THE ROLE OF MASSAGE IN SPORTS PERFORMANCE AND REHABILITATION: CURRENT EVIDENCE AND FUTURE DIRECTION

Jason Brummitt, MSPT, SCS, ATC[a]

ABSTRACT

Background. Massage is a popular treatment choice of athletes, coaches, and sports physical therapists. Despite its purported benefits and frequent use, evidence demonstrating its efficacy is scarce.

Purpose. To identify current literature relating to sports massage and its role in effecting an athlete's psychological readiness, in enhancing sports performance, in recovery from exercise and competition, and in the treatment of sports related musculoskeletal injuries.

Methods. Electronic databases were used to identify papers relevant to this review. The following keywords were searched: massage, sports injuries, athletic injuries, physical therapy, rehabilitation, delayed onset muscle soreness, sports psychology, sports performance, sports massage, sports recovery, soft tissue mobilization, deep transverse friction massage, pre-event, and post exercise.

Results. Research studies pertaining to the following general categories were identified and reviewed: pre-event (physiological and psychological variables), sports performance, recovery, and rehabilitation.

Discussion. Despite the fact clinical research has been performed, a poor appreciation exists for the appropriate clinical use of sports massage.

Conclusion. Additional studies examining the physiological and psychological effects of sports massage are necessary in order to assist the sports physical therapist in developing and implementing clinically significant evidence based programs or treatments.

Key Words: sports massage, sports rehabilitation, sports performance, sports recovery

CORRESPONDENCE:
Jason Brumitt
16322 SE Don Lino Ct
Damascus, OR 97089
jbrumitt72@hotmail.com

[a] Pacific University School of Physical Therapy
Hillsboro, Oregon

INTRODUCTION

Massage has been utilized in the treatment of illness and injury for thousands of years by health care practitioners.[1] Chinese writings dating back to 2500 BC describe the use of this modality for a variety of medical purposes.[1-3] Massage has been promoted as a treatment of choice for numerous conditions such as musculoskeletal injuries, cancer, stress, relaxation, and pregnancy.[2-4]

Physical therapists who specialize in sports medicine often utilize massage techniques to aid an athlete's recovery from intense exercise or as a treatment option when performing clinical rehabilitation.[5] Sports massage has been suggested as a means to help prepare an athlete for competition, as a tool to enhance athletic performance, as a treatment approach to help the athlete recover after exercise or competition, and as a manual therapy intervention for sports-related musculoskeletal injuries.[2,3,5] While massage is frequently performed by physical therapists (and other healthcare or alternative medicine practitioners) and is popular with athletes and coaches, its actual efficacy is questionable.[5,6]

The purpose of this paper is to review and present the current literature relating to sports massage and its roles in effecting an athlete's psychological readiness, in enhancing sports performance, in recovery from exercise and competition, and in the treatment of sports-related musculoskeletal injuries. Recommendations are discussed highlighting the need for additional research in sports massage.

METHODS

Selection of Papers

The following electronic databases were used to identify papers relevant to this review: Medline (from 1950-present), CINAHL (1982-present), PsycINFO (1985-present), Cochrane Database of Systematic Reviews, and SPORTDiscus (1830-present). Table 1 presents the Medical Subject Headings (MeSHs) and textwords (tw) utilized in the search strategy for this paper. If fewer than 300 articles were identified by a search strategy, the study abstracts were reviewed from that category in order to identify potentially relevant papers. The reference list of each of the selected papers was also reviewed in order to identify additional relevant publications.

Study Selection

Inclusion Criteria

1) The report's study design must have been one of the following: randomized controlled trial, quasi-experimental, single-case design, non-randomized historical cohort comparisons, case-series, or case report.
2) The report was published in a scientific peer-reviewed journal.
3) The sports massage protocol described in the report must have included at least one or more of the following techniques: effleurage, petrissage, or deep transverse friction massage (also known as cross-friction massage).
4) The purpose of the massage intervention was to impact one or more of the following facets of athletics: pre-event (warm-up and psychological readiness), sports performance, recovery from exercise and competition, or the treatment of sports-related injuries.

Exclusion Criteria

1) Papers that were not published within a peer-reviewed scientific journal.
2) Reports that detailed the use of massage for non-sports related injuries or functions.

The rationale for these inclusion and exclusion criteria was to identify papers that investigate the use of massage in all facets of athletic care. The massage techniques included for review in this paper were based upon their prevalence within the literature and their preference among physical therapists.[7] In specific situations where there was paucity in the literature, complementary paper(s) were presented (but not included in the overall review). Massage protocols investigating efficacy for non-sports related injuries or chronic conditions were considered beyond the scope of this review.

Description of Selected Massage Techniques

Sports massage is defined as a collection of massage techniques performed on athletes or active individuals for the purpose of aiding recovery or treating pathology.[8] Three forms of massage are frequently reported in the sports medicine literature: effleurage, petrissage, and deep transverse friction massage (DTFM).[7]

Effleurage techniques are performed along the length of the muscle, typically in a distal to proximal sequence.[1-3,8] These techniques are executed throughout a massage routine, with the strokes performed slowly utilizing light or gentle pressure.[1-3,8] The petrissage techniques include kneading, wringing, and scooping strokes.[1-3,8] These

Table 1. *Search Strategy*

MeSH or tw	MeSH or tw Defined	Number of Articles Identified	Number of Articles Determined as Potentially Relevant	Number of Articles Included in Critical Appraisal
1) MeSH or tw	Massage	14032	n/a	n/a
2) MeSH or tw	Sports Injuries	4675	n/a	n/a
3) MeSH or tw	Athletic Injuries	22785	n/a	n/a
4) MeSH or tw	Physical Therapy	53602	n/a	n/a
5) MeSH or tw	Rehabilitation	169190	n/a	n/a
6) MeSH or tw	Delayed Onset Muscle Soreness	764	n/a	n/a
7) MeSH or tw	Sports Psychology	1512	n/a	n/a
8) MeSH or tw	Sports Performance	1423	n/a	n/a
9) MeSH or tw	Sports Massage	253	22	13
10) MeSH or tw	Sports Recovery	90	4	2
11) MeSH or tw	Soft Tissue Mobilization	46	6	1
12) MeSH or tw	Deep Transverse Friction Massage	6	3	2
13) MeSH or tw	Pre-event	312	n/a	n/a
14) MeSH or tw	Post Exercise	2099	n/a	n/a
1 and 2		34	2	1
1 and 3		81	4	1
4 and 9		5	0	0
5 and 9		6	0	0
6 and 9		8	4	4
7 and 9		1	1	1
8 and 9		11	4	4
9 and 10		8	4	2
9 and 11		0	0	0
9 and 13		1	0	0
9 and 14		5	2	2

MeSH: Medical Subject Heading
tw: textword
n/a: not assessed

techniques are generally performed with deeper pressure to patient tolerance.[1-3,8] Deep transverse friction massage (also known as cross-friction massage) is performed by using the fingers to apply a force moving transversely across the target tissue.[1-3,8,9]

Description of Tables

The information about to be presented is summarized in Table 3-6. Part of each of these tables includes a column called "level of evidence." The definition of these levels is defined in Table 2. The reader should refer to Table 2 when referring to the information on Tables 3-6.

EFFICACY OF A PRE-EVENT MASSAGE

Athletes routinely prepare both physically and psychologically prior to competition. Athletes typically incorporate one or more of the following pre-competition preparation strategies: static stretching,[10,11] dynamic stretching,[12,13] warm-up drills, game simulations, and mental imagery.[14] A pre-event massage has been suggested as a strategy to decrease pre-competition anxiety and to prepare the muscles for competition.[2] Currently a paucity in the literature exists addressing the effects of a pre-event massage in order to reduce injury risk or enhance psychological readiness *(Table 3)*.

Effect on Blood Pressure

Camborn et al[15] investigated the effect of massage on a recipient's blood pressure (BP). Twenty five massage therapy students provided massage treatments to 150 current massage therapy clients.[15] The length of the massage and the techniques performed by the students were not controlled, but were instead based upon the students' perception of the clients' needs.[15] The massages ranged in time from 30 to 90 minutes. Six different massage techniques were used including Swedish, deep tissue, myofascial release, sports, trigger point, and craniosacral. The authors defined sports massage as "a more vigorous type of massage used to prepare athletes for peak performance and uses a combination of techniques including joint mobilization, stretching and/or postisometric relaxation, cross-fiber friction, and pressure point massage."[15]

The authors found that clients receiving Swedish massage (effleurage and petrissage) experienced the greatest reduction in blood pressure, whereas those who had received trigger point therapy and sports massage experienced an increase in blood pressure.[15] While this research provides findings that may have clinical significance, the study design challenges the overall strength of the findings. A large sample size was collected (n = 150), but 25 massage therapy students performed the non-uniform interventions to clients who were already receptive to this form of treatment. The study also lacked controls for the duration of the massage (30 to 90 minutes) and the massage techniques performed.[15]

Table 2. *Levels of evidence key.*

Level	Studies in Each Category
I	Large randomized trials with clear-cut results; low risk of false-positive error (_) and false-negative (_) error
II	Small, randomized trials with uncertain results; moderate to high risk of false-positive (_) and/or false negative (_) error
III	Nonrandomized, contemporaneous controls
IV	Nonrandomized, historical controls
V	Case series, uncontrolled studies, expert opinion

Adapted from Sackett DL [62]

Although this study[15] did not directly focus on an athletic population, a vigorous massage may be less desirable than a "Swedish" (or relaxation) type of massage in specific situations. Theoretically, an athlete who is experiencing pre-game anxiety or stress may increase his or her risk of sustaining an injury or of having a sub-par performance.[16] Future investigations should be performed with specific athletic populations receiving massages just prior to participating in a stressful simulation or actual competition.[15,17]

Effect on Mood and Anxiety

Leivadi et al[18] evaluated the effects of massage on mood and anxiety states in female dancers (mean age = 20.1 years, SD = 1.8 years). The dancers were randomly assigned to either a massage therapy (n = 15) group or a relaxation therapy (n = 15) group.[18] The massage therapy group received a 30-minute treatment twice a week for a five week period. The massages consisted of effleurage, petrissage, and friction techniques with a treatment emphasis on the upper torso.[18] Those assigned to the relaxation therapy group performed a series of muscle tensing and relaxation exercises while listening to a recorded tape.[18] Both groups demonstrated significant effects between the first and last treatment sessions for lowered anxiety levels and improved mood scores {as measured by the State Anxiety Inventory and the Profile of Mood States (POMS) respectively}.[18] The massage treatment group also demonstrated significantly lower cortisol levels compared to the relaxation group.

Limitations in study design threaten the strength of the findings. This investigation lacked a true control group. The subjects in the relaxation therapy group were required to independently perform the program on their own at home. To ensure that dancers fully complied with the relaxation program, each relaxation session should have been performed under the supervision an examiner.

Micklewright et al[19] investigated the effects of a pre-performance massage on mood state. Sixteen subjects (10 male and 6 female university students) participated in the study.[19] Each subject completed the POMS questionnaire to establish baseline mood state prior to receiving the treatment intervention. During the first session a subject received either 30 minutes of massage or rested 30 minutes on his or her back.[19] The subjects served as their own controls between the two sessions. After the treatment intervention subjects completed a standard Wingate anaerobic cycling test. The POMS questionnaires were also completed after the treatment intervention and after the cycling test.[19]

The investigators found that cycling performance was better after the massage compared to the control group, but this improvement was unrelated to changes in mood state.[19] The authors hypothesized that pre-performance psychological factors other than one's mood state may enhance performance.[19]

Additional studies have investigated how massage effects an athlete's perception of recovery and regeneration.[20-22] While these investigations support the beneficial psychological effects of massage; overall study design threatens the strength of the conclusions.[20-22]

EFFECTS OF MASSAGE ON SPORTS PERFORMANCE

Athletes and coaches are constantly fine tuning their training strategies in order to develop a competitive edge. The use of therapeutic modalities, such as thermal agents, electrical stimulation, and massage are often performed for this purpose. Despite the frequency that

Table 3. *Table Summarizing Studies Related to Pre-Event Massage*

Study (Year)	Study Design	Level of Evidence	Participants	Professional(s) Conducting the Intervention	Techniques	Treatment Time	Results and Authors' Conclusions
Cambron et al[15]	Quasi-experimental pre-test post-test design	3	150 massage therapy clients (mean age 42.5 years, range 19-79)	25 massage therapy students; 12 in their 2nd trimester and 13 in their 3rd (final) trimester	Swedish, deep tissue, myofascial release, sports, trigger point, craniosacral	One treatment session. 30 – 90 minutes per practitioner preference.	1) Nonsignificant decrease in systolic blood pressure (BP): average 1.8 (range: -24-34) mmHg and an average increase in diastolic BP of 0.1 (range: -53-18). 2) No association between BP and any of the following variables: duration, amount of pressure, and the massage therapy intern experience. 3) Swedish massage was associated with a nonsignificant decrease in systolic BP. 4) Systolic BP increased with trigger point and sports massage. When the two techniques were performed in combination both systolic and diastolic BP increases were statistically significant.
Leivadi et al[18]	Randomized controlled trial: Pre-test/Post-test group design	2	30 female adult dance majors (mean age 20.1 years, SD 1.8)	"Different trained massage therapists"	Effluerage, petrissage	Two sessions a week for 5 weeks. 30-minute sessions.	1) Significant pre-test/post-test treatment measures for anxiety levels, less depressed moods, less neck and shoulder pain, less low back pain for both groups. 2) Significant decrease in cortisol levels for the massage intervention group. 3) Those receiving massage treatment experienced a significant improvement in neck extension and shoulder abduction at the end of the study.
Micklewright et al[19]	Within subjects experimental design with counterbalanced design	3	16 university and students (10 male 6 female) mean age 22 years, SD 4.8)	One massage therapist	Effleurage, petrissage	30-minute standardized massage protocol	The massage treatment prior to Wingate Anaerobic Cycling Test significantly enhanced performance but had no effect on mood state.
Hemmings et al[20]	Within subjects experimental design with counterbalanced design	3	Eight amateur boxers (mean age 24.9 years, SD 3.8)	Sports massage therapist	Effleurage, petrissage	20-minute standardized protocol consisting of 8-minutes for the legs, 2-minutes for the back, and 10-minutes for the shoulders and arms	1) No significant difference between groups for performance. 2) Massage program significantly increased perceptions of recovery. 3) No statistical difference in blood lactate or glucose levels after either intervention. 4) Blood lactate concentration was significantly higher after the massage program.
Hemmings[21]	Within subjects experimental design with counterbalanced design	3	Nine Royal Navy boxing squad members (mean age 22 ± 3.1 years).	Sports massage therapist	Effleurage, petrissage	20-minute standardized	1) After massage, boxers' perceived recovery was significantly greater than resting and the touching control. 2) Massage did not affect saliva flow.
Hemmings[22]	Within subjects experimental design with counterbalanced design	3	Nine Royal Navy boxing squad members (mean age 22 ± 3.1 years)	Sports massage therapist	Effleurage, petrissage	20-minute standardized protocol	1) After massage intervention, significant main effects were found in the fatigue subscale and a trend towards significance in the tension subscale. 2) No main effects noted in the vigor, depression, and anger subscales.

Table 4. *Table Summarizing Studies Related to the Effects of Massage on Sports Performance*

Study (Year)	Study Design	Level of Evidence	Participants	Professional(s) Conducting the Intervention	Techniques	Treatment Time	Results and Authors' Conclusions
Leivadi et al[18]	Randomized controlled trial: pre-test/post-test group design	2	30 female adult dance majors (mean age 20.1 years, SD 1.8)	"Different trained massage therapists"	Effluerage and petrissage techniques	2 sessions a week for 5 weeks. 30-minute sessions	1) Significant pre-post treatment measures for anxiety levels, less depressed moods, less neck and shoulder pain, less low back pain for both groups. 2) Significant decrease in cortisol levels for the massage intervention group. 3) Those receiving massage treatment experienced a significant improvement in neck extension and shoulder abduction at the end of the study.
Micklewright et al[19]	Within subjects experimental design with counterbalanced design	3	16 university students (10 male and 6 female) mean age 22 years, SD 4.8)	One massage therapist	Effleurage, petrissage	30-minute standardized massage protocol	The massage treatment prior to Wingate Anaerobic Cycling Test significantly enhanced performance but had no effect on mood state.
Hemmings et al[20]	Within subjects experimental design with counterbalanced design	3	8 amateur boxers (mean age 24.9 years SD 3.8)	Sports massage therapist	Effleurage, petrissage	20-minute routine consisting of 8-minutes for the legs, 2-minutes for the back, and 10-minutes for the shoulders and arms	1) No significant difference between groups for performance. 2) Massage program significantly increased perceptions of recovery 3) No statistical difference in blood lactate or glucose levels after either intervention. 4) Blood lactate concentration was significantly higher after the massage program.
Barlow et al[23]	Within subjects experimental design with counterbalanced design	3	11 male volunteers (mean age 21 years ± 3)	Massage therapist	Effleurage, petrissage	One 15-minute massage	One massage to the hamstrings did not significantly change sit and reach performance.
Hopper et al[24]	Randomized controlled trial: pre-test/ post-test group design	2	35 competitive female field hockey players (mean age 19.8 ± 3.7, range 15 to 31). Classic group: (n=19) mean age 20.87±4.09. DSTM group: (n=16) mean age 19.13±3.15	Two physiotherapists	1."Classic" massage (consisting of effleurage, kneading, picking up, shaking) 2. Dynamic soft tissue mobilization (DSTM) that consisted of classic massage and "dynamic" longitudinal and and cross-fibre strokes strokes	1. A standardized 8-minute classic protocol for the classic massage treatment group. 2. The DTSM group received an 8-minute treatment consisting of classic massage and longitudinal and cross-fibre strokes to tight tissue.	1) Both massage types significantly improved hamstring length following treatment. 2) There was no statistical maintenance over a 24-hr time period for either group.
Hopper et al[25]	Randomized controlled trial: pre-test/post-test group design	2	45 healthy male volunteers (mean age 23.7 years, range 18-35 years).	"Therapist"	1."Classic" massage (consisting of effleurage, kneading, picking up, shaking) 2. Dynamic soft tissue mobilization (DSTM) that consisted of classic massage and "dynamic" longitudinal and and cross-fiber strokes	1. Control group: lying prone for 5 minutes 2. Classic protocol: 5-minutes of effleurage, kneading, picking up, and shaking 3. The DTSM group received an 8-minute treatment consisting of classic massage and longitudinal and cross-fiber strokes to tight tissue.	The DTSM protocol significantly increased hamstring flexibility as compared to either the classic massage protocol or the control group.
Brooks et al[27]	Randomized controlled trial: pre-test/post-test group design	2	52 volunteer massage-school clients, staff, faculty, and students (mean age 39 years, SD 13.63, range 18-71).	Two senior therapeutic massage students	Effleurage, friction	5 minutes	Massage intervention facilitated a significant improvement in grip strength recovery as compared to other interventions.
Mancinelli et al[28]	Randomized controlled trial: pre-test/post-test group design	2	22 NCAA Division I women basketball and volleyball players (mean age 20 ± 0.93 years).	Two massage therapists	Effleurage, petrissage, vibration	17-minute standardized protocol	1) Significant slowing in shuttle run times for the control group. 2) Significant changes in vertical jump displacement, perceived soreness, and algometer levels for the massage group.
Hilbert et al[47]	Randomized controlled trial: pre-test/post-test group design	2	18 volunteers (male and female), mean age 20.4 years ±1.0	A senior physical therapy student	Classic Swedish techniques (effleurage, percussion, petrissage)	20 minute standardized protocol	1) The massage protocol did not impact any of the following variables: range of motion, peak torque, neutrophil count, mood, or unpleasantness of soreness. 2) The massage protocol led to a significant decrease in intensity of soreness (Differential Descriptor Scale) in the massage group as compared to the control group.

massage treatments are performed, only a few studies exist in the literature that have investigated the effect of massage on sports performance *(Table 4)*.

