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Risk Factors for Low Back Pain in Recreational Distance Runners

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By

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Nova Southeastern University
College of Health Care Sciences
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December 31, 2016

We hereby certify that this dissertation, submitted by Jonathan E. Gallas, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirement for the degree of Doctor of Philosophy in Physical Therapy

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Purpose. The purpose of this study was to examine differences between runners with and without low back pain and a control group of non-runners in demographic, physical/running, and LBP variables. **Subjects.** This study included 102 subjects in three groups. Subjects, 18 to 55 years old, were from a running store, sports club, and physical therapy clinics in Rockford, IL. **Methods.** A pilot study of ten runners with LBP was conducted prior to data collection to assess testers' reliability. One hundred and twelve runners, with or without LBP, who run 20-30km/wk for at least one year were recruited. Runners with LBP are defined as one with a current episode of LBP for 2 weeks but less than 6 months. Subjects completed the informed consent form and demographic and training variable questionnaire prior to data collection. This study utilized demographic and physical/running variable data. Additional data was obtained on lumbar flexion/extension AROM, Biering-Sorensen test, passive lumbar extension test, right and left side bridge, and the Beighton Scale. An ANOVA test was performed to assess for group differences. T-tests, Mann Whitney U, and Chi square tests were conducted to determine differences among running groups. **Results.** Significant differences were found in the side bridge test between the control group and both running groups, Biering-Sorensen test between the control and runners without LBP, and BMI between the control and runners with LBP. Group differences were found between runners with and without LBP in days/wk, rest days/wk, years run, and marathons run. Group difference were also found in km/wk of running and age among running groups. **Discussion.** Further research is needed in runners with LBP to determine why they were able to run more miles, take less rest days, run more marathons, and more years. Future studies should address the characteristics of runners that allowed them to demonstrate greater trunk muscle endurance and core muscle stability and be prospective and longitudinal in nature. **Key Words.** low back pain, recreational distance runner.

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CHAPTER 1: INTRODUCTION

Chapter 1 discusses the relationship of distance running and low back pain (LBP). Specific risk factors of distance running and LBP are also discussed. A statement of the problem to be investigated and the purpose of this research study are provided. The relevance, significance, and need for this research study are discussed. Research questions are identified, and appropriate operational definitions of important terms related to this research study are provided, followed by a summary of the chapter.

The popularity of distance running in the United States is evidenced by the more than 19 million Americans who participated in running events in 2013.[1] Distance running has been growing in popularity since the 1980s. The most popular distance is the half marathon, whose participation has grown by 75% from 2006-2012.[2] In 2013 two million runners completed half marathons.[2] The One America 500 Festival was the most popular half-marathon in the U.S. with over 30,000 participants. Of the race's finishers, 57% were female, and 43% were male.[2] Second in popularity to the half marathon is the marathon. For instance, participation in the Boston Marathon has grown by almost 14,000 participants from 1998-2008.[3] With over 50,000 participants, the New York marathon is the most popular marathon in the United States.[1,2] Marathon participants grew by 40% from 2003-2013. There were 143,000 marathon finishers in 1980 and 541,000 finishers in 2013.[2]

The growth in participation is due primarily to increased awareness of the health benefits attributed to aerobic exercise. In a descriptive study, Roncarati et al reported that distance running has become more popular because runners achieve a sense of pride in their accomplishment.[4] This rise in popularity of distance running led to an increased incidence of LBP in runners.[5]

Low Back Pain

LBP ranks among the most common musculoskeletal injuries in the general population. In the United States, LBP affects over 74 million people per year,[6] and results in over 5 million dollars per year of medical costs.[5] Lifetime incidence of LBP in the general population falls between 60% and 90%.[7-11] Most LBP episodes subside in 2-4 weeks.[12] Subjects with LBP may have referred pain to the buttocks or legs and/or loss of sensory perception in the legs.[5] LBP is a common cause of injury in athletes.[13-15] Estimates of the lifetime incidence of LBP in runners reported in the literature are as high as 75%.[8,9,11,16] It has also been reported that runners experiencing LBP have had prior episodes of LBP.[17]

Relevance, Significance, and Need

A distance runner is defined as a person who runs a minimum distance of 16-30 km per week for a minimum of three months to one year.[18,19] Distance running has become the sport of choice for both men and women because of its convenience, health benefits, and economical nature.[20,21] Previous research showed that running was identified as a long-term protective factor against cardiovascular diseases such as heart attacks and strokes,[4,22,23] obesity,[24] and other chronic diseases.[25-28] Additional research showed that running demonstrated improved mental health due to cognitive changes that take place in the brain.[29] Running resulted in decreased depression and anxiety, and an improved sense of recognition and self-identity, coping strategies, and a positive self-image.[30] Further research identified that running resulted in better weight control, cessation of smoking, and improved energy levels.[24,31]

A few researchers had addressed the forces absorbed by the spine during running in athletics.[32-37] Garbutt et al reported that compressive loading of the spine was unavoidable in running.[33] Brody reported that depending on stride length the feet strike the ground 800-2000 times per mile.[38] Impact forces from running can vary from 1.5 to 6 times a runner's bodyweight, particularly at heel strike.[39-43] Langer stated that "an average 68 kg runner competing in a marathon absorbs several million pounds of impact."[44] With such high loads being projected to the lumbar spine on a repetitive basis, it is not surprising that LBP would occur in distance runners.[45] The low back was identified as one of the most common sites for injury in runners.[21,46] Ten percent of recreational distance runners experienced LBP during their first year of running,[46,47] similar to the general population of non-runners which demonstrated a one year incidence of LBP ranging between 6% and 15%.[48-51] However, differences in recurrence rates of LBP between runners and non-runners were significantly different.[6,52,53] Lewis and Roncarati and McMullen identified recurrence rates of LBP in athletes including runners ranging from 41% to 85%.[5,6]

Running injuries are more common in women than men.[14,54-56] Females with an increased BMI demonstrated a greater prevalence of LBP in the general population of non-runners.[57,58] In contrast, female athletes including runners with lower BMI were more susceptible to LBP.[14,54-56] Sixty percent of runners reported that they had an insidious onset of LBP.[59] Twenty-three percent of distance runners were unable to run because of their LBP. Forty-two percent of runners reported that LBP prevented them from achieving their full running potential,[5] thereby preventing them from receiving the health benefits associated with running such as decreased obesity, lower heart disease risk, decreased depression and anxiety, improved sense of recognition, self-identity and coping strategies, smoking cessation, and improved energy.[23,27,60]

The popularity of distance running has many male and female runners competing in running events every year. The forces associated with running result in a fairly high incidence of running injuries. LBP is one of these injuries. While the general population experiences a lifetime incidence of LBP ranging from 60% and 90%, reoccurrence rates of LBP appear to be greater in runners.[6,17] Prior research identified that variables such as gender, age, height, weight, BMI, and years of running experience may be risk factors for development of LBP.[14,47,54-58,61,62]

The purpose of this research study was to determine if a difference exists between runners with and without LBP and a control group of non-runners in relation to demographic, physical/training, and LBP variables and running. These variables were chosen because prior research showed them to be linked to LBP and/or LBP and running. It is possible that this study could identify that modification of these risk factors may prevent a decline in running performance and/or lost running time.

Research Questions

Research Question 1. Is there a difference between runners with and without LBP and a control group of non-runners in demographic variables and variables associated with LBP?

Research Question 2. Is there a difference between runners with and without LBP in relation to physical/training variables of running and variables associated with LBP?

Null Hypotheses

Null Hypothesis 1. There is no difference in demographic and variables associated with LBP between runners with and without LBP and a control group of non-runners.

Null Hypothesis 2. There is no difference in physical/training variables of running and variables associated with LBP between runners with and without LBP.

Definitions of Terms

Subacute LBP- current episode of LBP during running of more than 2 weeks but less than 6 months that originates at the lumbar region between the buttocks and rib cage and does not radiate to the lower extremities[5]

Recreational distance runner- runner who runs a minimum distance of 20 km/wk consistently for a minimum of 1 year.

Total lumbar flexion AROM- total lumbar flexion active range of motion using a single inclinometer method.

Total lumbar extension AROM- total lumbar extension active range of motion using a single inclinometer method.

Biering-Sorensen Test- test used to measure trunk extensor muscle endurance.[63] This test involves a subject lying prone on a plinth with his/her trunk from the waist up off the plinth and legs secured to the plinth with straps or belts.[63] The subject then places both arms across his/her chest and raises the upper body into a horizontal position for as long as possible.[63]

Side bridge test- test performed with subjects lying on their side with the legs extended. The ipsilateral leg of the side being tested is placed in front of the contralateral leg.

Subjects were instructed to lift their hips off the table and hold their body in a straight line while supporting themselves on one elbow and their feet.[63]

Passive lumbar extension test- placing the subject in a prone position with their arms at their side and both lower extremities passively elevated to an estimated 30 degrees and the knees extended while the researcher applied a distraction force to the subject's legs.[64]

Demographic variable- variable such as age, height, weight, gender, and BMI.

Physical/training variables of running- included variables such as number of running days/wk, number of rest days/wk from running, time of day that running took place, number of races run/yr, kilometers/wk of running, dominant running surface, years of running experience, number of marathons completed, average training pace, best 5k time. Also included, stretching pre vs. post running, current participation in hill/interval running, history of previous running injuries, past physical therapy treatment for a running injury, current participation in recreational sports, use of orthotics for running, dominant running surface, type or running shoes, and type of initial foot contact when running.

LBP variables- such as total lumbar flexion and extension AROM, passive lumbar extension test, side bridge test, Beighton scale scores, and Biering-Sorensen test

Soft running surface- any running surface consisting of treadmill, composite track, dirt or limestone trails.

Hard running surface- any running surface consisting of concrete or asphalt.

Days of running- number of days (0-7) that a person runs/wk.

Time of day- time of day that running normally takes place.

Summary

The purpose of this research study was to determine if differences existed between recreational distance runners with and without LBP and a control group of non-runners without LBP in terms of demographic, LBP, and physical/training variables of running. Demographic variables included age, height, weight, gender, and BMI. Physical/training variables of running were defined above. LBP variables included total lumbar flexion and extension active range of motion (AROM), Beighton scale scores, side bridge test, Biering- Sorensen test, and passive lumbar extension test. The relevance, significance, and need for this research study were demonstrated. Research questions were identified.

CHAPTER 2: LITERATURE REVIEW

Introduction

The average age of a distance runner in 2010 was 37-45; the runner was married, and had a college education.[2] The average distance runner ran 4 or more days/wk, and 37-46km/wk 12 months of the year.[2] Distance running has continued to grow for several reasons. Research demonstrated that in the midst of a poor economy, running provided an inexpensive way to relieve stress and gave one a sense of control. The rise in obesity has motivated some individuals to take up running; which could result in improved health status as well as a sense of achievement and personal satisfaction when meeting goals.[2]

Low Back Pain and Running

The annual incidence of running related injury ranges from 14% to 70%.[16,18,21,46,65,66] This wide range of annual incidence may be due to the use of different sample populations among researchers. Woolf et al reported annual incidence of 13.6% in their age groups of runners, while Lewis et al reported values closer to 47% in a similar age group of runners.[5,66] This discrepancy could be the result of sampling difference with regards to different numbers of male and female participants and different levels of runners (novice, recreational, elite). The study by Woolf et al[66] included walkers as well as runners, which might be the reason why the incidence rate was much lower.

While these values were similar to the general population, it was significant that the recurrence rate of episodes of LBP in runners was identified to be as high as 85% at one year.[6] This was much higher than the recurrence rates in the general population reported as ranging from 24-50% at one year to 60% at two years, and 70% at three years following the initial onset of LBP.[52,53] Greene et al reported in a study of recurrent back injuries in athletes, including runners, that athletes with a previous history of LBP were 3 to 6 times more likely to sustain a recurrent back injury, and that a current episode of LBP in distance runners may be a risk factor for future episodes of LBP.[67] This greater recurrence rate of LBP demonstrates the need to identify risk factors associated with LBP episodes that may lead to modification of risk factors, and may result in prevention of recurrent episodes of LBP in runners.

Age and LBP

Researchers were consistent in their findings that incidence of LBP increased over the age of 40.[11,48,62,68-73] Individuals in the general population over age 40 had a 67% greater risk of developing LBP.[68] Deyo et al demonstrated that prevalence of LBP was approximately 6% greater in non-running subjects aged 45 years and older compared to subjects who were 18-44 years old.[74] Palmer et al showed in a cross-sectional study that LBP rates were approximately 17 to 20% higher in non-running subjects over the age of 40.[75] These studies were important because they demonstrated the elevated prevalence of LBP in non-running subjects who were older than 40 years old (y/o).

