The 20th annual research meeting of the Performance Health Scientific Advisory Committee (TRAC) was held July 20–22, 2018, in New Orleans, Louisiana. TRAC research supports the evidence-based use of Performance Health products, providing a scientific basis for clinical application.

The vision of the committee is to be recognized as the global leader in interdisciplinary research on Performance Health-branded products to support safe and effective product development and evidence-informed practice. Its mission is to facilitate and disseminate research and education that improves, enhances, and promotes the development and use of Performance Health products “to help people feel good, perform better, and live great.”

Committee members exhibit these core values by demonstrating: (1) leadership through innovation, transparency, and openness in communication; (2) integrity in research design, dissemination, and knowledge translation; and (3) international and interdisciplinary collaboration. Committee members are appointed annually, and they present their research on Performance Health products at the annual TRAC meeting.

Abstracts Presented at TRAC July 20, 2018, New Orleans, Louisiana

**EMG activation of lower extremity and trunk muscles and translation of center of mass during elastic-resisted squatting in 4 different upper extremity positions**

Barbara Hoogenboom, Kacy Shetler, Mark Sulavik, and Taylor Witczak

*Grand Valley State University, Grand Rapids, MI*

**Background:** Rehabilitation practitioners use several upper extremity positions during squatting exercises. Arms can serve to add either resistance or load to a squat. The elastic bands of TheraBand® CLX provide the ability to add resistance to the upper extremities. The difference in muscular activation and the effects on body position (center of mass [COM]) during variations of squat with the added elastic resistance are unknown. Therefore, it is important to investigate electromyography (EMG) patterns of muscular activation and kinetics during squatting with elastic resistance placed on the upper extremities.

**Purpose:** The purpose of this study was to examine the differences in EMG activation in 6 trunk and lower extremity muscles and the displacement of the COM during 3 different squatting exercises, performed with elastic resistance.

**Design:** This study has a quasi-experimental, descriptive cohort design.

**Methods:** Resistance level/color of CLX needed to achieve a “resistance-training” stimulus was determined. Surface electrodes were placed on the right rectus femoris (RF), biceps femoris (BF), gluteus maximus (GMax), gluteus medius (GMed), erector spinae (ES), and rectus abdominis (RA) muscles. Subjects performed 6 repetitions of each of the 3 squatting conditions (hands at sides, arms flexed to 90°, and arms held overhead, to 60° of knee flexion, in a randomized order, to the beat of a metronome (80 bpm). Data were collected using both Vicon 3-dimensional motion capture and surface
EMG. Raw EMG signals were processed and normalized to the participant’s maximum voluntary isometric contraction (MVIC), and anterior-posterior (AP) displacement of COM was determined from kinematic data; all outcomes were statistically compared using ANOVA.

**Results:** Twenty (men, 10; women, 10; mean age, 24.95 years; mean height, 174 cm; mean weight, 70.85 kg; mean BMI, 23.18) healthy, uninjured adults participated in the study. Low %MVIC activations were seen in GMed, GMax, and RA (2.17%–13.20%), while BF (18.58%), ES (39.1%), and RF (52.4%) were activated to a greater extent. Statistically different activation of BF, RF, and ES was observed between conditions (P = 0.004, P = 0.001, and P = 0.001, respectively) with small to medium effect sizes (ES = 0.335, 0.667, and 0.667, respectively). No EMG activation differences between conditions were observed for GMed, GMax, and RA. AP COM translations during squatting between 33.92 and 42.14 mm were observed. A statistically significant difference in translation of COM between squat conditions (P = 0.024) was observed, with the greatest translation occurring in 90° arm position, followed by the overhead squat.

**Conclusion:** Significantly greater EMG activation of RF occurred during the hands at side condition, and significantly greater ES activation occurred during the 90° arm position. The significant differences in translation in COM that occurred were expected owing to positioning of the upper extremity relative to the base of support.

### The effects of upper body posture and instructional cues on shoulder muscle activity during elastic resistance exercise

Ashley Reece, James Parkinson, and Michael W.R. Holmes  
*Department of Kinesiology, Brock University, St. Catharines, Ontario, Canada*

**Background and Purpose:** The shoulder is a unique structure, coupling intricate geometry with unparalleled flexibility. Shoulder injuries are among the most common and expensive musculoskeletal injuries, placing a significant financial burden on our health-care system. For effective rehabilitation, a proper exercise technique is often considered essential. However, the effect of posture on shoulder muscle activity during shoulder-focused exercise is unclear. The purpose of this study was to examine the effects of upper body posture (and technique) on shoulder muscle activity during shoulder exercises using TheraBand® elastic resistance.

**Study Design:** This study used the repeated-measures design.

**Methods:** Twelve healthy participants performed 4 shoulder exercises using a TheraBand® CLX that generated a moderate rating on the subjective RISE scale of perceived exertion. The exercises included: external rotation; external rotation with towel; unilateral shoulder flexion to 90°, and bilateral shoulder flexion to 90°. Participants completed 3 sets of 5 repetitions for each exercise, and they performed each exercise with 3 different postural cues, including: no postural cues, poor posture (relaxed and slumped), and with postural cues (instruction and reinforcement). Rest intervals of 30 s and 2 min were given between sets and exercises/postures, respectively. 3D kinematics of the upper extremity and surface electromyography from 16 upper extremity muscles was recorded. Muscle activity was filtered and normalized to muscle-specific maximal voluntary contractions (MVC) and kinematic data determined concentric and eccentric phases of each repetition. Mean and maximum muscle activity and joint angles were determined.

**Results:** For the external rotation exercise, the infraspinatus muscle activity was the greatest during the poor posture condition (no cue: 27.8% ± 11.9%MVC; poor: 30.3% ± 11.6%MVC; corrected: 25.0% ± 14.1%MVC). For external rotation with towel, the middle and lower trapezius muscle activity increased by 21.3% and 16.8% from the poor to the corrected posture, respectively. For unilateral flexion, serratus anterior increased by 10.2%MVC from the corrected to the poor posture. Infraspinatus activity increased from 21.5% ± 15.7%MVC during the corrected posture to 30.4% ± 18.1%MVC during the poor posture.

**Conclusion:** During external rotation with postural cues, there was increased middle and lower trapezius muscle activity, which could suggest load sharing of muscle contributions. During unilateral and bilateral flexion, serratus anterior, cervical extensors, upper trapezius, and infraspinatus, all showed greater activity with poor posture, which could influence the effectiveness of targeted exercises for individual muscles.

**Clinical Relevance:** Upper body posture, in particular, a rounded (slouched) upper back and forward head translation, increased muscle activity during many of the shoulder exercises tested. Future work should consider the importance of patients’ perception of the exercise technique such that at-home, unsupervised exercise prescription can be most effective.
Dual- versus single-vector external rotation exercise: an analysis of rotator cuff and scapular muscle activation using elastic resistance (CLX)

T.S. Ellenbecker, S. Merriman, K. Kevorken, C. Mendes, and D.S. Bailie

Select Physical Therapy, ATP World Tour, and Arizona Institute for Sports Knees and Shoulders (AzISKS)

Background: Shoulder external rotation (ER) exercises with elastic resistance have been studied with both electromyography (EMG) and in training paradigms and have been found to be effective for increasing ER strength. This exercise is an essential part of any shoulder rehabilitation program as well as of preventative conditioning programs for overhead athletes. Combining typical ER in 90° of abduction with scapular retraction through the use of a “dual vector” (DV) technique may increase activation of the scapular and rotator cuff musculature.