Massage Effects on Flexibility

A common perception held by athletes and coaches is that adequate flexibility will decrease the risk of injury and enhance performance. While these claims may be debatable (and beyond the scope of this paper), massage has been investigated as a strategy to increase range of motion.

Barlow et al[23] investigated the immediate effects of massage on hamstring flexibility in physically active young men. Eleven active men (mean age 21 $\pm$ 3 years) were randomly assigned to attend two testing sessions each separated by one week. The subjects either received a 15-minute massage (performed by a massage therapist) consisting of effleurage and petrissage strokes to the hamstring muscles bilaterally or a 15-minute supine rest. Three pre-test and post-test sit and reach measurements were performed with the best one recorded. Investigators were blinded to who had received which intervention. The subjects were also blinded when performing the sit and reach test to avoid subject bias threats to validity. The authors concluded that a single bout of hamstring massage did not have a significant effect upon sit and reach scores. Although the authors found no significant change among the small sample size, they did find that those who had low pre-test reach scores (less than 15 cm) had a higher percentage of change in reach versus those who had a 15-cm or greater reach. This led the authors to suggest a larger sampling should be performed with a "tighter" population.[23] Also, future studies should investigate the effect on flexibility when massage is applied both proximally and distally to the target tissue.

While Barlow et al[23] failed to demonstrate a statistically significant change in flexibility, Hopper et al[24] found massage made significant short term changes in hamstring flexibility. Female field hockey players from Western Australia's Premier League were recruited for the study. Thirty-nine players met the study's inclusion criteria of experiencing a stretching sensation on the posterior thigh at an angle less than 70° during a straight leg raise (SLR), having full knee extension range of motion, and having full ankle plantarflexion.[24]

Athletes were randomized into one of two treatment groups; a group receiving a "classic" massage and a group receiving dynamic soft tissue mobilization (DSTM). The classic massage consisted of effleurage, kneading (petrissage), and shaking techniques for an 8-minute treatment. The DSTM treatment consisted of classic massage strokes and a dynamic treatment approach. The dynamic technique was performed using a "long slow stroke" with a fisted hand applied both longitudinally and across the muscle fibers. This technique was applied while first passively extending the subject's knee, then while the subject actively extended their own knee, and finally while the therapist passively extended the knee while the subject performed an eccentric contraction of their hamstring muscle.[5] The DSTM program was also performed for 8-minutes.[24] The passive straight leg raise (PSLR) and passive knee extension (PKE) tests were used to measure hamstring length prior to the treatment intervention, immediately after the massage, and 24 hours later. Both techniques immediately created statistically significantly changes in hamstring lengths as measured by the PKE test. The flexibility changes though were not maintained at 24 hours in either group.[24]

In a subsequent investigation by Hopper et al,[25] they reported significant increases in hamstring flexibility after performing the DSTM program when compared to a classic massage approach or a control group. In this investigation, the subject sample was 45 healthy males (mean age = 23.7 years, SD = 4.6, range = 18 to 35 years), whereas, the previous study's population consisted of female athletes.[24] The "classic" massage protocol utilized effleurage, kneading, picking up, and shaking techniques performed for 5-minutes.[25] The DSTM program was similar to the one described in Hopper et al.[24] The DTSM group demonstrated significantly greater increases in hamstring flexibility as compared to the classic approach or the control group. While the DTSM protocol had a greater effect on immediate hamstring flexibility gains (post-test measurements conducted 90-seconds after treatment), the clinical significance of these results is difficult to extrapolate.

While it appears that some athletes may experience improvements in hamstring flexibility after one massage, these changes appear to be transient. If a short term goal is to increase an athlete's flexibility, more efficient methods may exist (especially in the absence of an adequately staffed sports medicine team).[26] Future research should investigate which athletes are ideal candidates for massage intervention, how long each massage intervention should be performed, and what duration is necessary to establish permanent flexibility changes.

Massage Effects on Strength

Brooks et al[27] assessed the effects of massage on power grip performance after maximal exercise in healthy adults. The authors conducted a pre-test and post-test study design with subjects randomized to one of four intervention groups. The testing protocol consisted of a pre-test grip strength measurement, the exercise protocol to fatigue the muscles of the hand, the intervention, a 5-minute rest period, and the post-test strength measurement. To fatigue the muscles of the hand and the forearm, participants isometrically squeezed a hand exerciser until performance had declined to 60% of their baseline measurement. After the exercise period, the subjects were randomized to one of the following treatment groups: a 5-minute standardized massage to the dominant hand, a 5-minute standardized massage to the non-dominant hand, 5-minutes of passive shoulder and elbow range of motion, or 5-minutes of rest.[27] The 5-minute massage protocol, consisting of effleurage and circular friction strokes, was performed by two senior therapeutic massage students.[27] The authors found the massage intervention to be significantly superior to the non-massage interventions for post exercise grip performance. It was also observed that grip performance after massage was significantly greater in the non-dominant versus the dominant arm.

The most clinically relevant outcome was that the massage intervention demonstrated better results than the natural recovery of the control group.[27] The authors surmise that applying massage (in this case for 5-minutes) shortly after fatiguing exercise is beneficial.[27]

Mancinelli et al[28] investigated the effects of massage on female collegiate athletes when performed at the beginning of the basketball and volleyball seasons. Twenty-two NCAA division I women's basketball or volleyball players were recruited (11 allocated to the treatment group and 11 serving as controls). A 17-minute massage consisting of effleurage, petrissage, and vibration techniques was performed on the day of predicted peak soreness (as predicted by the strength coach). The authors found that the massage intervention helped to significantly increase vertical jump, led to a significant increase (a slowing) of shuttle run times, and significantly decreased the athlete's perceived soreness. While the results suggest that performing a massage at an opportune time will have positive functional outcomes, the results of this study are in question due to significant design flaws. These flaws include a small sample size, the inability to control for the pre-season conditioning levels of the athletes, and the reliance upon the subjective prediction by the strength coach as to the date of expected peak muscle soreness.[28]

EFFECTS OF SPORTS MASSAGE ON RECOVERY FROM EXERCISE AND COMPETITION

Effects on Delayed Onset Muscle Soreness

Delayed onset muscle soreness (DOMS) is a common physiological response experienced by athletes after initiating or resuming an exercise routine, after increasing exercise intensity, or after performing eccentric forms of training (i.e. downhill running).[29] Delayed onset muscle soreness has been associated with minor to severe pain occurring 24 to 72 hours after the exercise bout.[29] Athletic performance may be hampered due to DOMS, loss of range of motion, and decreased muscle strength.[30,31] While these symptoms may be temporary and part of the natural process of strength and conditioning training, the ramifications for sports performance during competition may be staggering. Theoretically, it would be beneficial to prescribe modalities that could either prevent the onset or decrease the impact of DOMS.

Six theories have been proposed to explain the mechanisms of DOMS.[29] The six theories are: lactic acid, muscle spasm, connective tissue damage, muscle damage, inflammation, and enzyme efflux.[29] Researchers have specifically investigated the effects of massage upon blood lactate levels and changes in blood flow *(Table 5)*.[20,32,33]

Effect of Massage on Blood Flow

Massage has been proposed as a treatment modality to increase blood flow.[2,3,8,34] Proponents of massage argue that local circulatory changes occur as evidenced by the changes in skin temperature and superficial hyperemia.[35] Initial studies measuring Xe-133 isotope clearance and venous occlusion plethysmography indicated that massage had an effect on blood flow, whereas more recent studies using Doppler ultrasound techniques have found that massage had no effect on arterial or venous blood flow.[36-40]

Blood Lactate Clearance

The rationale behind the lactic acid theory is that lactic acid produced after exercise contributes to the pain and soreness experienced by the athlete.[29] Massaging a muscle or muscle group experiencing DOMS could, theoretically, help to facilitate the removal of lactic acid from those areas.

Table 5. *Table Summarizing Research Related to the Effects of Sports Massage on Recovery from Exercise and Competition*

Study (Year)	Study Design	Level of Evidence	Participants	Professional(s) Conducting the Intervention	Techniques	Treatment Time	Results and Authors' Conclusions
Hemmings et al[20]	Within subjects experimental design with counterbalanced design	3	Eight amateur boxers (mean age 24.9 years, SD 3.8)	Sports massage therapist	Effleurage, petrissage	20-minute standardized protocol consisting of 8-minutes for the legs, 2-minutes for the back, and 10-minutes for the shoulders and arms	1) No significant difference. between groups for performance. 2) Massage program significantly increased perceptions of recovery 3) No statistical difference in blood lactate or glucose levels after either intervention. 4) Blood lactate concentration was significantly higher after the massage program.
Robertson et al[32]	Within subjects experimental design with counterbalanced design	3	Nine male games players, mean age not presented (range 20-22 years)	Physiotherapist	Effleurage, kneading, stroking, picking up, wringing, rolling	20-minute standardized protocol	1) Massage intervention did not affect blood lactate concentration or heart rate. 2) No difference in mean or maximum power after massage. 3) Subjects scored significantly lower on the fatigue index after massage.
Dolgener et al[33]	Randomized controlled trial: pre-test/post-test design	2	22 male recreational runners; passive recovery group (n=7, mean age 24.7±5.3), bicycle recovery (n=7, mean age 26.1±6.5), massage recovery (n=8, mean age 24.2±6.77)	Massage therapist	Effleurage, petrissage	20-minute standardized routine	Massage was no better than passive or active recovery methods in reducing blood lactate concentration.
Tiidus et al[36]	Quasi-experimental pre-test/post-test	3	Nine volunteers (4 male and 5 female), mean age not reported (age range 20 to 22 years)	Massage therapist	Effleurage	10-minute	1) Massage did not significantly increase either arterial or venous blood velocity above baseline resting levels. 2) Massage failed to improve isokinetic peak torque of the quadriceps versus the contralateral control leg.
Shoemaker et al[39]	Within subjects experimental design with counter-balanced design	3	10 healthy subjects (7 male, 3 female); mean age 35.8± 3.4 years)	Massage therapist	Effleurage, petrissage, tapotement	5-minute massage per location and technique	Massage did not increase muscle blood flow (pulsed Doppler echo Doppler) regardless of type of massage or the muscle group receiving the massage.
Hinds et al[40]	Within subjects experimental design with counter-balanced design	3	13 male volunteers, mean age 21±1.4 years	Physiotherapist	Effleurage and petrissage	Two 6-minute bouts separated by a 1-minute period	1. Massage did not significantly increase femoral artery blood flow, blood lactate, blood pressure, or heart rate as compared to a control condition. 2. Skin blood flow and skin temperature were significantly increased after massage as compared to controls.
Jonhagen et al[41]	Randomized controlled trial: pre-test/post-test group design	2	16 subjects (8 men and 8 women), mean age 28 years (range 20-38)	Sport physical therapist	Effleurage, petrissage	12-minute standardized protocol	1. No statistical difference between massage and control group for level or duration of pain. 2. No statistical difference for concentrations of CGRP and NPY between massage and control groups. 3. No statistical difference for maximal strength and functional measures between groups.

Many amateur sports (such as track and field, boxing, and swimming) may require athletes to participate in several events or matches during a short period of time. Hemmings et al[20] studied the effects of massage on both physiologic and perceived recovery in eight amateur boxers. The investigators designed a testing protocol to examine if massage performed between bouts of simulated boxing matches would help to improve physiologic variables (blood glucose and lactate concentrations), performance, and the athlete's perception of recovery. The experimental design consisted of a 10-minute active warm up period, five 2-minute rounds of simulated boxing matches with 1-minute rest periods between each round, an intervention period (20-minute massage or no massage), a 35-minute rest period (a time period representative of the period of time between events or matches), a second 10-minute active warm up period, and a repeat of the aforementioned boxing simulation. Four of the eight boxers served as controls during the first round of testing. During the second round of testing, the boxers switched groups.[20]

During the intervention period, the athlete either received a massage or rested lying on a mat. The 20-minute massage (effleurage and petrissage) protocol consisted of 8 minutes of treatment performed on the legs, 2 minutes on the back, and 10 minutes on the shoulders and arms. Blood lactate testing was performed

Table 5. *Table Summarizing Research Related to the Effects of Sports Massage on Recovery from Exercise and Competition (cont'd)*

Lightfoot et al[42]	Randomized controlled trial	2	31 college-age subjects (12 men and 19 female)	Massage therapist	Petrissage	10-minute to the left calf	Massage intervention to the left calf demonstrated no difference for soreness levels or leg volumes as compared to the control group.
Weber et al[43]	Randomized controlled trial: pre-test/post-test design	2	40 untrained volunteer female subjects, group mean age 23.7 years, SD 4.0	Physical therapist	Effleurage, petrissage	8-minute standardized protocol	No statistical difference between massage, active recovery, microcurrent, and controls for soreness ratings and force generation.
Hart et al[44]	Within subjects experimental design with counter-balanced design	3	19 college aged volunteers (10 men, 9 women), mean age 20.6±1.2 years	Certified athletic trainer	Petrissage (kneading) and effleurage (broad stroking)	5-minute standardized "sports" massage	The sports massage protocol did not significantly reduce either leg girth or pain as compared to the control leg within 72 hours of exercise.
Monedero et al[45]	Within subjects experimental design with counterbalanced design	3	18 healthy trained male cyclists, mean age 25±0.9 years	Certified masseur	Effleurage, stroking, and taponement	Massage group: 15-minute massage Combined recovery group: 7.5 minutes of massage and 7.5 minutes of active recovery	1. Combined recovery significantly better at removing blood lactate at 12-mintues (as compared to all interventions). 2. Combined recovery was a superior approach to maintaining performance over passive recovery and active or massage interventions.
Dawson et al[46]	Quasi-experimental pre-test/post-test	3	12 runners (8 males, 4 females), mean age 35.2±8.3 years)	Massage therapists	Effleurage, petrissage	30-minute standardized protocol	The use of massage, when compared to the control leg, did not facilitate a faster return to baseline measures for strength, soreness, or leg circumference.
Hilbert et al[47]	Repeated measures pre-test/post-test RCT	2	18 volunteers (male and female), mean age 20.4±1.0 years	A senior physical therapy student	Classic Swedish techniques (effleurage, percussion, petrissage)	20 minute standardized protocol	1. The massage protocol did not impact any of the following variables: range of motion, peak torque, neutrophil count, mood, or unpleasantness of soreness. 2. The massage protocol led to a significant decrease in intensity of soreness (Differential Descriptor Scale) in the massage group as compared to the control group.
Smith et al[48]	Randomized controlled trial: pre-test/post-test design	2	14 untrained males; massage group (n=7, mean age 20.1±1.1) and control group (n=7, mean age 18.8±0.3)	Physical therapist	Effleurage (stroking), shaking, petrissage (kneading), wringing, cross-fiber massage	30-minute standardized "sports" massage performed 2 hours after exercise	A significant trend analysis for treatment by time interaction effect with 1) the massage group reporting lower levels of muscle soreness; 2) reduced CK levels in the massage group; 3) massage group demonstrating elevated neutrophil levels.

before and after each boxing simulation and after the intervention. During the rest period, each boxer completed a perceived recovery scale. The authors chose to measure performance by comparing mean peak punching force per round.[20]

The authors found that regardless of whether the athlete received a massage or had rested in a supine position, the mean punching force decreased during the second boxing simulation. As previously indicated the authors found that the massage intervention had a statistically significant effect on the boxers' perception of recovery. Massage intervention also did not affect blood lactate concentrations and, surprisingly, boxers who had received the massage intervention presented with significantly higher lactate concentrations during the second simulation.[20] This finding was unexpected, for which the authors proposed that the perceived psychological recovery might have affected the boxers' later effort and energy expenditure.[20]

Robertson et al[32] examined the effects of massage on lactate clearance, muscular power output, and fatigue after bouts of high intensity training. Nine male athletes (rugby, football, or field hockey) were recruited for the study. A testing protocol began with a standardized warm up period consisting of 5-minutes of cycling and 3-minutes of static stretching for the hamstrings, calf, and quadriceps muscles.[32] Six 30-second bouts of high intensity training were performed on a cycle ergometer (with 30 seconds of active recovery between sets). Upon completition of the high intensity repetitions, the athletes performed 5-minutes of active recovery followed by a 20-minute intervention. Subjects were randomized into one of two interventions: a 20-minute massage or 20-minutes of "passive supine rest." The massage intervention was performed each time by the same physiotherapist. The massage sequence consisted of effleurage and petrissage techniques performed in a standardized protocol sequence of 5 minutes to the back of the left leg, 5 minutes to the back of the right leg, 5 minutes to the front of the right leg, and 5 minutes to the front of the left leg. After the intervention period, the athlete performed the same 8-minute warm up (5-minutes of cycling and 3-minutes of static stretching) followed by one 30-second high intensity bout (Wingate test). Blood samples were collected prior to testing, after the first high intensity training, after 10- and 20-minutes of the intervention time period, and 3 minutes after the final high intensity test.[32]

The authors found no statistical difference between the massage and passive rest interventions for blood lactate concentrations and power. A significant difference did occur between the massage intervention and the rest group for the fatigue index. The fatigue index is the percentage change in power output between the first 5-seconds and the last 5-seconds in a 30-second period. The authors suggested that additional investigations were necessary to identify the role of massage on an athlete's fatigue profile.[32]

Jonhagen et al[41] recruited 16 people (8 men and 8 women, mean age 28 years) in order to assess if sports massage can improve recovery after an eccentric exercise protocol. Subjects performed 300 maximal eccentric quadriceps contractions with each leg on a Kin-Com dynamometer (Harrison, TN).[41] A massage program was initiated 10 minutes after exercise, with one leg from each subject randomized to receive the massage treatment. The massage program consisted of 4-minutes of effleurage and 8-minutes of petrissage. The massage protocol was also performed daily each of the next two days. Testing was performed before the exercise protocol, after exercise, and on the third day. Strength testing was performed on the Kin-Com dynamometer, a vertical long jump was performed to measure functional changes, and a visual analog scale (VAS) was used to measure a subject's pain. The VAS was performed before and after exercise and before and after the massage treatment. Microdialysis was also performed in the vastus lateralis muscle to analyze levels of the neuropeptide Y (NPY) and calcitonin gene-related peptide (CGRP).[41] Both NPY and CGRP are neuropeptides involved in the vasodilatation of skin tissue and the modulation of pain.[41] The authors found that sports massage failed to influence any of the dependent variables. Resultant strength loss was significant in both treatment groups, even on the third day. Sports massage also failed to impact functional recovery. Both groups' demonstrated significantly lower long jump scores, with a normalization of scores occurring by day three. No statistical difference was observed either in pain scores between legs or for changes in CGRP and NPY levels.[41]

Additional studies evaluating the effects of massage on athletes experiencing DOMS have also failed to demonstrate positive effects.[42,43] Active recovery techniques have been shown to be consistently superior to massage for lactate clearance.[33,44,45] In addition, massage interventions have failed to effect post-exercise limb girth.[42,44,46] Subjects who received massage generally experienced no improvement in pain or soreness perception as compared with controls.[42,44,46] Hilbert et al[47] suggested massage can positively affect subjects' perceived intensity of DOMS related soreness, but not until 48 hours post exercise.

