2004

Instrument assisted soft tissue mobilization: effect on strength and range of motion

John Frederick Burnside
Louisiana State University and Agricultural and Mechanical College, jburns5@lsu.edu

INSTRUMENT ASSISTED SOFT TISSUE MOBILIZATION: EFFECT ON STRENGTH AND RANGE OF MOTION

A Thesis

Submitted To the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
Requirements for the degree of
Master of Science

in

The Department of Kinesiology

by
John Burnside
B.S., University of Central Florida, 2002
August 2004

ACKKNOWLEDGEMENTS

I would like to thank committee members Dr. Michael Welsch, PhD, Dr. Arnold Nelson, PhD, Dr. Ray Castle, PhD, ATC, and Jack Marucci, MS, ATC for helping me throughout the course of my study. Special thanks to “Graston Technique”, and Dr. Tom Hyde, DC, DACBSP, Dr. Dick Vincent, DC, and Terry Loghmami, MS, PT, MTC for allowing me access to the instruments used in the study. I would also like to thank all subjects who participated in the study.

TABLE OF CONTENTS

ABSTRACT

OBJECTIVE: The purpose of this study is to determine strength changes in the knee measured throughout full range of motion following Instrument Assisted Soft Tissue Mobilization.

METHODS: 13 subjects underwent pre-screening for existing soft tissue lesions. Subjects performed multiple angle isometric strength testing at the knee (15^o, 45^o, 60^o, 90^o, 115^o of knee flexion) prior to beginning a 4-week resistance training protocol. Subjects performed knee extension/flexion exercises (2x15) 3 times a week for 4 weeks. Following the training period, subjects were post tested using the same protocol as used in the pre-test.

DATA ANALYSIS: A paired sample t-test was used to determine the difference in isometric peak torque between the control knee and treatment knee. A (2x5) ANOVA was used to compare each angle of isometric force for both knee flexion and extension in the control knee vs. the treatment knee.

RESULTS: Improvements in strength were significant for knee extension in both legs following the 4-week resistance training protocol. No difference was observed between the two legs at each of the 5 angles examined. No significant change in range of motion was observed.

CONCLUSION: Instrument Assisted Soft Mobilization has no effect on ROM and strength changes for healthy subjects, who have no prior history of knee or thigh injury. Its success is documented for therapeutic purposes, but more research is needed in regards to its use for a healthy population.

INTRODUCTION

Cumulative Trauma Disorder (CTD) is a chronic inflammatory condition caused by a repetitive micro trauma to involved tendons, tendon sheaths, muscles, and vasculature. [1] CTD often results in soft tissue fibrosis when mature collagen cross links become disorganized and hypertrophic following repetitive movement. [1, 2] Granulation tissue is often detected as soft tissue adhesions and myofascial restrictions in patients with CTD. [2] Soft tissue restrictions lead to decreased function and limited range of motion in individuals affected. If not properly treated CTD can weaken the affected structure, and change the kinetic chain predisposing individuals to further injury.

Traditional therapy for CTD has been ineffective in eliminating excessive soft tissue fibrosis following injury. [1-4] "Tendonitis" is a common soft tissue diagnosis that traditionally has been treated with rest, ice, compression and elevation (RICE). However, recent histological evidence reports no acute inflammatory cells are found in tendons previously diagnosed with tendonitis. [5, 6, 7] Therefore, it has been suggested that the term "tendinopathy" be used instead of the largely misunderstood "tendonitis". [5, 6, 7] Clinicians are frustrated because of the inability to find a consistent treatment method effective in managing CTD and other chronic overuse disorders. [2, 3] Therefore, more advanced clinical techniques are being developed in order to effectively treat soft tissue disorders such as CTD.

Instrument Assisted Soft Tissue Mobilization (IM) is an advanced soft tissue treatment indicated for soft tissue fibrosis and chronic inflammatory disorders such as CTD. Following reconstructive knee surgery, two athletes requiring soft tissue mobilization developed the instruments in order to treat post-surgical scar tissue accumulation. After using the instruments they introduced the technique to Ball Memorial Hospital and Ball State University in Muncie, Indiana. [3] Further research led to the development of Graston Instrument-Assisted Soft Tissue Mobilization (GISTM), otherwise known as the "Graston Technique". Its success has been clinically documented, but there is a need for further research in order to establish its effectiveness in the clinical setting. [1-4, 8- 12]

Instrument Assisted Soft Tissue Mobilization (IM) has been successful in alleviating pain and dysfunction associated with CTD [1-4, 8-12] IM is indicated for both chronic overuse disorders such as CTD, and for patients requiring soft tissue mobilization following injury. [10] Its first purpose is to assist clinicians' in the evaluation and identification of soft tissue fibrosis. [10] Once damaged areas are detected, IM functions to mobilize areas of soft tissue fibrosis and loosen surrounding tissues. [10] IM delivers controlled micro trauma to the affected area, resulting in a local inflammatory response initiating the healing process. [1, 3, 10] The vascular response initiated by IM functions to promote soft tissue remodeling, bringing new nutrients, and fibroblasts to the area being treated. When used in combination with a stretching and therapeutic exercise protocol, IM has shown to correctly restore soft tissue structure and function. [2, 4, 8- 10] However, it is vital that adaptive stress be used in combination with IM in order to properly restore normal function. [10]

Rehabilitation requires strengthening in order to properly correct and remodel damaged soft tissue following injury. [13] During the healing process the body produces an immature collagen matrix, which accumulates at the site of injury. Unorganized scar tissue buildup may prevent a joint from achieving its normal range of motion. [1, 8] Thus, IM can be implemented post injury to achieve full range of motion prior to therapeutic exercise. Optimal rehabilitation requires full range of motion prior to strength training, and IM provides a direct method to achieve this goal. However, research has yet to show the relevance for using IM prior to strength training during rehabilitation. Therefore, in order to better understand the effects of IM application for rehabilitation purposes, we must first understand the effect IM has on subjects with no history of injury or limitation. The present study will investigate IM in conjunction with a progressive resistance exercise protocol in healthy subjects. The purpose of this study is to determine strength changes in the knee measured throughout full range of motion following Instrument Assisted Soft Tissue Mobilization. We believe that IM will loosen soft tissue surrounding the knee allowing strength to increase through a greater range of motion when compared to the control knee.

LITERATURE REVIEW

Proliferation involves the delivery of immature collagen to repair damaged tissue following injury. The proliferation phase of the healing process is characterized by delivery of fibroblasts to the injured area, and the synthesis of immature collagen fibers. Uncontrolled proliferation results in the accumulation of scar tissue, which can result in a loss of function due to connective tissue fibrosis. [14] The healing process functions to restore the body to its original status, however in some cases incorrect healing due to excessive fibroblast proliferation can result in soft tissue fibrosis and dysfunction.