Purpose: The purpose of this study was to quantify the muscular activation levels during a traditional ER exercise (single vector [SV]) with 90° of glenohumeral joint abduction with a DV ER exercise with scapular retraction in 90° of abduction.

Design: This study used the Repeated-measures experimental EMG investigation design.

Methods: In total, 22 (mean age, 29.86 years; average weight, 73.5 kg) healthy uninjured subjects performed both tradition SV and DV ER exercises with 90° of abduction in a randomized fashion using the dominant extremity during EMG of the upper trapezius (UT), lower trapezius (LT), infraspinatus (IF), middle deltoid (MD), and serratus anterior (SA). Five repetitions were sampled using a metronome to control for exercise speed using EMG with standardized normalization technique. A starting position in 90° of abduction and 90° of ER was used with standardized 100% elongation resistance levels using a red CLX band (Performance Health, Akron, OH) across all subjects.

Statistical Analysis: Data were rectified and smoothed using Noraxon Software and SPSS to compare peak and average peak EMG activity in the 5 muscles during the 2 exercise conditions (DV vs. SV). Descriptive analysis, in addition to dependent t-tests, was used to test for mean differences across exercise conditions.

Results: EMG data from the 2 exercise conditions, namely, SV and DV MVIC, for the 5 muscles tested in this study are listed below for average (A) and peak (P) activity.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>MVIC SV A</th>
<th>MVIC DV A</th>
<th>MVIC SV P</th>
<th>MVIC DV P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infraspinatus</td>
<td>17.05</td>
<td>20.8</td>
<td>30.1</td>
<td>35.6</td>
</tr>
<tr>
<td>Middle Delt</td>
<td>7.13</td>
<td>15.1</td>
<td>9.7</td>
<td>23.2</td>
</tr>
<tr>
<td>Serratus</td>
<td>18.4</td>
<td>19.2</td>
<td>26.2</td>
<td>27.5</td>
</tr>
<tr>
<td>Upper Trap</td>
<td>4.3</td>
<td>4.8</td>
<td>6.2</td>
<td>6.26</td>
</tr>
<tr>
<td>Lower Trapezius</td>
<td>12.5</td>
<td>15.1</td>
<td>22.4</td>
<td>26.5</td>
</tr>
</tbody>
</table>

Note: All data are represented as (%MVIC).

Conclusion: DV and SV ER exercise movement patterns elicit similar muscular activity in the rotator cuff and scapular musculature. The DV exercise combines resistive external rotation with scapular retraction and shows a 5% greater activation level in the infraspinatus but also shows increased deltoid muscle activation. Further, 3%-5% greater lower trapezius activation was measured using the DV ER exercise compared with the SV ER exercise. While clinically applicable, these mean differences were not statistically significant between exercise conditions (DV vs. SV).

Clinical Application: Both DV and SV ER exercise movement patterns elicit favorable muscular activity levels for clinical rehabilitation of patients with shoulder dysfunction. These exercises are recommended in both the progression of rehabilitation and the preventative conditioning for the shoulder.

Time course of neuromuscular alterations in middle-distance runners following a CLX conditioning stimulus and subsequent 5-km time trial run

Jonathan Low, Hamed Ahmedi, and David G. Behm
School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John’s, Newfoundland, Canada

Background: Postactivation potentiation (PAP) is a prominent neuromuscular alteration that aids in the
enhancement and maintenance of force production. Most research has examined PAP effects either on evoked contractile properties or strength and power activities. There is scarce research that examines the time course of neuromuscular alterations that occur during middle- to long-distance running. Furthermore, the use of explosive exercises using CLX bands that allow task-specific activities lacks sufficient research.

**Purpose:** The aim of this study was to characterize the time course of the effects of a PAP conditioning stimulus (CLX explosive squat protocol) on a subsequent 5- × 1-km running trial.

**Design:** This study used a randomized within-subjects, repeated-measures experimental study design.

**Methods:** In total, 12 healthy, endurance-trained male athletes completed 2 familiarization and 2 intervention sessions in a randomized order and separated by a minimum of 72 h. The familiarization sessions included a run to volitional exhaustion (VO₂ max) and familiarization of testing, estimation of the individual’s 5RM, and testing of evoked contractile properties. The intervention sessions included a running-specific warm-up, the conditioning exercise intervention (4 × 5RM jump squats with CLX bands or no squats), and a 5- × 1-km time trial runs. Tests were conducted immediately prior to the intervention, after each kilometer, immediately following the 5- × 1-km run, and at 7 and 10 min after the 5-km run. These measures included the interpolated twitch technique (ITT) as an estimate of muscle activation, evoked contractile properties (peak twitch torque, rate of force development, half-relaxation time, M-wave), maximum voluntary isometric contractions (MVIC) to determine peak ankle plantar flexor force, force produced in the first 100 ms (F₁₀₀), 30-cm drop jump (height, contact time, and reactive strength index), rate of perceived exertion (RPE), and heart rate.

**Statistical Analysis:** A repeated-measures, within-subjects ANOVA (2 conditions × 8 times) was used.

**Result:** The CLX jump squat condition yielded a 3.6% reduction in the aggregate time to complete the 5 km (P = 0.05, d = 0.55, 3% †). Greater MVC forces were evident with the squat stimulus compared with control at 10 min post run as compared with pretest. In addition, only the squat condition showed significantly higher MVC force for the squat condition at 4 km (d = 0.29, P = 0.034, 8% †) and 10 min post run (d = 0.36, P = 0.036, 9.5% †) compared with pretest. %VA was significantly greater when comparing squat stimulus with control at 7 min post run (P = 0.05, d = 0.54, 10% †) and 10 min post run (P = 0.05, d = 0.53, 11.5% †) compared with pretest. Temporal effects were apparent, with the squat condition revealing lower TPT at 3 km (P = 0.061, d = 0.5, 5% †) and 10 min post run (P = 0.032, d = 0.6, 5% †) versus control. Similarly, there was a near-significant main effect for condition (P = 0.07, d = 0.51) with lower potentiated TPT in the squat condition. Participants showed significantly increased drop jump height in the squat condition during 2 km (d = 0.47, P = 0.015, 9% †), 3 (d = 0.42, P = 0.05, 8% †), and 4 (d = 0.51, P = 0.011, 8.5% †) as compared with the control.

**Discussion:** The CLX jump squat induced PAP, improving the time to complete 5 km with associated improvements in force, muscle activation, temporal characteristics, and jump height.