A single cross-sectional study by Ferburger et al reported that based on the data collected in 1992 and 2006, the overall prevalence of LBP increased in all age groups between 21 and 75.[71] They reported a 50% or greater increase in prevalence in 2006 compared to 1992 in age groups 45-54, 55-64, and greater than 65 years of age.[71] The study by Ferburger et al[71] was important because it demonstrated the elevated prevalence of LBP in subjects older than 40 years old. Strengths of this study included: provision of a Spanish language version of which made their results more applicable to the general population with LBP. Allowing the inclusion of Hispanic subjects in their study made the results of their study more representative of the general population with LBP. A second strength was the use of the same inclusion criteria with both surveys in 1992 and 2006. Weaknesses of this study included: the study did not have a unified group as the inclusion criteria was too broad to include subjects with and without radicular symptoms, and the inclusion criteria changed from 1992 to 2006.

A cross sectional study by Leboeuf-Yde et al analyzed close to 35,000 subjects in the general population. This study concluded a similar trend in higher prevalence of LBP in subjects over 40 years old. These subjects missed work for more days than did younger subjects with LBP.[62] The weakness of this study was that subjects were divided into upper, mid-back, and lower back pain without specific diagnoses. This non-specific classification makes their results lack of specifics for applying to the general population with LBP.

Taunton et al reported in a survey study of 844 recreational runners that runners older than age 50 years of age, especially females, were more likely to develop running injuries including LBP.[21] These results were consistent with another study of running subjects.[28] The biomechanics of running was different in older runners resulting in a lower shock absorbing capacity. This was related to higher impact forces with the running surface, vertical impact speeds, and initial loading rates in older runners and differences in kinetics and kinematics between older and younger runners because of musculoskeletal weaknesses.[76]

Roncarati et al reported that runners between the ages of 30 and 50 y/o compared to younger subjects were at greater risk for LBP. These results were associated with decreased flexibility of the low back muscles.[4] Other researchers did not find a difference in incidence of LBP in runners at age greater than 50 years old. Ahrens et al reported no difference in runners between the ages of 20 and 27 and 50 and 57 y/o in LBP and no vertebral column changes associated with running.[36] The differences between the results of these studies could attribute to the differences in other variables of demographic and physical/training variables of running such as weight, running speed, gender, and distance/wk of running.

Gender and LBP

Research findings were also consistent with females tending to have higher incidences of LBP than males.[11,70,77] Studies demonstrated that females in the general population were more likely to experience LBP.[11,78] They suggested that this was due to females having greater degrees of lumbar lordosis and increased trunk flexor co-contraction to maintain lumbar stability.[11,78] Hoy et al and Smith et al identified a greater prevalence of LBP in women, which resulted in women's greater amount of sick time, and higher use of medical services for LBP.[79,80] Several studies in various countries identified female incidence of LBP to be higher than males.[60,81-85] A clinical review by Fillingim et al summarized that these differences were related to biological and psychosocial factors such as hormones, endogenous pain modulatory systems, gender roles, and cognitive/affective factors.[70]

According to the literature, postmenopausal women using hormone replacement demonstrated greater risk for LBP.[86,87] Additional endogenous pain modulatory systems included dopamine and serotonin levels in females. Estrogens appear to help regulate dopamine and serotonin in the female body. Any factor that disrupted these levels of estrogen in the female body, such as menopause, resulted in dysfunction of the pain modulating abilities of dopamine and serotonin and could lead to LBP.[86,87]

Robinson et al showed that gender roles affected pain. Both men and women considered women more sensitive to pain, less able to endure pain, and more likely to report pain; resulting in greater incidence and prevalence of LBP in females.[88] Cognitive/affective factors were possible factors contributing to higher incidence of LBP in females.[88] Researchers reported that females were linked to greater levels of anxiety that were correlated with higher levels of LBP.[89,90]

A cross-sectional study by Leboeuf-Yde et al revealed that women more commonly reported spinal pain and consequences of spinal pain.[62] The researcher clearly defined the purpose of the study and presented the details of the study. The sample size was large (34,902) and included a wide age range (20-71 y/o). However, the study survey was not included as part of the appendix, and it was written in Danish without English translation. It was difficult for other researchers to replicate the study and to verify the information they presented.

Malina reported that female runners tend to have approximately 10% more body fat than male runners, thereby increasing their risk for LBP.[91] It is possible that this elevated BMI in female runners could be associated with LBP.

Height and LBP

A study by Hershkovich et al of 829,791 adolescents with LBP examined the association of LBP with BMI and height. They identified that height was positively associated with LBP in male and female adolescents. They also identified linear trends in LBP rate in adolescents as height increased.[92] However, the definition was unclear of what age range was considered “adolescent”. Abbas et al revealed that in adult female subjects with LBP height was associated with greater prevalence of LBP. Females of short stature, compared to tall females, exhibited larger BMI, and greater prevalence of LBP.[93]

Obesity (increased body weight)/BMI and LBP

There has been controversy with regards to the consideration of obesity as a risk factor for LBP. Some researchers identified obesity as a risk factor for LBP,[58,94] while others consider obesity as an indirect risk.[94-97] In a systematic review of 65 studies on LBP, a positive correlation was found between LBP and obesity and/or elevated BMI in 32% of the studies. It was identified that sample size played a large role in subjects' association of obesity with LBP.[57] Studies with fewer than 3,000 subjects found less association between LBP and obesity (19%); while studies with greater than 3,000 subjects found a 50% association.[57]

The Nord-Trondelag Health Study (HUNT study) analyzed 6,293 men and 8,923 women with chronic LBP.[58] Results indicated greater prevalence of LBP with increasing values of obesity/BMI for both males and females. The association between LBP and obesity/BMI was slightly greater in females than in males.[58] The study concluded that this slightly greater prevalence in females may be related to specific hormonal factors or elevated levels of physical or work activities that may present exposure to other risk factors for LBP.[58]

Researchers reported that runners with lower body weight/BMI tended to demonstrate less core muscle stability leading to onset of LBP with distance running.[14,54] Nadler et al identified in a group of college athletes (including runners) that female athletes were more likely to require treatment for LBP compared to male athletes. This was suspected to be related to effects of underreporting by males, oral contraceptives, presence of menstrual cycles, or other unknown factors.[14] Taunton et al reported that increased body weight and BMI >26 was a protective factor for running injuries including LBP.[46] These results were inconsistent with results of research on LBP in the general population which upheld that males and females with greater body weight are at greater risk for LBP.[98,99] Further research is needed in this area to determine the exact effects of these potential causes.

Some evidence indicated that female runners with greater BMI were at greater risk for developing LBP.[46,66,91] These researchers believed that greater body weight lead to greater physiological stresses on the musculoskeletal system resulting in pain with physical activity such as running.[100,101] Buist et al reported in a 2010 study of 532 novice runners that elevated body weight/BMI in males was associated with increased risk of running injuries including LBP. This was determined to be related to the excess physiological stress on the low back and lower extremity muscles from increased body weight.[102] A more recent study of 974 novice runners reported elevated BMI was a risk factor for running injuries including LBP.[103]

In a study by Woolf et al on 539 runners and walkers, greater body weight, in runners only, was associated with a previous history of LBP in both males and females.[66] Limitations to this study were that gender was not controlled, and there was a broad range of subjects that ranged 11-73 years old, and having a disproportionate 74% of subjects with LBP.

Lumbar AROM and LBP

Active range of motion limitations were identified in both lumbar flexion and extension in subjects with LBP. These limitations were related to pain, tightness of lumbar muscles, hip inflexibility, and weakness in lumbar paraspinal musculature.[54,56,61] Fritz et al identified in a study of 50 subjects that lumbar flexion AROM greater than 53 degrees and extension AROM greater than 26 degrees were associated with LBP and other spinal conditions identified through radiographs.[61] Spinal conditions can often be ruled in or ruled out with various clinical tests based on prediction values called sensitivity and specificity. The results of the lumbar AROM cutoff values (greater than 53 degrees flexion and greater than 26 degrees) identified by Fritz et al[61] demonstrated fair sensitivity and good specificity. These results along with interclass correlation coefficients (ICC) values can be found in Tables 1 and 2 below.

Table 1.
Sensitivity, Specificity, Positive Likelihood Ratios, and Negative Likelihood Ratios for Total Lumbar Flexion and Extension AROM[a]

Clinical Test	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio
TLF AROM- >53°	.68	.86	4.8	.38
TLE AROM- >26°	.50	.76	2.1	.66

[a]TLF AROM-Total lumbar flexion active range of motion. TLE AROM-Total lumbar extension active range of motion. All referenced data presented with 95% confidence interval.

Table 2.
Reliability Coefficients (Interclass Correlation Coefficient (ICC)) for Total Lumbar Flexion and Extension AROM in Subjects with LBP[a]

Variables	All Subjects
TLF AROM	.60 (.33-.79)
TLE AROM	.61 (.37-.78)

[a]TLF AROM-Total lumbar flexion active range of motion. TLE AROM-Total lumbar extension active range of motion. All referenced data presented with 95% confidence interval.

Wong and Lee studied 61 subjects, with 41 of them having LBP, and found that lumbar flexion AROM and straight leg raise (SLR) were limited in subjects with LBP. The restriction was related to limitations in hip flexion mobility due to tight posterior tissues of the hip.[104] Limitations in hip flexion were significantly related to limitations in lumbar extension AROM.[104] The amount of time that subjects with LBP took to complete lumbar flexion and extension AROM when standing was approximately twice the time as subjects without LBP. The authors felt the longer duration was related to muscle guarding associated with LBP and limitations in hip flexion mobility.[104] These results need to be taken with caution because of the small number of subjects per group (20, 24, and 17) and a lower mean age (34 y/o) in the LBP with limited SLR group compared to the other two groups (41 y/o and 42 y/o). It is difficult to generalize these results to the entire population of subjects with and without LBP with limitations in lumbar AROM.

Trunk Muscle Endurance and LBP

Research showed that lack of trunk muscle endurance and core strength is correlated with LBP.[54,105-110] The Biering-Sorensen test was previously validated as to demonstrate the difference in trunk muscle endurance between subjects with and without LBP.[107] This test demonstrated a mean holding time of 176 seconds for subjects with a history of LBP compared to 198 seconds in subjects without LBP.[109] Hultman et al identified that subjects with LBP had a mean holding time of 85 seconds compared to 150 seconds in subjects without LBP.[111]

Latimer et al reported good reliability (ICC = .76-.90) of this test in subjects with and without LBP. Subjects with LBP averaged 94 seconds compared to 132 seconds in subjects without LBP.[107] See reliability results of the Biering-Sorensen test in Table 3 below. The greatest reliability was identified in subjects with current LBP. Latimer et al reported that this was because of one subject with current LBP that was deleted due to a holding time of 9.5 standard deviations greater than the mean. With this subject, the ICC value for subjects with current LBP was .83.[107]

Table 3.
Reliability Analysis of Subjects With and Without LBP-Biering-Sorensen Test[a]

	All Subjects	**Subjects with Current LBP**	**Subjects with Previous LBP**	**Subjects without LBP**
ICC	.85	.88 (.83)	.77	.83
95% CI	.76-.90	.73-.95	.52-.90	.62-.93
SEM(s)	15.6	11.6	17.5	17.4

[a]ICC- Interclass Correlation Coefficient. CI- Confidence Interval. SEM- Standard Error of Measurement.

Arab et al researched trunk muscle endurance in male and female subjects with and without LBP (ICC = .78 -.80).[108] Their findings showed similar reliability values for the Biering-Sorensen test compared to the results of Latimer et al.[107] Specificity of the test ranged from 76.0 to 84.6, and sensitivity ranged from 84.3 to 92.3. Positive predictive values ranged from 80.8 to 84.3, and the negative predictive values ranged from 84.6 to 90.0. The study used age and gender matching of subjects in groups with and without LBP, and documented a clear methodology for others to replicate.[108] See results in Table 4 below.

Table 4.
Sensitivity, Specificity, Positive Predictive Values, and Negative Predictive Values for Clinical Tests for Trunk Muscle Endurance[a]

Clinical Test	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	Cutoff Score
BST Men- Women-	92.3 84.3	76.0 84.6	80.8 84.3	90.0 84.6	>28 >29

[a]BST-Biering-Sorensen Test.