Cumulative Trauma Disorder

Cumulative Trauma Disorder (CTD) is a chronic inflammatory condition caused by a repetitive micro trauma to an involved tendon. CTD results in soft tissue fibrosis when mature collagen cross-links become disorganized and hypertrophic.[1] Granulation tissue is often detected as soft tissue adhesions and myofascial restrictions in patients with CTD. Soft tissue restrictions lead to decreased function and limited range of motion in individuals affected.

CTD is often mistreated, because clinicians lack understanding of the chronic inflammatory process.[5] Clinicians often choose ineffective conservative treatment methods for chronic inflammation, leaving soft tissue restrictions unresolved.[1, 5, 6] Ignoring the primary cause of CTD, while only treating the symptoms is a common problem facing clinicians.[1] Evaluation of CTD can be difficult, because underlying soft tissue restrictions are not easily detected. A common misconception is that “tendonitis” will result in acute inflammation to the affected tendon. However, recent histological evidence has recently discovered that no acute inflammatory cells exist in most chronic pathologic tendons.[5] Therefore, it is more appropriate to refer to a chronic tendon overuse disorder as a tendonipathy. This evidence suggests that injured tendons should be classified by stages of healing instead of the broad and misused term "tendonitis". [2,5,6]

Traditional Therapy

Traditional therapy for CTD involves rest, ice, compression, elevation (RICE), anti-inflammatories (NSAIDS), splinting, bracing, soft tissue massage, physical therapy and surgery.[1] Conservative management strategies for tendonitis and cumulative trauma disorder have had minimal success in eliminating the underlying problem.[1, 8, 9] Manual therapy techniques such as myofascial release and cross friction massage have been successful in helping eliminate scar tissue and palpable adhesions.[15] Anti-inflammatory medications are commonly prescribed, but may have long-term side effects that prohibit continued usage. Splinting and bracing are commonly used in combination with other traditional forms of therapy. However, frustration with the lack of results from traditional therapy has increased the need for new treatment and research for cumulative trauma disorder.

Instrument Assisted Soft Tissue Mobilization

Instrument Assisted Soft Tissue Mobilization (IM) has been successful in alleviating pain and dysfunction associated with CTD.[1, 2, 4, 8, 9, 10] IM is indicated for cases requiring soft tissue mobilization such as CTD and other chronic inflammatory conditions.[10] Following reconstructive knee surgery, two athletes developed instruments that they used to treat soft tissue fibrosis. Following successful treatment with the instruments the technique was introduced to Ball Memorial Hospital and Ball State University in Muncie, Indiana. Whereupon, further research was conducted resulting in the development of the "Graston Technique", or Graston Instrument-Assisted Soft Tissue Mobilization (GISTM). [3] For the purpose of this study, the instruments and the technique will be referred to as Instrument Assisted Soft Tissue mobilization (IM).

The first purpose of IM is to assist the clinician in identifying areas of soft tissue fibrosis.[1, 2, 8, 9, 10] Once damaged areas are detected, IM functions to mobilize areas of fibrosis and loosen surrounding tissues. IM functions by delivering controlled micro trauma to the affected area, resulting in a local inflammatory response.[1, 2, 10] The Inflammatory response represents the initial step in the healing process. The vascular response generated by IM will promote tissue remodeling by bringing in new nutrients, and fibroblasts to the injured area.[1, 2, 10] When used in combination with a stretching and a therapeutic exercise protocol IM is designed to correctly restore soft tissue structure and function.[1, 2, 4, 8, 9, 10] However, it is vital that adaptive stress be used in combination with IM in order to properly restore normal function. [10]

Clinical Benefits

Clinical benefits from IM involve improvements range in motion, strength, and pain perception following treatment.[10] Melham, Sevier, Malnofski, Wilson, and Helfst found that IM significantly improved range of motion in a college football player following 7 weeks of IM and physical therapy. Melham et al. found that scar tissue surrounding the lateral malleolus was reduced and remodeled structurally following IM application.[8] Long periods of immobilization result in decreased extensibility of collagen fibers due to increase collagen cross links and a loss of ground substance that aids the extra cellular matrix. [15] As a result, connective tissue will contract and cause a net loss in range of motion following immobilization. [15] Reproducing an inflammatory response, following immobilization may be beneficial for improving range of motion by mobilizing adhesive tissue and increasing blood flow to the affected area. Therefore, IM is indicated for soft tissue following long periods of immobilization. [10]

Sevier, Helfst, Stover, and Wilson found that IM resolved a chronic case of lateral epicondylitis for a 34-year-old textbook salesperson. IM significantly improved her wrist and forearm strength, and allowed her to return to daily activity with minimal pain recurrence. [2] Fowler, Wilson, and Sevier performed an experiment using workers from an automobile manufacturing plant who reported failed therapy for one or more chronic injuries. Fowler et al. found that physical therapists in both the clinical and industrial settings have had a 71% success rate in achieving results with instrument assisted IM. [1] Fowler et al. concluded that IM alleviated symptoms in 71% of the patients treated for CTD in the outpatient clinical setting. Patients receiving IM in the workplace had an 86% success rate within the first 6 months of therapy. [1] Therefore, IM has the potential to significantly reduce insurance payments, worker comp cases, and increase the total productivity of the plant by limiting the number of restricted workdays for injured workers. [1]

Physiological Benefits

Studies have also addressed the benefits of IM at the cellular level. Benefits include increased fibroblast proliferation, reduction in scar tissue, increased vascular response, and the remodeling of unorganized collagen fiber matrix following IM application. [10] Gehlsen, Ganion, and Helfst investigated the effects of 3 separate IM pressures on rat Achilles tendons. They concluded that fibroblast production is directly proportional to the magnitude of IM pressure used by the clinician. [11] Davidson, Ganion, Gehlsen, Verhoestra, Roepke, and Sevier supported Gehlsen et al. by concluding that IM significantly increased fibroblast production in rat achilles tendons by using electron microscopy to analyze tissue samples following IM application. [12] Davidson et al. found morphologic changes in the rough endoplasmic reticulum following IM application. Thus, indicating micro trauma to damaged tissues, resulting in an acute fibroblast response. [12]

IM has been compared with traditional physical therapy techniques in the treatment of lateral epicondylitis. Sevier, Gehlsen, Wilson, Stover, and Helfst found IM to be much more effective in treating lateral epicondylitis than traditional physical therapy without IM. [4] IM is effective because it attacks the underlying problem causing pain and dysfunction in soft tissue. Various forms of traditional therapy often treat the symptoms created by the problem, ignoring its primary cause. By eliminating the primary cause IM enhances collagen synthesis in damaged tissues, and gives the clinician the opportunity to change the structural integrity of adhesive tissues. [10, 11, 12]

Purpose

Rehabilitation requires strengthening in order to properly correct and remodel damaged soft tissue following injury. [13] Achieving full range of motion is a critical component of rehabilitation that may be assisted through IM application. Literature has previously suggested that IM improves range of motion in the injured population following application. Is it possible that IM will function to increase ROM in healthy as well as injured individuals? How will IM used prior to a progressive resistance exercise protocol effect strength adaptations measured throughout the entire range of motion in the knee? In order to fully understand the effects of IM for the purpose of rehabilitation we must look at its effects on an uninjured population.