**Clinical Interpretations:** CLX are portable and efficient devices that can be used before competitions to improve running performance.

---

**Effects of multicomponent and power training programs using elastic devices on motor function, body composition, and metabolic, bone and inflammatory profile in older adults**


1Research Group in Prevention and Health in Exercise and Sport, University of Valencia, Spain
2Research Unit in Sport and Health, University of Valencia, Spain
3Service of Clinical Analysis, Hospital Universitario Doctor Peset-FISABIO, University of Valencia, Valencia, Spain

**Background:** It is needed to understand what type of training strategy can be the most effective for contributing to a healthier, active, and more independent elderly population. Nowadays, there are novel types of training interventions and devices, but only little is known regarding whether these can provoke positive benefits in this target population. Concretely, no evidence has examined the effectiveness of high-speed resistance training and multicomponent training in older adults in respect of not only physical function but also bone, immunity, and metabolic status. Developing an understanding these novel training strategies can ultimately provide a viable alternative to traditional modes of exercise training for a broader range of participants.

**Purpose:** The purpose of this paper was to investigate the effects of a high-speed resistance training and multicomponent training program with variable
resistance on molecular, body composition, and physical functions in older adults.

**Design:** This study used a randomized clinical trial with the following 3 parallel arms: (1) high-speed/power elastic band CLX resistance training group (P) (6 exercises at 10–12 repetitions (R) at 4–6 rate of perceived exertion (RPE), 3–4 sets, 60-s rest); (2) multicomponent training group (MC) (balance, aerobic [65% at 85% maximum heart rate], flexibility, muscular endurance [2 exercises with CLX elastic bands, 3–4 sets, 15 R at 8–9 RPE, 60-s rest and ratio 2/2] and coordination); and (3) control group (CG). Subjects developed a 20-week training program with 2 sessions each week: each session lasted 75 min for P (325 kcal/session) and 60 min for MC (317 kcal/session). Variables analyzed were bone metabolism; metabolic, inflammatory, and immune profile; functional performance; and fat mass. Statistical analysis was developed with SPSS (Version 24.0, SPSS Inc., Chicago, IL). All data were reported as mean and standard deviation. The assumption of normality and homogeneity of the dependent variables was verified with the Kolmogorov–Smirnov and Levene tests, respectively. An analysis of repeated measures was used to determine the effects of the group and moment on the variables analyzed. When significant differences were found, Bonferroni post hoc test was applied. A 95% confidence level was accepted (significance of $P < 0.05$).

**Results:** There were no significant changes for CG in assessment of hip perimeter, glycosylated hemoglobin, C-reactive protein, osteocalcin; up and go, Romberg, functional, 5-repetition sit-to-stand, 30-s chair stand, 30-s elbow flexion, and manual dynamometry; 4-Meter Gait Speed and 6-min walk tests. CG got significantly worse in percent body fat, waist perimeter, glycemia, cholesterol, LDC-c, triglycerides, type I cross-linked C-telopeptide, and climbing stairs and 10-meter gait speed’s tests. P and MC had positive significant changes in all these variables without differences between them and with significant changes regarding CG. MC had positive changes in C-reactive protein level for P and CG, and the P group showed significant and positive differences in osteocalcin level, 5-repetition sit-to-stand and 30-s chair stand, and manual dynamometry tests for MC and CG. MC was the only group with significant changes in lymphocytes, although without intergroup differences.

**Conclusions:** Although both groups had similar caloric consumption in each session, the most important findings of this study were that a P program with high volume can improve metabolic risk parameters like an MC program, in which endurance activities are predominant. Moreover P training provoked larger positive adaptations in bone profile and strength. Meanwhile MC training had a larger influence on inflammatory and immune profiles. Positive improvements were equal in both groups regarding body composition, balance, and mobility. Trainers, physicians, and physiotherapists must take into account the different adaptations for prescribing more efficient training programs in this type of population. CLX bands could provoke very significant health improvements in older people.

**Effectiveness of progressive TheraBand® strength training performed in primary care for patients with chronic low back pain: randomized controlled trial**

Joaquin Calatayud,1,3 José Casaña,1 Yasmin Ezzatvar,1 Amparo Sánchez-Mañez,2 and Lars L. Andersen3

1Physiotherapy Department, University of Valencia, Valencia, Spain
2Primary Care Health Department Valencia Arnau-Llíria, Valencia, Spain
3National Research Centre for the Working Environment, Copenhagen, Denmark

**Background:** Low back pain (LBP) is the leading cause of disability. Despite most episodes of LBP being short-lasting, 33% of cases are recurrent during the first year, converting LBP into a chronic condition (CLBP). In primary health-care services, Back School Programs (focused on exercise and education) are the most common CLBP rehabilitation treatments. However, a recent review found that there is no effect supporting this treatment. While physical exercise has shown to be effective in many studies, simple and cost-effective exercise programs that can simultaneously be performed by several patients in primary care at cheap cost are warranted.

**Purpose:** To evaluate the effectiveness of a progressive strength training program in patients with CLBP in primary care services compared with usual care (back school).

**Design:** This study used a randomized controlled trial design.
Methods: In total, 66 patients with CLBP were randomly assigned to 2 groups (intervention or back school). The intervention group performed a progressive strength training program during 8 weeks, 3 times/week. The intervention program comprised dynamic exercises (performed with TheraBand CLX) and isometric exercises. The intensity of the dynamic exercises started from 20 repetition-maximum (RM) and progressively increased every 2 weeks to 15RM, 12RM, and finally 10RM, respectively. Pain intensity, pain areas, lumbar extensor strength, handgrip strength, and disability were evaluated.

Results: Compared with usual care, the intervention group had significantly better odds of a relevant LBP reduction, defined as a decrease in pain of at least 2 on a scale of 0–10, with an odds ratio of 3.08 (95% CI, 1.05–9.00). Although a similar trend was observed for the Roland Morris disability score (odds ratio of 1.93 for a decrease in 95% CI of at least 3.5), this was not statistically significant. For other outcomes, the intervention group showed significantly better results in left-hand grip strength (Cohen’s $d = 0.24$) and lumbar extensor strength (Cohen’s $d = 1.23$) and a greater reduction in a number of pain areas (Cohen’s $d = 0.34$).

Statistical Analysis: Using SAS version 9.4., between-group comparisons from baseline to follow-up were performed using logistic regression (odds ratios) and linear mixed models. Statistical analyses were performed blinded regarding group allocation and only revealed after the final analysis.

Conclusions: Compared with usual care consisting of a traditional back school program, a progressive resistance training program using TheraBand CLX improves the odds of reducing LBP and is more effective for reducing the number of painful areas in the body and improving muscle strength.