Core Weakness and LBP

Impaired core stability has been shown to be related to LBP and lower extremity injury in athletes.[55] Previous studies demonstrated differences in muscle recruitment, trunk stiffness, and balance in subjects with and without LBP. It was suggested that subjects with LBP demonstrated increased trunk muscle activity and greater trunk stiffness.[112-114] The side bridge test was established as an effective way to address core muscular endurance.[63]

McGill et al examined endurance times with the side bridge test in healthy men and women (31 men/44 women). They identified a mean right side bridge time of 94 seconds in males and 72 seconds in females. The mean left side bridge time was 97 seconds in males and 77 seconds in females.[105] Waldhelm reported slightly lower results in 15 healthy college males. He reported average side bridge times of 82 seconds and 77 seconds for right and left side bridge respectively.[115] Leetun et al reported mean side bridge times of 84 seconds in males and 59 seconds in females. Side bridge times were an average of 72 seconds in subjects without injury vs. 65 seconds in subjects with injury.[116]

The side bridge test has been shown to demonstrate good reliability.[63,105] Both McGill et al and Evans et al examined reliability of the side bridge test in healthy subjects.[63,105] McGill et al reported ICC values of .96 for right side bridge and .99 for the left side bridge.[105] Evans et al reported similar values of .91 and .89 on two occasions for right side bridge, and .82 and .91 for the left side bridge.[63]

Additional Anatomical and Biomechanical Risk Factors and LBP

Inadequate timing of the erector spinae muscles was linked to chronic LBP. Paquet et al examined hip and spine mechanics of 10 subjects with LBP and 10 subjects without LBP. They identified that subjects with LBP moved slower by 73% in spinal flexion and 66% in extension. This increased slowness was related to the inability of the erector spinae muscles to relax at the end of spinal flexion AROM resulting in LBP and limiting spinal extension AROM.[117] Vogt et al identified that subjects with LBP took shorter strides when walking. The researchers determined that the shorter strides were related to proprioceptive deficits in the lumbar spine that resulted in compensatory gait strategies to create an effective manner of walking with the least energy expenditure.[118]

Running Anatomical Risk Factors and Gender

Researchers had identified that running injuries were more common in women than men.[18,19,21,119] These injuries were more common in women than men for several reasons such as: lower lean body mass in women resulting from having only 60% cross-sectional area of muscle in females compared to males,[120] wider pelvic structure, greater Q angle, increased incidence of femoral anteversion, and genu valgum.[14,21,46,51,121] A wider pelvic structure and greater Q angle in females required greater hip abduction and external rotation strength during the midstance phase of the running gait cycle to stabilize the hip and prevent knee valgus, foot overpronation, and lateral trunk lean.[54-56,121]

Several studies by Nadler et al reported that female athletes demonstrated a 6-11% greater likelihood to develop LBP than male athletes. It was identified that this difference was related to factors including: differences in gait/running style and/or pelvic anatomy.[14,54-56] Nadler et al reported that females with LBP demonstrated greater side-to-side hip weakness than females without LBP.[54] Nadler et al and other researchers identified differences in endurance of the hip, spine, and abdominal musculature as contributing factors to gender differences.[55,105]

Tightness in the hamstring and hip flexor muscles in both males and females was also related to LBP because they placed additional stress on the lower lumbar spine and pelvis by either posterior or anterior tilting of the pelvis and decreasing or increasing the lumbar lordosis.[7] Dimitriadis et al found decreased lordosis after 1 hour of running in runners with LBP.[122] Evidence showed that weakness of the hip extensor and abductor muscles was associated with chronic LBP in athletes.[123,124] It is not clear, however, whether the compensations associated with the LBP caused the weakness or weakness caused the LBP. Additional research reported leg length discrepancy to be a risk factor for LBP.[125,126] Although evidence showed that being of shorter stature was associated with LBP in runners, it is inconclusive as to why.[4]

Running and Surface as a Risk Factor

Pinnington and Lloyd et al reported that running on softer surfaces such as sand, compared to asphalt, resulted in increased stance time, increased cadence, decreased stride length, increased hip flexion angles at initial contact and midstance, and greater forward trunk lean.[127] The literature documented that this type of initial contact pattern is associated with decreased peak impact forces.[128-131] The softer surface acted as a "dampener" limiting initial impact forces.[127] Kurumadani et al examined 5 male runners across asphalt and grass. They concluded that peak impact forces were higher for asphalt running and that grass running resulted in lower risk of running injuries and stronger lower leg muscles.[132] Therefore, it is of importance to look at the training surface when studying running injuries and associated factors.

Running Training Variables and LBP

Previously researchers had suggested that runners with increased training volumes were at greater risk for running-related injuries including LBP. [21,46,47,119] Koplan et al found a linear relationship between increased weekly running distance and injury.[25] A review article by Fredericson and Misra concluded that weekly running distance of greater than 64km was associated with a high chance of running injuries including LBP, especially in marathoners with less running experience.[119]

Stretching pre and post exercise has been identified to prevent running injuries. Static/passive stretching of any muscle group for 15-30 seconds has been shown to increase flexibility for up to 90 minutes.[133,134] In a systematic review, Thacker et al concluded that 3-4 weeks of static stretching following performance may lead to improvements in maximum strength and overall performance as well as injury prevention in athletes that demonstrated limited ROM prior to beginning a stretching program.[134]

Garbutt et al examined 14 male marathon runners with and without LBP at 70%, 85%, and 100% of their marathon pace. They identified that the marathon runners demonstrated greater “spinal shrinkage” at faster training speeds.[33] It also appeared that a significant amount of this loading took place in the first half of the running distance.[135] Results indicated that “spinal shrinkage” was greater at faster speeds and in the first part of the run.[33]

Healey et al established a quicker plateau in loss of stature in subjects with chronic LBP compared to a control group.[136] Demura et al identified a loss of stature in males and females from 22-41y/o after walking and running at preferred speeds; however, recovery time following the loading activities was greater following running due to the increased loads placed on the spine with running.[137] A study by White and Malone examined the effects of running on intervertebral disc height with respect to time of day.[32] Seventeen elite male subjects participated in a15km run in the PM time of day. Vertebral column height measurements were taken in the AM, pre-run, and post-run. Results indicated that vertebral column height was significantly reduced post run and that running significantly loaded the spine and its supporting structures.[32]

Summary

Estimates of lifetime incidence of LBP in runners reported in the literature ranged from 12-70%. The wide range of annual incidence was due to different sample populations and configurations used by the researchers including disproportionate numbers of male and female participants, multiple levels of runners (novice, recreational, elite) and sample sizes ranging from 539-7,669 subjects.[8,9,11,16] The recurrence rate of LBP in runners was as high as 85%.[6] Some researchers have suggested that runners over age 40 y/o may be at greater risk for LBP.[4,21] Previous research identified females, particularly those with higher BMI, tended to have higher instances of LBP.[11,58,70,78,79] Female runners of lower bodyweight/BMI were more susceptible to running injuries, including LBP; however this conclusion was controversial among researchers.

Limitations in lumbar AROM, trunk muscle endurance weakness, and lack of core stability were also identified as risk factors for LBP in non-running subjects.[61,104,105,107,108] Other training/physical variables of running such as running surface, biomechanics, speed, distance, and presence of stretching prior to running were previously linked to LBP and running.[33,119,127,132,133] Therefore, it is imperative that we understand the relationships of all of these variables to running and LBP.

CHAPTER 3: METHODOLOGY

Chapter three provides a summary of the research methods that were employed in this study. Research subjects, research setting, the specific procedures that were used in this study, and a pilot study performed prior to this study are described. The specific tests and measures utilized in this research study are discussed. The data analysis procedures section lays out the statistical analyses that were implemented in this study. A summary concludes chapter 3.

Pilot Study

Purpose and Procedures of the Pilot Study

The purpose of the pilot study was to establish inter-rater reliability of the researchers involved in this study on lumbar extensor endurance, total lumbar flexion and extension AROM, Beighton scale, passive lumbar extension test, and side bridge test. Following Nova Southeastern University IRB approval, three researchers were involved with a 15 subject pilot study on runners with LBP. However, because of the procedural issues, researchers were not able to test on all subjects. One researcher was only able to test on limited number of subjects and later withdrew herself from the pilot study. Results reported here are based on a completed dataset from 10 subjects that were tested by 2 researchers. These two testers later participated in the main study. A research assistant brought subjects to each researcher and recorded data during the pilot study. Results were recorded and interclass correlation coefficients (ICC), two-way random effects model, were run on this data to assess inter-rater reliability. Reliability statistics were computed with data from the pilot study of ten subjects with LBP. Each subject from the pilot study completed all of the testing once with each researcher. Establishing inter-rater reliability determined the level of confidence in the tests and measures between the two researchers in this research study, and whether each researcher was adequately trained in obtaining valid measurements for each test. Pilot study subject characteristics are provided in Table 5 below.

Table 5.
Pilot Study Subject Characteristics

Variable	**Mean (range) Count (%) (n=10)**	**Standard Deviation**
Height (cm)	168 (163-175)	4.3
Weight (kg)	64.3 (55-73)	5.3
Age (y) ≤40 y/o >40 y/o	 5 (50%)[b] 5 (50%)[b]	
Gender (# subjects) Male Female	 2 (20%)[b] 8 (80%)[b]	
BMI (kg/m^2)	22.8 (21-26)	1.4

[a]Values are mean (range) unless otherwise indicated. [b]Other values are counts.

Pilot study results demonstrated moderate interrater reliability for total lumbar flexion AROM (ICC= .65) and good interrater reliability for total lumbar extension AROM (ICC= .83). The results of total lumbar flexion AROM (ICC= .65) were lower than the works of Fritz et al[61] (ICC= .91). Results of the total lumbar extension AROM (ICC= .83) were slightly greater than the results of Fritz et al[61] (ICC= .61). Moderate reliability results were demonstrated for the Beighton scale (ICC= .70). The researchers demonstrated moderate reliability for the Biering-Sorensen test, with an ICC value of .61. The reliability of the Biering-Sorensen test (ICC= .61) was lower than values reported by Latimer et al[107] (ICC= .88). ICC values for the right and left side bridge tests were .90 and .67, respectively, demonstrating good (right) and moderate (left) reliability. The result for the right side bridge test was slightly better than results reported by Evans et al[63] (ICC= .82 right side bridge, ICC= .85 left side bridge), but lower than results reported by McGill et al[105] (ICC= .99). Results are displayed in Table 6 below.

Results of the side bridge test (ICC= .90-right, ICC= .67-left) demonstrated good and moderate reliability respectively. The result for the right side bridge test was slightly better than results reported by Evans et al[63] (ICC= .82 right side bridge, ICC= .85 left side bridge), but lower than results reported by McGill et al[105] (ICC= .99). The results of the Beighton scale (ICC= .70) were similar to the results of Hicks et al[138] (ICC= .76) and Fritz et al[61] (ICC= .72).

Table 6.
Inter-rater Reliability[a]

TLF AROM	**TLE AROM**	**BST**	**Beighton Scale**	**Side Bridge Test-Right**	**Side Bridge Test-Left**
.65 (.08-.90)	.83 (.45-.95)	.61 (.01-.89)	.70 (.13-.91)	.90 (.66-.98)	.67 (.10-.91)

[a]Intraclass Correlation Coefficients (ICC) two-way random model (lower/upper bound of 95% confidence interval). TLF AROM-Total lumbar flexion active range of motion. TLE AROM-Total lumbar extension active range of motion, BST-Biering-Sorensen test.

One of the researchers had not used the inclinometer method for measuring total lumbar flexion AROM by Waddell et al[139] prior to being trained for this research study. This lack of experience may have led to lower reliability of total lumbar flexion AROM. Total lumbar flexion AROM also required 2 measurements be taken (T12 and S2 spinal levels); it is possible that errors were made in subtracting these 2 measurements to get total lumbar flexion AROM. There was not a clear definition of how much or how long below horizontal a subject could go before terminating the Biering-Sorensen test. This may have accommodated for only moderate reliability of this test.