Although it is commonly thought that lactic acid accumulation after exercise leads to the pain associated with DOMS, this theory has been recently rejected.[29] Any increased lactic acid levels after exercise return to baseline in approximately one hour after exercise.[29] Lactic acid likely only contributes to acute pain versus the pain experienced 24 to 48 hours after exercise.[29]

Massage Effects on Creatine Kinase and Neutrophil Levels

Smith et al[48] designed a study to investigate the effects of massage on variables other than lactic acid. The authors theorized a massage intervention performed two hours after exercise interferes with neutrophil emigration which may reduce the intensity of pain due to inflammation. Initial results indicated that the 30-minute massage protocol applied two hours after the exercise program helped to reduce DOMS and creatine kinase levels.[48] This particular protocol appeared to demonstrate promising results, but the results are challenged by a small sample size (n = 14).[48] Although the authors called for continued studies, to date, no further clinical studies have been published on this aspect.[48]

ROLE OF SPORTS MASSAGE IN THE TREATMENT OF SPORTS INJURIES

Both classic massage techniques and deep transverse friction massage (DTFM) are performed in clinical rehabilitation settings *(Table 6)*. Despite the popularity of these forms of massage by both therapists and patients, very few studies have been conducted on this intervention, making it a challenge to draw conclusions regarding the efficacy of their use.

Paucity of Sports Massage Reports

Despite the prevalence of low back pain, a review of the literature was unable to identify any randomized controlled trials or quasi-experimental studies investigating the role of massage in the treatment of sports-related back injuries. Two "non-sports" massage papers are presented

Table 6. *Table Summarizing Research Related to the Role of Sports Massage in the Treatment of Sports Injuries*

Study (Year)	Study Design	Level of Evidence	Participants	Professional(s) Conducting the Intervention	Techniques	Treatment Time	Results and Authors' Conclusions
Preyde et al[49]	Randomized controlled trial	2	Four groups: comprehensive massage therapy (n=25, mean age 47.9±16.2); soft-tissue manipulation (n=25, mean age 46.5±18.4); remedial exercise and education (n=22, mean age 48.4±12.9); placebo (n=26, mean age 41.9±16.6)	Two massage therapists (each > 10 years experience)	Friction, trigger points, neuromuscular therapy	30 to 35 minutes each session.	The comprehensive massage therapy group experienced significant changes in function/RDQ scores, less pain, and a decrease in PRI score.
Furlan et al[50]	Systematic Review	1	MEDLINE, Embase, Cochrane Controlled Trials Register, HealthSTAR, CINAHL, and dissertation abstracts	Not applicable	Any type of massage (using the hands or mechanical device)	Not applicable	1. Massage in combination with exercise and education may be beneficial for patients experiencing subacute or chronic nonspecific low back pain. 2. Acupuncture massage may be more effective than classic massage. Further studies are necessary to confirm this conclusion.
Pettitt et al[51]	Case report	5	19-year old female distance runner	Athletic trainer	Effleurage	5-minutes each weekday	Massage one of several treatments employed in the recovery of the subject.
Blackman et al[52]	One group-repeated measures design	3	Seven athletes (6 men and 1 woman). Mean age not provided (range 21 to 29 years)	Not provided	Longitudinal gliding, transverse gliding, digital ischemic pressure, myofascial release	15-minute standardized protocol. Each patient received 6 treatments over a 5 week period.	1. Anterior compartment pressures after the 5-week massage protocol demonstrated a nonsignificant increase. 2. Mean values for work output in dorsiflexion significantly increased after 5 weeks.

here to demonstrate the challenges in interpreting the literature.

Preyde[49] researched the application of massage in the treatment of patients with subacute low back pain. In this study, subjects were randomized to one of four groups: a comprehensive massage therapy group (CMT), a soft tissue mobilization only group, a remedial exercise and postural education only group, and a placebo group who received a sham ultrasound. Subjects in the CMT group experienced a statistically significant improvement in function, reported less intense pain, and experienced a decrease in the quality of pain as compared to the other three groups.[49]

Even though the author concluded that patients with subacute low back pain benefited from massage therapy, the CMT group received massage (utilizing a non-standardized treatment protocol), exercise prescription consisting of a lower extremity stretching program, were encouraged to walk, swim, do aerobics, and strengthening exercises, and received education on posture and body mechanics. While at the 1-month follow up period, a significant number of patients in the CMT group had no pain; it would be a leap to attribute all of this to the massage (only 27% of subjects in the massage only group were pain free at one month). Rather this research may demonstrate that those who receive posture/body mechanics education, perform exercises, and receive massage have better outcomes versus those who only receive one treatment modality.[49]

A recent Cochrane Collaboration Back Review has concluded that the use of massage might benefit patients with subacute and chronic nonspecific low back pain, especially when the massage is combined with patient education and exercise prescription.[50] Despite this conclusion, the panel highlights the need for additional studies to confirm the efficacy of massage for subacute and chronic LBP and to assess the effect of massage on returning-to-work.[50]

Pettitt et al[51] reported the use of massage in the management of a 19-year old female middle distance runner suffering from sport-related chronic knee pain. The patient underwent an iliotibial band release after initial failure of conservative treatment. Despite a course of post-operative therapy, the patient continued to experience symptoms. The authors implemented a treatment program consisting of joint and soft tissue (massage) mobilization, therapeutic exercise, and neuromuscular electric stimulation. The massage protocol consisted of effleurage strokes. The authors reported that the subject was able to return to running and complete an entire season of indoor track and field after receiving this 10-week course of rehabilitation. While massage was one component of the rehabilitation program, the authors acknowledge the fact that the unique role of any one treatment can not be known.[51]

Blackman et al[52] investigated the effects of massage on chronic exertional compartment syndrome (CECS). This study again highlighted the design challenges that researchers investigating massage effects have experienced. Athletes suffering from CECS complain of cramping or aching pain that develops with exercise and resolves with cessation of activity.[53,54] The authors recruited seven athletes (age range 21 to 29 years) with a confirmed diagnosis of anterior CECS.[52] Each athlete participated in a 5-week rehabilitation program. A standard massage intervention consisted of various techniques for 15-minutes each session. Massage was performed two times a week during the first two weeks and one time a week for the remaining three weeks.[52] Patients were also instructed to perform a standard stretching program for both anterior and posterior musculature twice a day. After the 5 week course of therapy, no significant changes were found in compartment pressures after exercise. The authors did find a significant change in the amount of exercise that could be performed prior to pain onset. Study limitations included the small sample size and the prescription of multiple treatments.[52]

Efficacy of Deep Transverse Friction Massage

Deep transverse friction massage (DTFM) has been suggested as a treatment option for tendon injuries such as tennis elbow.[9] Paucity in the literature exists regarding the use of DTFM in the treatment of sports-related injuries. Despite the popularity of its use,[9] a review of the available research literature fails to support the use of DTFM,[55,56] whereas, eccentric exercise has demonstrated efficacy in the conservative management of tendinopathies.[57-61]

DISCUSSION

Despite the fact that massage has been used as a treatment modality for centuries, a poor appreciation for its clinical effectiveness exists. Although several unique studies have been designed to investigate the effects of sports massage, further investigations are warranted.

Indirect evidence exists suggesting that massage may be beneficial on factors related to an individual's psychological state. While these investigations demonstrated improvements in blood pressure,[15] mood states,[18,19] and perception of recovery,[20-22] study design flaws limit the strengths of the conclusions. Future research should investigate the application of massage immediately prior to stressful sports performance situations, the effects of massage on an athlete's perception of recovery between bouts or events, and the effects of massage on an athlete's mood state throughout an entire season.

Massage has generally failed to demonstrate positive effects upon sports performance.[20,32,41] One study utilizing massage at the beginning of the season demonstrated an increase in the experimental groups' vertical jump, but the study's conclusions are threatened by several design flaws.[28] Researchers have demonstrated an association between massage and temporary changes in hamstring flexibility[23-25] and grip performance.[27] While the results from these studies do not predict future sports performance, these studies should provide guidance in the development of future investigations. Additional research should be directed at performing a massage prior to immediate athletic performance (e.g. massage to the upper extremity prior to a discus throw).

Massage has also generally failed to effect physiological parameters related to DOMS.[20,32,33,40-45] The few studies that have reported positive effects from massage on a subject's pain or soreness perception have had study design flaws and no follow-up investigations to date.[47,48] To account for the individuals who report decreased pain or a perceived improvement after a massage, future research should investigate local concentrations of chemo-inflammatory factors.

Minimal studies have been performed investigating the role of massage in sports rehabilitation.[51,52] Paucity in the literature exist related to sports massage and the management of sports-related injuries. Evidence appears to suggest that massage is efficacious for use with patients with subacute and chronic low back pain.[49,50] Clinical research and case reports are greatly needed to help guide physical therapy decision making when rehabilitating sports injuries.

CONCLUSION

Research evidence has generally failed to demonstrate massage significantly contributing to the reduction of pain associated with delayed onset muscle soreness, or significantly enhancing sports performance and recovery, or playing a significant role in the rehabilitation of sports injuries. Design flaws in research have challenged some of the positive outcomes. Additional studies examining the physiological and psychological effects of sports massage are necessary in order to enhance the sports physical therapists' ability to develop and implement clinically significant evidence based programs or treatments.

REFERENCES

1. Goats GC. Massage – the scientific basis of an ancient art: Part 1. The techniques. *Br J Sports Med.* 1994;28:149-152.
2. Cassar MP. *Handbook of Clinical Massage: A Clinical Guide for Students and Practitioners.* 2nd ed. Edinburgh: Churchill Livingstone; 2004.
3. Holey E, Cook E. *Evidence-Based Therapeutic Massage. A Practical Guide for Therapists.* 2nd ed. Edinburgh: Churchill Livingstone; 2003.
4. Vickers A, Zollman C. ABC of complimentary medicine: Massage therapies. *BMJ.* 1999;319:1254-1257.
5. Galloway SD, Watt JM. Massage provision by physiotherapists at major athletics events between 1987 and 1998. *Br J Sports Med.* 2004;38:235-237.
6. Nichols AW, Harrigan R. Complementary and alternative medicine usage by intercollegiate athletes. *Clin J Sport Med.* 2006;16:232-237.
7. Callaghan MJ. The role of massage in the management of the athlete: A review. *Br J Sports Med.* 1993;27:28-33.
8. Benjamin PJ, Tappan FM. *Tappan's Handbook of Healing Massage Techniques: Classic, Holistic, and Emerging Methods.* 4th ed. Upper Saddle River, New Jersey: Prentice Hall; 2005.
9. Stasinopoulos D, Johnson MI. Cyriax physiotherapy for tennis elbow/lateral epicondylitis. *Br J Sports Med.* 2004;38:675-677.
10. Egan AD, Cramer JT, Massey LL, et al. Acute effects of static stretching on peak torque and mean power output in national collegiate athletic association division I women's basketball players. *J Strength Cond Res.* 2006;20:778-782.
11. Church JB, Wiggins MS, Moode FM, et al. Effect of warm up and flexibility treatments on vertical jump performance. *J Strength Cond Res.* 2001;15:332-336.
12. McMillian DJ, Moore JH, Hatler BS, et al. Dynamic vs. static-stretching warm up: The effect on power and agility performance. *J Strength Cond Res*. 2006;20:492-499.
13. Faigenbaum AD, Bellucci M, Bernieri A, et al. Acute effects of different warm-up protocols on fitness performance in children. *J Strength Cond Res.* 2005; 19:376-381.
14. Murphy SM. Imagery interventions in sport. *Med Sci Sports Exerc.* 1994;26:486-494.
15. Cambron JA, Dexheimer J, Coe P. Changes in blood pressure after various forms of therapeutic massage: A preliminary study. *J Altern Complement Med.* 2006;12:65-70.
16. Carr CM. Sport psychology: psychologic issues and applications. *Phys Med Rehabil Clin N Am.* 2006;17:519-535.
17. Aourell M, Skoog M, Carleson J. Effects of Swedish massage on blood pressure. *Complement Ther Clin Pract.* 2005; 11:242-246.
18. Leivadi S, Hernandez-Reif M, Field T, et al. Massage therapy and relaxation effects on university dance students. *J Dance Med Sci.* 1999;3:108-112.
19. Micklewright D, Griffin M, Gladwell V, Beneke R. Mood state response to massage and subsequent exercise performance. *The Sport Psychologist.* 2005;19:234-250.
20. Hemmings B, Smith M, Graydon J, et al. Effects of massage on physiological restoration, perceived recovery, and repeated sports performance. *Br J Sports Med.* 2000; 34:109-115.
21. Hemmings B. Sports massage and psychological regeneration. *Br J Ther Rehabil.* 2000;7:184-188.
22. Hemmings B. Psychological and immunological effects of massage after sport. *Br J Ther Rehabil.* 2000;7:516-519.
23. Barlow A, Clarke R, Johnson N, et al. Effect of massage on the hamstring muscle group on performance of the sit and reach test. *Br J Sports Med.* 2004;38:349-351.
24. Hopper D, Conneely M, Chromiak F, et al. Evaluation of the effect of two massage techniques on hamstring muscle length in competitive female hockey players. *Phys Ther Sport.* 2005;6:137-145.
25. Hopper D, Deacon S, Das S, et al. Dynamic soft tissue mobilization increases hamstring flexibility in healthy male subjects. *Br J Sports Med.* 2004;39:594-598.
26. Nelson RT. A comparison of the immediate effects of eccentric training vs. static stretch on hamstring flexibility in high school and college athletes. *North Am J Sports Phys Ther*. 2006;1:56-61.
27. Brooks CP, Woodruff LD, Wright LL, et al. The immediate effects of manual massage on power-grip performance after maximal exercise in health adults. *J Altern Complement Med.* 2005;11:1093-1101.
28. Mancinelli CA, Davis DS, Aboulhosn L, et al. The effects of massage on delayed onset muscle soreness and physical performance in female collegiate athletes. *Phys Ther Sport.* 2006;7:5-13.
29. Cheung K, Hume PA, Maxwell L. Delayed onset muscle soreness: treatment strategies and performance factors. *Sports Med.* 2003;33:145-164.
30. Weerapong P, Hume PA, Kolt GS. The mechanisms of massage and effects on performance, muscle recovery, and injury prevention. *Sports Med.* 2005;35:235-256.
31. Ernst E. Does post-exercise massage treatment reduce delayed onset muscle soreness? A systematic review. *Br J Sports Med.* 1998;32:212-214.
32. Robertson A, Watt JM, Galloway SD. Effects of leg massage on recovery from high intensity cycling exercise. *Br J Sports Med.* 2004;38:173-176.
33. Dolgener FA, Morien A. The effect of massage on lactate disappearance. *J Strength Cond Res.* 1993;7:159-162.

34. Goats GC. Massage – The scientific basis of an ancient art: Part 2. Physiological and therapeutic effects. *Br J Sports Med.* 1994;28:153-156.

35. Travell JS. *Myofascial Pain and Dysfunction: The Trigger Point Manual*, 1st ed. Vol 1. 1st ed. Williams and Wilkins, Baltimore, MD: Williams and Wilkins; 1983.

36. Tiidus PM. Manual massage and recovery of muscle function following exercise: a literature review. *J Orthop Sports Phys Ther.* 1997;25:107-112.

37. Hovind H, Nielsen SL. Effect of massage on blood flow in skeletal muscle. *Scand J Rehabil Med.* 1974;6:74-77.

38. Tiidus PM, Shoemaker JK. Effleurage massage, muscle blood-flow and long term postexercise strength recovery. *Int J Sports Med.* 1995;16:478-483.

39. Shoemaker JK, Tiidus PM, Mader R. Failure of manual massage to alter limb blood flow: Measures by Doppler ultrasound. *Med Sci Sports Exerc.* 1997;29:533-538.

40. Hinds T, McEwan I, Perkes J, et al. Effects of massage on limb and skin blood flow after quadriceps exercise. *Med Sci Sports Exerc.* 2004;36:1308-1313.

41. Jonhagen S, Ackermann P, Eriksson T, et al. Sports massage after eccentric exercise. *Am J Sports Med.* 2004; 32:1499-1503.

42. Lightfoot JT, Char D, McDermott J, Goya C. Immediate postexercise massage does not attenuate delayed onset muscle soreness. *J Strength Cond Res.* 1997;11:119-124.

43. Weber MD, Servedio FJ, Woodall WR. The effects of three modalities on delayed onset muscle soreness. *J Orthop Sports Phys Ther.* 1994;20:236-242.

44. Hart JM, Swanik CB, Tierney RT. Effects of sport massage on limb girth and discomfort associated with eccentric exercise. *J Athl Train.* 2005;40:181-185.

45. Monedero J, Donne B. Effect of recovery interventions on lactate removal and subsequent performance. *Int J Sports Med.* 2000;21:593-597.

46. Dawson LG, Dawson KA, Tiidus PM. Evaluating the influence of massage on leg strength, swelling, and pain following a half-marathon. *J Sports Sci Med.* 2004;3:37-43.

47. Hilbert JE, Sforzo GA, Swensen T. The effects of massage on delayed onset muscle soreness. *Br J Sports Med.* 2003; 37:72-75.

48. Smith LL, Keating MN, Holbert D, et al. The effects of athletic massage on delayed onset muscle soreness, creatine kinease, and neutrophil count: A preliminary report. *J Orthop Sports Phys Ther.* 1994;19:93-99.

49. Preyde M. Effectiveness of massage therapy for subacute low-back pain: A randomized controlled trial. *CMAJ.* 2000; 162:1815-1820.

50. Furlan AD, Brosseau L, Imamura M, et al. Massage for low-back pain: A systematic review within the framework of the Cochrane collaboration back review group. *Spine.* 2002;27:1896-1910.