Clinical Application: A progressive training program performed with low-cost equipment, performed by several patients at the same time, and supervised by only 1 person can be conducted in the primary care setting, providing a more effective and efficient approach than traditional back school programs.
Abstracts Presented at TRAC July 21, 2018, New Orleans, Louisiana

Effect of Biofreeze®, TheraBand® kinesiology tape, or the combination of products, on acute low back pain and disability

Barton N. Bishop,1 Jay Greenstein,¹ Jena Etnoyer-Slaski,¹ Phil Page,² and Robert Topp³
1Sport and Spine Rehab Clinical Research Foundation, Rockville, MD
²Performance Health, Baton Rouge LA
³University of San Diego School of Nursing and Health Science, San Diego, CA

Background: Low back pain (LBP) affects up to 70%–80% of people in their lifetime. LBP has been shown by multiple studies to persist at 3, 6, and 12 months in 35%–79% of people experiencing LBP. In the USA, it is estimated that combined direct and indirect costs of LBP range from $19.6 to 118.8 billion.

Purpose: The purpose of this study was to compare the effect of a combination of therapies of Biofreeze® and TheraBand Kinesiology tape to advice on acute pain, disability, and fear avoidance among patients with LBP over 1 week.

Study Design: This study used a randomized control trial design.

Methods: A total of 120 patients with acute LBP comprised a convenience sample. Exclusionary criteria included pregnancy, history of back surgery, cancer, or a corticosteroid injection within the past 2 weeks. Patients were recruited if they reported LBP for <2 weeks and are ≥18 years of age. Subjects completed the demographics information questionnaire, numeric pain rating scale (NPRS), Roland Morris LBP and Disability Questionnaire (RMDQ), and Fear Avoidance Beliefs Questionnaire (FABQ). Subjects were randomized into 1 of 4 at-home pain management groups (Group 1 [Biofreeze® + Tape]; Group 2 [Tape]; Group 3 [Biofreeze]; and Group 4 [advice]) were followed for 1 week. The groups followed the same protocol, rating their pain at their second (T2) and third (T3) office visits. At 1 week (T4), patients completed the NPRS, RMDQ, and FABQ. In addition to pain and outcomes, at-home pain management compliance and pain medication were documented on a daily basis for the week.

Statistical Analysis: Categorical variables were compared between the groups using chi-square tests, and continuous variables between the groups were compared using 1-way ANOVA with Tukey post hoc comparisons (but no differences were detected between the groups, so post hoc tests were not indicated). Outcomes were assessed with repeated-measures ANOVA with Tukey post hoc comparisons at the $P < 0.05$ level of significance using time group and interaction as the independent variables.

Results: A total of 120 participants were recruited, with 14 dropouts, totaling 106 who completed the study procedures (Group 1 = 25, Group 2 = 28, Group 3 = 26, Group 4 = 27). Group 1 significantly changed their FABQ-Physical Activity score over time ($P = 0.000$) from T1 ($x$ = 19.2) to T2 ($x$ = 14.2). There was also a significant decrease in FABQ total scores over time ($P = 0.002$) for all groups except Group 4. In all groups, except Group 4, significantly improved ($P = 0.000$) RMDQ scores from T1 to T4 were observed. Pain also significantly declined ($P = 0.000$) in all groups over time.

Clinical Relevance: Combining TheraBand® Kinesiology tape and Biofreeze® improved pain reduction and functional ability in patient with acute, noncomplicated LBP. Results from this study will further support the clinical use of products for at home pain relief of acute LBP.

The effect of Biofreeze® vs. a placebo on knee osteoarthritis walking gait characteristics and pain

Barton N. Bishop,¹ Jay Greenstein,¹ Robert Topp,² and Jena Etnoyer-Slaski¹
¹Sport and Spine Rehab Clinical Research Foundation, Rockville, MD
²University of San Diego School of Nursing and Health Science, San Diego, CA

Introduction: In the USA, an estimated 9 million people suffer from symptomatic knee osteoarthritis (KOA) and seek therapy ranging from medication and physical therapy to total knee replacements. Individuals with mild and severe KOA exhibit greater pelvic anterior tilt, reduced knee abduction, smaller hip flexor moments, and smaller knee extensor moments during the stance phase of walking. One study found that following a 10-ml lidocaine injection, KOA joint loads increased to a comparable level of a reference group and pain decreased during single limb support of the gait cycle. Biofreeze® is a topical analgesic that is noninvasive and has been found to provide short-term pain relief.
Purpose: The purpose of this paper was to determine the effect of Biofreeze® versus a placebo on walking gait characteristics and pain during walking in individuals with bilateral KOA.

Methods: A total of 20 participants, ≥40 years with previously diagnosed bilateral KOA, comprised the convenience sample. Participants must have been diagnosed with bilateral knee OA and be able to perform all study procedures. Exclusionary criteria included <40 years of age, pregnancy, cancer, rheumatoid arthritis, a total or partial knee replacement, and/or a corticosteroid injection within the past 4 weeks. All participants reported in comfortable clothing and sneakers. After explanation of the study and consent, participants completed the demographics questionnaire, numeric pain rating scale (NPRS), Western Ontario and McMaster Universities Arthritis Index (WOMAC), and knee function survey. Participants then completed a 3-mph 3-min walking baseline assessment. Following the assessment, participants rated their pain and were randomly assigned to receive a blinded topical of either Biofreeze® or a placebo; 5 mL of both gels was administered per knee. The participants then waited for 15 min, rated their pain, repeated the 3-minute walking assessment, and rated their pain again. There was a minimum of a 24- to 72-h washout period after which the participants repeated the same protocol using the other topical agent.

Outcome Measures: The test consisted of a 3-min walk; the last 30 s of this time frame was considered as the data collection period. Body biomechanics data collected during this 30-s interval were averaged and included trunk (flexion/extension/lateral flexion), hip (flexion/extension), knee (flexion/extension), and ankle (dorsiflexion/plantarflexion) range of motion, bilateral step length, and step symmetry. Additional variables collected included bilateral load symmetry, contact time, vertical displacement, average step cycle time, step length, and step length variation. Pain was assessed using the NPRS, and it was measured at the following 4 time points: baseline, after the 3-min walking assessment, 15 min after topical application, and after the second walking assessment during both testing sessions.

Statistical Analysis: The analysis to test the hypotheses was conducted in 2 steps. During the first step, descriptive statistics (mean, SD, skew, range, etc.) were conducted to determine if the assumptions of parametric statistics are met. Once the data were validated and the assumptions were met, a series of repeated-measures ANOVA statistics were calculated.

Results: At this time, only 6 participants were recruited, with 1 dropout, resulting in 5 participants who completed data collection procedures. Initial results indicate Biofreeze® had better perception of improving knee pain, allowing usual activities to resume, and very good overall outcome.

Clinical Relevance: Biofreeze® has been shown to reduce pain during functional tasks, such as timed get up and go, timed chair stand, and going up and down stairs in a KOA population. Therefore, the use of Biofreeze® could provide pain relief during normal activities such as walking, allowing them to be more active. Owing to the small sample size, conclusions cannot be drawn at this time.

