcare provider diagnose? (Please mark all that apply.)

○ Fracture
○ Bone bruise (contusion)
○ Ligament sprain or tear
○ Dislocation/subluxation
○ Ligament instability
○ Meniscal injury (torn cartilage)
○ Chondral injury
○ Osteochondral injury
○ Muscle strain, tear, or pull
○ Muscle bruise (contusion)
○ Tendinitis
○ Tendon rupture
○ Tenosynovisitis
○ Plica syndrome
○ Plantar fasciitis
○ Bursitis
○ Nerve entrapment
○ Nerve compression (pinched nerve)
○ Nerve injury
○ Disc protrusion or herniation
○ Carpal tunnel syndrome
○ Compartment syndrome
○ Frozen shoulder
○ Fibromyalgia
○ Groin pull
○ Heel spur
○ IT Band syndrome
○ Jumper's knee
○ Osgood Schlotter's Disease
○ Rotator cuff syndrome
○ Shin splints
○ Tennis elbow or Golfer's elbow
○ Thoracic outlet syndrome
○ Turf toe
○ Other

Was surgery performed?

○ Yes ○ No

Have you had a joint replacement?

○ Yes ○ No

If **yes**, which joints?

○ Shoulder ○ Hip ○ Knee ○ Ankle ○ Other

Thank you for your time and your interest in the WIN Study!

Participant ID | | | | | | | | |

APPENDIX D

Photographs of Inclinometers

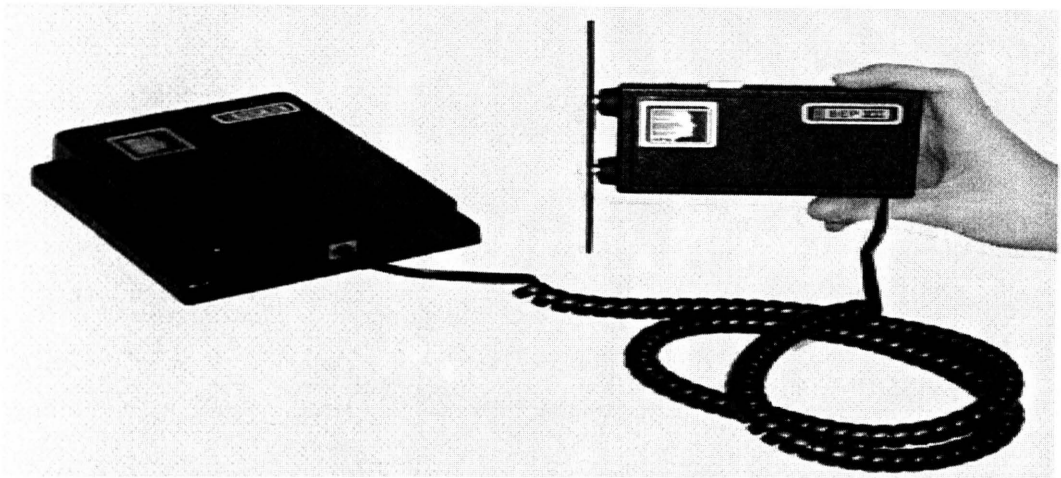

Figure 1. Model BEP VII is a modular system designed to measure extremes and ranges of motion for most joints of the human body. For lumbar flexion and extension will be used without guide bar attachment. (Human Performance Measurement, Inc., 2715 Ave E East, Suite 614, Arlington, TX 76011)

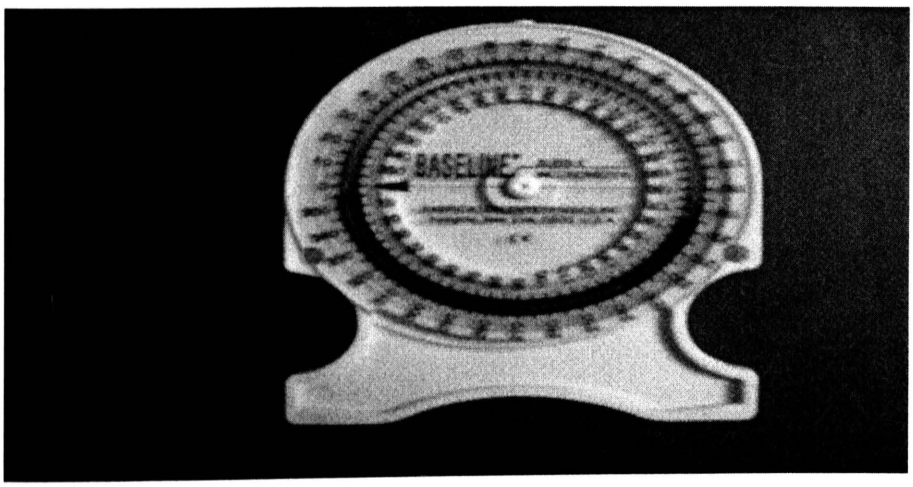

Figure 2. Baseline™ Bubble Inclinometer. A portable protractor with a fluid-level indicator used to assess lumbar flexion and extension motion in degrees.
(Fabrication Enterprise Inc., White Plains, NY)