51. Pettitt R, Dolski A. Corrective neuromuscular approach to the treatment of iliotibial band friction syndrome: A case report. *J Athl Train.* 2000;35:96-99.

52. Blackman PG, Simmons LR, Crossley KM. Treatment of chronic exertional anterior compartment syndrome with massage: a pilot study. *Clin J Sports Med.* 1998;8:14-17.

53. Wilder RP, Sethi S. Overuse injuries: Tendinopathies, stress fractures, compartment syndrome, and shin splints. *Clin Sports Med.* 2004;23:55-81.

54. Howard J, Mohtadi N, Wiley JP. Evaluation of outcomes in patients following surgical treatment of chronic exertional compartment syndrome in the leg. *Clin J Sport Med.* 2000; 10:176-184.

55. Pellecchia GL. Hamel H. Behnke P. Treatment of infrapatellar tendinitis: a combination of modalities and transverse friction massage versus iontophoresis. *J Sport Rehabil.* 1994;3:135-145.

56. Stasinopoulos D. Comparison of effects of Cyriax physiotherapy, a supervised exercise programme and polarized polychromatic non-coherent light (Bioptron light) for the treatment of lateral epicondylitis. *Clin Rehabil.* 2006; 20:12-23.

57. Knobloch K, Kraemer R, Jagodzinski M, et al. Eccentric training decreases paratendon capillary blood flow and preserves paratendon oxygen saturation in chronic Achilles tendinopathy. *J Orthop Sports Phys Ther.* 2007;37:269-276.

58. Woodley BL, Newsham-West RJ, Baxter GD. Chronic tendinopathy: effectiveness of eccentric exercise. *Br J Sports Med.* 2007;41:188-198; discussion 199.

59. Alfredson H, Cook J. A treatment algorithm for managing Achilles tendinopathy: new treatment options. *Br J Sports Med.* 2007;41:211-216.

60. Young MA, Cook JL, Purdam CR, et al. Eccentric decline squat protocol offers superior results at 12 months compared with traditional eccentric protocol for patellar tendinopathy in volleyball players. *Br J Sports Med.* 2005; 39:102-105.

61. Alfredson H, Lorentzon R. Chronic Achilles tendinosis: Recommendations for treatment and prevention. *Sports Med.* 2000;29:135-146.

62. Sackett DL: Rules of evidence and clinical recommendations on the use of antithrombotic agents. *Chest.* 1989; 95:2(Suppl):2S-4S.

CLINICAL SUGGESTION

IMMOBILIZATION IN NEUTRAL ROTATION FOR A GLENOHUMERAL DISLOCATION USING A SLING AND SPLINT

Carrie W. Hoppes, DPT, ATC[a]

ABSTRACT

The purpose of this manuscript is to provide an expedient means of immobilizing a glenohumeral dislocation in neutral rotation. This technique for post-reduction immobilization of a glenohumeral dislocation is inexpensive and easy to fabricate. Anterior glenohumeral dislocations often involve an avulsion of the labrum from the glenoid rim. In contrast to immobilization in internal rotation, positioning the shoulder in 0-45º of external rotation approximates the labrum and glenoid rim. It is hypothesized that placing the shoulder in a more externally rotated position could allow for better healing and increased joint stability. This technique places the shoulder in neutral rotation, because 45º of external rotation is awkward and may interfere with certain activities of daily living. Structural aluminum malleable (SAM) splints are used as an alternative to a bolster sling. The SAM splints are lightweight, simply shaped, and easily stored.

Key Words: glenohumeral dislocation, immobilization, neutral rotation

CORRESPONDENCE:

Captain Carrie W. Hoppes
Unit # 5934
C Co, 407th BSB, 2 BCT, 82nd ABN DIV
APO AE 09378
carrie.witherel@us.army.mil

ACKNOWLEDGEMENTS

The author would like to acknowledge Specialist Jose Yenderrozos (Combat Medic) for his ingenuity in conceptualizing and fabricating the sling and splints for immobilizing a shoulder in neutral rotation.

The views expressed in this manuscript are those of the author and do not reflect the official policy of the U.S. Army, Department of Defense, or U.S. Government.

[a] Brigade Physical Therapist, 2nd
Camp Taji, Iraq

PROBLEM

Anterior glenohumeral dislocations are a common athletic injury. Initial treatment can include immobilization followed by physical therapy for range of motion and strengthening exercises, immediate surgery, or delayed surgery.[1-4] Following a traumatic dislocation, many patients report glenohumeral joint instability.[2-5] Anterior glenohumeral dislocations often involve an avulsion of the labrum from the glenoid rim.[6-11] Immobilization in a standard arm sling places the glenohumeral joint in internal rotation and adduction. This position does not allow the avulsed labrum to contact the glenoid rim[6-9] which could result in the labrum not healing, possibly leading to chronic glenohumeral instability. Positioning the shoulder in 0-45° of external rotation approximates the labrum and glenoid rim.[6-9] It is hypothesized that placing the shoulder in a more externally rotated position could allow for better healing and increased joint stability.[11] Physical therapists may encounter a traumatic glenohumeral dislocation on the playing field or on the battlefield and not have a bolster sling readily available to immobilize the joint in an optimal position post-reduction.

SOLUTION

The shoulder can be immobilized in neutral rotation using two structural aluminum malleable (SAM) splints (SAM Medical Products, Portland, OR), one standard arm sling, and one ace bandage *(Figure 1)*. The two SAM splints are shaped into a triangle, and one is placed inside the other. Additionally, the edges should be slightly C-curved for increased strength and molded to the patient's flank and forearm *(Figure 2)*. The patient's affected arm is placed in the standard sling and secured to one side of the SAM splint using the ace bandage. The other side of the SAM splint rests against the patient's flank. The arm is effectively immobilized in neutral rotation *(Figure 3)*. This technique places the shoulder in neutral rotation, because 45° of external rotation is awkward and may interfere with certain activities of daily living.

Figure 1. *Necessary supplies*

Figure 2. *SAM splints are shaped into a triangle and the edges are slightly C-curved (top and side views).*

Figure 3. *Patient with shoulder immobilized in neutral rotation.*

DISCUSSION

The materials used in this technique are inexpensive, easy to use, and can be easily stored in a sports medicine bag. The splinting materials are lightweight, so as not to impart a significant traction force to the healing joint. This technique allows for efficient and effective immobilization of the glenohumeral joint in neutral rotation, which may contribute to improved healing and decreased instability following a dislocation.[11]

REFERENCES

1. Arciero RA, St. Pierre P. Acute shoulder dislocation. Indications and techniques for operative management. *Clin Sports Med.* 1995;14:937-953.
2. Arciero RA, Taylor DC. Primary anterior dislocation of the shoulder in young patients. A ten-year prospective study. *J Bone Joint Surg Am.* 1998;80:299-300.
3. Arciero RA, Wheeler JH, Ryan JB, et al. Arthroscopic Bankart repair versus non-operative treatment for acute, initial anterior shoulder dislocations. *Am J Sports Med.* 1994;22:589-594.
4. Hovelius L, Augustini BG, Fredin H, et al. Primary anterior dislocation of the shoulder in young patients. A ten-year prospective study. *J Bone Joint Surg Am.* 1996; 78:1677-1684.
5. DeBerardino TM, Arciero RA, Taylor DC, et al. Prospective evaluation of arthroscopic stabilization of acute, initial anterior shoulder dislocations in young athletes. Two- to five-year follow-up. *Am J Sports Med.* 2001;29:586-592.
6. Edwards BT, Lassiter TE, Easterbrook J. Immobilization of anterior and posterior glenohumeral dislocation. *J Bone Joint Surg Am.* 2002;84-A:873-874.
7. Hart WJ, Kelly CP. Arthroscopic observation of capsulolabral reduction after shoulder dislocation. *J Shoulder Elbow Surg.* 2005;14:134-137.
8. Itoi E, Sashi R, Minagawa H, et al. Position of immobilization after dislocation of the glenohumeral joint. A study with use of magnetic resonance imaging. *J Bone Joint Surg Am.* 2001;83-A:661-667.
9. Miller BS, Sonnabend DH, Hatrick C, et al. Should acute anterior dislocations of the shoulder be immobilized in external rotation? A cadaveric study. *J Shoulder Elbow Surg.* 2004;13:589-592.
10. Suder PA, Frich LH, Hougaard K, et al. Magnetic resonance imaging evaluation of capsulolabral tears after traumatic primary anterior shoulder dislocation. A prospective comparison with arthroscopy of 25 cases. *J Shoulder Elbow Surg.* 1995;4:419-428.
11. Deyle GD, Nagel KL. Prolonged immobilization in abduction and neutral rotation for a first-episode anterior shoulder dislocation. *J Orthop Sports Phys Ther.* 2007; 37:192-198.

ORIGINAL RESEARCH

THE EFFECTS OF TWO ADHESIVE ANKLE-TAPING METHODS ON STRENGTH, POWER, AND RANGE OF MOTION IN FEMALE ATHLETES

Katherine E. Quackenbush, BKin[a]
Paula R.J. Barker, BKin[a]
Shauna M. Stone Fury, BSc[b]
David G. Behm, PhD[c]

ABSTRACT

Background. Taping is a ubiquitous strategy to help prevent ankle sprains. The restrictive qualities of various taping methods may impair athletic performance.

Objective. The objective of the study was to compare the Gibney closed basket weave taping method with heel-locks to heel-locks and figure-eights in order to determine their effect on vertical jump performance and active range of motion (ROM) before and after exercise.

Methods. Eleven female varsity basketball athletes were subjected to three conditions of no ankle support (control), heel-locks, and figure-eights. The dependent variables of ankle active ROM, plantarflexor maximum voluntary contraction and jump height for the countermovement jump (CMJ), drop jump (DJ), and concentric only squat jump (COSJ) were randomly ordered. Following taping or control conditions, participants were pre-tested, completed a ten-minute treadmill run at 9.6 km/hr with a 3 minute cool down and then repeated the testing procedures.

Results. There were no significant differences in jump performance between taping methods or the effect of exercise. However significant differences for pre-/post-exercise for plantarflexor ($p < 0.0001$) and dorsiflexor ($p = 0.007$) active ROM and between no support and taping for plantarflexor ROM ($p = 0.004$) was found.

Conclusions: Despite plantarflexor active ROM being restricted by both taping procedures compared to the control, no effect on jump performance occurred.

Key words: flexibility, drop jump, countermovement jump, squat jump, ankle sprain

CORRESPONDENCE:
David Behm PhD, Professor
School of Human Kinetics and Recreation
Memorial University of Newfoundland
St. John's, Newfoundland,
Canada, A1M 3L8
dbehm@mun.ca
709-737-3408 (tel)
709-737-3979 (fax)

ACKNOWLEDGEMENTS
The Natural Science and Engineering Research Council (NSERC) of Canada supported this research.

[a] Student: School of Human Kinetics and Recreation
Memorial University of Newfoundland
St. John's, Newfoundland, Canada

[b] Athletic Therapist
School of Human Kinetics and Recreation
Memorial University of Newfoundland
St. John's, Newfoundland, Canada

[c] David Behm PhD, Professor
School of Human Kinetics and Recreation
Memorial University of Newfoundland
St. John's, Newfoundland, Canada

INTRODUCTION

Ankle sprains are the most common musculoskeletal injury found among all athletes regardless of age or level of participation.[1] As a result of the high incidence of these injuries, medical personnel, coaches, and athletes are eager to find the optimal ankle stabilizer that will help to reduce injuries while minimizing the effect it may have on performance. Research has shown that the mechanical stability and increased proprioception external supports create on the ankle joint work to help prevent ankle injury during physical activity.[2-6] If, however, the restrictive qualities of these supports were detrimental to athletic performance, then athletes, coaches and athletic trainers would be deterred from using the supports despite these preventive measures.

The types of ankle stabilizers commonly used are adhesive tape and ankle braces with the main goal of both being to support the unstable ankle from injury without having an effect on athletic performance.[7] Many sports medicine personnel and athletes prefer taping over bracing due to increased comfort, increased support and decreased interference with normal ankle function.[6] The most prevalent taping method utilized today is the Gibney closed basketweave in conjunction with the heel-lock or the figure-eight.[5,7-10]

With the application of adhesive tape being highly utilized for supporting the ankle joint during exercise and with more than one taping method available, it is important to determine and understand the differences, if any, between the methods used. However, the majority of the research in this area has dealt with comparisons between taping and bracing on athletic performance.[11-14] Different performance parameters have been tested with inconclusive results found in relation to ankle supports and vertical jump height. Some studies have found a significant reduction in vertical jump height as a result of the application of an external support,[1,8,10] while others found no significant effect on vertical jump height with the application of tape or a brace when compared to no support.[7,10,11,15] Therefore, the purpose of this study was to compare the effect of the Gibney closed basketweave taping method with heel locks to the Gibney closed basketweave with heel-locks and figure-eights on vertical jump performance.

METHODS

Experimental Design

Participants were tested before and after the application of a Gibney closed basketweave with heel locks (HL), Gibney closed basketweave with heel locks and figure - eights, and a control condition. Following the application of the tape, participants ran on a treadmill for 10 min at 9.6 km.h-1 with a level grade and then were re-tested with the same cadre of tests used in the pre-test. These measures consisted of ankle active range of motion (ROM); drop, countermovement, and concentric only squat jumps; and plantarflexor maximal voluntary contraction.

Subjects

Eleven female college basketball athletes (height = 172.1 ± 6.7cm, weight = 69.2 ± 12.9kg, age = 20.6 ± 1.4, range, 19 to 25 years) with no ankle injury in the past three months volunteered to participate in this study. The attending athletic therapist assessed all subjects for healthy ankle function. Approval from the Interdisciplinary Committee in Ethics in Human Research (ICEHR) at Memorial University of Newfoundland was obtained and written informed consent was obtained from all subjects.

Instruments

All vertical jumps were performed using a contact mat (Innervations, Muncie, IN) and analyzed using the Kinematics Measurement Systems (Innervations, Muncie, IN) software program.[16,22,26] The software program recorded jump height based on flight time. In order to ensure validity of the test, participants were asked to have their knees as fully extended as possible and ankles completely plantarflexed at both take off and landing.[16]

Subjects performed plantarflexor maximal voluntary control while seated in a straight-backed chair with hips and knees at 90°. Isometric contractions were performed with their leg secured in a modified boot apparatus[16] with their ankles flexed at 10° of dorsiflexion.[17] All torques were detected by strain gauges, amplified (Biopac Systems Inc., DA 100: analog-digital converter; Holliston, MA) and monitored on a computer (Sona Phoenix, St. John's, Newfoundland). Data were stored on a computer at a sampling rate of 2000 Hz. Data were recorded and analyzed with a commercially designed software program (AcqKnowledge III, Biopac Systems Inc., Holliston, MA).

Taping Method

The same certified athletic therapist applied the tape bilaterally to each subject. Cramer® Tuf-Skin tape adherent (Gardner, Kansas) was initially sprayed on the feet of each participant. Next, Cramer® heel and lace pads (Gardner, Kansas) were applied to both feet at the posterior calcaneus and dorsum of the foot at the ankle (talocrural joint) to help prevent blistering from friction associated with the tape application. Cramer® Skin Lube lubricating ointment (Gardner, Kansas) had been placed on the heel and lace pads prior to application. The tape, 1 1/2 inch zinc oxide Johnson and Johnson Coach® athletic tape (Princeton, New Jersey), was then applied bilaterally to the participants in either the heel-lock or figure-eight methods, as according to Perrin.[18]

The Gibney closed basketweave with HL taping procedure had the ankle positioned at 90° of dorsiflexion. Two anchor strips were placed on the distal leg (foot anchors were left out as they frequently cause constriction and discomfort).[18] A stirrup was applied from the medial aspect of the leg and pulled under the heel to the lateral aspect of the leg using the malleoli as landmarks. A horizontal horseshoe strip was placed from the medial to lateral aspect of foot, while another stirrup was placed in a weaving fashion. The horseshoe and then the stirrup process were continued until three stirrups were applied. The leg was enclosed with horizontal strips ensuring no skin was visible. Heel-locks were applied in a single manner (pulling in upward direction).

The other taping condition included the Gibney closed basketweave with heel-lock as well as a figure-eight. The additional figure-eight taping started on the lateral malleolus and continued down and under the medial aspect of the foot pulling up over the dorsum of the foot to the medial malleolus and around the back of the Achilles tendon and returning to the lateral malleolus. This process was repeated twice for the Figure 8 option.

Testing

Testing was conducted before and after exercise under three conditions: control, heel-locks and figure-eights. The treatment order was randomly assigned. Each testing condition occurred on separate days. Separate testing conditions were conducted within a range of 24–72 hours. Measurements included ankle joint active ROM, plantarflexor maximal voluntary control, and vertical jump tests involving concentric only squat jump (COSJ), countermovement jump (CMJ), and drop jumps (DJ). Ankle active ROM was always tested initially since dynamic jumping movements could loosen the tape adhesion. All jump measures were completed in a randomized order to prevent any effects from fatigue or learning.

Measurements of active ROM at the ankle joint were taken between full dorsiflexion and full plantarflexion for both feet *(Figures 1 and 2)*. The focus of the paper was on the effects of these two adhesive ankle-taping methods on performance (strength, power, and ROM). Thus, changes in the plantarflexor and dorsiflexor ROM could possibly affect jump performance by hindering impulse (force x time) and work (force x distance) performed. Dorsiflexion *(Figure 1)* and plantarflexion *(Figure 2)* active ROM were measured as the participant sat with their leg hanging from a bench. Participants then contracted either their dorsiflexors or plantarflexors maximally in order to achieve the greatest active ROM possible. A goniometer was used with one lever of the goniometer placed on the proximal fibular head, while the other was placed on the fifth metatarsal. The pivot was positioned on the lateral malleolus. The ROM was recorded based on the position of the lever on the fifth metatarsal. The same certified athletic therapist completed all active ROM measurements.

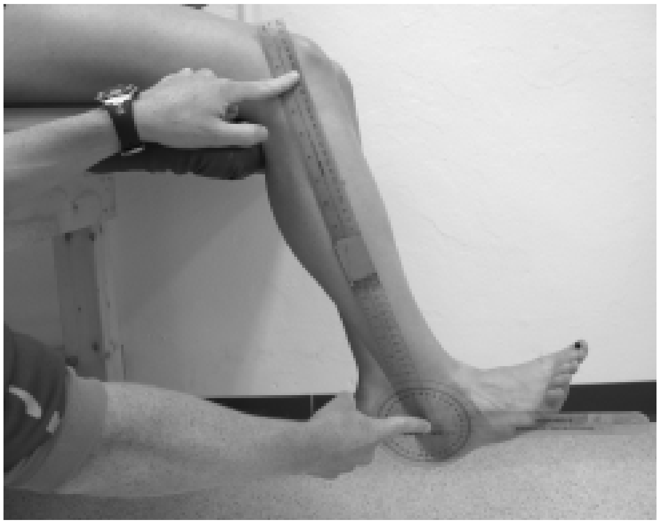

Figure 1: *Illustration of positioning of the goniometer for measurement of active dorsiflexion range of motion.*

For the maximal voluntary contraction, participants placed their dominant leg in the modified boot apparatus, with their ankle at 10° of dorsiflexion, which is the optimal angle for plantar flexion force production.[16] Participants were instructed to plantarflex their foot as fast and as hard as possible. The contraction was held for three seconds at which point they were given a three-minute rest before the second trial began. If a third trial was necessary (greater than 5% difference in force between first two trials) another three-minute rest was allocated.