Immediate and short-term effect of Biofreeze® versus placebo on acute neck pain and disability

Jay Greenstein,1 Jena Etnoyer-Slaski,1 Barton N. Bishop,1 Phil Page,2 and Robert Topp3

1Sport and Spine Rehab Clinical Research Foundation, Rockville, MD
2Performance Health, Baton Rouge LA
3University of San Diego, School of Nursing and Health Science, San Diego, CA

Background: Annually, 30%-50% of adults experience some form of neck pain. A common treatment option for neck pain is cervical manipulation but pain may remain a barrier for treatment post manipulation. Biofreeze® is a commonly used topical analgesic and has been reported to be helpful in the treatment of neck pain among other conditions.

Purpose: The purpose of this paper is to compare the effect of Biofreeze® (BF) versus placebo on neck pain and disability before and after cervical manipulation over 1 week among patients with acute neck pain.

Study Design: This study used a double-blind randomized control trial design.

Methods: A total of 60 acute neck pain patients with pain for <2 weeks and of ≥18 years comprised the convenience sample. Exclusionary criteria included pregnancy, cancer, history of neck surgery, or a corticosteroid injection within the past 2 weeks. At baseline (T1), patients completed the informed consent, demographics questionnaire, numeric pain rating scale (NPRS), and neck disability on the neck disability index (NDI). Following baseline, patients were randomized into either the placebo (n = 30) or Biofreeze® (n = 30) group. Both the patient and investigator were blinded to the group that received the active product. The groups followed the same protocol, rating their pain 10 min after application (T2),
received a cervical manipulation, and rated their pain on the NPRS within 5 min of manipulation (T3). Next, all subjects were given the same at-home pain management regimen, applying their assigned topical agent to the neck 4 times day for 1 week (T4). At 1 week, all patients complete the NPRS, NDI, and ROM.

**Statistical Analysis:** Categorical variables were compared between the groups using the chi-square test. Continuous variables between the groups were compared using independent t-tests. Outcomes were assessed using repeated-measures ANOVA with Tukey post hoc comparisons at the $P < 0.05$ level of significance using time group and interaction as independent variables.

**Results:** A total of 59 participants were recruited, with 7 dropouts, resulting in 52 completed responses (29 placebo, 23 Biofreeze). There was a decline in NDI scores ($P = 0.000$) from T1 ($x = 33.217$) and T2 ($x = 23.913$) within the Biofreeze group. There was also a significant decline in pain ($P = 0.000$) from T1 ($x = 6.333$) to all other time points (T2 = 4.524, T3 = 4.19, T4 = 4.357) within the Biofreeze group. There were no between-group differences.

**Clinical Relevance:** Pain and disability significantly reduced in the Biofreeze group over the course of a week. Results from this study will further support the clinical use of Biofreeze® in pre- and postmanipulation pain and improving pain, disability, and ROM through at-home pain management.

---

**The effect of Biofreeze® vs. a placebo on chronic low back pain walking gait characteristics and pain**

Jay Greenstein,¹ Barton N. Bishop,¹ Robert Topp,² and Jena Etnoyer-Slaski¹

¹Sport and Spine Rehab Clinical Research Foundation, Rockville, MD
²University of San Diego School of Nursing and Health Science, San Diego, CA

**Introduction:** Low back pain (LBP) is a number-1 global burden, affecting 80% of people in the USA at some point in their life. Walking patterns are affected by chronic low back pain (cLBP), with reduced speeds, shorter steps, and asymmetrical gait patterns compared with healthy controls. Therefore, patients with LBP walk with a more cautious walking pattern, more slowly, with shorter stride length, decreased push-off rate, and decreased weight acceptance. Biofreeze® is a topical analgesic, which is nonpharmacologic and has been shown to be as effective as ice and TENS (transcutaneous electrical nerve stimulation) at reducing pain. The use of Biofreeze® has also been proven to reduce musculoskeletal pain, including LBP. The purpose of this study is to determine the effect of Biofreeze® versus a placebo on walking gait characteristics and pain during walking in individuals with cLBP.

**Methods:** A total of 20 participants, of ≥18 years with cLBP, comprised the convenience sample for this study. Participants must have cLBP and be able to perform all study procedures. Exclusionary criteria included pregnancy, cancer, spinal or hip surgery, or a corticosteroid injection within the past 4 weeks. All interested participants reported in comfortable clothing and sneakers. After explanation of the study and obtaining consent, participants completed the demographics questionnaire, NIH cLBP minimal data set, 10-point numeric pain rating scale (NPRS), and the Roland Morris Low Back Pain and Disability Questionnaire (RMDQ). Participants then completed a 3-min walking baseline assessment. Following the assessment, participants rated their pain and were randomly assigned to receive a blinded topical agent of either Biofreeze® or a placebo. Both the participants and the investigator were blinded to the assigned products; 5 mL of both gels was applied on the low backs of the designated participants. Each participant waited 15 min, rated their pain, repeated the 3-min walking assessment, and rated their pain again. There was then a minimum of a 24- to 72-h washout period, after which time, the participants returned and repeat the same protocol using the other topical agent.

**Outcome Measures:** The test consisted of a 3-min walk; the last 30 s of this time frame was considered as the data collection period. Body biomechanics data collected during this 30-s interval were averaged and included trunk (flexion/extension/lateral flexion), hip (flexion/extension), knee (flexion/extension), and ankle (dorsiflexion/plantarflexion) range of motion, bilateral step length, and step symmetry. Additional variables collected included bilateral load symmetry, contact time, vertical displacement, average step cycle time, step length, and step length variation. Pain was assessed using the NPRS, and it was measured at 4 time points: baseline (T0), after the 3-min walking assessment (T1), 15 min after topical application (T2), and after the second walking assessment (T3) during both testing sessions.

**Statistical Analysis:** The analysis to test the hypotheses was conducted in 2 steps. During the first step, descriptive statistics (mean, SD, skew, range, etc.) were conducted to determine if the assumptions of
parametric statistics are met. Once the data were validated and the assumptions were met, a series of repeated-measures ANOVA statistics were calculated.

Results: At this time, 11 participants have completed this study. There were no significant differences between groups for trunk flexion, hip flexion, step length, or cycle time; however, the sample size is too small to make conclusions. The study will continue until at least 20 participants have completed the protocol.

Clinical Relevance: A consequence of cLBP is altered walking and running biomechanics. The recommendation for noninvasive treatment of cLBP is nonpharmacologic treatment with exercise. If proven to be effective, the use of Biofreeze® could provide pain relief, allowing individuals to perform normal activities such as walking.

The effect of topical menthol vs. ice on postural sway: a feasibility study

Andre’ Labbe’, Albert Lindon, and Tyler Tunnell
Athletic Department, Tulane University, New Orleans, LA

Background: Topical menthol has been suggested as an alternative to cryotherapy or traditional ice applications after acute injury. Previous research has suggested that ice decreases arterial blood flow similar to ice. In contrast to ice, topical menthol might have less adverse effects on postural sway. If so, topical menthol application might be an alternative to ice application when returning athletes to competition after acute injury without affecting the postural sway.

Purpose: The purpose of this study was to examine the feasibility of a study design comparing the effects of topically applied ice and Biofreeze® topical analgesic (containing 4% menthol) on postural sway when applied to healthy, uninjured ankles.