According to Welsch, Williams, Pollock, Graves, Foster, and Fulton multiple angle isometric testing shows a significant difference in torque generated at specific angles during knee flexion/extension. [16] This study will examine isometric flexion/extension measurements at specific joint angles throughout the entire range of motion for the knee. IM in conjunction with a progressive resistance exercise protocol must be investigated to help determine its place for rehabilitation in the clinical setting. By examining strength at specific angles throughout knee range of motion it may provide a better understanding about the effect IM has on strength training following application. We believe that when IM is used in conjunction with a progressive resistance exercise protocol will provide a greater overall strength curve than the control leg.

METHODS

Subjects

Thirteen college students (7 male, 6 female) ranging from 18 to 28 years old are randomly selected from the total student population. All subjects involved in the study reported no prior history of a significant knee or thigh injury. All subjects completed and signed a consent form indicating they were willing to fully participate in all aspects of the study. Following consent each subject was pre-screened to rule out any further possibility of knee injury or other conditions that may affect the results of the study.

Pre-Screening

Each subject was evaluated for height, weight, and knee range of motion prior to pre-testing. Dominant leg was determined by having each subject kick a stationary soccer ball from a standing position. Prior to pre-testing subjects were evaluated by using the scanner (GT1) instrument in order to reveal any soft tissue lesions existing in both the quadriceps and hamstrings. The scanner was applied to each muscle group in multiple directions for approximately 20 strokes. Each stroke provided feedback about the integrity of the tissue being screened. The screening was done by a Certified Athletic Trainer (ATC) who is trained and certified in Graston-Assisted Soft Tissue Mobilization (GISTM), otherwise known as "Graston Technique" Each muscle group was individually graded on a scale of 0-5. Any muscle group that received a grade of 3 or higher was eliminated from the study. Refer to table 1 for grading criteria.

Table 1: Pre-screen grading criteria

0	1	2	3	4	5
No crepitus, smooth soft tissue	Very little crepitus	Moderate crepitus	Crepitus evident indicating pathology	Significant crepitus	Severe crepitus, scar tissue accumulation

Assessment

Strength: The Cybex NORM Testing and Rehabilitation System was used to measure isometric strength values. Multiple angle isometric strength measurements, taken at 5 different angles throughout knee flexion, were tested in each knee. The dominant leg for each subject was tested first, followed by the non-dominant leg. The dynamometer was placed at 40 degrees for each knee, with the seat positioned at 40 degrees towards the knee being tested. All straps and belts were used and properly adjusted to ensure subject comfort and optimal position. Measurements were taken multiple angles of 15^{o}, 45^{o}, 60^{o}, 90^{o}, and 115^{o} of knee flexion. Both the treatment and control knee were pre-tested prior to the beginning of the 4-week IM and resistance training protocol. At the completion of the training protocol each subject was post-tested in order to determine any isometric strength changes that may exist for each angle of knee flexion. Welsch, Williams, Pollock, Graves, and Foster demonstrated high reliability and validity assessments for isometric knee flexion/extension strength testing at (r= .88, r= .98). [16] High reliability coefficients were vital for the use of this instrumentation used in this study.

Range of Motion: Subjects were assessed for changes in knee flexion and extension. Flexion and extension were measured in both the treatment and control knee during the 4-week training period. Knee flexion and extension were assessed using a standard goniometer measurement prior to each training session. Measurements were taken three times per week for four weeks throughout the training period. Knee flexion was measured by positioning the subject in a supine position, as the subject actively bends the knee as far as possible. The goniometer was placed on the lateral aspect of the knee with its fulcrum placed at the lateral joint line, the axis was placed superiorly at the head of the femur and inferiorly at the lateral malleolus. The subject was then asked to extend the knee in a prone position with the lower leg unsupported by the table to detect any knee hyperextension. This process was the same for both the treatment knee and control knee.

Intervention

Thirteen subjects involved in the study performed a 4-week progressive resistance training protocol (PRE). The left knee (non-dominant) served as the treatment leg, receiving IM treatment, while the right knee (dominant) served as the control knee. The control knee began resistance exercise immediately following a 5 minute cardiovascular warm up on stationary bicycle without any prior soft tissue manipulation. Exercises consist of seated knee extension and standing hamstring curls. Two sets of 15 repetitions were performed on each exercise with 60 seconds between each set. PRE was performed 3 times per week for 4 weeks.

The treatment (non-dominant) knee received IM on both the quadriceps and hamstring muscle groups following training on the control (dominant) knee. All resistance exercise was performed unilaterally to account for any changes in range of motion that may occur following IM application. The treatment knee performed the same set and rep cycle as the control knee. The resistance was increased by 5-10 % per session as tolerated by each subject to provide a progressive resistance protocol. Once the subject was able to complete 15 reps at a particular weight, the resistance was increased in order to influence strength gains and training adaptations. Following the 4 – week intervention, subjects were post-tested on the Cybex NORM with the same protocol used for the pre-test to determine the strength values for both knees.

Instrumentation

The instruments used in the current study were supplied by “Graston Technique”, and consisted of 5 stainless steel instruments with both single and double beveled edges. There are 7 different treatment strokes that can be applied with IM to achieve optimal treatment effects. However, for the purpose of this study all treatment strokes were performed in a linear fashion in accordance with the muscle fibers being treated. The edge and treatment area provided by the instrument was changed depending upon the area being treated. In the current study the scanner (GT4) was the first instrument used to desensitize and evaluate the tissue being treated. The scanner provided a wider surface area for the detection of any lesion or crepitus that existed within the tissue. The handlebar (GT1) provided the remainder of the treatment by using 15-20 strokes in the same direction as the muscle fibers in both hamstring and quadriceps muscle groups. The strokes were directed at an angle between 30-60 degrees, using soft tissue mobilization cream to provide a medium between the instrument and the skin. Force was directed deep enough to detect any lesion that may exist, avoiding too much pressure to maintain subject coherence and treatment effectiveness. [10] Once the treatment knee was finished, a range of motion assessment was provided then followed by PRE intervention.