The CMJ is similar to sport specific situations, therefore, emphasizing game-like maneuvers. Participants stood with their feet shoulder width apart and flat on the contact mat. With hands on hips, they were instructed to jump as high as possible by using their own choice of depth and pace. Allowing the subject a choice ensured that participants were using a comfortable jumping technique that they would normally utilize in an athletic setting. An athletic population was utilized due to their familiarity with the jumping technique, thereby, reducing variability.

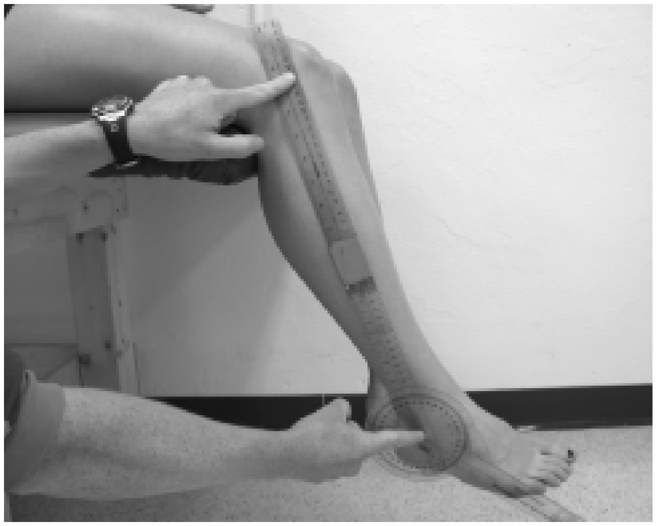

Figure 2: *Illustration of positioning of the goniometer for the neutral ankle position for active range of motion measurements.*

The DJ, which emphasized the stretch-shortening cycle of the ankle, was performed with the participants standing with both feet flat on a 30cm high platform. This height has been used in previously published studies[16,19,20] to ensure an optimal combination of jump height and minimum contact time. With hands on hips, participants were instructed to drop off the platform by stepping forward with whichever foot felt most comfortable. This foot was then used to initiate the DJ for all further testing. Upon contacting the mat with both feet, they were told to jump as high and as fast as possible. Subjects attempted to limit excessive knee flexion such that the ankle was emphasized to a greater extent in the generation of the jump forces.

The COSJ was tested due to its emphasis on impulse generation.[16] With hands on hips, participants stood with feet shoulder width apart and flat on the contact mat with their knees flexed at 90º. This position was held for two seconds. After the two-second period they were told to jump as high as possible.

A thirty-second recovery was provided between all jump trials. Jump height was used as the indicator of best performance for all jumps. The three jumps were chosen to ascertain the effect of taping on three physiological parameters. This particular form of DJ was performed with specific instructions to mainly involve a rapid stretch-shortening cycle action of the ankles.[16,19,20] In contrast, the CMJ used a moderate speed stretch-shortening cycle (angular speed dependent on participant's preference) which emphasized both knees and ankles which contrasted with the COSJ that lacked a significant stretch-shortening cycle.

Previous research from our laboratory[22] has reported the following intraclass correlation coefficients (ICC) for plantarflexor range of motion (0.94), squat jump (0.96), countermovement jump (0.93) and drop jump (0.89) respectively. Other research from our laboratory utilizing the plantarflexor maximal voluntary control has shown ICC values ranging from 0.91 – 0.99.[17]

Participants then completed a ten-minute exercise protocol on a treadmill (9.6 km.h-1) at a level grade followed by a three minute cool down (4.5 km/hr) to initiate the loss of the tape's restrictive properties. The treadmill speed was chosen to provide a typical pace used in a pre-competition warm-up by these athletes. This speed was based on pilot studies utilizing the same athletes. At completion of the exercise protocol the testing procedures were repeated in a randomized order with active ROM again being completed first. Only two trials of each testing procedure were necessary unless there was more than a five percent difference between the two measurements and then a third measurement was conducted. All measurements were recorded with the best performance (maximal voluntary control force and jump heights) used for the data analysis

Data Analysis

The data was analyzed using a two way ANOVA (two times: pre- and post-exercise x 3 tape conditions: control, heel-locks, figure-eights) with repeated measures. An alpha level of $p < 0.05$ was considered statistically significant. If significant differences were found, a Bonferroni-Dunn's procedure was conducted to identify where the significant change occurred. Effect sizes (ES = mean change / standard deviation of the sample scores) were also calculated and reported.[21] Cohen[21] applied qualitative descriptors for the effect sizes with ratios of <0.40, 0.41-0.70 and >0.7 indicating small, moderate and large changes, respectively. Means and standard deviations (SD) are reported in the text and figures.

RESULTS

Overall, for all dependent variables tested (maximal voluntary contraction force, CMJ, DJ, COSJ), except the active ROM, no significant differences existed for the taping method or the effect of exercise when comparing any of the independent variables (control, heel-locks, figure-eights)*(Table)*. The control condition exhibited 24.9% and 27.5% significantly ($p < 0.05$) greater plantarflexion active ROM as compared to HL (ES = 0.99) and F8 (ES = 1.11) tape methods respectively *(Figure 3)*. In addition, 25.7% and 9.6% significantly greater plantarflexion ($p < 0.05$; ES = 0.85) and dorsiflexion ($p < 0.05$; ES = 0.5) active ROM for both ankles were detected following exercise independent of the taping method *(Figure 4)*.

DISCUSSION

The results of our study indicate that a significant reduction in plantarflexion active ROM occurred as a result of the two different tape application methods (heel-lock and figure-eight) as compared to the control. This is in agreement with other studies that reported similar conclusions as a result of the utilization of external ankle supports.[2,4,9]

It had been theorized that tape restriction would impede the force generated by the plantarflexors. However, the present study indicated that maximum force production was not reduced as a result of tape application as no significant maximal voluntary control differences existed between the type of taping method (heel-locks or figure-eights) and the control, pre-, or post-exercise groups.

Table: *Pre- and post-exercise means and standard deviations for all variables. The following definitions are defined as df = degrees of freedom, F = F ratio and p = probability value, MVC = maximal voluntary control.*

	Heel lock Pre-exercise	Heel lock post-exercise	Figure 8 pre-exercise	Figure 8 post-exercise	Statistics
Countermovement jump (cm)	24.9 ± 3.6	24.7± 5.6	23.6 ± 3.2	25.3 ± 2.8	df = 32 F = 0.04 p = 0.43
Drop jump (cm)	20.7 ± 4.3	21.4 ± 4.7	21.2 ± 4.4	22.1 ± 4.6	df = 32 F = 0.05 p = 0.94
Drop jump contact time (ms)	232.9 ± 38.7	230.1 ± 31.1	216.6 ± 46.1	241.2 ± 30.1	df = 32 F = 0.07 p = 0.48
Concentric only squat jump (cm)	24.2 ± 3.4	23.5 ± 2.2	23.7 ± 3.4	24.7 ± 4.1	df = 32 F = 1.44 p = 0.25
Plantarflexors MVC (Newtons)	251.7 ± 55.6	253.6 ± 51.8	232.9 ± 51.1	217.3 ± 69.5	df = 17 F = 0.35 p = 0.71
Dorsiflexion ROM (degrees)	10.4 ± 1.0	11.1 ± 1.8	10.1 ± 0.6	11.5 ± 0.7	df = 32 F = 8.19 p =0.007
Plantarflexion ROM (degrees)	27.9 ± 10.8	35.5 ± 11.8	26.0 ± 8.5	35.3 ± 11.6	df = 32 F = 37.8 p<0.0001

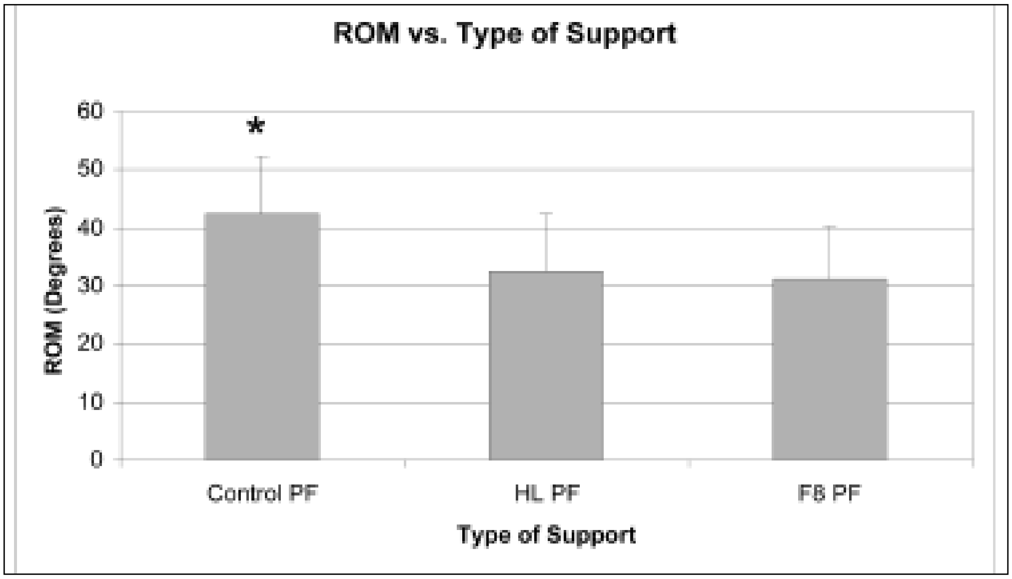

Figure 3. *The asterisk (*) indicates a significant ($p < 0.05$) difference in plantarflexors (PF) ROM between the control (NS: no support) and type of taping (HL: heel lock, F8: heel lock, and figure 8) method. The acronyms PF, DF, HL and F8 refer to plantarflexors, dorsiflexors, Gibney closed basket weave with heel lock, and Gibney closed basket weave with heel lock and figure 8, respectively.*

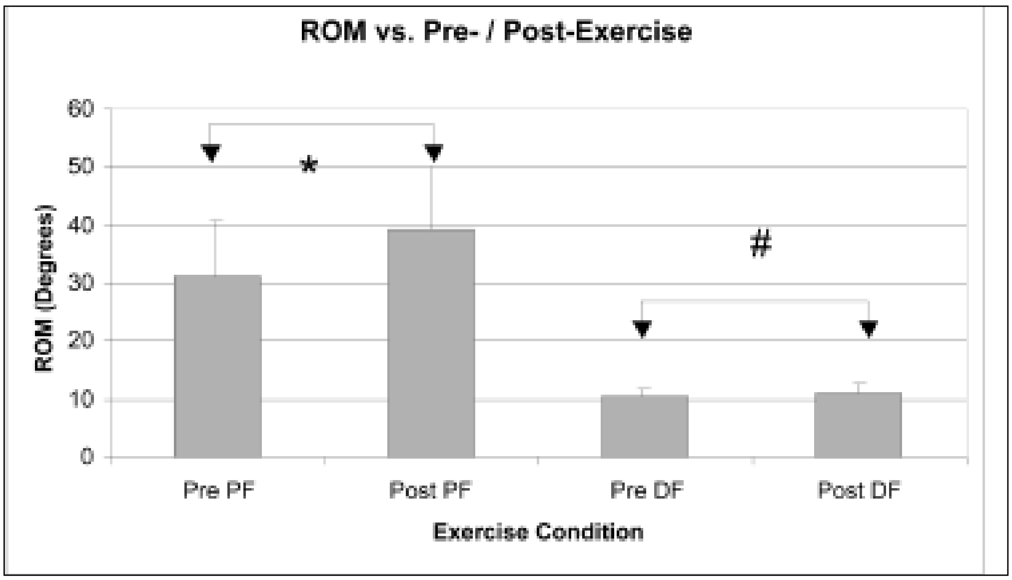

Figure 4. *The asterisk (*) indicates a significant difference ($p < 0.05$) between plantarflexors (PF) ROM pre- and post-exercise. The number sign (#) indicates a significant difference ($p = 0.05$) between dorsiflexors (DF) ROM pre- and post-exercise. The acronyms PF and DF refer to plantarflexors and dorsiflexors, respectively.*

These results concur with previous research that has tested maximum force production when ankles have been taped.[2,4,7]

Cordova et al[4] reviewed the literature indicating that taping did not decrease the magnitude of the forces produced, but the rate at which they were produced was slower. Alternatively, the present research did not find a significant difference in DJ contact time with taping. Muscle force and power have been reported to be compromised with increased muscle compliance.[22,23] The elongation of tendinous tissues can also have a deleterious effect on force output.[24] Belli and Bosco[25] suggested that a stiffer musculotendinous unit would enhance the work performed during stretch-shortening cycle movements. Perhaps the restricted ROM of the taping methods contributed to a stiffer or less compliant ankle joint which permitted a more rapid stretch-shortening cycle during the DJ contact time. Hence, although the tape restricted ankle ROM, the tape did not decrease the maximal voluntary contraction force generated by the ankle-foot complex during the DJ.

Plantarflexion is required for propulsion[5,6] and during the push off phase[11] of a vertical jump. The results of the present study indicate that no significant reductions in vertical jump height occurred with any condition tested. Similar research also reports a lack of change in vertical jump height with the application of external ankle supports.[7,10,11,15] Verbrugge[7] utilized the heel-lock method while Paris[10] utilized the figure-eight method. Neither study recorded a significant reduction in vertical jump height under these conditions. Other studies however have recorded significant reductions in vertical jump heights as a result of external ankle supports.[1,8] Possible reasons for the lack of vertical jump impairment would include the aforementioned insignificant effects of ankle taping on maximal voluntary contraction force and the possible positive effect of increased ankle joint stiffness on the stretch-shortening cycle. Furthermore, ankle taping has also been found to increase proprioception and sensorimotor function through the stimulation of cutaneous mechanoreceptors.[3,4,13] It has been theorized that the activity of these mechanoreceptors are enhanced as a result of the pressure an external ankle support places on the lower leg.[13] If prime movers such as the plantarflexors are stimulated, these muscles could counteract the effect of the restricted plantarflexor ROM.

A study by Kean et al[26] implementing six weeks of wobble board training, found an increase in vertical jump height. This study demonstrated that an improvement in stability could positively affect vertical jump height, as enhanced stability helps to direct jump forces in a vertical direction as opposed to slight deviations from vertical. In addition, improved stability can allow for a greater amount of force to be produced.[17,27] The muscles involved in the movement can be dedicated more to producing motion rather than joint stabilization.[26,27] As ankle taping improves stability, both of these factors have the potential of counteracting some of the negative effects from a reduction in ankle ROM.

The results of this study also indicated that significant increases occurred in plantarflexion active ROM across all conditions pre- and post-exercise. This finding is in agreement with other studies that attributed the increased ROM to the loosening of the tape as a result of exercise.[7,15,28] Researchers have reported 40-50% of the tape's initial restrictive support is lost following just 10 minutes of activity.[7] Despite the loosening of the tape and the increase in ROM, the tape still provides adequate restriction of ROM to aid in injury prevention.[28] The proprioceptive stimulation provided by the adhesive tape to the lower leg would also be an aid for injury prevention.

Limitations of the present study include the small sample size (n = 11) and the convenience sample. As the sample included only female varsity athletes, the application of the present findings to other populations may be somewhat limited. Further research should examine the effect of other taping methods on performance, inversion/eversion range of motion and more varied samples (males, recreationally active individuals, younger and older individuals, individuals with present or former ankle sprains). More sophisticated analysis could be accomplished if similar research was conducted on a reaction force platform which could monitor changes in three planes, as well as proprioceptive testing.

CONCLUSION

Despite ankle active ROM being restricted by both taping procedures (heel-locks and figure-eights), no effect on vertical jump performance, contact time, or maximal voluntary contraction force occurred. As a result, the personal preference of the clinician, athlete, or coach can be used to determine the taping method without the possibility of decreasing vertical jump height.

REFERENCES

1. MacKean LC, Bell G, Burnham RS. Prophylactic ankle bracing vs. taping effects on functional performance in female basketball players. *J Orthop Sports Phys Ther.* 1995; 22:77-81.
2. Bot SDM, van Mechelen W. The effect of ankle bracing on athletic performance. *Sports Med.* 1999;27:171-178.
3. Cordova ML, Ingersoll CD. Peroneus longus stretch reflex amplitude increases after ankle brace application. *Br J Sports Med.* 2003;37:258-262.
4. Cordova ML, Ingersoll CD, Palmieri RM. Efficacy of prophylactic ankle support: an experimental perspective. *J Athletic Training.* 2002;37:446-457.
5. Lindley TR, Kernozek TW. Taping and semirigid bracing may not affect ankle functional range of motion. *J Athletic Training.* 1995;30:109-112.
6. Wilkerson GB. Biomechanical and neuromuscular effects of ankle taping and bracing. *J Athletic Training.* 2002; 37:436-445.
7. Verbrugge JD. The effects of semirigid Air-Stirrup bracing vs. adhesive ankle taping on motor performance. *J Orthop Sports Physical Ther.* 1996;23:320-325.
8. Metcalfe RC, Schlabach GA, Looney MA, Renehan EJ. A comparison of moleskin tape, linen tape, and lace-up brace on joint restriction and movement performance. *J Athletic Training.* 1997;32:136-140.
9. Nishikawa T, Kurosaka M, Mizuna K, Grabiner M. Protection and performance effects of ankle bracing. *Int Orthop.* 2000;24:285-288.

10. Paris DL. The effects of the Swede-O, New Cross, and McDavid Ankle Braces and adhesive ankle taping on speed, balance, agility, and vertical jump. *J Athletic Training.* 1992;27:253-256.

11. Gross MT, Everts JR, Robertson SE, et al. Effect of DonJoy Ankle Ligament Protector and Aircast Sport-Stirrup orthoses on functional performance. *J Orthop Sports Phys Ther.* 1994;19:150-156.

12. Hodgson B, Tis L, Cobb S, Higbie E. The effect of external ankle support on vertical ground-reaction force and lower body kinematics. *J Sport Rehabilitation.* 2005;14:301-312.

13. Kaminski TW, Gerlach TM. The effect of tape and neoprene ankle supports on ankle joint position sense. *J Physical Therapy Sport.* 2001;2:132-140.

14. Verhagen EALM, van der Beek AJ, van Mechelen W. The effect of tape, braces and shoes on ankle range of motion. *J Sports Med.* 2001;31:667- 677.