It is not clear why the L side bridge test was so much lower than the right side bridge test. Both tests were performed by each researcher in the same manner. The right side bridge test was listed first on the data sheet and most likely performed first on each subject. It is possible that all ten pilot subjects were concentrating better on the right side bridge test since it was performed first. The researchers may have provided more precise instructions on the right side bridge test since it was performed first. It is also possible that all ten pilot subjects were right hand dominant allowing them to use greater upper extremity strength to complete the right side bridge test. It is mentioned later in this document that some subjects ran prior to the testing. This may have also occurred in the pilot study subjects. It is possible that running prior to testing fatigued core and hip musculature leading to lower side bridge times on their left side. I am confident that I was able to generate pilot study results that are comparable to other studies, with the exception of total lumbar flexion AROM, Biering-Sorensen test, and side bridge left which all demonstrated only moderate reliability compared to good reliability by other researchers.[61,63,107]

Research Methods

Subjects and Setting

Sampling of subjects was a sample of convenience and performed in an attempt to obtain subjects for all groups (runners with LBP, runners without LBP, control group of non-runners) at convenient locations. Subjects included males and females between the ages of 18-55. Subjects from running groups with and without LBP were running at least 20-30km/wk for at least 1 year. Subjects for the runners with LBP group were required to have had a current episode of LBP for at least 2 weeks but not longer than 6 months that had impeded their running. One hundred subjects were estimated via a sample size estimation in Portney and Watkins[140] with 80% power, a .20 effect size, and .05 alpha level (2 degrees of freedom). The sample size estimation was based on a one-way ANOVA calculation. One hundred and twenty subjects were planned to be recruited with approximately 40 subjects, 20 males and 20 females, in each group.

Potential subjects were excluded if they had a history of known spinal spondyloarthrosis or stenosis, spinal malignancy or high risk for cancer, history of fracture of the lumbar spine, history of spinal infection or spinal fusion, cauda equine syndrome, referred pain from the gastrointestinal and genitourinary tracts, and inability to flex or extend the spine to perform the lumbar flexion and extension AROM testing. Potential subjects were excluded as well if they were currently receiving physical therapy for LBP that included stabilization exercises as part of their rehabilitation (this was asked to subjects during screening prior to becoming a research subject), or were currently experiencing running related injuries other than LBP that may alter their normal running form. Non-English speaking subjects were excluded from participation due to the inability of the researchers to communicate without a translator. Subjects were included or excluded based on their answers on a questionnaire (Appendix D). No physical exam took place prior to participation in this research study. History indicating items of the exclusion criteria was verbally indicated by subjects previously diagnosed by a physician; subjects were not referred by physicians.

Subjects who expressed interest in taking part in the research study contacted the primary researcher by phone, e-mail, or in person at Runner's Image. Data collection sessions were also advertised at Runner's Image and a local sports club in Rockford, IL as an event for qualified participants. Subjects were screened for inclusion/exclusion criteria by questionnaires distributed at the recruitment sites; other potential participants that heard about the study through the sports club and Runner's Image contacted the primary researcher by phone/e-mail and were screened for inclusion/exclusion criteria. The primary investigator who screened the potential subjects in person, by phone, or through e-mail determined the LBP designation. Subjects were also instructed to refrain from running and other forms of physical activity on testing day.

Fliers including contact information by phone/e-mail were posted to advertise the research study (Appendix A) after the approval from Nova Southeastern University Institutional Review Board (IRB) (Appendix B) and written permission from two Rebound Physical Therapy clinics in Rockford, IL (Appendix C) were obtained. Employees at Runner's Image, a Rockford, IL running store, informed local runners about the study and posted contact information. Coaches of distance running groups and one sports club in the Rockford, IL area were asked to post contact information and refer distance runners interested in participating in the study.

Two data collection sessions took place at Rebound Physical Therapy in Rockford, IL. Two researchers were located in separate treatment rooms, and the research assistant brought the subjects to them. Subjects were scheduled in 15 minute intervals during the time allotted (two subjects at 15 minute intervals, one for each researcher). Each subject completed all of the clinical tests by one of the two researchers.

Procedures, Demographic Data, and Training Variables of Running

Once subjects that met the inclusion criteria agreed by e-mail or in person to participate in the study, they were provided with the informed consent form (Appendix B) and a demographic and training variable questionnaire (Appendix E) by e-mail prior to their scheduled session. All subjects were asked to sign an informed consent form that provided information about the required activities and their rights. The completed and signed forms were brought back by subjects to their data collection session. Those subjects who did not have a valid e-mail address were required to complete the forms at the data collection session. Completing the forms ahead of time reduced the time commitment for each subject at the time of testing. Subjects were instructed to allow 45 minutes for testing and to wear appropriate clothing, specifically to wear the shoes that they customarily used for running.

Demographic data collected via a questionnaire (Appendix E) asked for demographic data (height, weight, gender, BMI, and age) and physical/running variables (number of running days/wk, number of rest days/wk from running, time of day that running took place, number of races run/yr, kilometers/wk of running, dominant running surface, years of running experience, number of marathons completed, average training pace, best 5k time, stretching pre vs. post running, current participation in hill/interval running, history of previous running injuries, past physical therapy treatment for a running injury, current participation in other recreational sports, use of orthotics for running, dominant running surface, type or running shoes, and type of initial foot contact when running). Each subject was asked to bring the completed informed consent forms and questionnaire to the data collection session. Subjects that forgot their informed consent form and questionnaire were requested to fill it out prior to data collection during their assigned session.

Instrumentation

Instrumentation utilized for the testing included: two BASELINE® bubble inclinometers (Fabrication Enterprises Inc. White Plains, NY). The current study used the AROM technique used by Waddell et al;[139] the single inclinometer method was a reliable method for measuring flexion and extension range of motion of the lumbar spine. This method did not involve stabilizing the pelvis.

Lumbar flexion AROM measurement involved inclinometer measurements taken at the S2 and T12-L1 spinal levels in an erect position and as the subject bent forward and reached towards the floor with knees straight. Subjects were requested to remove their shoes and stand with hands at their side, knees straight, and feet at shoulder width apart.

The S2 spinal segment was identified by lowering the waistline of the subject's shorts/pants while the researcher first palpated the S1 segment and palpated down one bony spinal segment to identify the S2 segment. S2 segment was marked with a black felt-tip marker. T12 spinal segment was identified by the researcher finding the S1 segment and counting up 6 spinal segments to T12. T12 segment was marked with a black felt tip marker. Subjects were asked to bend forward at their waist without bending their knees and reach toward the floor while keeping their neck flexed. Subjects returned to an erect position and were asked to bend forward for a second measurement in the same manner. Isolated lumbar flexion AROM was determined by subtracting the total flexion measurement (T12-L1) from the pelvic flexion measurement (S2). This technique is demonstrated in Figures 1-3 below. The middle of the inclinometer was aligned in the center of each black mark in Figure 1 below.

Figure 1.
Measurement landmarks for lumbar flexion and extension AROM
taken at theT12 and S2 spinal levels.

Figure 2.
First measurement of lumbar flexion AROM
taken at S2 as the subject bends forward with the neck flexed.

Figure 3.
Second measurement of lumbar flexion AROM
taken at T12 as the subject bends forward with the neck flexed.

Total lumbar extension AROM was determined by taking inclinometer measurements at the T12-L1 spinal level only in an erect position and as the subject bent backward as far as possible, without stabilizing the pelvis, while looking up at the ceiling and keeping the knees straight.[139] This technique is demonstrated in Figure 4 below. Three measurements were taken for lumbar flexion and extension AROM in the research study, and the mean was recorded.

Figure 4.
Measurement of lumbar extension AROM in standing at T12.

The Biering-Sorensen test is used to measure trunk extensor muscle endurance.[63] The test involves a subject lying prone on a plinth with his/her trunk from the waist up off the plinth and his/her legs secured to the plinth with straps or belts.[63] This position was standardized by aligning the top of each subject's iliac crest with the edge of the plinth. The subject then places his/her arms on his/her chest and raises the upper body into a horizontal position for as long as possible.[63] The test was concluded when the subject dropped his/her upper body below a horizontal position or was able to hold this position for ninety seconds. This technique is depicted in Figure 5 below. Each subject completed this test only once. Total time was recorded with a stopwatch.

Figure 5.
Biering-Sorensen Test.

The side bridge test has been shown to provide an adequate assessment of core muscle stability.[63] The side bridge test is performed with subjects lying on their side with the legs extended. The ipsilateral leg of the side being tested is placed in front of the contralateral leg. Subjects were instructed to lift their hips off the table and hold their body in a straight line while supporting themselves on one elbow and their feet. The uninvolved arm was placed across the chest with the hand on the involved shoulder. This position was held until muscle fatigue prevented proper form, the subject dropped his/her pelvis below a horizontal position, or ninety seconds was completed; therefore, the test was stopped by the tester.[141] The side bridge test is designed to measure stability of the quadrates lumborum and anterolateral muscles of the trunk.[142,143] See Figure 6 below.

Figure 6.
Side Bridge Test.

The Beighton Scale is a nine-point scale that addresses generalized ligamentous laxity. The 4 bilateral tests performed included: passive hyperextension of the elbow > 10°, passive hyperextension of the fifth finger > 90°, passive abduction of the thumb to contact the forearm, and passive hyperextension of the knees > 10°. Standard goniometric measurements were taken for each Beighton Scale test. One additional test for the Beighton Scale involved flexing the trunk and placing both hands on the floor without bending the knees.[138,144]

Subjects extended their elbows in front of their body in standing while the investigator passively extended each elbow to its passive limits of ROM and goniometric measurements were taken by placing the axis of the goniometer at the elbow with the stationary arm pointed towards the acromion and the reference arm pointed at the radial styloid process. Subjects actively abducted their thumbs and relaxed them as the investigator passively moved their thumbs toward their forearm in an attempt to touch the thumb to their forearm. Subjects relaxed their hands with their elbows extended while the investigator passively hyper-extended the fifth metacarpophalangeal joint of each hand to its limits with the goal of extending it >90°. The axis of the goniometer was placed at the base of the 5^{th} metacarpal joint while the stationary arm was pointed towards the elbow, and the reference arm was pointed towards the tip of the 5^{th} digit. Subjects stood with their feet at shoulder width apart while the investigator passively hyperextended their knees. The axis of the goniometer was placed at the knee joint line while the stationary arm was pointed towards the greater trochanter, and the reference arm was pointed towards the lateral malleolus. Finally, subjects stood with their feet at shoulder width apart and placed the palms of their hands on the floor. Subjects straightened their knees as much as possible without lifting their palms off of the floor. See Figure 7- Figure 11 below.

Figure 7.
Beighton Scale-Passive Elbow Hyperextension.

Figure 8.
Beighton Scale-Passive Thumb Abduction.

Figure 9.
Beighton Scale-Passive Fifth Digit Hyperextension.

Figure 10.
Beighton Scale-Passive Knee Hyperextension.

Figure 11.
Beighton Scale-Knees Straight with Hands on the Floor.

The passive lumbar extension test involved placing the subject in a prone position with their arms at their side and both lower extremities passively being elevated to an estimated 30 degrees and the knees extended while the researcher applied a distraction force to the subject's legs. A positive test was indicated when the subject complained of pain or a heavy feeling in the lumbar region or feeling as though his back is "coming off."[64] This test is demonstrated in Figure 12 below. Kasai et al revealed good reliability values for the passive lumbar extension test.[64] That study examined 122 subjects with spinal stenosis, lumbar spondylolithesis, or lumbar degenerative scoliosis. Radiographs were used to validate the passive lumbar extension test for detecting lumbar segmental instability in subjects aged 39-88 y/o.[64]

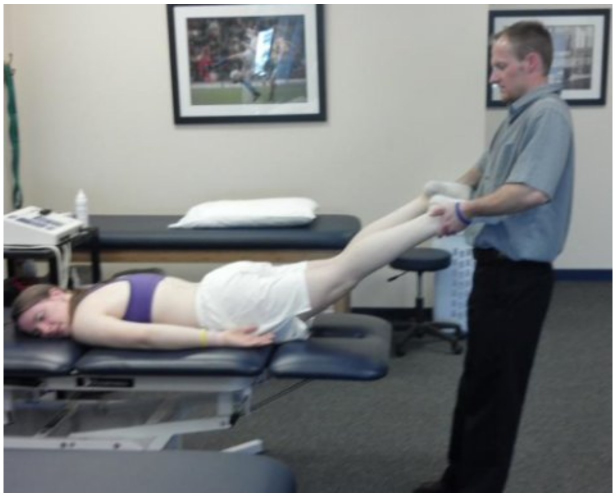

Figure 12.
Passive lumbar extension test performed in prone
with subjects' legs elevated to estimated 30° and a distraction
force applied to both of the subject's legs.

Data Analysis

All data analysis was completed using PASW (IBM® SPSS® Statistics Gradpack 22 for Windows®/Mac®) statistics package. Statistical analysis began by performing descriptive analyses including central tendency and variability on all variables. Outcomes variables were compared among the three groups using a one-way analysis of variance for each variable. Post hoc analysis was performed using the Tukey's test when significance was identified. Outcomes data for all ordinal data was compared using a Mann Whitney U test. Outcomes data for all categorical data was compared using a Chi square test or Fisher exact test. The significance level was set at the .05 level, using a 2-tailed test for all hypotheses.