Data Analysis

Range of motion and strength changes were analyzed following completion of the data collection. Data was analyzed for changes in the strength of the treatment knee compared to the control knee. Comparisons were examined at each specific angle tested.

Quadriceps/Hamstring ratios will be compared through the total range of motion, and at each specific angle. The average range of motion before and after IM application in the treatment knee were analyzed for any change, indicating a direct impact on strength training.

Statistical Analysis

A pared sample t-test was used to determine the difference in isometric peak torque between the control knee and treatment knee. A (2x5) ANOVA was used to compare each angle of isometric force for both knee flexion and extension in the control knee vs. the treatment knee.

RESULTS

Subject Characteristics

Thirteen (7 male, 6 female) subjects participated in the study with a mean of 21.75 years of age. Average height of the 13 subjects was 61.7 inches, with an average body weight of 156.7 pounds. Average range of motion in the right knee was 131.5 degrees of flexion, and -2.6 degrees of extension. Average range of motion in the left knee was 131.5 degrees of flexion, and -3.2 degrees of extension.

Table 2: Average Values for Participant Characteristics.

Subjects	Age	Height	Weight	RKE	LKE	RKF	LKF	Dom. Leg
13	21.75	61.7	156.7	-2.6	-3.2	131.5	132.5	R

Subjects were pre-screened for previous scar tissue lesions that may have existed prior to the study. Results for quadriceps and hamstring muscle groups are listed in table 3 below. Each subject graded below 3 for each individual muscle group, indicating minimal scar tissue lesions.

Table 3: IM pre-screen lesion detection for hamstring/quadriceps. (13 subjects)

Subject	L Quad	L Ham	R Quad	R Ham
1	1	1	1	1
2	1	1	1	1
3	1	2	1	2
4	1	2	1	1
5	1	2	1	1
6	1	1	1	1
7	1	2	0	1
8	1	2	2	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	2	1	1
13	1	2	1	2

Pre-Training Strength Measures

The average knee extension/flexion isometric strength measures for the 5 angles tested (15^o, 45^o, 60^o, 90^o, 115^o of knee flexion) are presented in Table 4 and Table 5. The data indicate a gradual increase in peak torque for knee extension as the angle of knee flexion increased.

Table 4: Pre-training strength values for RKE and LKE

Descriptive Statistics

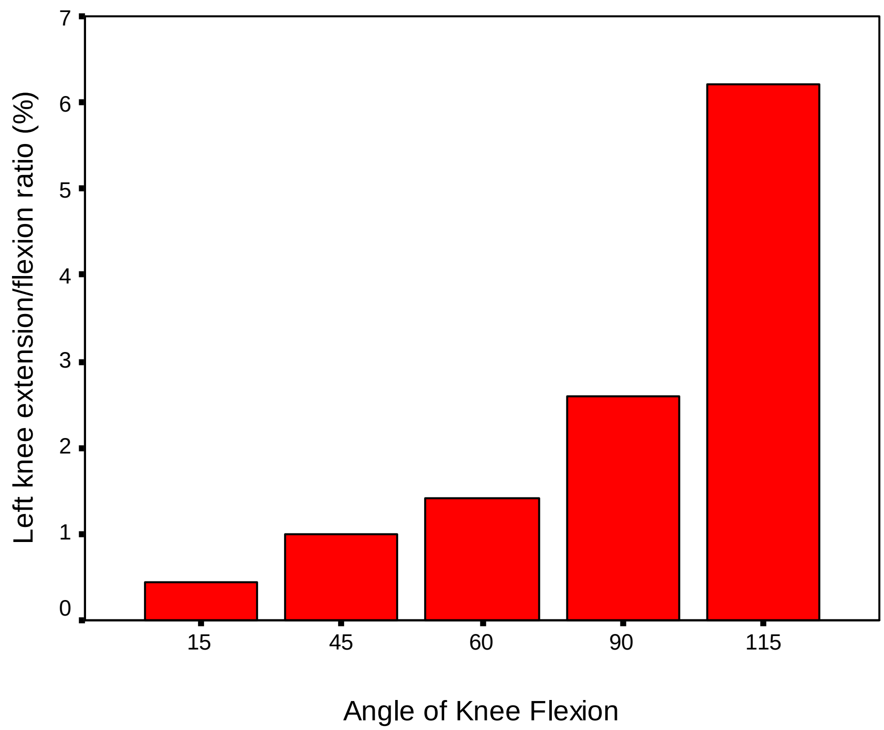
	ANGLE	Mean	Std. Deviation	N
LKE	1.00	32.2308	12.41742	13
	2.00	70.6154	30.02926	13
	3.00	94.7692	40.81289	13
	4.00	135.0769	53.72222	13
	5.00	131.6154	63.77766	13
	Total	92.8615	57.69881	65
RKE	1.00	29.5385	12.62679	13
	2.00	68.3077	27.35076	13
	3.00	89.1538	34.35803	13
	4.00	137.0769	54.07782	13
	5.00	125.0769	58.81675	13
	Total	89.8308	55.91779	65

Table 5: Pre-training strength values for LKF and RKF

Descriptive Statistics

	ANGLE	Mean	Std. Deviation	N
LKF	1.00	85.0000	25.51144	13
	2.00	80.6923	26.88675	13
	3.00	72.7692	24.49882	13
	4.00	57.1538	25.41275	13
	5.00	26.6923	16.24492	13
	Total	64.4615	31.53573	65
RKF	1.00	87.1538	34.26088	13
	2.00	79.5385	31.12238	13
	3.00	74.6923	30.63871	13
	4.00	54.1538	24.82890	13
	5.00	21.5385	15.48986	13
	Total	63.4154	36.12517	65

Knee extension/flexion ratios were examined at all five angles (15^o, 45^o, 60^o, 90^o, 115^o). Data for pre-training left and right knee extension/flexion ratios are presented in figures 1 and 2. Extension/flexion ratios were highest in both legs at 115^o degrees of knee flexion, and smallest at 15^o of knee flexion.



.