15. Macpherson K, Sitler M, Kimura I, Horodyski M. Effects of semirigid and softshell prophylactic ankle stabilizer on selected performance tests among high school football players. *J Orthop Sports Phys Ther.* 1995;21:147-152.

16. Behm DG, Anderson K, Curnew RS. Muscle force and activation under stable and unstable conditions. *J Strength Condition Res.* 2002;16:416-422.

17. Power K, Behm D, Cahill F, et al. An acute bout of static stretching: effects on force and jumping performance. *Med Sci Sports Exerc.* 2004;36:1389-1396.

18. Perrin DH. *Athletic Taping and Bracing.* 2nd ed. Champaign, IL: Human Kinetics; 2005.

19. Young WB, Behm DG. Effects of running, static stretching and practice jumps on explosive force production and jumping performance. *J Sports Med Physical Fitness.* 2002; 34:119-124.

20. Young W, Elias G, Power J. Effects of static stretching volume and intensity on plantarflexor explosive force production and range of motion. *J Sports Med Physical Fitness.* 2006;46:403-411.

21. Cohen J. *Statistical Power Analysis for the Behavioral Sciences.* 2nd ed. Hillsdale NJ: L. Erbaum Associates Publishing; 1988.

22. Behm DG, Kibele A. Effects of differing intensities of static stretching on jump performance. *Eur J Appl Physiol.* 2007; 101:587-594.

23. Young W, Elliott S. Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximal voluntary contractions on explosive force production and jumping performance. *Res Quart Exerc Sport.* 2001;72:273-279.

24. Kawakami Y, Kubo K, Kanehisa H, Fukunaga, T. Effect of series elasticity on isokinetic torque-angle relationship in humans. *Eur J Appl Physiol.* 2002;87:381-387.

25. Belli A, Bosco C. Influence of stretch-shortening cycle on mechanical behaviour of triceps surae during hopping. *Acta Physiol Scand.* 1992;144:401-408.

26. Kean CO, Behm DG, Young WB. Fixed foot balance training increases rectus femoris activation during landing and jump height in recreationally active women. *J Sports Sci Med.* 2006;5:138-148.

27. Anderson K, Behm DG. Maintenance of EMG activity and loss of force output with instability. *J Strength Condition Res.* 2004;18:637-640.

28. Ricard MD, Sherwood SM, Schulthies SS, Knight KL. Effects of tape and exercise on dynamic ankle inversion. *J Athletic Training.* 2000;35:31-37.

ORIGINAL RESEARCH

THE EFFECTS OF LOADED VERSUS UNLOADED ACTIVITIES ON FOOT VOLUMETRICS IN OLDER HEALTHY ADULTS

J. Wesley McWhorter, PT, MPT, PhD [a]

ABSTRACT

Background. Health care practitioners, including sports physical therapists, commonly prescribe and recommend aerobic exercise for those patients seeking to improve their cardiovascular fitness across all ages. Current literature demonstrates that weight bearing activities such as walking or running may lead to foot and ankle edema.

Objectives. The purpose of this study is to determine if a significant difference exists between foot volumes (edema) in pre versus post-exercise measurements during a loaded activity (treadmill walking) or an unloaded activity (upright exercise bike) in 31 healthy subjects 50 years of age and older.

Methods. After a rest period, a pre-exercise volumetric measurement of the right leg was obtained by the use of a foot volumeter. The first condition (walking or cycling) was randomly chosen. Each subject completed two 10-minute exercise sessions. Immediately following both exercise sessions, a post-exercise volumetric measurement was completed.

Results. A statistically significant difference in foot volume was found between pre (mean = 742.39ml, 95% CI: 685.23 – 799.55) and post (mean = 753.03ml, 95% CI: 697.51ml – 808.55ml) measurements for the treadmill (weight bearing) protocol. When considering each sex separately, males produced significant increases in foot volume following treadmill walking (pre mean = 871.00ml, 95% CI: 793.95ml – 948.05ml; post mean = 886.20ml, 95% CI: 811.28ml – 961.13ml), while females displayed no significant changes.

Discussion and Conclusion. This study demonstrated a 1.4% increase in foot volume after 10 minutes of treadmill walking. Based on these results, it may be advisable to prescribe non-weight bearing exercise to active older individuals with pre-existing conditions for edema.

Key words: edema, volumetrics, unloaded and loaded activities

CORRESPONDENCE

J. Wesley McWhorter PT, MPT, PhD
Associate Professor
Chair, Department of Physical Therapy
School of Allied Health Sciences
University of Nevada, Las Vegas
4505 Maryland Parkway
Box 453029
Las Vegas, NV 89154
James.McWhorter@UNLV.edu

[a] University of Nevada, Las Vegas
Las Vegas, NV

INTRODUCTION

Health care practitioners (including sports physical therapists) commonly prescribe and recommend aerobic exercise for those individuals of all ages seeking to improve their cardiovascular fitness. These aerobic activities often include walking, running, and cycling programs. Current literature demonstrates, however, that weight-bearing activities, such as walking or running, may lead to foot and ankle swelling.[1-4] This acute swelling, which is a common complication resulting from weight bearing activities, can lead to more serious conditions such as fibrosis, joint stiffness, pain, and dysfunction.[1,5-13]

One of the problems that results from aerobic exercise is edema formation in the lower extremities which can lead to peripheral vascular disease or other circulatory insufficiencies.[1,3,13] Other research has shown an opposite effect, with aerobic activity resulting in a decrease in lower extremity volume.[1,2,14] This decrease in lower extremity volume may be the result of the muscle-pumping effect of the gastroc-soleus complex.[1,2,15,16] In addition to aerobic activities resulting in an increase in swelling, static activities have also been shown to produce edema in the lower leg.[14,15,17,18]

Other research has examined the discrepancies involving the effects of loaded dynamic activity on lower extremity volume. Cloughley and Mawdsley[3] found a greater increase in foot volume during running as compared to walking. These findings are supported by McWhorter et al[13] who found significant increases in foot swelling during walking and running. Other researchers found increases in foot volume during running, but a decrease during walking.[1] Evidence also exists demonstrating increases in interstitial and intracellular volume during and after exercise which are directly related to exercise workload.[19]

During quiet static standing, subjects have been shown to increase lower extremity edema formation as a result of pooling of fluid in the lower extremity.[17] Specifically, foot volume during standing has been shown to increase compared to a supine position, possibly the result of a decrease in perfusion of the veins that return to normal when the supine position is resumed.[18]

Stationary bicycle ergometry is an example of an unloaded dynamic activity. Research by Stick et al[14] found that stationary bicycling demonstrated a gradual decrease in foot volume. They also discovered a more significant decrease in foot volume occurred when subjects pedaled against a stronger resistance.

Other studies have examined the effects of differing postures on changes in foot volumes. Seated positioning has been shown to cause an increase in foot volume.[14] Another posture, supine lying with or without leg elevation, has demonstrated a significant decrease in foot volume.[20,21] All of these studies demonstrate that foot volume can be affected by its gravitational position.

In the young or recreational athlete, the small changes that occur as a result of running or walking may not be a problem. However, in older or geriatric adults, these small increases in foot volume when coupled with chronic resting edema could prove to be harmful.[22,23] Peripheral edema is a common finding in the elderly, however, actual figures for prevalence are not known. A survey conducted on peripheral edema in elderly patients admitted to a geriatric ward found that 48% of patients had an overall presence of edema during their admission.[24] Compounding the effects of existing edema with co-morbidities will make exercise prescription increasingly more difficult.

The increasing incidence of morbidities involving resting edema, such as coronary heart disease (CHD) and diabetes, showcases the need for further research in this area.[8,10,24-26] Arnold et al[25] reported the incidence of CHD to be 39.6 per 1,000 persons in men and 22.3 per 1,000 persons in women. Moreover, the incidence of CHD increases 9% with each year of age past 65. Bertoni et al[26] reported a high incidence of mortality among older adults with diabetes and heart failure; 32.7 per 100 persons-years compared with 3.7 per 100 person-years among those with diabetes who did not suffer from congestive heart failure (CHF).

The purpose of this study is to determine if a significant difference exists between foot volumes (edema) in pre versus post-exercise measurements during a loaded activity (treadmill walking) or an unloaded activity (upright exercise bike) in the active healthy older population. Based on the findings of McWhorter et al,[13] the hypothesis tested was that loaded activities will result in greater edema in the foot and ankle than unloaded activities. Additionally, it is hypothesized that the unloaded position of the bike coupled with the active and passive movement of the ankle may result in a reduction in foot volume secondary to a muscle pumping action moving fluid out of the area.[26] Results of this study may help health care practitioners prescribe a more appropriate exercise mode when addressing the cardiovascular health of the active geriatric individuals.

METHODS

Subjects

The subjects consisted of 21 female and 10 male volunteers between the ages of 50 to 67 years without a history of musculoskeletal injuries, health problems, or surgery to the lower extremities, and who had no difficulty or discomfort during walking on a treadmill of riding a bicycle ergometer. The mean age of all 31 participants was 56.26 (SD = 4.89) years. For the 21 females, the mean age was 56.1 (SD = 3.97) years and for the males was 56.6 (SD = 6.33) years. All subjects were recruited by using emails sent throughout the university. All participants completed the Physical Activity Readiness Questionnaire (PAR-Q)[27] and signed an informed consent to participate. This research study was approved by the Institutional Review Board at the University of Nevada, Las Vegas. Participants were excluded if they met any of the following conditions: injury to the right lower extremity within the past year, abnormal swelling in the ankles or feet, history of bone or joint disorders that is aggravated by exercise, or any other physical reason provided by a physician that they should not exercise.

Instrumentation

All lower extremity measurements were obtained using a Lucite (Foot Volumeter, P.O. Box 146, Idyllwild, CA, 92349) foot volumeter set *(Figure 1)* which included the volumeter container, an obturator which was used to calibrate the water levels prior to each measurement, a receiver to catch the water overflow, and a 1000-ml gradated cylinder with 10-ml gradations. All measurements were taken following the manufacturer's guidelines. Several studies have been performed establishing the reliability and validity of obtaining foot/ankle volume measurements using this equipment.[1-3,5,6,13,28]

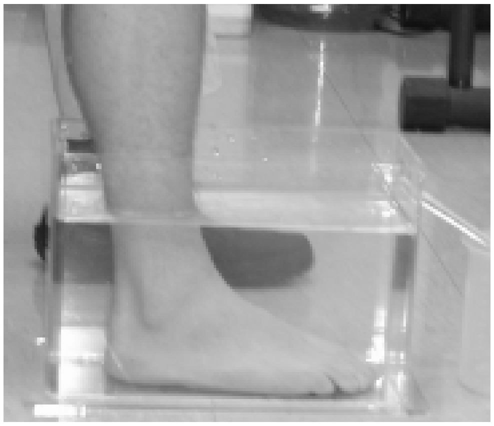

Figure 1: *Lucite foot volumeter.*

The displaced water was captured in a plastic container and subsequently measured in a gradated cylinder. All data was immediately recorded on a personalized data sheet. As water has a tendency to creep up the sides of the plastic cylinder, measurements were taken from the lowest level at the water line. Each volume measurement was taken by the same observer to ensure proper consistency.

A pilot test was performed previously in order to allow the testers to practice taking foot volumetric measurements. At this time, the researchers performed the volumetric measurements on 10 volunteers. The three researchers involved in data collection were asked to take the measurements from the participants. The data were recorded by an independent observer. Two days later, the researchers, who were blinded to the previous results, took the measurements from the same participants. All measurements were compared for reliability and demonstrated a reliability intra-class correlation coefficient of 0.99 (95% limits of agreement +/- 7.54 ml).[29]

Procedure

The subjects were given an individual instructional session at which time all aspects of the research study were explained and possible complications as a result of participation were discussed. All subjects were tested at the same time of day. They were informed to not exercise or consume alcoholic beverages on the days prior to being tested and to maintain their present eating habits. Each subject was required to sit in a straight back chair and slowly lower their right leg into the foot volumeter until the foot rested flat against the bottom. They remained in this position until all of the displaced water was collected. All subjects were tested during walking and cycling, thus serving as their own controls.

Prior to each exercise session, all subjects were instructed to bring their athletic footwear. All subjects were required to rest in a supine position for at least 10 minutes prior to testing. The subjects were seated in a chair immediately following their 10-minute rest period. At this time, a pre-exercise volumetric measurement of the right leg was obtained by having the subject slowly lower the right foot into the volumeter.

The activity for the first condition (walking or cycling) was randomly chosen by a flip of a coin. The treadmill (Star Trac Unisen, Inc., 4500 Treadmill, Star Trac, 14410 Myford Rd., Irvine, CA. 92606) speed and cycling (Fitron Cycle, First Fitness

Equipment International, 4750 Bryant Irvine Rd., Ste 808, PMB 229, Ft. Worth, TX 76132-3631) cadence were set at a self-selected comfortable pace for each individual participant. The speed of the treadmill and cadence of the cycle ergometer were recorded on the data sheet. These values were then used for the post-test measure. Due to the fact that walking and cycling speeds vary greatly among individuals, each individual was allowed to determine their own comfortable speed to more closely mimic a real life scenario.[30,31]

As the exercise session began, each subject performed a 2-minute warm-up session on the treadmill or cycle ergometer at which time they gradually increased their speed until they felt comfortable for the remaining 8 minutes. Subjects were not allowed to grip the handrails on the treadmill during the exercise sessions. The treadmill was kept at a level (zero degrees) elevation for all exercise sessions. During cycling, the seat was adjusted for each participant individually and used for all subsequent sessions. In addition, all cycling sessions used toe straps to minimize foot extraneous movements. The cycle tension was chosen by the participant and used for all subsequent sessions. At least 48 hours of rest was allowed between the two exercise sessions. All procedures were performed in a consistent manner for both sessions.

Data Analysis

Means and standard errors for the fluid volume data were calculated. Given the repeated measures in each exercise protocol, a 2 (exercise) x 2 (time) within factorial ANOVA was utilized to determine if statistical interaction existed in the data. The alpha level was set at 0.05. If statistical interaction was found, simple main effects were calculated using paired t-tests to determine if statistical significance was present.

RESULTS

Factorial results of the 2 x 2 ANOVA revealed a statistical interaction *(Figure 2)*. Because statistical interaction was observed $\{F(1,30) = 5.705,\ p = .023\}$, simple main effects were analyzed. Two paired samples t-tests using a Bonferroni correction ($p = .025$) were used to determine the effect of weight-bearing vs. non-weight bearing exercise on foot volume *(Table 1)*. A statistically significant dif-

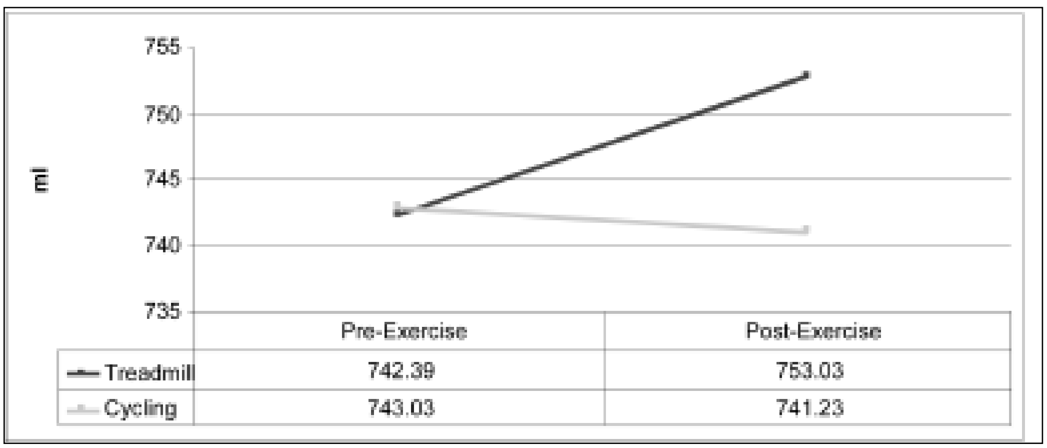

Figure 2: *2 x 2 within factorial ANOVA*

Mode of Exercise N=31	Mean Volume (ml)	Standard Error	*t*-values	*p*-values
Pre-walk	742.39	27.99	-2.952	.006*
Post-walk	753.03	27.19		
Pre-bike	743.03	29.22	0.376	.710
Post-bike	741.23	28.30		

*** Significance at $\alpha = .025$**

Table 1: *Comparison of Fluid Volume Changes During Treadmill Walking (Weight Bearing) and Cycle Ergometry (Non-weight Bearing)*

ference in foot volume was found between pre (mean = 742.39, 95% Confidence Interval: 685.229 – 799.546) and post (mean = 753.03, 95% Confidence Interval: 697.511 – 808.553) measurements for the treadmill protocol (weight-bearing), t = -2.952, $p = .006$ *(Figure 3)*. There was no statistically significant difference between the pre (mean = 743.03, SD = 162.68) and post (mean = 741.23, SD = 155.83), cycle ergometry measurements (non-weight bearing), t = .376, $p = .710$.

A 2 (exercise) by 2 (time) within factorial ANOVA was also utilized to determine if statistical interaction was present in data sorted by sex. Because statistical interaction was observed for males ($F(1,9) = 10.545$, $p = .010$), simple main effects were analyzed. Paired samples t-testing using a Bonferroni correction ($p = .0125$) found a statistically significant difference in male foot volumes *(Figure 4)* between pre (mean = 871.00, SD = 107.706) and post (mean = 886.20, SD = 104.739) measurements for the treadmill protocol, t = -5.429, $p < .0005$. Statistical interaction was not observed for females ($F(1,20) = .990$, $p = .332$) and no further statistical analysis was performed.