Summary

Chapter 3 discussed the research subjects and research setting in which this study was conducted. A description of the pilot study data was presented and discussed. Results of the pilot study were presented and data analysis procedures that were performed for each research question were identified. A detailed description of the procedures employed in this study was provided. The specific tests and measures utilized in this research study were discussed and data analysis procedures for answering each research question were described.

CHAPTER 4: RESULTS

Introduction

Chapter 4 begins with an introduction to the chapter followed by a description of the results of this research study. A summary concludes chapter 4.

Subjects

A total number of 120 subjects were recruited and 18 of them did not meet the inclusion criteria for the study. One hundred and two subjects, 35 runners with LBP (16 males, 19 females), 33 runners without LBP (16 males, 17 females), and 34 non-running control group subjects (12 males, 22 females), were included in this study.

Descriptive Statistics

Descriptive analyses were conducted on all variables of interest for runners with and without LBP and a control group of non-runners. These values can be found in Table 7 below. Runners with LBP weighed ~5kg less than the other two groups. Control group subjects had a higher percent of female subjects than the running groups. The runners with LBP group had more subjects over 40 y/o than the other two groups. The analysis of variance revealed no significant difference among the control and runners with and without LBP groups for height ($F=1.41$, $df=2$, $p = .248$), and weight ($F=2.07$, $df=2$, $p = .132$). A significant difference was identified among the groups for BMI ($F=5.35$, $df=2$, $p = .006$). Post-hoc analysis indicated that the control group demonstrated a higher mean BMI (24.9) compared to both running groups (22.5, 23.8).

The analysis of variance revealed no significant difference among the control, runners with and without LBP groups for total lumbar flexion ($F=.343$, $df=2$, $p = .710$) but marginal in extension ($F=2.90$, $df=2$, $p = .060$) AROM. The control group demonstrated more total lumbar extension AROM (40.4°) than both running groups (34.1, 37.2). The analysis of variance revealed a significant difference among the groups for the Biering-Sorensen test (F=3.84, df=2, p = .025). Post-hoc analysis indicated that runners without LBP (52.3 sec) demonstrated significant greater endurance than the controls (40.1).

There was no significance difference among the control, runners with and without LBP groups for the Beighton scale (F=1.37, df=2, p = .258). The results of the side bridge test were significantly different among the control, runners with and without LBP groups for both the right (F=7.29, df=2, p = .001) and left (F=8.00, df=2, p = .001) sides. Post-hoc analyses indicated that both running groups demonstrated significant greater core strength than the control group. See Table 7 below.

Table 7.
Subject Characteristics and Differences Between Groups[a]

Variable	Runners with LBP (n=35)	Runners without LBP (n=33)	Control (n=34)	F	P
Height (cm)	171.5±7.9 (157-188)	172.7±9.4 (155-196)	169.0±10.2 (142-188)	1.42	.248
Weight (kg)	66.4±10.0 (50-85)	71.3±11.7 (49-95)	71.3 ±12.8 (47-102)	2.07	.132
Age (y)[b]					
18-19	0	3	2		
20-24	1	3	2		
25-29	6	4	9		
30-34	6	7	8		
35-39	2	6	6		
40-44	7	4	4		
45-49	6	3	1		
50-55	7	3	2		
BMI (kg/m^2)	22.5±2.5 (18-31)	23.8±2.5 (19-29)	24.9±3.8 (19-34)	5.35	.006*
Gender (# subjects)[b]					
Male	16	16	12		
Female	19	17	22		

TLF AROM[c]	47.5±10.2 (19-70)	45.4±12.1 (20-64)	47.4±12.1 (27-70)	.343	.710
TLE AROM[c]	34.1±10.1 (13-55)	37.2±10.1 (15-53)	40.4±12.0 (14-60)	2.90	.060
BST (sec)[c]	45.9±19.6 (10-90)	52.3±20.3 (23-90)	40.1±14.0 (5-65)	3.84	.025*
Beighton Scale	2.0±1.6 (0-6)	2.7±1.4 (1-7)	2.4±1.9 (0-8)	1.37	.258
Side Bridge Test-Right (sec)	48.3±20.4 (15-90)	48.1±19.0 (25-90)	32.9±17.6 (6-75)	7.29	.001*
Side Bridge Test- Left (sec)	45.4±20.2 (5-90)	49.1±19.0 (17-90)	31.7±15.8 (6-75)	8.00	.001*

[a]Values are mean ±SD (range). [b]Other values are counts. [c]TLF AROM-Total lumbar flexion active range of motion, TLE AROM-Total lumbar extension active range of motion, BST-Biering-Sorensen test. [d] F=F value. [e]*Significant difference between groups (p<.05).

Table 8.
Tukey Post Hoc Comparison for Demographic and LBP Variables Between Groups[a]

Variable	Mean Differences Control and NLBP	Mean Differences Control and LBP	Mean Differences LBP and NLBP
Biering-Sorensen Test	12.4 (1.4-23.3)*	5.1 (-5.2-15.5)	7.1 (-3.4-17.5)
Side Bridge R	15.1 (4.0-26.2)*	15.5 (4.5-26.4)*	.34 (-10.7-11.4)
Side Bridge L	17.4 (6.4-28.3)*	13.7 (2.9-24.4)*	3.7 (-7.2-14.6)
BMI	1.1 (-.61-2.9)	2.4 (.65-4.1)*	1.2 (-.50-3.0)

[a]Values are mean difference (95% confidence interval) unless otherwise indicated. [b]*Significant difference between groups (p<.05).

To determine whether a difference existed between runners with and without LBP in relation to physical/training variables of running and variables associated with LBP, a series of 2-tailed independent t-tests were performed on both running groups. Results of the t-test did demonstrate a significant difference between running groups in years run ($p = .004$), marathons run ($p = .030$), rest days ($p = .035$), and running days/wk ($p = .035$). No significant difference was identified between running groups in races/yr. See results in Table 9 below.

Table 9.
Subject Running Characteristics and Differences Between Groups[a]

Variable	Runners with LBP (n=35)	Runners without LBP (n=33)	Difference Between Running Groups	T[b]	P
Days of Running/wk	4.8±1.0 (3-7)	4.2±1.2 (3-7)	.6	-2.15	.035*
Rest Days	2.2±1.0 (0-4)	2.8±1.2 (0-4)	.6	2.15	.035*
Years Run	14.8±10.7 (1-36)	8.5±6.0 (1-20)	6.3	-2.99	.004*
Races/yr	9.4±8.3 (0-40)	7.8±8.7 (0-30)	1.6	.738	.463
Marathons	7.8±12.7 (0-60)	2.6±4.0 (0-15)	5.2	-2.23	.030*

[a]Values are mean ±SD (range). [b]t=t value. [c]*Significant difference between groups (p<.05).

Chi square tests (Table 10) or Fisher exact tests (any cell <5) for categorical data between running groups failed to find a difference between gender, time of day of running, stretching pre/post running, hill/interval running, previous history of running injuries, previous physical therapy for running injuries, participation in other sports besides running, wearing orthotics during running, type of running surface, type of running footwear, type of running initial foot contact, or the passive lumbar extension test. A significant difference was identified among running groups for age ($p = .05$). For ordinal variables, a Mann Whitney U test was performed (Table 11). This test did not reveal a significant difference between running groups for average running pace or best 5k time. The Mann Whitney U test did identify a marginally significant difference between running groups in km/week of running ($p = .05$).

Table 10.
Chi Square Test Between LBP and NLBP Group Running Variables[a]

Variable	Runners with LBP (n=35) Count (%)	Runners without LBP (n=33) Count (%)	Chi Square	P
Gender (# of subjects) Female	19 (54%)	17 (52%)	.052	.819
Age >40 y/o	21 (60%)	10 (30%)	6.39	.011†*
Time of Day PM	19 (54%)	18 (55%)	.000	.983
Stretch Pre Run Yes	27 (77%)	23 (70%)	.484	.487
Stretch Post Run Yes	31 (89%)	31 (94%)	.608	.674†
Intervals/Hills Yes	20 (57%)	20 (61%)	.084	.772
Previous Hx Injury Yes	27 (77%)	21 (64%)	1.49	.222
Previous PT No	22 (63%)	13 (70%)	.355	.551
Other Sports No	19 (54%)	15 (45%)	.530	.467
Orthotics No	29 (83%)	26 (79%)	.182	.670
Running Surface Asphalt Concrete Trail Track	 23 (66%) 6 (17%) 5 (14%) 1 (3%)	 27 (82%) 2 (6%) 3 (9%) 1 (3%)	 2.76	 .430
Footwear Cushion/Neutral Stability Motion Control Unknown	 21 (60%) 13 (37%) 0 (0%) 1 (3%)	 20 (61%) 9 (27%) 4 (12%) 0 (0%)	 5.70	 .127
Foot Contact Toe Heels Midfoot Unknown	 3 (9%) 15 (43%) 12 (34%) 5 (14%)	 0 (0%) 14 (43%) 9 (27%) 10 (30%)	 5.08	 .166
Passive Lumbar Extension Test Negative	32 (91%)	33 (100%)		.093

[a]*Significant difference between groups (p<.05). [b]† indicates a Fisher exact test value was used.

Table 11. Mann Whitney U Test Between LBP and NLBP Group Running Variables[a]

Variable	Runners with LBP (n=35) Median (Interquartile Range)	Runners without LBP (n=33) Median (Interquartile Range)	P
Average Pace/mi (min)	8-9 (7-10)	8-9 (7-10)	.236
Best 5k Time (min)	19-21 (17-25)	23-25 (19-27)	.072
Km/wk	48.3 (32.2-64.4)	35.4 (24.9-56.3)	.050*

[a]*Significant difference between groups, (p<.05)

Summary

Descriptive statistics were calculated for each group and listed in Tables 7 and 9, and supporting text was provided. Findings of the statistical tests for the research questions were identified in Tables 7-11. The results of these tables were discussed briefly. The research questions for this study identified differences between the control, runners with, and runners without LBP groups through one-way ANOVA and Tukey post hoc tests. Additional differences were identified between the runners with and without LBP groups through an independent t, Chi square, and Mann Whitney U tests. These results will be discussed in more detail in Chapter 5.

CHAPTER 5: DISCUSSION

Introduction to the Chapter

Chapter five begins with an introduction to the chapter followed by a detailed discussion of the results and an interpretation and examination of their meaning to this research study. Implications of this study to the field of physical therapy and runners with and without LBP are discussed. Recommendations for future research studies in this area are identified. Delimitations and limitations of this research study are delineated. A summary concludes chapter five followed by a summary of this entire dissertation document.

Demographic and LBP Variables

Prior to discussing the results of the current study, it is important to mention that the primary researcher found out after all data collection was completed that some subjects, although very small in number, ran prior to the testing. It is possible that this negatively affected the results of this study.

The current study results did not demonstrate a significant difference in height or weight between groups. In prior studies, researchers identified a greater body weight in non-running LBP subjects comparing to subjects without LBP.[57,58] Also in non-running subjects there was a linear relationship between greater height and LBP.[92,93] The small sample size of the current study may be why a difference in weight was not identified among groups.

The researchers identified a significant difference in BMI between runners with LBP and a control group of non-runners (22.6 vs. 24.9). BMI for runners without LBP

(23.8) was not significantly different from the other two groups. While none of the BMI values were considered “obese”, the control group BMI was very close to being considered overweight (25-30 BMI). It is possible that participating in regular running activities was contributing to increased fitness and a lower BMI in runners. Works by Nadler and Taunton et al indicated that runners with lower BMI were more likely to encounter LBP related to running.[14,46] Runners with LBP in the current study did demonstrate a slight lower BMI comparing to runners without LBP. However, the difference was not statistically significant.

The current study did demonstrate a significant difference in age among running subjects with LBP compared to running subjects without LBP. Runners with LBP possessed 60% runners who were ≥40 y/o while runners without LBP tended to be younger with 30% of them being ≥ 40y/o. These results were consistent with previous studies conducted on subjects in the general population.[68,71,74,75] Taunton et al and Roncarati et al identified this increased incidence of LBP in runners over the age of 40 and 50 y/o.[4,21] Bus showed that the biomechanics of running was different in older runners resulting in a lower shock absorbing capacity[76] This was related to higher impact forces with the running surface, vertical impact speeds, and initial loading rates in older runners and differences in kinetics and kinematics between older and younger runners because of musculoskeletal weaknesses.[76] Further research would need to be conducted to conclude whether these factors were related the differences in age or difference in running biomechanics among running groups.