Figure 1: Pre-training left knee extension/flexion ratios

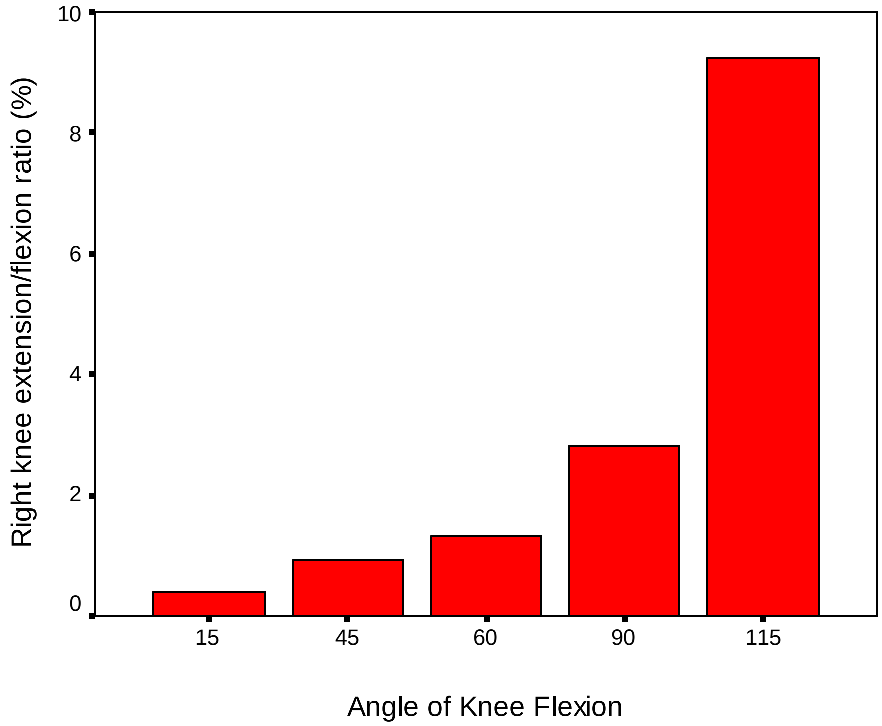


Figure 2: Pre-training right knee extension/flexion ratios

Training Responses

The average workload used for both knee extension/flexion at the beginning and end of the 4-week training period are presented in figure 3. The average increase for right and left (IM) knee extension were16% ($p=0.05$) and 19% ($p=0.01$), respectively. The average increase for right and left (IM) knee flexion was 24% ($p=0.001$) and 31% ($p=0.001$), respectively.

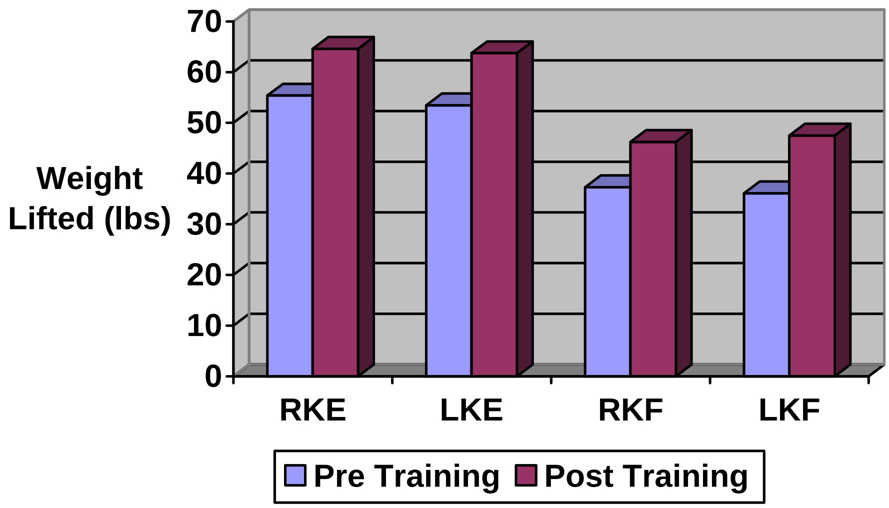


Figure 3: Average training effects for both right and left legs following 4-weak training period.

Post-Training Strength Measures

Due to technical complications during the knee flexion tests a decision was made to only report the knee extension results. The technical difficulties were consistent for all subjects and dealt with the inability to stabilize the leg and lever arm sufficiently to obtain reliable knee flexion results.

Average post-training strength measurements for both left knee extension (LKE) and right knee extension (RKE) are listed in table 5. The average increase for right and left (IM) isometric knee extension was 23% ($p=0.03$) and 19% ($p=0.03$), respectively. The isometric knee extension strength gains were observed at each of the 5 angles (15^o, 45^o, 60^o, 90^o, 115^o of knee flexion) tested. The absolute strength was greatest in the larger angles, however, the percent change for each angle tested was similar (see figure). Peak torque was the highest at 90^o of knee flexion, which was similar to pre-training results.

Table 6: Post-training strength measures for LKE and RKE

Descriptive Statistics

	ANGLE	Mean	Std. Deviation	N
LKEPOST	1.00	37.0000	12.30447	11
	2.00	83.4545	29.75017	11
	3.00	111.7273	41.23370	11
	4.00	164.2727	56.50680	11
	5.00	157.8182	72.81733	11
	Total	110.8545	66.14194	55
RKEPOST	1.00	37.2727	15.72953	11
	2.00	83.9091	28.34944	11
	3.00	112.0909	44.80726	11
	4.00	163.0000	75.18776	11
	5.00	155.3636	87.74768	11
	Total	110.3273	72.43952	55

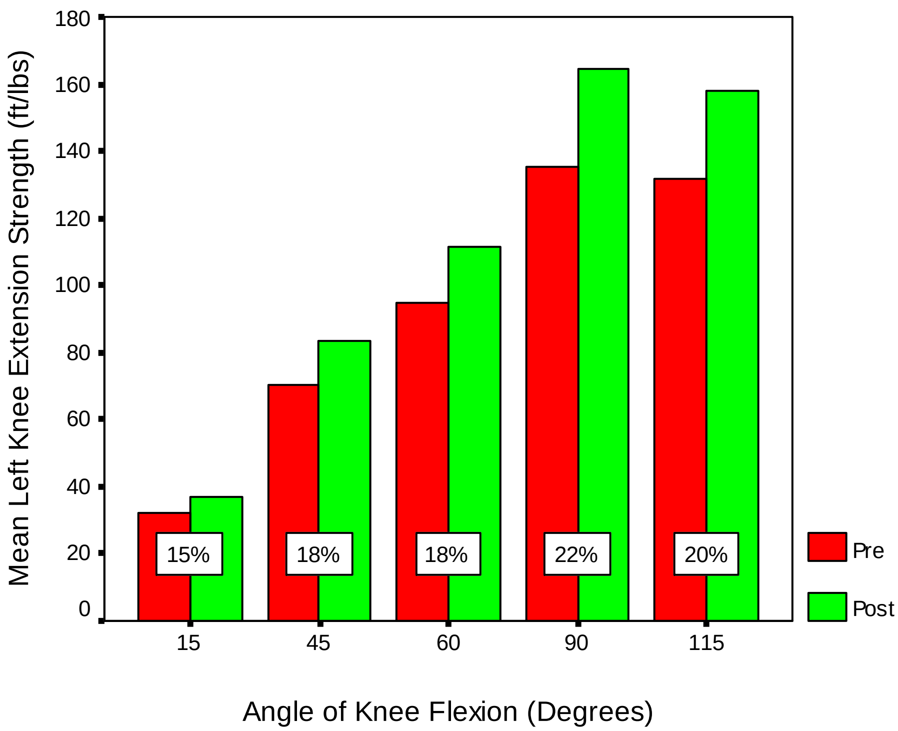


Figure 4: Represent pre and post conditions for absolute and percent change.