DISCUSSION

Numerous methods have been used to measure extremity volume. Previous research has demonstrated the water displacement method of volumetry to be valid and reliable, and thus is known to be the gold standard.[32-34] Many variables need to be considered when taking volumetric measurements. These include time of day, water temperature, positioning of subject, the temperature of the room, and recent musculoskeletal injuries. However, Moholkar and Fenelon[28] showed that time of day does not significantly effect volume measurements of the extremities. Tepid water temperatures between 20 and 35° C did

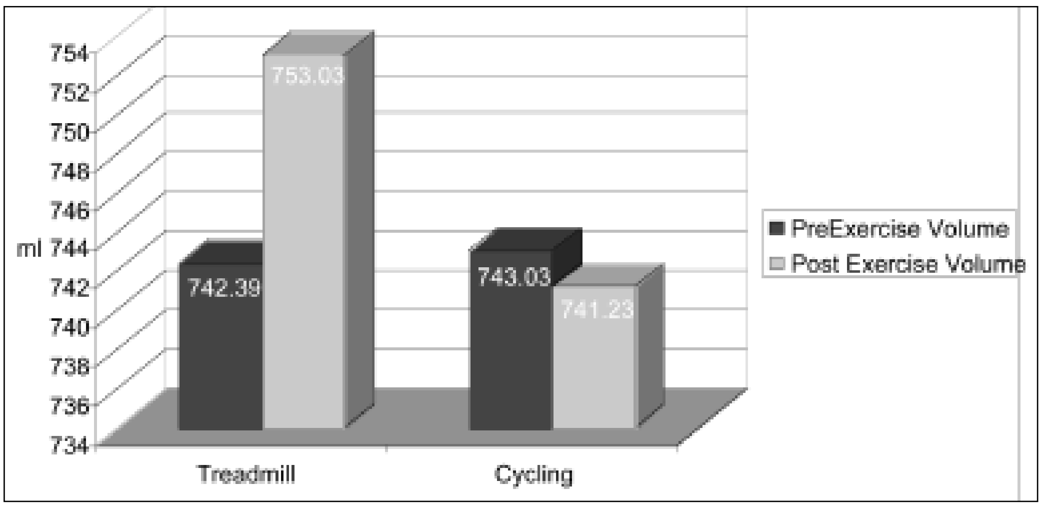

Figure 3: *Pre and Post Foot Volume Measurements*

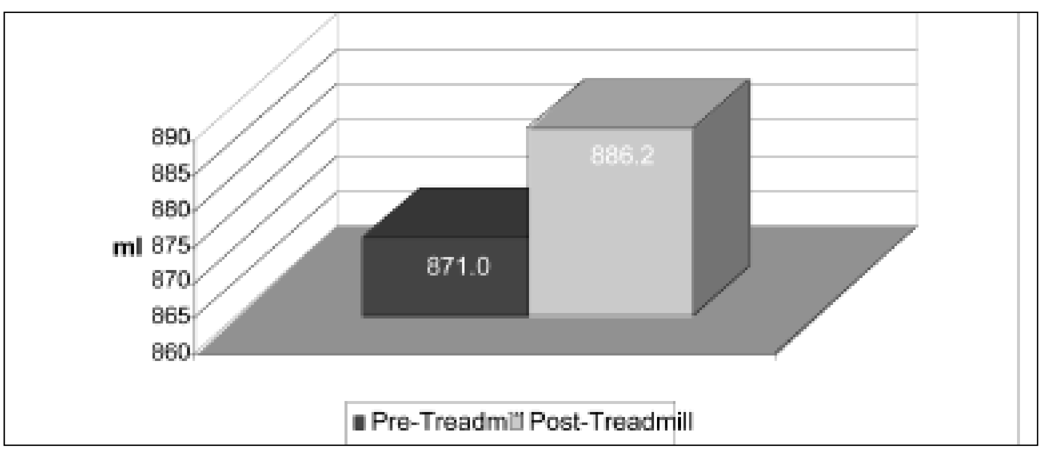

Figure 4: *Pre and Post Foot Volume Measurements for Males*

not significantly increase or decrease volume measurements, however, extreme hot or cold temperatures have been shown to affect volume.[21,35,36] The temperature of the room was not shown to have an effect on the measurements of foot volumes following quiet standing.[16] It also has been shown that individuals with a recent history of musculoskeletal injuries in the lower extremity will have an increase in edema formation.[37] Therefore, it can be safely assumed that the performance of an activity rather than the previously mentioned variables affects foot volumes, except for the conditions of extreme water or room temperatures and recent injuries.

The data from this study showed that, in healthy older subjects, treadmill walking resulted in significant increases in foot and ankle fluid volumes compared to resting measurements. This finding was in agreement with the original hypothesis that weight-bearing exercise will increase foot volume. Additionally, when considering each sex separately, males produced significant increases in foot volume following treadmill walking, while females displayed no significant changes. However, when comparing pre and post-test measurements for biking, no significant changes were observed in the present sample. This lack of change also held true when considering each sex separately. The results did not support the hypothesis that the biking protocol would cause a significant decrease in foot volume.

The edema in the foot and ankle during walking can be attributed to the increase in blood flow to the exercising muscles. The increase in edema following weight-bearing activity has been shown to increase foot volume by as much as 8%.[26]

Stegall[38] has demonstrated an 80 mmHg drop in venous pressure at the saphenous vein in the ankle during running as compared to quiet standing. As a result, the author suggests that there is an inability of the lower extremities to maintain a steady rate of venous return following vigorous weight-bearing activities.

Prior to this study, the hypothesis was made that the bike protocol would cause a significant decrease in foot volume secondary to a muscle pumping action. However, as previously mentioned, no significant difference was found. After analyzing the data, one possible explanation for these results was that riding an upright exercise bike does not require enough active foot and ankle muscular activity to cause a muscle pumping effect away from the distal lower extremities. Although movement does occur in the foot and ankle during this activity, much of the movement may be passive, thus not adequately activating the muscle pumping mechanism.

Sochart et al[39] examined the relationship between passive and active movement of the foot and ankle related to venous return in the lower extremity. They found that an active "combined" movement (plantarflexion/dorsiflexion and inversion/eversion) produced a significantly larger increase in mean blood velocity than any of the three passive movement patterns. The results found by Sochart et al[39] could help explain why a significant decrease in foot volume for the bike protocol was not observed in this present study.

A difference in fluid volumes after treadmill walking was also found to be significant between sex. In the present study, the participants demonstrated a mean increase in foot volume after a 10 minute walk on the treadmill, but significance between genders was only found in males. The females' 1.2% increase in foot volume failed to produce significance. A review of the literature failed to identify any studies of post-exercise foot and ankle volume changes based on sex. Chalk et al[26] demonstrated a slight non-significant decrease in foot volume in female inter-collegiate volleyball players after a 2-hour rigorous exercise session. In addition, the benefits of reducing foot volume in females during weight-bearing activities may be offset by the greater benefit of osteoporosis prevention.[40-42] It should be noted that the sample size for this study is not large enough to draw firm conclusions with regard to sex and foot swelling.

The results of this study provide important clinical implications for physical therapists. This study demonstrated a 1.4% increase in foot volume after 10 minutes of treadmill walking. It is important to note that this statistically significant increase in foot volume occurred only after 10 minutes. Ambulating patients in the acute or rehab settings often takes longer than 10 minutes secondary to their age, medical condition, and other physical limitations. This information is also important for the older recreational athlete who may walk for an extended period of time. Keeping these patients on their feet for longer periods of time could cause further increases in foot volume, resulting in potential further constriction of venous return with possible negative consequences in those with already compromised circulation.[3,43] Even in cases with mild edema, instability may result due to poorly fitting foot wear as well as the increased weight of the edematous limb.[24] Patients may experience a decline in walking confidence and become immobile, further aggravating the problem. It may be safer and more effective to prescribe non-weight bearing exercise as a warm-up or treatment alternative to patients with pre-existing peripheral edema or conditions that place them at risk for impaired venous return. Based on the small sample size, no concrete clinical suggestions can be made with regard to sex at this time.

This study had several limitations. For example, the statistical results would be more convincing if the sample had more subjects, particularly when considering statistics sorted by sex. The total sample of 31 provides a fairly strong field to draw conclusions, but when considering each sex separately, the sample size was reduced significantly. Another limitation in this study is the inability to control each subject's activity level prior to testing. A subject that was active versus sedentary could have a different circulation status upon arrival for exercise testing which could affect foot volume pre and post exercise testing. The non-weight bearing exercise protocol in this study utilized an upright exercise bike. The upright exercise bike caused a considerable flexion angle in the hip that could potentially impair venous return to the heart. A better alternative would be to use a recumbent bike, thus reducing the hip flexion angle.

Future studies should focus on patients with real pre-existing co-morbidities that cause foot edema to determine if these results hold true in such populations. Studies utilizing more subjects with these conditions could help draw firm conclusions regarding sex and foot edema. Although an upright stationary bike was utilized in this study, other forms of non-weight bearing exercise equipment are available. Future studies involving these different exercise modes could help determine the optimal piece of exercise equipment to help minimize foot swelling.

CONCLUSION

The results from this study suggest that treadmill walking (loaded exercise) results in an increase in foot edema when compared to riding an upright stationary exercise bike (unloaded exercise). Although it is difficult to conclude that riding an exercise bike is an effective way to decrease foot edema, these results suggest that stationary biking is a safer mode of exercise than treadmill walking in controlling foot edema, especially in older men. Therefore, unloaded activities may be the most appropriate exercise to prescribe when an increase in foot volume is unwanted. Further investigations into the injured (ankle sprains) and chronically ill (congestive heart failure, peripheral vascular disease, diabetes) patients are necessary to ascertain whether similar findings would result. This knowledge would be very applicable for clinical use of the cycle ergometer as a modality to positively influence venous stasis and decrease the problems associated with ankle and foot edema.

REFERENCES

1. Stick C, Jaeger H, Witzleb E. Measurements of volume changes and venous pressure in the human lower leg during walking and running. *J Appl Physiol.* 1992;72:2063-2068.
2. Chalk PJ, McPoil T, Cornwall MW. Variations in foot volume before and after exercise. *J Am Podiatr Med Assoc.* 1995;85:470-472.
3. Cloughley WB, Mawdsley RH. Effect of running on volume of the foot and ankle. *J Orthop Sports Phys Ther.* 1995;22:151-154.
4. McPoil TG, Hunt GC. Evaluation and management of foot and ankle disorders: present problems and future directions. *J Orthop Sports Phys Ther.* 1995; 21:381-388.
5. Lundvall J, Mellander S, Westling H, et al. Fluid transfer between blood and tissues during exercise. *Acta Physiol Scand.* 1972;85:258-269.
6. Baker CH, Davis DL. Isolated skeletal muscle blood flow and volume changes during contractile activity. *Blood Vessels.* 1974;11:32-44.
7. Schnizer W, Hinneberg H, Moser H, et al. Intra- and extravascular volume changes in the human forearm after static hand grip exercise. *Eur J Appl Physiol Occup Physiol.* 18 1979;41:131-140.
8. Evanski P. *The Geriatric Foot. Disorders of the Foot.* In: M J, ed. Phildelphia: WB Saundersn Co; 1982:964-978.
9. Stick C, Stofen P, Witzleb E. On physiological edema in man's lower extremity. *Eur J Appl Physiol Occup Physiol.* 1985;54:442-449.
10. Shereff MJ. Geriatric foot disorders: How to avoid undertreating them. *Geriatrics.* 1987;42:69-72, 75-80.
11. McGough C, Zurwasky, ML. Effect of exercise on volumetric and sensory status of the asymptomatic hand. *J Hand Ther.* 1991;4:177-180.
12. Gordon GM, Cuttic MM. Exercise and the aging foot. *South Med J.* 1994;87:S36-41.

13. McWhorter JW. The effects of walking, running, and shoe size on foot volumetrics. *Physical Therapy in Sport.* 2003;4:87-92.

14. Stick C, Grau H, Witzleb E. On the edema-preventing effect of the calf muscle pump. *Eur J Appl Physiol Occup Physiol.* 1989;59:39-47.

15. Man LG, Morrissey MC, Cywinski JK. Effect of neuromuscular electrical stimulation on foot/ankle volume during standing. *Med Sci Sports Exerc.* 2003; 35:630-634.

16. Stick C, Hiedl U, Witzleb E. Volume changes in the lower leg during quiet standing and cycling exercise at different ambient temperatures. *Eur J Appl Physiol Occup Physiol.* 1993;66:427-433.

17. Gardner AM, Fox RH. The venous pump of the human foot–preliminary report. *Bristol Med Chir J.* 1983; 98:109-112.

18. Mayrovitz HN, Larsen PB. Effects of compression bandaging on leg pulsatile blood flow. *Clin Physiol.* 1997; 17:105-117.

19. Jacobsson S, Kjellmer I. Accumulation of fluid in exercising skeletal muscle. *Acta Physiol Scand.* 1964; 60:286-292.

20. Ciocon JO, Galindo-Ciocon D, Galindo DJ. Raised leg exercises for leg edema in the elderly. *Angiology.* 1995; 46:19-25.

21. Sims D. Effects of positioning on ankle edema. *JOSPT.* 1986;8.

22. Guyton AC, Hall JE. *Textbook of Medical Physiology.* 10th ed. Philadelphia: Saunders; 2000.

23. Sorenson MK. The edematous hand. *Phys Ther.* Dec 1989; 69:1059-1064.

24. Smith E. A survey of peripheral oedema in elderly patients admitted to a geriatric ward. *Br J Clin Pract.* 1996; 50:20-21.

25. Arnold AM, Psaty BM, Kuller LH, et al. Incidence of cardiovascular disease in older Americans: the cardiovascular health study. *J Am Geriatr Soc.* 2005; 53:211-218.

26. Bertoni AG, Hundley WG, Massing MW, et al. Heart failure prevalence, incidence, and mortality in the elderly with diabetes. *Diabetes Care.* 2004;27:699-703.

27. *ACSM's Guidelines For Exercise Testing And Prescription.* 7 ed. Philadelphia: Lippincott Williams & Wilkins; 2006.

28. Moholkar K, Fenelon G. Diurnal variations in volume of the foot and ankle. *J Foot Ankle Surg.* 2001;40:302-304.

29. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet.* 1986;1:307-310.

30. Rodgers MM. Dynamic biomechanics of the normal foot and ankle during walking and running. *Phys Ther.* 1988; 68:1822-1830.

31. Winter D. Kinematic and kinetic patterns in human gait: Variability and compensating effects. *Human Movement Science.* 1984;3:51-76.

32. Bednarczyk JH, Hershler C, Cooper DG. Development and clinical evaluation of a computerized limb volume measurement system (CLEMS). *Arch Phys Med Rehabil.* 1992;73:60-63.

33. Karges JR, Mark BE, Stikeleather SJ et al. Concurrent validity of upper-extremity volume estimates: comparison of calculated volume derived from girth measurements and water displacement volume. *Phys Ther.* 2003; 83:134-145.

34. Waylett-Rendall J. Sensibility evaluation and rehabilitation. *Orthop Clin North Am.* 1988;19:43-56.

35. King TI. The effect of water temperature on hand volume during volumetric measurement using the water displacement method. *J Hand Ther.* 1993;6:202-204.

36. McCulloch J BV. The effects of whirlpool and the dependant position of lower extremity volume. *J Orthop Sports Phys Ther.* 1992;16:169-173.

37. Powell AA, Armstrong MA. Peripheral edema. *Am Fam Physician.* 1997;55:1721-1726.

38. Stegall H. Muscle pumping in the dependent leg. *Circ Res.* 1966;19:180-190.

39. Sochart DH. The relationship of foot and ankle movements to venous return in the lower limb. *J Bone Joint Surg.* 1999;81:700-704.

40. Keen R. Osteoporosis: Strategies for prevention and management. *Best Pract Res Clin Rheumatol.* 2007; 21:109-122.

41. Lewiecki EM, Silverman SL. Redefining osteoporosis treatment: Who to treat and how long to treat. *Arq Bras Endocrinol Metabol.* 2006;50:694-704.

42. Schmiege SJ, Aiken LS, Sander JL et al. Osteoporosis prevention among young women: Psychosocial models of calcium consumption and weight-bearing exercise. *Health Psychol.* 2007;26:577-587.

43. Sheriff D. The muscle pump raises muscle blood flow during locomotion. *J Appl Physiol.* 2005;99:371-375.

ORIGINAL RESEARCH

THE EFFECTS OF DIFFERENT STRETCHING TECHNIQUES OF THE QUADRICEPS MUSCLES ON AGILITY PERFORMANCE IN FEMALE COLLEGIATE SOCCER ATHLETES: A PILOT STUDY

H. W. Wallmann, PT, DPTSc, SCS, LAT, ATC, CSCS[a]
C. B. Gillis[b]
N. J. Martinez[c]

ABSTRACT

Background. Stretching has long been an integral component of pre-performance activities for a multitude of athletic endeavors. Previous research has demonstrated that stretching may have detrimental effects on performance. Specific knowledge of the precise effects of stretching may influence the decision to appropriately apply stretching techniques in the sport and therapeutic settings.

Objective. The purpose of this pilot study was to examine the effects of static stretching, proprioceptive neuromuscular facilitation (contract-relax) stretching, and no stretching of the quadriceps muscle group on agility performance.

Methods. Twelve healthy, female, collegiate soccer players aged 18 – 25 performed one of the three stretching protocols (static, contract-relax, no stretch) and the agility test (T-test) on three non-consecutive days. Agility times were recorded and compared based on stretching technique and day that each test was performed.

Results. No significant difference was found among the means of the different stretching techniques. The t-test agility performance times were as follows: control, = 9.7 seconds; static stretch, = 9.73 seconds; and contract-relax, = 9.62 seconds.

Conclusion. The results of this study suggest that agility performance may be independent of stretching technique of the quadriceps performed in female collegiate soccer athletes. It is recommended that female soccer athletes about to engage in agility activity may perform either no stretch, static stretch, or contract-relax stretching according to individual preference.

Key words: agility performance, contract-relax stretching, static-stretching, female athletes.

CORRESPONDENCE:
Harvey W. Wallmann, PT, DPTSc, SCS, ATC
Associate Professor
Department of Physical Therapy
School of Allied Health Sciences
University of Nevada, Las Vegas
4505 Maryland Parkway, Box 453029
Las Vegas, Nevada 89154-3029
Work: (702) 895-4213
Fax: (702) 895-4883
e-mail: harvey.wallmann@unlv.edu

[a] University of Nevada. Las Vegas
Las Vegas, Nevada

[b] Tru Physical Therapy
Las Vegas, Nevada

[c] Sunrise Hospital and Medical Center
Las Vegas, Nevada

INTRODUCTION

Stretching is a common component of pre-performance activities for many athletic events. As such, the literature is rich with evidence supporting the effects of stretching on flexibility, with mounting evidence as to the effects of stretching on performance.[1-5] However, limited research exists concerning the acute affects of different stretching techniques on athletic performance variables, specifically, agility.[6]

Several types of stretching techniques are currently incorporated by athletes for pre-event activities. Static stretching and proprioceptive neuromuscular facilitation (PNF) are common techniques used by therapists, athletic trainers, strength and conditioning professionals, and athletes to enhance flexibility.[1,7-11] In most cases, these stretching activities are integrated as part of a warm-up session.

Some researchers studying the effects of stretching on performance have reported significant deficits in performance-related variables,[9,10,12-17] while others found little or no difference.[11,18] Church et al[9] examined the effects of warm-up and flexibility treatments on vertical jump performance in females. Results demonstrated a decrease in vertical jump height for the PNF treatment group, leading researchers to speculate that performing PNF stretching techniques before a vertical jump test may be detrimental to performance. Wallmann et al[10] investigated the effects of static stretching of the gastrocnemius on vertical jump performance in healthy adults. Researchers concluded that, since vertical jump height decreased by 5.6%, static stretching of the gastrocnemius had an immediate adverse effect on maximal jumping performance.