Prior research has identified that female non-running subjects are more likely to demonstrate LBP.[70,79] The current study did not identify this difference in non-running subjects and runners with and without LBP. Further research is needed to determine if a difference exits among runners with and without LBP in terms of gender.

Fritz et al suggested that total lumbar flexion AROM > 53 degrees and total lumbar extension AROM > 26 degrees were predictors for LBP.[61] In the current study all groups demonstrated total lumbar flexion AROM outside of these cutoff values. The mean total lumbar flexion value (range) for each group, 47.4 (27-70), 47.5 (19-70), and 45.4 (20-64), was less than the cutoff value suggested by Fritz et al[61] of >53 deg. The mean total lumbar extension value (range) for each group, 40.4 (14-60), 37.2 (15-53), and 34.1 (13-55), exceeded the cutoff value suggested by Fritz et al[61] of >26 degrees. The study by Fritz et al[61] did not report minimum and maximum values for total lumbar flexion and extension. The current study and the study by Fritz et al[61] were different in the study purpose. The current study was designed to determine if there was a difference in running related risk factors for LBP between groups of runners and a control group. The study by Fritz et al[61] was designed to find predictors of risk factors for LBP that were utilized in the current study in running subjects with LBP. Difference between the two studies were possibly related to differences in sample size and characteristics. The study by Fritz et al[61] included 49 non-running subjects, all with LBP and possible radicular symptoms; the current study included subjects with LBP whom were all runners without radicular symptoms. Subjects with radicular symptoms and degenerative LBP tend to prefer lumbar flexion opposed to lumbar extension AROM as lumbar extension AROM often aggravates radicular symptoms. Since runners in the current study did not possess radicular symptoms, it could be why they demonstrated greater lumbar extension and less lumbar flexion AROM compared to subjects in the

Fritz et al[61] study. It is not clear the ages of the subjects with radicular symptoms or whether stabilization was applied to the pelvis in the study by Fritz et al.[61]

This study is the first that the side bridge and Biering-Sorensen tests were evaluated in runners with and without LBP. Previous evidence suggested that core musculature and low back muscles are challenged during running.[54,55] The side bridge test was established as an effective way to address core muscle endurance.[63] The current study did show significant differences between the control group and both running groups for the right side bridge test (32.9, 48.1, 48.3 sec). A significant difference was also found among the control group and both running groups for the left side bridge test (31.7, 45.4, 49.1 sec). It is likely that the participation of the running groups in this challenging core activity had contributed to their superior core muscle stability and trunk endurance compared to the control group of non-runners.[55]

The results of the side bridge tests were lower than reported in previous literature by Leetun et al[116] (65 sec in subjects experiencing injury and 72 sec in subjects without injury) and Waldhelm[115] (82 sec on the right side and 77 sec on the left side for healthy male subjects). The current study identified greater side bridge times in running subjects compared to the control group. The control group in the current study possessed a greater female to male ratio than the other groups (12 males, 22 females). The running groups demonstrated a similar number of males and females (16 males and 19 and 17 females). The control group and runners without LBP demonstrated lower average side bridge times in females while runners with LBP showed greater average side bridge times in females compared to males.

It is not clear what type of injuries were sustained in the study by Leetun et al.[116] The sample size of runners was small (68 runners) in the current study and included more female runners than males (57% female, 43% male). Waldhelm[115] included only male subjects (15) while Leetun et al[116] included male and female subjects (57% female, 43% male). The lower side bridge times demonstrated in the current study were possibly related to the greater ratio of female to male subjects as was the case in the study by Leetun et al.[116] While the study by Leeten et al[116] demonstrated a similar ratio of male to female subjects compared to the current study, their study included subjects competing in basketball and a variety of running activities. The current study only included subjects participating in recreational running activities. Different sports require different muscle groups to be active for competition. More dynamic sports such as basketball require that many different muscle groups be used. Jumping is part of basketball as well as running. The difference in the core muscle groups required for basketball opposed to recreational running may have resulted in lower side bridge times for the current study.[116] It was previously mentioned that a small number of subjects may have run prior to their data collection which may have skewed their results on the side bridge test due to core muscle fatigue from running.

The current study limited side bridge times to ninety seconds based on previous research showing mean side bridge times less than this time.[115,116,146] Three subjects in each of the running groups reached the ninety second limit in one or both of the side bridge tests. Since there were only three subjects in each group, it is not likely that stopping the testing at ninety seconds affected the results much.

A significant difference was found among the control group and runners without LBP for the Biering-Sorensen test (40.1, 52.3 sec). Results of the Biering-Sorensen test were much lower than values reported by Latimer et al (95 sec for subjects with LBP or a history of LBP episodes and 133 sec for subjects without LBP).[107] The study by Latimer et al was performed on non-running subjects with and without a current episode of LBP.[107] A previous study examined the Biering-Sorensen test in runners vs. non-runners and revealed average hold times of 66 sec for runners and 48 sec for non-runners. These values are similar to what was found in the current study. The previous study also examined runners in the same age groups as the current study (18-55 y/o) and identified greater hold times for running subjects vs. control group.[145,146]

The results of the current study indicated that a control group of non-runners had less core muscle stability and trunk muscle endurance than runners with and without LBP. It was possible that the control group was composed of less fit subjects and possibly greater BMI which contributed to lower trunk endurance. These results were similar to the results of Leetun et al,[116] Hultman et al,[111] and Latimer et al[107] who identified that subjects with LBP demonstrated less core stability and trunk muscle endurance compared to healthy subjects. The current study was first to identify differences in trunk muscle endurance and core stability in runners with and without LBP and a control group. The current study did stop the Biering-Sorensen test at ninety seconds due to time constraints of the data collection sessions for each subject. This may have contributed to lower hold times for the Biering-Sorenen test compared to results by Latimer et al.[107] There were two subjects in the LBP group and three in the NLBP group that maxed out the Biering-Sorensen test at ninety seconds.

The recurrence rate of episodes of LBP in runners was identified to be as high as 85% at one year.[6] This was much higher than the recurrence rates in the general population reported as ranging from 24-50% at one year, 60% at two years, and 70% at three years following the initial onset of LBP.[52,53] The passive lumbar extension test demonstrated good reliability for identifying LBP associated with instability and was used in the current study.[64] However, the current study did not find a difference in the passive lumbar extension test among runners with and without LBP and a control group of non-runners. It is possible that the subject population of runners with LBP in the current study did not have lumbar instability but general LBP. Running subjects with LBP demonstrated superior core strength and trunk muscle endurance to a control group of non-runners. Subjects with a positive passive lumbar extension test would most likely lack core strength and trunk muscle endurance. To the author's knowledge, the current study was the first to examine the passive lumbar extension test in runners with and without LBP.

Physical Running Variables

A significant difference was identified between runners with and without LBP in some physical/running variables. These variables included: days/wk of running, number of rest days from running/wk, number of years run, marathons run, and km/wk of running. The effect of years of running experience and km/wk of running on injury incidence have been studied previously by other researchers,[24,119] but their effect on LBP in runners has not been studied.

Previous researchers suggested that runners with less running experience were more subject to various running injuries including LBP,[5,18,21] which was the only injury addressed in the current study. The results from these earlier studies suggested that runners with less running experience were more subject to LBP. The current study did not find this to be the case, but did demonstrate a significant difference in km/wk of running and years of running experience between runners with and without LBP. In the current study, runners with LBP were older, had been running for more years, and were running an average of more km/wk than runners without LBP. Runners with LBP were also running more frequently and taking less rest days. It is possible that total lifetime running distances among runners with LBP may have been greater than runners without LBP. Prior research demonstrated that non-running subjects of older age experienced greater instances of LBP.[68,74] Increased age also accounted for increased years of running in the runners with LBP group. Therefore, because runners with LBP had been running more years, they had run greater cumulative lifetime mileage.

Early researches showed that females in the general population had a greater incidence of LBP.[11,62,78] Malina suggested that female runners were more likely to encounter LBP from running.[91] Several studies by Nadler et al reported that female athletes demonstrated a 6-11% greater likelihood to develop LBP than male athletes.[14,54-56] The current study did not find this to be the case as gender ratio was not significantly different between runners with and without LBP. The subject population in the studies by Nadler et al[14,54-56] included college-aged athletes from different sports participation physicals which may have accounted for the difference from the current study which included older running subjects.

A study by White and Malone investigated the relationship between the vertebral height, LBP, and the time of day that running took place in runners between 17 to 29 years of age.[32] They found a difference in LBP among runners based on time of day that running took place.[32] The current study did not find a difference in time of day that running took place between runners with and without LBP. The definition of LBP and the age difference between the current study and the study by White and Malone may be the reason for difference in outcome.

Prior researches have identified that lack of pre/post running stretching was related to running injuries including LBP.[133,134] Stretching pre and post exercise also has been shown to prevent running injuries but has not been examined in runners with LBP. Researchers showed that stretching of any muscle group for 15-30 seconds has been shown to increase flexibility for up to 90 minutes.[133,134] The current study did not find a difference in pre/post run stretching time between runners with and without LBP. The current study asked via questionnaire whether stretching was performed, and the total time that was spent stretching before and after running. It is possible that runners focus more on the lower extremity musculatures during stretching exercises. Therefore, even if they may help to prevent lower extremity injuries they do not have direct impact on the incidence of LBP. The current study did not ask in the questionnaire how long the stretches were being held, but did record total stretching time. It did not identify how many days/wk each runner was stretching before and after running. These differences may have accounted for the lack of significance in pre/post stretching and running in the current study.

Garbutt et al identified that running at various speeds was related to increased LBP.[33] They examined 14 male marathon runners between ages 22 and 38 with and without LBP at 70%, 85%, and 100% of their marathon pace and found that loading on the spine was greater at faster speeds and in the first part of the run.[33] The current study attempted to identify a difference between runners with and without LBP on their running speed in terms of best 5k time, hill/interval training, and average running pace. A significant difference was not identified between running groups in average running pace or inclusion of hill/interval running. Marginal significance was identified in best 5k time. This marginal/lack of significance may have been related to inclusion of older running subjects and lack of testing subjects at different running speeds in the current study. To the author's knowledge, the current study is the first to attempt to identify this difference in runners with and without LBP. Future studies may examine maximum running speed in runners with and without LBP since fastest 5k time demonstrated marginal significance among running groups. It may prove beneficial to compare current training pace and race paces between runners with and without LBP.

No differences were identified between running groups in previous history of running injury, previous physical therapy, participation in other sports, running in a specific type of footwear, with a certain kind of foot contact, and running with orthotics. The current study chose to examine these variables of running as they had not been previously addressed in the literature in runners with and without LBP as being risk factors for LBP. The current study did not find differences between runners with and without LBP in terms of dominant running surface. The current study included subjects from 18-55 y/o and asked what their dominant running surface was from a list of five surfaces (asphalt, cement, trails, track, and grass). Further research is needed to determine if a difference exists between runners with and without LBP in terms of dominant running surface.

Gucciardi et al defined mental toughness as “a capacity to produce consistently high levels of subjective or objective performance despite everyday challenges and stressors.”[150] Runners take pride in their ability to suffer. Maximizing race performance is about “overriding the brain’s power to slow down.”[151] Since runners with LBP were running more marathons and more miles/wk they may have been more competitive and possessed a stronger training motive than runners without LBP. This may be why runners with LBP were older, able to run farther, more days, more marathons, and more years.

Implications

The rise in participation of recreational distance runners in road races demonstrated increased numbers of people engaging in distance running to achieve personal goals and overall fitness.[2] The rise in distance running participation has been shown to be a risk factor for LBP, previously reported 41% to 85% recurrence rates in runners.[16,17,47,66,147] Researchers had identified several demographic and training variables that are associated with LBP in running.[21,33,66,91,119] This study found a difference between runners with and without LBP and a control group of non-runners in demographic, physical/training variables of running, and physical testing.

While the results of the current study are descriptive in nature, they may help those involved in the prescription of exercise (physical therapists, athletic trainers, personal trainers, strength and conditioning specialists) to understand the mental toughness of runners with LBP that allowed them to run more miles/wk with less rest days, participate in running more years, and run more marathons despite being older. The cross-sectional nature of the current study prevents knowing the long-term effect of those runners with LBP that continue to run long distances for long periods of time. The results of this study may lead to future longitudinal studies in runners. The difference identified between the control group and runners with and without LBP in terms of core stability and trunk muscle endurance may warrant further investigation. It is important to understand what demographic and training variables resulted in superior core stability and trunk muscle endurance in runners compared to a control group of non-runners.

Recommendations

The differences in risk factors identified during the current study between runners with and without LBP could lead to additional research in this area of study. Subject blinding is recommended to prevent selection and observational bias.