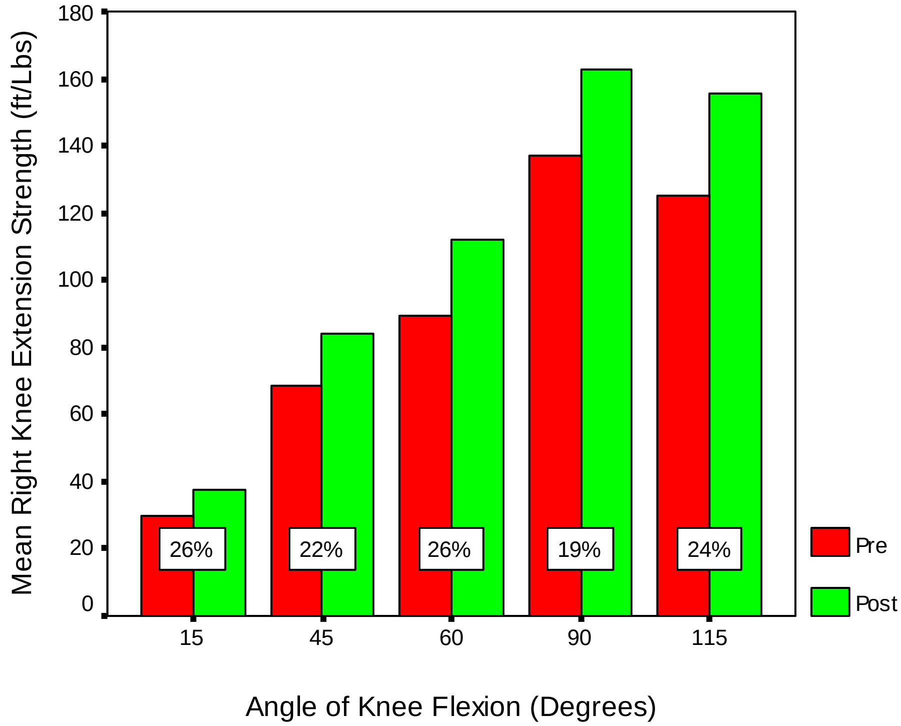


Figure 5: Represent pre and post conditions for absolute and percent change.

Figures 4 and 5 demonstrate significant improvements for both left and right knee peak torque values following 4-weeks of training. No difference in strength gains were observed between the left and right legs for isometric peak torque at any of the five angles tested.

Tables 7 and 8 represent the ANOVA results for LKE (Table 4), and RKE (Table 6). The results indicate a significant pre to post training effect (condition: p=0.033), but no interaction for condition by angle, indicating the strength gains were evenly distributed throughout the ROM. A similar result was seen for RKE (Table 7.).

Table 7: Post-training ANOVA results for LKE

Tests of Between-Subjects Effects

Dependent Variable: LKE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	230523.172[a]	9	25613.686	12.335	.000
Intercept	1236361.401	1	1236361.401	595.382	.000
COND	9645.001	1	9645.001	4.645	.033
ANGLE	220768.387	4	55192.097	26.578	.000
COND * ANGLE	2355.954	4	588.988	.284	.888
Error	228424.420	110	2076.586		
Total	1685695.000	120			
Corrected Total	458947.592	119			

a. R Squared = .502 (Adjusted R Squared = .462)

Table 8: Post-training ANOVA results for RKE

Tests of Between-Subjects Effects

Dependent Variable: RKE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	230216.841[a]	9	25579.649	10.587	.000
Intercept	1193550.744	1	1193550.744	493.986	.000
COND	12515.677	1	12515.677	5.180	.025
ANGLE	217538.714	4	54384.678	22.509	.000
COND * ANGLE	1895.280	4	473.820	.196	.940
Error	265778.084	110	2416.164		
Total	1677467.000	120			
Corrected Total	495994.925	119			

a. R Squared = .464 (Adjusted R Squared = .420)

Table 9 represents the average absolute improvement in ft/lbs for each angle for left vs. right. The data indicate that the overall improvement was similar for both legs at 13 and 14 ft. lbs respectively. Moreover, the improvements were similar for the right and left leg at each angle. Interestingly, when the data is presented as a percentage gain, the change for each angle was quite similar.

Table 9: Post-training strength differences in both LKE and RKE

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
LKEPODII	1.00	11	-3.1818	8.70423	2.62442	-9.0294	2.6658	-20.00	11.00
	2.00	11	-8.8182	15.41959	4.64918	-19.1772	1.5408	-36.00	23.00
	3.00	11	-11.8182	27.81301	8.38594	-30.5032	6.8669	-67.00	36.00
	4.00	11	-24.4545	38.14279	11.50049	-50.0792	1.1701	-107.00	27.00
	5.00	11	-17.2727	46.37260	13.98187	-48.4263	13.8808	-119.00	73.00
	Total	55	-13.1091	30.37889	4.09629	-21.3217	-4.8965	-119.00	73.00
RKEPODI	1.00	11	-6.2727	16.11888	4.86002	-17.1015	4.5561	-50.00	11.00
	2.00	11	-11.3636	11.99394	3.61631	-19.4213	-3.3060	-37.00	7.00
	3.00	11	-17.3636	20.52449	6.18837	-31.1522	-3.5751	-64.00	19.00
	4.00	11	-18.0000	40.15470	12.10710	-44.9763	8.9763	-81.00	68.00
	5.00	11	-21.8182	50.05361	15.09173	-55.4447	11.8083	-94.00	95.00
	Total	55	-14.9636	30.75649	4.14720	-23.2783	-6.6490	-94.00	95.00

DISCUSSION

Instrumented Assisted Soft Tissue Mobilization (IM) has successfully been documented in effectively alleviating pain and dysfunction associated with soft tissue injury. [1-4, 8-10] It is recommended that IM be used in conjunction with a progressive resistance exercise protocol (PRE) to stimulate optimal healing post-injury. [10] IM may be used as a stimulus prior to rehabilitation in order to improve ROM pre-exercise. Thus, allowing patients to work through a greater ROM when performing PRE. The present study asked the question pertaining to whether IM would benefit healthy subjects prior to PRE by allowing them to exercise through a greater ROM.