In contrast to the aforementioned findings, Unick et al[11] examined the acute effects of stretching on vertical jump performance in female collegiate basketball players and concluded that vertical jump performance was not affected by stretching. They measured the effects of static and ballistic stretching, as well as power output at 15 and 30 minutes post-stretch. They reported no significant difference between power output and vertical jump values pre and post-stretch. Likewise, Behm et al[13] reported that static stretching showed a 6.9% decrease in maximal voluntary contraction of the quadriceps while a control group experienced a 5.6% decrease in maximal voluntary control of the quadriceps from pre-test to post-test.

A major component of sport performance that has been poorly researched in the stretching literature is agility.[19] The American College of Sports Medicine describes agility as the "…ability to rapidly change the position of the entire body in space with speed and accuracy[20]." Agility can be thought of as a systemic integration of neuromuscular coordination, reaction time, speed, strength, balance. This complex nature of agility performance has lead many researchers to conduct studies that involve a breakdown of its component parts.

Cochrane et al[21] additionally noted the complexity of factors that interact to produce agility performance and the difficulty in actually identifying and measuring those components. McMillian et al[6] examined the effects of static versus dynamic warm-up protocols on agility performance, utilizing a common standardized agility test called the T-test. Results revealed a difference between the dynamic warm-up and both the static warm-up and no warm-up groups. Researchers concluded that a dynamic warm-up protocol may provide performance benefits that are superior to static or no warm-up protocols.

Given the paucity of literature regarding the effects of stretching on agility, the purpose of this pilot study was to examine the effects of three different stretching techniques (static, contract-relax stretching, and no stretch) on the quadriceps muscle group with regards to agility performance. The quadriceps muscle group was chosen primarily because females have been shown to be quadriceps dominant and it was thought that this dominance may be affected by stretching.[27-29] The hypothesis to be tested is that agility performance would decrease in association with bouts of static stretching and PNF.

METHODS

Subjects

Twelve female Division I collegiate soccer players ages 18 – 25 (mean = 19.17; SD = 0.94) participated in this study. The following criteria were used to select the subjects: a member of the women's soccer team, age 18-25, not currently pregnant, and no lower extremity orthopaedic injuries sustained within the last six months that would hinder the ability to give maximal effort during the T-test. Before initiating the study, the Biomedical Institutional

Review Board of the University of Nevada, Las Vegas approved the study. Each subject gave both written and oral consent before engaging in the research protocol.

Equipment

The T-test *(Figure 1)* is a common test used to measure 4-directional agility, and evaluates the ability of the subject to rapidly change direction while maintaining balance without loss of speed.[19] The subject starts with both feet behind a line and sprints 10 yards forward, then shuffles 5 yards to the left, followed by 10 yards to the right, then 5 yards to the left, and finally, 10 yards backward to the original starting point. Pauole et al[19] demonstrated that the T-test is a reliable and valid measure of leg speed, leg power, and agility.

Four cones were placed on the floor using the standard parameters for the T-test as described by Pauole et al.[19] Additionally, two timing photocells (Lafayette Instrument Co., Lafayette, IN) were placed 6 ft apart at the start/finish position to record the time it took each subject to complete the T-test. One plinth was used for the PNF stretching station and one stool was used for the stretching subject to hold on to for balance during the static stretching station. One stopwatch was utilized to measure the duration of stretch at each station, and one stop-watch was used to time the 5-minute self-selected jog warm-up.

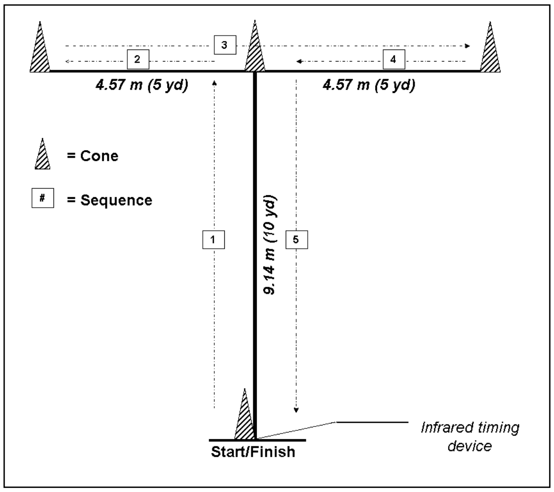

Figure 1: *T-test*

Procedure

A repeated-measures design was used to determine the effectiveness of different stretching techniques on agility performance in female college soccer players over a one week period. The dependent variable was the time it took each athlete to complete the T-test. The independent variable consisted of three stretching techniques: contract-relax, static stretching, and a control group.

A pre-study information session was conducted in which subjects were instructed on the testing protocol as well as the proper method for each technique. A demonstration of the T-test was given and all subjects were asked to perform the T-test one time to allow for familiarity with the test. Subjects were also instructed not to participate in excessive physical activity prior to the testing sessions, but to continue with their normal workout routines.

Data was collected on three non-consecutive days over the course of one week. Using a balanced Latin square[22] to reduce test order bias, subjects were randomly assigned into one of three different test orders as follows:

a) Group A performed no stretching on Monday, static stretching on Wednesday, and contract-relax stretching on Friday.

b) Group B performed contract-relax stretching on Monday, no stretching on Wednesday, and static stretching on Friday.

c) Group C performed static stretching on Monday, contract-relax stretching on Wednesday, and no stretching on Friday.

Prior to engaging in the stretching protocols, each subject completed a 5-minute warm-up jog at a self-selected speed. The purpose of this jog was to provide a general warm-up to minimize the risk of straining the quadriceps muscles during a maximal agility effort. Subjects then completed the assigned stretch protocol for that day. Immediately after completing the protocol, subjects performed the T-test one time. The three stretching protocols were as follows:

a. *Static stretching.* This activity consisted of actively stretching the quadriceps muscles of each leg alternately three times each for 30 seconds each (3 minutes total) for both legs. The knee of the leg being stretched was flexed and held by the same upper extremity as the lower extremity being stretched. In order to maintain consistency with this technique and enhance the feeling of inducing a stretch, the subjects were instructed to push their hips forward during the stretch to facilitate a posterior pelvic tilt. An investigator stood with each subject and called out the 30-second increments with the use of a stopwatch so that the subject could maintain the appropriate time frame for each stretch *(Figure 2)*.

Figure 2: *Quadriceps static stretch*

b. *Contract-relax.* This activity consisted of interactive stretching between the subject and the tester. The tester provided resistance to active contraction of the quadriceps for 6 seconds with a 4 second relaxation phase for a total of 30 seconds alternately three times each (3 minutes total) for both legs. The subject was placed supine on a plinth with the leg to be stretched hanging off of the table. The other leg was held in a knee to chest position in which the knee and hip were both flexed. The tester asked the subject to push the stretching leg into the tester's hand giving approximately 30% of maximal effort. The subjects were then asked to relax the stretching leg and the tester then pushed the leg into its new available range of motion *(Figure 3)*.

Figure 3: *Quadriceps contract-relax stretch*

c. *No stretching*. No stretching was performed; the subject sat on the ground for 3 minutes. This group served as the control group.

Statistical Analyses

A one-way repeated measures analysis of variance (ANOVA) was used to analyze the differences among the three different stretching protocols. Statistical significance was set at p= 0.05 and all analyses were carried out using the Statistical Package for the Social Sciences version 13.0 (SPSS, Inc, Chicago, IL).

RESULTS

A repeated measures ANOVA revealed no statistically significant difference among the means, $F(2,22) = 0.759$, $p=0.480$, power = 0.162 for the control (no stretch), static stretching, and contract-relax stretching techniques in T-test agility performance times. The mean T-test performance times and standard deviations for control, static stretching, and contract-relax stretching as well as 95% confidence intervals are displayed in Table 1.

DISCUSSION

The purpose of this pilot study was to examine the differences among three different stretching techniques on agility performance in female collegiate soccer athletes. The results of this study revealed no differences among the three treatment groups on agility performance times.

An accurate comparison of this study to other studies is difficult secondary to a lack of published literature about the topic. However, results of this study are consistent with a similar study conducted by Faigenbaum et al[5], in which researchers examined the acute effects of pre-event static stretching, dynamic exercise, and static stretching and

Table 1. *Means (± standard deviation) and confidence intervals for T-test agility performance times (seconds)*

Technique (n=12)	Mean Times T-test (seconds)	SD	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	9.701	.524	9.37	10.03
Static Stretching	9.735	.537	9.39	10.08
Contract-Relax	9.624	.413	9.36	9.89

dynamic exercise combined on vertical jump, medicine ball toss, 10-yard sprint, and pro-agility shuttle run in teenage athletes. Prior to testing, participants performed 5 minutes of walking/jogging followed by one of the warm-up protocols. Results revealed that performance on the vertical jump, medicine ball toss, and 10-yard sprint were significantly improved after dynamic exercise, and dynamic exercise and static stretching combined, as compared to static stretching alone. No significant difference was noted in the agility performance after the three different warm-up protocols. These results led researchers to believe that pre-event dynamic exercise or static stretching followed by dynamic exercise may be more beneficial than pre-event static stretching alone in teenage athletes participating in power activities.

Little and Williams[18] examined the effects of different stretching protocols during warm-ups on high-speed motor capacities in 18 professional soccer players. Their design was similar, in that they examined the effects of no stretching and static stretching on agility performance. However, their design differed as they incorporated a dynamic stretch, rather than a PNF stretching technique. In addition, the agility task was performed on a zigzag course, versus the T-test used in the current study. These authors concluded that there was no difference between the control and static stretching groups. This result is consistent with the results revealed in the present study; however, the authors did report that the dynamic stretch protocol produced significantly faster agility performance than did both the control and static stretch groups.

Although a paucity of literature exists regarding the effects of stretching on agility performance, other components of agility have been researched, namely, speed and strength. The evidence on the effect of stretching on sprint performance provides conflicting results with questionable research quality making definitive conclusions difficult.[24] However, work by other researchers[4,17] supports the hypothesis that static stretching has a detrimental effect on sprint performance.

The evidence regarding the effects of stretching on force, torque, and jump performance also appears to provide inconclusive results.[9-11,13,25] Whereas Wallmann et al[10] and Church et al[9] reported significant decreases in vertical jump height after bouts of static stretching and PNF stretching, respectively, Unick et al[11] reported no difference in vertical jump scores as a result of static or ballistic stretching. The Unick et al[11] study included 16 actively trained women who performed a series of vertical jumps at 4 minutes, 15 minutes, and 30 minutes after stretching the hamstrings, quadriceps, and gastrocnemius/soleus muscle complex. The protocol required the stretch to be held for a period of 15 seconds. This short time period may not have been long enough to induce a tissue extensibility change within the muscle. Research has shown that at least 30 seconds is needed to be effective in bringing about a change in flexibility.[2,26] In addition, the vertical jumps were performed after 4 minutes of walking; which may have allowed the muscle to return to its pre-stretched length, thereby, affecting the results.

Power et al[25] found that no difference existed in vertical jump scores after a static stretching routine. However, decreases in isometric maximal voluntary contraction and an increase of inactivation of the quadriceps were found to be statistically significant. Maximal voluntary contraction force of the quadriceps muscle showed a 9.5% decrease over the course of the 120 minute measurement period, while a 5.4% increase of inactivation of the quadriceps muscle was revealed, suggesting that static stretching may adversely affect these variables. Behm et al[13] reported similar results in regard to maximal voluntary contraction of the quadriceps muscle. In their study, the static stretching group showed a 6.9% decrease in maximal voluntary contraction of the quadriceps muscles while the control group experienced a 5.6% decrease in maximal voluntary contraction of the quadriceps muscle from pre-test to post-test.

Although these previous studies revealed decreases in both speed and strength, which are components of agility, the studies do not appear to be consistent with the present results, which showed no differences in agility T-test performance scores. This may be because much of the current literature involves examining the effects of stretching on performance utilizing the hamstrings and triceps surae musculature.

In the present study, the authors chose to isolate the quadriceps muscle group, primarily because females have been shown to be quadriceps dominant and it was thought that this dominance[27-29] may be affected by stretching. Additionally, there is very little, if any, literature investigating the effects of stretching on performance of only the quadriceps muscles. However, the results of this study reveal that the quadriceps muscle group may only play a small role in the variance of agility performance. Consequently, agility performance does not appear to be immediately affected by stretching only the quadriceps muscle group.

Strengthening other muscle groups may have varied the results. But it would be difficult to determine effects of stretching several muscle groups at once as this stretching may allow the muscles to return to their pre-stretched length prior to athletic performance due to the length of time between stretches.

Limitations

Other limitations in this study include varying of testing times, activity level of the subjects prior to our testing time, and a small testing sample. There were some variations regarding data collection times due to time constraints on the part of the soccer team. For example, on Monday and Wednesday, data were collected at 2:00 p.m., while on Friday, data collection occurred at 9:00 a.m. Concerning activity level, the subjects were in a pre-season conditioning program, so we could not control the activity level of each subject prior to data collection, although we did ask the participants to maintain their current level of physical activity during the testing week. This variance in activity level may have affected the effort given by each subject while performing the T-test. The number of subjects participating in this study was small; a larger sample size would be more desirable and may have increased the power of the study. As such, the power was very low for the study. Consequently, the chance of making a type 2 error was high. However, as this was a feasibility study, we believe that the results from this study offer evidence for investigating the effects of stretching using the quadriceps and other muscle groups on agility performance using a more rigorous design.

Research Importance

This study holds relevance to the field of sport research in that current literature has demonstrated both the positive and adverse effects of stretching on flexibility, running, jumping, muscle strength, and power output; however, despite the availability of such literature, little research exists that investigates the acute effects of stretching on agility performance. Agility is a major component of many popular sports. Scientific knowledge regarding the effects of stretching on agility may be beneficial in the development of a training regimen designed to enhance athletic performance.

CONCLUSION

In conclusion, the results of the present study suggest that static stretching, contract-relax stretching, and no stretching of the quadriceps muscle group have no immediate adverse effect on agility performance in female collegiate soccer players. Further controlled-randomized trials are needed to fully examine and understand the complex nature of this topic. Also, a follow-up study with a larger sample size is needed. In addition, future research should also examine other muscle groups, motivational factors involved in stretching and performance, and athlete preferences and beliefs towards the effects of stretching and performance. It is recommended that female soccer athletes about to engage in agility activity may perform either no stretch, static stretch, or contract-relax stretching according to individual preference with no adverse effects on performance.

REFERENCES

1. Davis DS, Ashby PE, McCale KL, et al. The effectiveness of three stretching techniques on hamstring flexibility using consistent stretching parameters. *J Strength Cond Res.* 2005; 19:27-32.
2. Bandy WD, Irion JM, Briggler M. The effect of time and frequency of static stretching on flexibility of the hamstring muscles. *Phys Ther.* 1997;77:1090-1096.
3. Cornwell A, Nelson AG, Sidaway B. Acute effects of stretching on the neuromechanical properties of the triceps surae muscle complex. *Eur J Appl Physiol.* 2002;86:428-434.
4. Gribble PA, Guskiewicz KM, William EP, et al. Effects of static and hold-relax stretching on hamstring range of motion using the FlexAbility LE1000. *Journal of Sport Rehabilitation.* 1998;8:195-208.
5. Faigenbaum AD, Kang J, McFarland J, et al. Acute effects of different warm-up protocols on anaerobic performance in teenage athletes. *Pediatric Exercise Science.* 2006;17:64-75.
6. McMillian DJ, Moore JH, Hatler BS, et al. Dynamic vs. static-stretching warm up: The effect on power and agility performance. *J Strength Cond Res.* 2006;20:492-499.

7. Voss DE, Ionta MK, Myers BJ. *Proprioceptive Neuromuscular Facilitation: Patterns and Techniques.* 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 1985.
8. *Donatelli R. Sports-Specific Rehabilitation.* St. Louis: Churchill Livingstone; 2007.
9. Church JB, Wiggins MS, Moode FM, et al. Effect of warm-up and flexibility treatments on vertical jump performance. *J Strength Cond Res.* 2001;15:332-336.
10. Wallmann HW, Mercer JA, McWhorter JW. Surface electromyographic assessment of the effect of static stretching of the gastrocnemius on vertical jump performance. *J Strength Cond Res.* 2005;19:684-688.
11. Unick J, Kieffer HS, Cheesman W, et al. The acute effects of static and ballistic stretching on vertical jump performance in trained women. *J Strength Cond Res.* 2005; 19:206-212.
12. Marek SM, Cramer JT, Fincher AL, et al. Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. *J Athl Train.* 2005;40:94-103.
13. Behm DG, Bambury A, Cahill F, et al. Effect of acute static stretching on force, balance, reaction time, and movement time. *Med Sci Sports Exerc.* 2004;36:1397-1402.
14. Fletcher IM, Jones B. The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *J Strength Cond Res.* 2004;18:885-888.
15. Faigenbaum AD, Bellucci M, Bernieri A, et al. Acute effects of different warm-up protocols on fitness performance in children. *J Strength Cond Res.* 2005;19:376-381.
16. McNeal JR, Sands WA. Static stretching reduces power production in female gymnasts. *Technique.* 2001;5-6.
17. Siatras T, Papadopoulos G, Mameletzi D, et al. Static and dynamic acute stretching effect on gymnasts' speed in vaulting. *Pediatr Exerc Sci.* 2003;15:383-391.
18. Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res.* 2005;19:76-78.
19. Pauole K, Madole K, Garhammer J, et al. Reliablity and validity of the T-test as a measure of the agility, leg power, and leg speed in college-aged men and women. *J Strength Cond Res.* 2000;14:443-450.
20. American College of Sports Medicine, Kenney WL, Humphrey RH, et al. *ACSM's Guidelines for Exercise Testing and Prescription.* 6 ed. Baltimore, MD: Williams & Wilkins; 2000.
21. Cochrane DJ, Legg SJ, Hooker MJ. The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. J Strength Cond Res. 2004;18:828-832.
22. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice.* 2nd ed. Upper Saddle River, NJ: Prentice Hall; 2000.
23. Little T, Williams AG. Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. *J Strength Cond Res.* 2006; 20:203-207.
24. Shrier I. Does stretching improve performance? A systematic and critical review of the literature. *Clin J Sport Med.* 2004;14:267-273.
25. Power K, Behm D, Cahill F, et al. An acute bout of static stretching: Effects on force and jumping performance. *Med Sci Sports Exerc.* 2004;36:1389-1396.
26. Bandy WD, Irion JM. The effect of time on static stretch on the flexibility of the hamstring muscles. *Phys Ther.* 1994; 74:845-850.
27. Hewett TE, Myer GD, Ford KR. Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *Am J Sports Med.* 2006;34:299-311.
28. Hewett TE, Stroupe AL, Nance TA, et al. Plyometric training in female athletes. Decreased impact forces and increased hamstring torques. *Am J Sports Med.* 1996; 24:765-773.
29. Quatman CE, Ford KR, Myer GD, et al. Maturation leads to gender differences in landing force and vertical jump performance: A longitudinal study. *Am J Sports Med.* 2006; 34:806-813.