Further studies in runners with and without LBP should focus on the physical (running days/wk, rest days/wk, cumulative running years, total running km/wk, maximum running speed) and demographic (age, height, weight, BMI) characteristics that contributed to their mental toughness which allowed runners with LBP to run despite their symptoms of LBP. Additional studies may want to research running subjects with LBP >40 y/o and running biomechanics. Running biomechanics has been shown to be different in older runners which may be related to their ability to run more miles, days/wk, marathons, years, and take less rest days.[76]

Future studies should also address what physical and demographic characteristics of runners with and without LBP allowed them to demonstrate greater trunk muscle endurance and core muscle stability with the side bridge and Biering-Sorensen tests. Hold times for these tests should be investigated and not cut off at 90 seconds to accurately determine maximum hold times for each group of subjects.

Additional core stabilization exercises should be compared in runners and non-runners such as the plank or sit up exercise to isolate where the difference in core muscle strength may lie between groups. It is recommended that running subjects are prevented from running prior to testing to eliminate skewed data of the core stabilization tests.

Additional research should address lumbar flexion and extension AROM between a control group of non-runners and runners; the current study demonstrated a marginally significant difference in total lumbar extension AROM between the control group and runners with LBP. This variable should be examined with stabilization provided to the pelvis during lumbar AROM to prevent compensatory rotational motion of the pelvis during testing and isolate true lumbar AROM. Researchers have identified that stabilizing the pelvis in a seated position for lumbar AROM testing is an effective way to isolate lumbar musculature for ROM testing.[148,149]

In order to explain why runners with LBP were able to run more miles, days/wk, took less rest days, run more marathons, and more years, despite the fact that they were older, mental toughness should be examined in runners with and without LBP. There are a different indexes and questionnaires available for measuring mental toughness.[153-158]

An appropriate follow-up study to the current study would be a prospective cohort study that would follow a group of recreational runners without a current episode of LBP over a 12 month period to determine the characteristics of runners that develop LBP. There would be one group of male and female subjects, aged 18-65 or similar, acting as their own control. Portney and Watkins[140] suggested that approximately 50 subjects would be necessary with 90% power, .40 effect size, and .05 alpha level. I would suggest recruiting 65 subjects to account for attrition. Baseline demographic and physical training characteristics should be measured via questionnaire; which could include many of the same characteristics examined in the current study and additional ones that may be appropriate. I would recommend including the MDI, MTQ, or SMTQ to measure outcomes data. Lumbar ROM, core stabilization (side bridge test, plank test, and/or sit up test), and trunk muscle endurance would all be appropriate objective data to measure. Subjects should be encouraged to keep a training long to record their daily and weekly mileage and any episodes of LBP. Subjects should identify whether episodes of LBP prevented them from running, allowed them to run with pain, resulted in pain only after running, or did not affect their running. Multivariate statistical analysis can then be run to determine the relative contribution of the predicted risk factors to LBP in recreational runners.

Limitations and Delimitations

Delimitations

This study was delimited to recreational distance runners with and without LBP who were:

A. Between the ages of 18-55 y/o currently running at least 20-30km/wk for a minimum of 1 year to exclude adolescent and older running subjects with degenerative LBP.
B. Experiencing LBP lasting >2 weeks but less than 6 months in duration to avoid acute episodes of LBP.
C. Running during the AM/PM hours of the day

D. Not currently seeking medical care for their LBP (examining functional not debilitating LBP subjects)

E. LBP is originating at the lumbar region between the buttocks and rib cage that does not radiate to the lower extremities.

This study was also limited to non-runners who were between the ages of 18-55 y/o. Subjects were recruited from a variety of settings including local running groups, Rebound Physical Therapy clinics, and one local running store; therefore, were limited to the geographical area of Rockford, Illinois and surrounding areas. The delimitation of age groups 18-55 possibly excluded some subjects over the age of 55 that may have demonstrated signs of LBP. The delimitation of running at least 20-30km/wk for a minimum of 1 year may have excluded "newer" runners that were running < 1 year and/or <20-30km/wk that would have demonstrated signs of LBP.

There were threats to validity of the tools used in this study. Testing effects were a concern during the pilot study. During the 10 subject pilot study of runners with LBP, each subject was tested by two different researchers to establish inter-rater reliability values for the clinical tests used in this study. The subjects may have been fatigued from their first testing session resulting in a lower performance on their second testing session during the pilot study negatively affecting the reliability. Testing effect was not a concern during other data collection sessions outside of the pilot study since repeated testing of subjects was not taking place.

History effects were possible during the pilot study between testing performed by the two researchers. If the second researcher was still testing another subject, subjects were waiting for a few minutes and may have talked to other subjects. History effects were also a concern as some subjects revealed to other subjects that they ran prior to the testing which may have affected their core and low back muscle endurance prior to testing. Selection effects may have been an issue as well as subjects were assigned to each of the groups as they met the inclusion criteria (non-random assignment). This resulted in runners with LBP being older than runners without LBP and the control group possessing more females than the running groups.

One threat to external validity included selection and adherence. It was already previously stated that some subjects revealed to other subjects that they had run prior to their testing. This was an inability of those few subjects to comply with the experimental protocol. This resulted in less ability to generalize the results of this study to similar studies.

Limitations

A second pilot study was not performed on those clinical tests with only moderate reliability. A second pilot study would have increased the confidence of the researchers moving forward with data collection on research subjects that the statistical tests performed on all subject data would demonstrate good reliability.

This study did not have control over whether a subject experienced muscle soreness or fatigue as a result of the clinical tests. It was specified for each subject how to deal with the muscle soreness/fatigue in the informed consent form. Not all runners with and without LBP were able to be tested at the same time of day. Even though subjects were requested to not run prior to their testing, these guidelines were not always followed. The primary researcher assumed that each subject followed the guidelines e-mailed to them prior to participating in the study. The researcher found out after all data collection was completed that some subjects, although very small in number, ran prior to the testing. This may have negatively affected the external validity of this study. However, that data could not be removed because it was unclear which subjects had run prior to their data collection and was still included in the results of this study. Inclusion of that data may have skewed the results of some of the statistical tests used in this study including lumbar AROM, Biering-Sorensen test, and side bridge tests due to muscle fatigue or stiffness from running.

During total lumbar flexion and extension AROM measurements, the researchers chose not to stabilize the pelvis during these testing procedures. The pelvis was not stabilized during these measurements because the researchers were following the procedures for total lumbar AROM outlined by Waddell et al[139] whom did not stabilize the pelvis. Lack of stabilization of the pelvis may have allowed rotational movement in the pelvis from activation of the gluteal and hamstring muscles that increased lumbar extension AROM measurement;[148] which may have been a source of error leading to lack of significance in total lumbar AROM measurements among groups. Not stabilizing the pelvis can result in compound lumbopelvic AROM preventing true lumbar AROM from being measured.[148]

Fritz et al[61] demonstrated a total lumbar flexion value of 48° in subjects with LBP while the current study found a similar value of lumbar flexion AROM in runners with LBP (47°). Similar values were also found in runners without LBP (45°). Fritz et al identified 27° of lumbar extension AROM in subjects with LBP.[61] The current study found 34° and 37° in runners with and without LBP. The current study included runners with and without LBP, and the study by Fritz et al[61] included non-running subjects with LBP and possible radiculopathy. This may have also accounted for this difference in

ROM between studies. To my knowledge, the current study is the first to address lumbar AROM in runners with and without LBP.

Summary

Chapter 5 began with an introduction and discussion of results of the statistical analyses performed and their relationship to each of the established research questions. Implications of this study to the field of physical therapy were discussed, and recommendations for future research studies on risk factors for LBP in runners with and without LBP vs. a control group of non-runners were made. Limitations and delimitations of this research study were discussed. Suggestions for changes in research methods and topics for future research in conjunction with LBP and risk factors in runners were addressed.

Summary of the Research Study

For the purpose of this study, LBP was defined as a current episode of LBP during running (identified on a questionnaire, by participants not currently seeking medical care for their LBP). One of the inclusion criteria was LBP episodes of greater than 2 weeks but less than 6 months duration originating at the lumbar region between the buttocks and rib cage that does not radiate to the lower extremities.[5] This study included 102 subjects classified into 3 research groups. The groups consisted of 35 male and female recreational distance runners with LBP (19 males, 16 females), 33 male and female recreational distance runners without LBP (17 males, 16 females) and 34 non-running control group subjects (21 females, 12 males). Prior to data collection, a pilot study of ten recreational distance runners with LBP (5 males, 5 females) was performed by the two participating researchers. Subjects for the running groups with and without LBP were recruited from a local running store, sports club, and two physical therapy clinics in Rockford, IL. To answer the research questions differences were compared among the three groups using a one-way analysis of variance for each variable. Post hoc analysis was performed using the Tukey test. Differences between running groups were compared using a t test. Chi square and Mann Whitney U tests were performed for categorical and ordinal data.

Research question 1 addressed whether there was a difference between runners with and without LBP and a control group of non-runners in demographic variables and variables associated with LBP. Results of the one-way analysis of variance test revealed no significance between the control and runners with and without LBP groups for the Beighton scale, total lumbar flexion and extension AROM, age, gender, height, and weight. A significant difference was identified among the groups for the right and left side bridge tests between both running groups and the control group. A significant difference was found in BMI between the control group and runners with LBP. A significant difference was also found between the control group and runners without LBP in the Biering-Sorensen test.

Research Question 2 addressed whether there was a difference between runners with and without LBP in relation to physical/training variables of running and variables associated with LBP. Results did not find a significant difference between running groups in weight, height, races/yr, lumbar flexion and extension AROM, side bridge right and left, BMI, and the Biering-Sorensen test. A t test between running groups did demonstrate a significant difference between running groups in days/wk of running, rest days/wk, years run, and marathons run. Chi square test results did not determine any significant differences in physical/running variables between running groups but did identify a difference in age. The Mann Whitney U test did establish a difference between runners with and without LBP in km/wk of running but not average training pace or best 5k time.

Further studies in runners with and without LBP should focus on the physical (running days/wk, rest days/wk, cumulative running years, total running km/wk, maximum running speed) demographic (age, height, weight, BMI) characteristics, nd mental toughness that allowed runners with LBP to run more miles, days/wk, takes less rest days, run more marathons, and more years despite their symptoms of LBP. Additional studies may want to research running subjects with LBP >40 y/o and running biomechanics. Running biomechanics has been shown to be different in older runners which may be related to their ability to run more miles, days/wk, marathons, years, and take less rest days.[76]

Future studies should also address what physical and demographic characteristics of runners with and without LBP allowed them to demonstrate greater trunk muscle endurance and core muscle stability with the side bridge and Biering-Sorensen tests. Additional core stabilization tests may be useful in this population including sit ups and/or the plank test.

Further research should address lumbar AROM between a control group of non-runners and runners with LBP with stabilization of the pelvis. It may also prove beneficial to research runners with and without LBP for a difference in miles of running per day and running speed. Current training and maximum race paces should be compared between runners with and without LBP. Further studies in runners should emphasize strict adherence to study protocol to prevent subjects from running prior to testing.

An appropriate follow-up study to the current study would be a prospective cohort study that would follow a group of male and female recreational runners, aged 18-65 or similar, without a current episode of LBP over a 12 month period to determine the characteristics of runners that develop LBP. Baseline demographic and physical training characteristics should be measured via questionnaire and include a mental toughness scale to measure outcomes data. Lumbar ROM, core stabilization (side bridge test, plank test, and/or sit up test), and trunk muscle endurance would all be appropriate objective data to measure. Subjects should be encouraged to keep a training log to record their daily and weekly mileage and any episodes of LBP. Multivariate statistical analysis can then be run to determine the relative contribution of the predicted risk factors for LBP in recreational runners.

APPENDIX A:

Doctoral Research Project

If you are a recreational runner between the ages of 18-55 running at least 10miles/wk with recurrent low back pain, you are eligible to participate in a doctoral research study conducted by Jonathan Gallas, PT, DPT, CSCS. You will be required to commit approximately 45 minutes one time only. There will be no compensation for participating. Refreshments will be provided following your data collection session. Your will be provided feedback on your results and how they may relate to your low back pain. If interested, please e-mail/call Jonathan Gallas at:

runfar17@hotmail.com (815)985-8891.