Results indicated that there was a training effect in both the right and left legs. Improvements were observed throughout the training intervention, as the load was increased to accommodate the progressive resistance exercise protocol. The work load used for right knee extension training increased approximately 16%, while the work load increased by 19% for left knee extension. Thus, improvements in volume of training were observed in both legs throughout the 4-week training period.

Post training isometric strength tests at all 5 angles (15^{o}, 45^{o}, 60^{o}, 90^{o}, 115^{o} of knee flexion) demonstrated significant improvement in both legs post-training. However, our data failed to show any significant difference in the magnitude of the strength gains between left and right knee extension following the 4-week intervention. The data also demonstrated no significant difference in the magnitude of the strength gains for each specific angle of knee flexion examined. This indicates that strength gains were attained equally throughout the ROM at each of the angles examined.

The strength curves observed for left and right knee extension are similar to both isokinetic and isometric strength curves observed in other studies. [17, 18, 19] Welsch et al. observed a bell shape curve for unilateral isometric knee extension, with a maximal isometric torque observed at 60^o for both legs. [16] Welsch et al. also observed the weakest angles for isometric torque to be 6^o and 108^o of knee flexion. [16] Previous studies observed knee extension peak torque the highest when the muscle being tested was in its lengthened position, and weakest in the shortest position. [20, 21] The present study revealed a bell shape curve for both left and right knee extension, with the highest mean peak torque at 90^o of knee flexion.

Knee extension/flexion ratios for both left and right legs were similar to other studies examining extension/flexion strength ratios in the knee. The present study observed the highest the highest extension/flexion ratio at 115^o of knee flexion. While, hamstring strength was at its strongest compared to the quadriceps. The lowest extension/flexion ratio was observed at 115^o. On the basis of the previous work in this area it would appear the subjects' had a fairly normal quadriceps/hamstring ratio throughout the ROM. [16] Isokinetic flexion/extension ratios are often computed by using the peak value for both the hamstrings and quadriceps throughout ROM, ignoring angle specific strength values for knee flexion. Angle specific ratios are important in determining hamstring/quadriceps ratios, because of the ability to investigate deficits at different angles throughout the entire ROM.

The strength gains observed in the present study are similar to other studies using a 4-week resistance training protocol. Folland, Irish, Tarr, and Jones (2002) reported a 13.3% increase in strength for males performing high frequency knee extension training, 3 times per week for 4.5 weeks.[22] Folland et al. also demonstrated that strength gains following 4.5 weeks did not occur at the same rate as the initial gains. [20] This suggests a possible neuromuscular adaptation occurred during the first 4.5 weeks allowing greater strength gains to occur during that time. In general it is believed that strength gains during the first 2-8 weeks of resistance training are attributed to neural adaptations, such as motor neuron recruitment, decreased antagonist co activation, and increased agonist activation. [23] According to Kraemer, neural factors play a significant role in strength gains during the early phase of a resistance training program, when improvements cannot be attributed to muscle mass. [23]

The current study examined the possible influence of IM on strength gains. The results did not reveal a difference in the strength gains between the legs. Several possible reasons could have contributed to the lack of differences observed. These possibilities include: (1) neuromuscular versus muscle volume adaptations, (2) lack of evidence of ROM deficits, (3) Inconsistencies in the individual IM applications, and (4) lack of soft tissue lesions.

In regards to the first point mentioned, it is possible that all strength gains observed were a result of neuromuscular adaptations. Previous findings indicate short-term resistance exercise provided strength gains without evidence of significant muscle hypertrophy. [24, 25] While, EMG results demonstrated increased voluntary muscle activation and antagonist relaxation occurred. [24, 25, 26] Therefore, the influence of IM on the strength gains may not become apparent until training contributes to muscle mass changes. Since the duration of the training did not last longer than 4 weeks, skeletal muscle mass adaptation may have not been a factor in the strength gains observed.

In regards to the second point, subjects involved in the study did not appear to have significant deficits in ROM prior to training. Consequently, the strength gains observed throughout the ROM are not unexpected. Clearly, future studies need to examine the influence of IM on patients with ROM deficits, such as post ACL repairs, menisectomies, etc. In addition, participants in this study showed little evidence of soft tissue adhesions. In fact, the average IM pre-screen clinical assessment score was 1.5 on a scale from 0 to 5, with the score of 0 indicating no adhesions, and a score of 5 indicating significant and debilitating adhesions. Thus, it could be argued that there was little need for IM in this group. Ideally we would have preferred subjects with evidence of more significant soft tissue lesions, which may have contributed to a restricted ROM. However, it was deemed important to conduct the study on a healthy population first to determine the safety of the IM intervention. Previous studies demonstrate the breakdown of restrictive soft tissue lesions following IM improves ROM in subjects recovering from soft tissue pathology. [8, 9, 10] Strength and range of motion are both critical components of the rehabilitation of injured patients, but failed to show any significant influence on each other in the current study. Thus, the current study cannot determine whether improvements in ROM following IM allowed greater strength gains to occur throughout the ROM.

In regards to the third point, individual subjects responded differently to the IM treatment, requiring different pressure, intensity, and duration of IM treatment. Subjects had different pain tolerance, with some subjects responding better than others in regards to the treatment. Previous studies demonstrate that the amount of pressure applied with the instruments is proportional to the fibroblast response produced. [11, 12] Fibroblast proliferation is the result of a vascular response provided by the instruments following treatment. It is possible that the treatment may have lacked sufficient consistency, intensity, and duration necessary to obtain optimal vascular responses. Therefore, possibly limiting the desired effects IM application had on subjects.

In terms of the fourth point, it is important to recognize that all subjects in the present study had no prior history of knee injury, and therefore minimal to no scar tissue lesions were found in the pre-screening evaluation. IM is not indicated for healthy people without any history of soft tissue pathology. [10] It is most commonly used in the clinic as a therapeutic modality, and not as stimulus for training. The prospective design of the current study investigated IM for benefits unrelated to previously reported findings. As a result, the current study did not demonstrate any clinical relevance for IM and its effects on strength training in healthy subjects. However, other findings relating to IM were found during the course of the study that may or may not have affected the results.

Isometric knee flexion testing demonstrated some inconsistencies, which contributed to its removal from the post training data. The present study observed difficulty in securing the velcro supports straps, which held the distal thigh secure to the chair. Movement of the distal thigh during isometric knee flexion tests may have changed the length-tension relationship in the muscle. No problem was observed securing the leg to the chair during isometric knee extension testing. Therefore, it was felt that the results obtained from knee flexion post testing were inconsistent with results obtained from knee extension testing..