Design: This study used within-subjects’, crossover, repeated-measures design with survey.

Methods: In total, 19 health subjects were tested (female subjects, 8; male subjects, 11). Subjects did not have current acute lower body injury or any reported deficits with balance or sway. Subjects underwent baseline testing with single limb stance bilaterally; 24 h later, ice was applied to 1 ankle and Biofreeze to the other for 7 min, which were randomly assigned. The subjects were then tested on the Biodex Balance System to assess postural sway through a proprietary algorithm. There was a 24-h washout, and the modality application and test were repeated, crossing over to the application of the ice and Biofreeze on the opposite ankle. Subjects were asked about their preference between Biofreeze and ice.

Results: There was no significant difference in postural sway with either ice or Biofreeze in this healthy population; 54% of subjects preferred Biofreeze and 30% preferred ice, while 15% had no preference.

Conclusion: The study seems feasible to be repeated in an injured population.

The effect of Biofreeze® on delayed onset muscle soreness–induced changes to running biomechanics

Ryan G. Gagnon,1 Michael W.R. Holmes,1 and Duane C. Button2
1Department of Kinesiology, Brock University, St. Catharines, Ontario, Canada
2School of Human Kinetics and Recreation, Memorial University, St. John’s, Newfoundland, Canada

Background and Purpose: Delayed onset muscle soreness (DOMS) can occur from exercise-induced muscle damage and can lead to changes in running biomechanics. Runners often experience DOMS, especially in the knee extensors, and the pain induced by DOMS can cause an individual to adopt altered movement strategies. Altered mechanics could lead to improper loading of compensating structures, suggesting an increased risk of injury. One potential way to alleviate the effects of DOMS on running biomechanics is to use a topical analgesic. The purpose of this study was to determine the interactive effect of DOMS and a topical analgesic on running biomechanics.

Study Design: This study used a single blinded randomized control study design.

Methods: Ten participants were divided into the following 2 groups: (1) Biofreeze® (n = 5) and (2) placebo (n = 5). Participants ran >20 km/week and had no current injuries. Each group completed a 10-min baseline (BASE) run followed by a downhill running protocol to induce DOMS; 48 h following the DOMS protocol, participants returned and had their pain pressure threshold (PPT) measured. Following measurement, another 10-min run was completed (DOMS); participants then rested for 15 min while Biofreeze® (BIOF) or the placebo (PLAC) were applied to the plantar flexors and knee extensor musculature. After the rest period, PPT was measured again followed by completing a final 10-min run. A
comparative pain scale (CPS) was used during each session to compare relative perceived pain. A preferred transition speed (PTS) was predetermined by the runner and was used for all sessions. 3D kinematics and muscle activity of the lower extremity were tracked using motion capture and electromyography during each session. Heel strike was determined for each stride and kinematic data normalized to percent of gait cycle.

**Results:** For the Biofreeze® group, maximum knee flexion increased from the DOMS (86.8° ± 12.6°) to BIOF (91.7° ± 12.3°) sessions. The placebo group had no change in maximum knee flexion (DOMS: 96.7° ± 3.1°; PLAC: 97.6° ± 8.4°). PPT increased at all assessment sites for Biofreeze® (average: DOMS = 56.4 ± 14.2; BIOF = 80.2 ± 16.8), while the placebo group reported a decrease at all assessment sites (average: DOMS = 85.1 ± 27.5, PLAC = 80.6 ± 20.6). The Biofreeze® group had average pain scale ratings of 0.6 ± 0.89, 5.6 ± 2.3, and 3.0 ± 2.1 at BASE, DOMS, and BIOF, respectively. The placebo group had average pain scale ratings of 0.75 ± 0.5, 5.8 ± 2.2, and 4.75 ± 1.7 at BASE, DOMS, and PLAC, respectively.

**Conclusion:** The application of Biofreeze® led to an increase in knee flexion and overall knee range of motion, which closely matched the prefatigue situation. The Biofreeze® group also had lower reported pain and an increased PPT compared with the placebo group.

**Clinical Relevance:** The decrease in pain and the increase in knee flexion angle following the application of Biofreeze® may help restore normal movement patterns for an individual experiencing DOMS. Further investigation of muscle activity and ankle kinematics will help clarify any neuromuscular control adaptations.

---

**TheraBand® roller massager increases cutaneous blood flow and neurosensory threshold of Aδ and Aβ sensory nerve fibers**

Daniel H. Craighead, Ashlee E. Snyder, Billie K. Alba, and Lacy M. Alexander

Department of Kinesiology, The Pennsylvania State University, PA

**Background:** Roller massage is a common therapeutic technique used to alleviate delayed onset muscle soreness (DOMS). Despite abundant use, the mechanisms through which roller massage attenuates DOMS remain equivocal.

**Purpose:** The purpose of this study was to determine the effect of TheraBand® Roller Massager+ on muscle soreness, cutaneous blood flow, and neurosensory threshold.

**Study Design:** Subjects performed single-leg squat exercises to exhaustion with each leg to elicit DOMS. One leg received daily treatment with the TheraBand® Roller Massager+, while the other leg served as control. Outcome measures were assessed before the squat exercise, and at 24, 48, and 72 h post exercise (before and after self-administered roller massage).

**Methods:** Muscle soreness was rated using a 0–10 visual analog scale. Cutaneous blood flow was measured via laser speckle contrast imaging. Aδ, Aβ, and C fiber neurosensory threshold was measured with a Neurometer® CPT; 1 min of roller massage (9-kg load) was performed daily over the ventral thigh (rectus femoris and vastus intermedius muscles).

**Results:** Self-ratings of muscle soreness were significantly elevated 24 (P < 0.001) and 48 h (P = 0.001) after exercise. There was no effect of roller massage on muscle soreness (P = 0.39). Cutaneous blood flow was elevated post massage (P < 0.001). The roller massage did not change C fiber neurosensory threshold (P = 0.22) but increased both Aδ (P = 0.01) and Aβ (P = 0.02) threshold compared with the control leg.

**Conclusion:** Self-administration as used in this study had no effect on muscle soreness, likely because C fiber neurosensory threshold was unaffected. However, roller massage did increase local cutaneous blood flow and Aδ/Aβ fiber neurosensory threshold, providing greater physiological understanding of this commonly used therapeutic technique.

---

**The effects of kinesiology tape on active knee flexion**

Michael E. Rogers and Alexis Montgomery

Department of Human Performance Studies, Wichita State University, Wichita, KS

**Background:** Kinesiology tape (KT) is used in therapeutic clinics, chiropractic clinics, and sports settings as a tool to prevent or treat injuries. Some of the reported benefits of KT include decreasing pain, decreasing edema, increasing muscle strength, and improving circulation throughout the body. However, placing elongated KT over a joint could potentially limit the range of motion (ROM) of that joint and thus impact performance.

**Purpose:** The purpose of this study was to evaluate the effects of KT on active knee flexion ROM.
Design: This study used a cross-sectional design.