Nova Southeastern University, Health Professions Division
College of Allied Health and Nursing, Physical Therapy Program
3200 S. University Drive, Fort Lauderdale, FL 33328

APPENDIX B:

Consent Form for Participation in the Research Study Entitled: Risk Factors for Low Back Pain in Recreational Distance Runners
Funding Source: None

IRB approval #

Principal investigator(s)
Jonathan E. Gallas
12411 Lakeview Dr. Loves Park, IL. 61111
(815) 885-8416
runfar17@hotmail.com

Co-investigator(s)
Dr. Leah Nof
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Dr. John Echternach (deceased)
Nova Southeastern University

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Initials: ________ **Date:** ________ **Page 1 of 4**

Institutional Review Board
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Site Information

Rebound Physical Therapy
3616 N. Main St.
Rockford, IL. 61103
(815) 877-5932

Rebound Physical Therapy
4675 Bluestem Rd
Roscoe, IL 61073
(815) 623-9930

Description of the Study: The purpose of this research study is to describe a group of runners with and without LBP and whether they are associated based on a group of modifiable and non-modifiable risk factors. Subjects are invited to participate in this study if they are between the ages of 18-55 and do not have a history of narrowing of the spine, spinal cancer, spinal fracture of the low back, spinal infection, metal placement in the low back, inability to flex or extend the spine to complete the testing, are not currently receiving physical therapy for LBP that includes abdominal exercises as part of their rehabilitation, or do not have a current running related injury that may alter their normal running form.

Subjects will be asked to complete a demographic data form and will be evaluated for risk factors associated with LBP. Subjects will be asked to perform the following:

- Stand and bend forward and backwards as far as possible

This test will be used to evaluate the range and motion and strength of the muscles of subjects' lower spine. Approximately 45 minutes of time commitment will be required for participation in this study (approximately 15 minutes will be required to fill out a demographic and training variable questionnaire and the remaining 30 minutes subjects will perform the test mentioned above). Refreshments will be provided for subjects at the end of their data collection session.

Risks /Benefits to the Participant:

Subjects may be at risk for some physical muscle soreness in the lower back following the testing. If this occurs, subjects will be instructed to ice the sore area for 20 minutes 2-3X/day for 48-72 hours. Nova Southeastern University will not be responsible for any costs related to medical expenses associated with medical injury from participation in this research project. Participants and distance runners in general may benefit from the results of this study which may lead to successful injury prevention programs. If subjects have any concerns about the risks or benefits of participating in this study, they may contact the principle investigator, [Jonathan Gallas], or the university's human research oversight board (the Institutional Review Board or IRB) at the numbers indicated above.

Costs and Payments to the Participant:

There are no costs or payments made to subjects for participating in this study. Complimentary refreshments will be provided following the data collection session.

Confidentiality and Privacy:

Subjects will be assigned a code number by the research assistant whom will be checking in subjects and assigning them to each group. Subjects will be instructed not to use their name when the clinical tests are performed on them by the researchers. All clinical data collected will be placed in separate envelopes and locked in a cabinet for each subject to ensure security and confidentiality. All information obtained in this study is strictly confidential unless disclosure is required by law. Nova Southeastern University's human research oversight board (the Institutional Review Board or IRB) and regulatory agencies may review these research records.

Participant's Right to Withdraw from the Study:

All subjects have the right to refuse to participate or to withdraw from this study at any time, without penalty. If subjects choose to withdraw, subjects may request that any of your data which has been collected be destroyed unless prohibited by state or federal law.

Other Considerations:

If significant new information relating to the study becomes available, which may relate to subjects' willingness to continue to participate, this information will be provided to subjects by Jonathan E. Gallas.

Voluntary Consent by Participant:

I have read the preceding consent form, or it has been read to me, and I fully understand the contents of this document and voluntarily consent to participate in the research study entitled: Risk Factors for Low Back Pain in Recreational Distance Runners. All of my questions concerning the research have been answered. I hereby agree to participate in this research study. If I have any questions in the future about this study they will be answered by (Jonathan E. Gallas).
A copy of this form has been given to me. This consent ends at the conclusion of this study.

Participant's Signature: ____________________________ Date: ________________

Witness's Signature: ______________________________ Date: __________________

APPENDIX C:

REBOUND
THERAPY CENTER

Permission Letter

We, Rebound Physical Therapy, authorize Jonathan E. Gallas to complete data collection for the following research project: **Risk Factors for Low Back Pain in Recreational Distance Runners.** We authorize this data collection at the following Rebound Physical Therapy sites if necessary:

Rebound Physical Therapy	Rebound Physical Therapy
3616 N. Main St. Rockford, IL 61103	4675 Bluestem Rd Roscoe, IL. 61073

Sincerely,

K. Mark Fischer
Rebound Physical Therapy

APPENDIX D:

Participation Survey for Research Study Entitled:
Risk Factors for Low Back Pain in Recreational Distance Runners

	(circle one)
Are you between the ages of 18-55?	Yes No
Have you run at least 20-30km (10-12miles) a week for at least 1 year?	Yes No
Do you have a current episode of low back pain lasting greater than 2 weeks but less than 6 months duration?	Yes No
Do you have a history of known:	
Degenerative disease of the spine?	Yes No
Spinal cancer or family history of spinal cancer?	Yes No
Fracture of the lumbar spine?	Yes No
Spinal infection or spinal fusion?	Yes No
Cauda equine syndrome?	Yes No
Pain related to gastrointestinal or genitourinary problems?	Yes No
Inability to flex or extend the spine in standing?	Yes No
Currently receiving physical therapy for LBP?	Yes No
Current receiving treatment for a running related injury?	Yes No
Do you speak English fluently?	Yes No

APPENDIX E:

Consent Form for Participation in the Research Study Entitled: Do recreational distance runners demonstrate clinical signs of instability of the lumbar spine, and is there a relationship between specific training variables of distance running and clinical signs of instability?

Funding Source: None

IRB approval #

Principal investigator(s)
Jonathan E. Gallas
6564 Thomas Pkwy
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Co-investigator(s)
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jechtern@netzero.net

Initials: ________ Date: ________

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(815) 877-5932

Rebound Physical Therapy
4675 Bluestem Rd
Roscoe, IL 61073
(815) 623-9930

Description of the Study:

The purpose of this research project is to determine if distance runners with LBP demonstrate clinical signs of lumbar instability compared to distance runners without LBP and a control group of non-runners without LBP and similar characteristics. You are invited to participate in this study because you are between the ages of 18-55 and do not have a history of spinal stenosis, spinal malignancy, history of fracture of the lumbar spine, presence of spinal infection, history of spinal fusion, inability to flex or extend the spine to complete the testing, currently receiving physical therapy for LBP that includes stabilization exercises as part of their rehabilitation, or current running related injuries that may alter their normal running form. Subjects will be evaluated for their results on tests for signs of clinical lumbar instability including: the prone instability test, Beighton Scale, passive accessory mobility testing for all five lumbar segments, lumbar flexion and extension total active range of motion, passive lumbar extension test, side-bridge test, and the Biering-Sorensen Test. These tests will be used to evaluate the range and motion and strength of the muscles of your lower spine. Approximately 45 minutes of time commitment will be required for participation in this study. Approximately 15 minutes will be required to fill out a demographic and training variable questionnaire. The additional 30 minutes will be to perform the tests mentioned above. Refreshments will be provided for you at the end of your data collection session. Thank you for participating in this research study.

Initials: ________ **Date:** ________

Risks /Benefits to the Participant:

Potential risks include: loss of time due to 45 minute time commitment. Loss of pay may be a risk if you work during the weekend. Subjects will not be at risk for any type of emotional discomfort. Subjects may be at risk for some physical muscle soreness in the lower back following the testing. There are no direct benefits to subjects in this research study. If you have any concerns about the risks or benefits of participating in this study, you can contact [Jonathan Gallas] or the university's human research oversight board (the Institutional Review Board or IRB) at the numbers indicated above.

Costs and Payments to the Participant:

There are no costs or payments made to you for participating in this study. Complimentary refreshments will be provided following your data collection session.

Confidentiality and Privacy:

Subject names will only be viewed by the research assistant whom will be checking in subjects and assigning them to each group. Subjects will be instructed not to use their name when the clinical tests are performed on them by the researchers. All clinical data collected will be placed in separate envelopes for each subject and stored under lock and key by Jonathan E. Gallas to ensure security and confidentiality. All information obtained in this study is strictly confidential unless disclosure is required by law. Nova Southeastern University's human research oversight board (the Institutional Review Board or IRB) and regulatory agencies may review these research records.

Use of Protected Health Information (PHI):

As part of this study, you are asked to authorize, Jonathan E. Gallas, access to your demographic data form. The purpose of this authorization is to allow the researcher to obtain the following specific information to be used as part of this research study. This information includes: age, gender, height, weight, and number of weeks since last menstrual cycle. You may change your mind and revoke (take back) this authorization at any time, except to the extent that the researchers have already acted based on this authorization. To revoke this authorization you must write to: Jonathan E. Gallas
6564 Thomas Pkwy Rockford, IL. 61114. Your treatment at NSU (or Rebound Physical Therapy) will not be affected in any way by your refusal to give this authorization or to later decide to revoke authorization. You will not be able to participate in the study

procedures if you decide that you will not give authorization. If you allow this information to be used, this information will no longer be protected by federal or state law and; thus, it is possible that this information could be re-disclosed. However, we will protect the confidentiality of this information as discussed in the Confidentiality section. You have the right to refuse to sign this authorization and informed consent. This will not affect your treatment in any manner, but you will be unable to participate in the treatments and procedures associated with this research study.

Restriction of Access to Records

Because of the nature of this study, it is necessary to temporarily restrict your access to your data in order to insure the validity of the study. You will be restricted from seeing or reviewing the following records during the course of the study: demographic data and training variable form, results of clinical tests. You will be given complete access as defined under federal and state law approximately 1 year when this research study is complete.

Participant's Right to Withdraw from the Study:

Subjects will also be informed that they will not benefit from the study in any therapeutic way. All subjects have the right to refuse to participate or to withdraw from this study at any time, without penalty. If you choose to withdraw, you may request that any of your data which has been collected be destroyed unless prohibited by state or federal law.

Other Considerations:

If significant new information relating to the study becomes available, which may relate to your willingness to continue to participate, this information will be provided to you by Jonathan E. Gallas.

Initials: ________ Date: ________ **Page 4 of 5**

Voluntary Consent by Participant:

This paragraph must be included exactly as written in bold face type:

I have read the preceding consent form, or it has been read to me, and I fully understand the contents of this document and voluntarily consent to participate in the research study entitled "(Do recreational distance runners demonstrate clinical signs of instability of the lumbar spine, and is there a relationship between specific training variables of distance running and clinical signs of instability?)". All of my questions concerning the research have been answered. I hereby agree to participate in this research study. If I have any questions in the future about this study they will be answered by (Jonathan E. Gallas).
(If applicable: I also voluntarily agree to the release of my PHI as described in this document.) A copy of this form has been given to me. This consent ends at the conclusion of this study.

Participant's Signature: ___________________________ Date: ________________

Witness's Signature: _____________________________ Date: __________________

REBOUND
THERAPY CENTER

Permission Letter

We, Rebound Physical Therapy, authorize Jonathan E. Gallas to complete data collection for the following research project: **Do recreational distance runners demonstrate clinical signs of instability of the lumbar spine, and is there a relationship between specific training variables of distance running and clinical signs of instability?** We authorize this data collection at the following Rebound Physical Therapy sites if necessary:

Rebound Physical Therapy	Rebound Physical Therapy
3616 N. Main St. Rockford, IL 61103	4675 Bluestem Rd Roscoe, IL. 61073

Sincerely,

K. Mark Fischer
Rebound Physical Therapy

Demographic Data and Training Variable Questionnaire

Do recreational distance runners demonstrate clinical signs of instability of the lumbar spine, and is there a relationship between specific training variables of distance running and clinical signs of instability?

(circle/write-in correct response where appropriate)

Demographic Data

Age 18-19 20-24
25-29 30-34 35-39
40-44 45-49 50-55

Gender Male Female

Weight ____________LBS

Height ____________inches (60 inches= 5 ft)

Training Variables

Miles run per week
____

Number of days run per week
____

Number of rest days per week
____

Time of day that training normally takes place AM PM

Years of running experience
____

Number of races run per year
____

Number of marathons run
____

Average training pace
____

Best 5K time
____

Approximate time spent stretching before/after running
__________ Before
__________After

Currently performing interval/hill training
Yes No

History of previous running injuries
Yes No
If yes, specify____________________

PT Treatment
Yes No
If yes, when ___________

Dominant running surface
Asphalt Cement Trails
Track Grass

Current participation in other recreational sports
Yes No

Use of orthotics
Yes No

Type of running shoes
Cushion Stability
Motion Control

Type of initial foot contact (if known)
Toes Heel Midfoot

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