A unique finding of the present study was subject’s perception of soreness. Subjects recovering from a bout of resistance exercise noted less soreness in the treatment leg compared to the control leg. This finding was consistent throughout the course of the study. Four subjects noted that the treatment leg felt looser following resistance exercise than the control leg. A future study investigating perceived soreness following resistance exercise is needed to determine if IM has any impact of post exercise muscle soreness.

In conclusion, the present study found that IM has no significant effect on strength gains seen throughout the ROM. However, strength gains in the current study may have been affected by other factors unrelated to IM. Thus, while it is clear that IM serves clinicians in evaluating, treating, and manipulating soft tissue its effect on strength changes in conjunction with resistance training remains unclear. Future research involving the rehabilitation of injured subjects is needed to determine if IM has an impact on strength gains throughout ROM.

REFERENCES

1. Fowler, S, Wilson, J, and Sevier, TL, Innovative approach for the treatment of cumulative trauma disorders, *Work*. 2000; 15:9-14.

2. Sevier, TL, Helfst, RH, Stover, SA, and Wilson, JK. Clinical trends on tendinitis. *Work*. 2000; 14:123-226.

3. Hyde, T. Graston Technique for Athletic Injuries. *D.C. Tracts.* 2003; 15(3):1-3.

4. Sevier, TL, Gehlsen, JK, Wilson, JK, Stover SA, and Helfst RH. Traditional physical therapy versus augmented soft tissue mobilization (ASTM) in the treatment of lateral epicondylitis. *Med Sci Sports Exerc*. 1995; 27:S52

5. Khan, KM, Cook, JL, Taunton JE, Bonar, F. Overuse tendinosis, not tendinitis – Part 1: A new paradigm for a difficult clinical problem. *The Physician and Sports Medicine.* 2000; May 28 (5).

6. Cook, JL, Khan, KM, Maffulli, N, Purdam C. Overuse tendinosis, not tendinitis – part 2: Applying the new approach to patellar tendinopathy. *The Physician and Sports Medicine.* 2000; June 28 (6).

7. Khan, KM, Cook, JL, Bonar F, Hartcourt P, Astrom M. Histopathology of common tendinopathies. Update and implications for clinical management. *Sports Med*. 1999; June 27(6):393-408.

8. Melham, TJ, Sevier, TL, Malnofski, MJ, Wilson, JK, and Helfst, RH, Chronic ankle pain and fibrosis successfully treated with a new non-invasive augmented soft tissue mobilization (ASTM): A case report. *Med Sci Sports Exerc.* 1997; 30:801-804.

9. Sevier, TL, and Wilson, JK, Treating Lateral Epicondylitis, *Sport Med J.* 1999; 5: 375-380.

10. Carey, MT, and Hammer, W, *The Graston technique instructional manual*. Indianapolis: Therapy Care Resources, Inc, 2001.

11. Gehlsen, GM, Ganion, LR, and Helfst, RH, Fibroblast responses to variation in soft tissue mobilization pressure, *Med Sci Sports Exerc*. 1999; 31:531-535.

12. Davidson, CL, Ganion, LR, Gehlsen, GM, Verhoestra, B, Roepke, JE, and Sevier TL, Rat tendon morphologic and functional changes resulting from soft tissue mobilization. *Med Sci Sports Exerc.* 1997; 29:313-319.

13. Prentice, William, *Rehabilitation Techniques in Sports Medicine*. 3rd edition. United States of America: McGraw Hill Company, 1999.

14. Starkey, Chad. *Therapeutic modalities*. 2nd edition. Philadelphia: F.A. Davis Company, 1999.

15. Houglum, Peggy. *Therapeutic Exercise for Athletic Injuries*. 1st edition. United States of America: Human Kinetics Athletic Training Education Series, 2001.

16 Welsch, MA, Williams, PA, Pollock, ML, Graves, JE, Foster, DN, Fulton, MN, Quantification of full range of motion unilateral and bilateral knee flexion and extension torque ratios. *Arch Phys Med Rehabil*. 1998; 79:971-978.

17. Graves, J, Pollock M, Jones A, Colum A, Leggett S. Specificity of limited range of motion variable resistance training. *Med Sci Sports Exerc.* 1989; 21:84-9.

18. Kulig, Andrews J, Hay J. Human strength curves *Exer Sport Sci Rev*. 1984; 12:417-66.

19. Osternig L. Isokinetic dynamometry: implications for muscle testing and rehabilitation. *Exerc Sport Sci Annu Rev*. 1986; 14:45-80.

20. Bandy, WD, Hanten, WP, Changes in torque and electromyographic activity of the quadriceps femoris muscles following isometric training. *Physical Therapy* 1993; July; 73 (7):455-65.

21. Mohamed, O, Perry, J, Hislop H. Releationship between wire EMG activity, muscle length, and torque of the hamstrings. *Clin Biomech*.)Oct 2002; 17(8):569-79.

22. Folland, JP, Irish, CS, Roberts, JC, Tarr, JE, Jones DA, Fatigue is not a necessary stimulus for strength gains during resistance training. *Br J Sports Med*. 2002; 36:370-3.

23. Kraemer, WJ, *Essentials of Strength and Conditioning/National Strength and Conditioning Association.* 2nd Edition. Baechle T, Earle R. United States of America. Human Kinetics, 2000.

24. Carolan, B, Cafarelli E, Adaptations in coactivation after isometric resistance training. *J Appl Physiol*. 1992; 73(3):911-7.

25. Hakkinen, K, Pakarinen, A, Kallinen, M, Neuromuscular adaptations and serum hormones in women during short-term intensive strength training. *Eur J Appl Physiol Occup Physiol.* 1992; 64(2):106-11.

26. Pensini, M, Martin A, Maffiuletti NA, Central versus peripheral adaptations followingeccentric resistance training. *Int J Sports Med*. Nov 2002; 23(8):567-74.

VITA

John Frederick Burnside Jr. was born to Fred and Nan Burnside on October 31, 1979. He completed his Bachelor of Science with a concentration in athletic training from the University of Central Florida in May, 2002. After attaining his degree from Central Florida, John passed the National Athletic Trainers Association Certification Exam. Once he became a Certified Athletic Trainer, John began his master degree in kinesiology at Louisiana State University. As a Graduate Assistant Athletic Trainer at Louisiana State University, John worked with the National Championship Football and Track and Field teams. John has currently accepted a season long internship with the Carolina Panthers for the 2004 season. He looks forward to working in the NFL, while gaining another valuable professional experience as a Certified Athletic Trainer.