Methods: In total, 40 individuals (women, 29; men, 11; mean age, 19–26 years) participated in the study. Two strips of KT were applied to the medial and lateral side of the patella on the right knee under the following conditions: no tape, 0% elongation, 25% elongation, and 50% elongation. ROM was measured using the Microfet-3.

Results: A 1-way analysis of variance (ANOVA) with repeated measures found no significant difference in the effects of KT on active knee flexion [Greenhouse–Geisser $F(2.38, 92.8) = 2.673, P = 0.065$].

Conclusion: KT applied at 0%, 25%, and 50% elongation was shown to have no significant effect on active knee flexion.

Clinical Application: These results suggest that KT does not restrict ROM when applied with tension over a joint. Future research needs to be conducted to determine the possible effects of KT over longer periods of time.

Effects of bilateral kinesiology tape application on prevention of anterior tibial pain (shin splints)

Michael E. Rogers
Department of Human Performance Studies, Wichita State University, Wichita, KS

Background: Anterior tibial pain (shin splints) accounts for ~15% of all running injuries. Additionally, 22% of aerobic dancers and 8% of those involved in military basic training report this condition. Kinesiology tape (KT) has been used to treat a variety of painful conditions (e.g., low back pain, neck pain), but its effects on anterior tibial pain prevention are unknown.

Purpose: The purpose of this study is to determine whether bilateral KT application prevents anterior tibial pain.

Design: This study used a cross-sectional design.

Methods: In total, 10 untrained women of age 20–22 years participated in the study. Baseline measures consisted of the following: (1) self-reported lower leg pain using a numerical scale ranging from 0 (no pain) to 10 (worst pain possible); (2) plantarflexion and dorsiflexion range of motion (ROM) using a goniometer on each ankle; and (3) pain threshold using a digital algometer applied to both the tibialis anterior belly and the distal gastrocnemius medial to the tibia of each leg. KT was then applied bilaterally along the right tibia at 50% elongation, extending from the proximal tibia to the distal metatarsals. The left leg was not treated. Participants then walked for 30 min at 4 mph on a treadmill with a 12% decline; 24 h later, the KT was removed and baseline measures were repeated.

Results: All participants reported baseline pain levels of 0. Average pain levels were higher ($P > 0.05; 3.1 ± 0.5$) 24 h after walking but there was no difference between legs. Plantarflexion and dorsiflexion ROM was not different between legs at baseline or at 24 h. However, dorsiflexion ROM in both legs was 6% less at 24 h, while plantarflexion ROM was unchanged. Pain thresholds were also not different between legs at baseline or at 24 h or on the medial tibia tissue at baseline vs. at 24 h. However, pain threshold on the tibialis anterior did significantly decrease by 8% 24 h after walking.

Conclusion: Downhill walking causes anterior tibial pain that results in increased self-reported lower leg pain, reduced dorsiflexion ROM, and increased anterior tibialis pain. However, KT application does not appear to prevent anterior tibial pain when applied bilaterally along the tibia.

Clinical Application: Further research is needed to determine if different KT applications (e.g., spiral around the lower leg) effectively prevent this condition and if KT is effective in treating anterior tibial pain after it is induced.

Effect of TheraBand® kinesiology tape and Biofreeze® on pain and functional performance in runners with shin splints

Suimin Guo, Longfei You, Bebei Feng, and Gong ChenLeo Yuling Wang
Department of Rehabilitation Medicine, The Sixth Affiliated Hospital of Sun Yat-sen University, Guangdong Sheng, China

Background and Purpose: More and more runners join the flourishing marathon and running contests. Shin splints are one of the comprehensive injured symptoms that are highly recurrent and incident and are associated with running. The purpose of this study was to determine the persistence, effects, and potential mechanism of TheraBand® kinesiology tape (KT) and Biofreeze® in shin splints.

Study Design: This study used a randomized controlled trial design.

Methods: In total, 35 participants with shin splints caused by running were recruited after screening survey in persons who are amateur runners via designed...
questionnaires. The participants were randomly allocated to the following 3 groups: KT group (tape + exercise training; n = 12), BF group (Biofreeze + exercise training; n = 13), control group (exercise training; n = 10). KT group received treatment of TheraBand® kinesiology tape on both anterior tibia muscle and posterior tibia muscle of the affected limb, which was maintained for >24 h. The BF group accepted treatment including Biofreeze® on the pain area of the affected limb for 3 times a day and this lasted a week. And the 3 groups of KTG, BFG, and the control group received family exercise interventions after the therapist’s guidance, which including muscle stretching, relaxation therapy, and active muscle strength training for a week.

The measures were conducted with visual analogue scale (VAS), navicular drop test (NDT), navicular position test (NPT), peripheral blood flow perfusion, running test, pressure pain threshold (PPT), plantar-flexion, and dorsiflexion force (Microfet3, Hoggan). A trained physical therapist performed the assessment before baseline and on day 7 and day 14 after the intervention and follow-up assessment in the second week. Each participant has signed the informed consent form. Ethics were approved by The Ethic Committee of The Sixth Affiliated Hospital of Sun Yat-sen University.

Statistical Analysis and Results: There are significant differences of the primary outcome measurements for VAS and PPT in the KT group and the BF group that were compared with control group after 2 weeks’ intervention. There is an interesting finding on the running test with better performance in the KT group and the BF group. For other measurements, there are no significant improvements among 3 groups after 2 weeks.

Conclusions and Clinical Application: The main findings of this study indicated that it is suitable, simple, and more effective treatment protocol for shin splints runners who could use the KT and Biofreeze® cold therapy. Although the mechanism of taping treatment is not very clear, previous studies have shown that it could relieve muscle tension, promote proprioceptive input and improve peripheral micro-circulation. Biofreeze® has shown that it can reduce blood flow and reduce pain caused by musculoskeletal diseases more efficiently. The limitation of this study is the small sample size, which might not find the changes in specific parameters, and a further study should be conducted.

A prospective randomized study of opioid use following orthopedic surgery with the use of nonpharmacological pain relief kit

Timothy Tyler, Shannon Tyler, Malachy P. McHugh, Denis O’Hara, Robert Topp, Raymond Chin, Brandon Schmitt, Dan Villanova, Stephanie Squitieri, Lauren Walczewski, Ben Bedford, and Stephen Nicholas

ProSports Therapy, NISMAT, New York, NY

Background and Purpose: Opioids are commonly administered for the treatment of pain and are among the most prescribed drugs in the USA. Between 2003 and 2011, opioid prescriptions increased from 149 million to 238 million. Orthopedists regularly prescribe a fixed amount of opioids following surgery. The purpose of this study was to determine the effect of a nonpharmacological postoperative pain relief kit (PRK) on opioid consumption of individuals recovering from orthopedic surgery over a 4-week duration.

Study Design: This study used a prospective randomized control trial design.

Methods: In total, 52 patients who presented for rehabilitation following orthopedic surgery that included bone drilling of the shoulder, hip, or knee were recruited (total joint arthroplasty, 12; shoulder/elbow surgery, 15; other lower extremity procedures, 25). DASH (Disabilities of the Arm Shoulder and Hand) scores for upper extremity procedures and LEFS (Lower Extremity Functional Scale) scores for lower extremity procedures were collected on initial evaluation and after 4 weeks. Patients were randomized to a PRK group (n = 29) or a control group (n = 23) who received the usual postoperative care (both groups underwent the same physical therapy). All subjects provided a daily rating of their pain and documented daily opioid and OTC (over the counter) medication usage. Patients in the PRK group also documented compliance with the pain relief modalities (Biofreeze gel, elastic tape, topical heat, elastic resistance exercise). The data were analyzed using a treatment by time analysis of variance.

Results: The subjects in the PRK group were younger than those in the control group (32 ± 18 years vs. 45 ± 21 years; P = 0.016) with no other differences between groups at baseline. Three patients in the PRK group dropped out. The following compliance with the 4 PRK modalities in days per week was notes: Biofreeze, 2.0 ± 1.7; Kinesiology tape,
1.5 ± 1.7; thermal therapy, 3.0 ± 2.6; and TheraBand exercises, 3.8 ± 2.5. Opioid use was not different between treatment groups (PRK, 3.9 ± 7.7 pills per week vs. 5.7 ± 5.4 for the control group; \( P = 0.36 \)). OTC pain medication (\( P = 0.917 \)) and total medication (\( P = 0.362 \)) did not differ between groups. There was no difference in average weekly pain scores between the groups (\( P = 0.63 \)). There was no effect of the time from surgery to initial evaluation on opioid use (\( r = -0.07, P = 0.64 \)). There was no effect of the time patients had the pathology until surgery on opioid use (\( r = -0.17, P = 0.26 \)). Outcome scores (DASH and LEFS) improved from baseline to 4 weeks (\( P < 0.001 \)) with no difference between treatment groups (\( P = 0.23 \)). VAS pain scores were reduced from week 1 to week 4 (\( P < 0.001 \)) with no difference between groups (\( P = 0.63 \); week 1 to week 6: PRK, 3.8 to 1.4 out of 10; control, 5.0 to 2.0).

**Conclusion:** A nonpharmacological PRK was unable to reduce the consumption of prescription or nonprescription pain medication in the early postoperative period after orthopedic surgery. Both treatment groups had marked symptom relief over the 4 weeks of the study.

**Clinical Relevance:** While the nonpharmacological pain relief intervention did not affect narcotic use in these patients, it is notable that the overall narcotic use was low. It is possible that the increased media coverage throughout the nation has had an effect on opioid medication usage following the commencement of this project.
Biofreeze and rolling alone or in combination did not increase flexibility, pain pressure threshold or fatigue performance

David G. Behm, Colin Duffett, Shawn Wiseman, and Israel Halperin
Memorial University of Newfoundland, St John’s, Newfoundland, Canada

Background: Prior studies have reported increased range of motion (ROM) and pain pressure thresholds (PPT) with the use of roller massage. It has been suggested that a possible mechanism for the increased ROM is increased stretch (pain) threshold. The effects of a topical analgesic alone or in combination with rolling may provide additional benefits for ROM, PPT, and the ability to tolerate discomfort during a fatigue protocol.

Purpose: The purpose of this study is to investigate the effect of the use of a topical analgesic alone or a roller massager alone and a combination of both on ROM, PPT, and performance in a fatiguing protocol.

Design: This study used a repeated-measures, randomized, within-subjects design.

Methods: Sixteen healthy, active male participants (age range, 18–27 years) free from musculoskeletal injuries participated in the study that included 5 conditions, namely, control, placebo gel, topical analgesic gel, rolling and placebo gel, and rolling and topical analgesic gel. All sessions involved 2 ROM and PPT pretests separated by 5 min. Further, after a 20-min recovery period, 2 posttests of ROM, PPT, and heel raises to failure (HRF) were completed at 5-min intervals. In sessions including gel application, immediately after posttest 2, the gels were manually applied on the dominant-leg calf muscles. In sessions including self-massage, 18 min after posttest 2, a rolling massage protocol of 3 sets of 30 s with 10-s rest for a score of 7/10 on the pain scale to cadence of 1 s for the full length of the muscle was conducted from the same sitting position.

Statistical Analysis: A 5 conditions × 4 times repeated-measures ANOVA (1) was used to analyze PPT and ROM, whereas a 5 conditions × 2 times ANOVA was used for HRF.

Results: There were no significant main effects for condition or any interactions. A main effect for time (P = 0.031) showed meaningful but no statistically significant (P = 0.1) increases in PPT with near-significant increases between pretest 1 (35.9 ± 10.1 kg) and pretest 2 (38.3 ± 12.6 kg) and significant (P = 0.02) increases from posttest 1 (36.3 ± 11.4 kg) to posttest 2 (38.9 ± 12.8 kg). ROM also showed a main effect for time (P < 0.0001), with significant improvements between all times and with the exception of results from posttest 1 to posttest 2 [pretest 1 (13.8 ± 3.1 cm), pretest 2 (14.08 ± 3.2 cm), posttest 1 (14.28 ± 2.9 cm), posttest 2 (14.4 ± 3.3 cm)]. HRF showed a main effect for time, with a significant (P = 0.006) decrease in repetitions from posttest 1 (22.1 ± 6.7) to posttest 2 (20.4 ± 4.4).

Conclusions: In contrast to prior rolling studies, there was no augmentation of ROM or PPT and there was no isolated or additive effect with the use of topical analgesic. This lack of significance might be attributed to the inclusion of 2 pretests, a nonclinical healthy young population (no pain or injuries), a more restricted ROM associated with the ankle joint, or type II errors (false negatives with a relatively small sample population).

Clinical Applications: The use of roller massagers and topical analgesic alone or in combination may have limited effects in the ankle joint model of a healthy population, and further research should investigate clinical populations and other joint/muscle complexes/regions.

Quadriceps’ and hamstrings’ foam rolling and stretching increases passive shoulder range of motion

Estêvão Rios Monteiro,1 Aline Gomes Ferreira de Melo Fiuza,1 Julio Cesar de Oliveira Muniz Cunha,1,2 Giovanni da Silva Novaes,3 Jeferson Macedo Vianna,5 David G. Behm,4 and Jefferson da Silva Novaes1,5

1School of Physical Education and Sports—Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
2Estacio de Sá University, Rio de Janeiro, Brazil
3Castelo Branco University, Rio de Janeiro, Brazil
4School of Human Kinetics and Recreation, Memorial University of Newfoundland, Canada
5College of Physical Education and Sports, Federal University of Juiz de Fora, Minas Gerais, Brazil

Background: Foam rolling (FR) is a technique similar to physiotherapeutic massage reported to acutely
increase range of motion (ROM). Static (SS) stretching can improve ROM in both the stretched muscle and nonstretched muscles.

**Purpose:** The study objective was to compare the effect of different volumes (60 and 120 s) of lower body FR, SS, and proprioceptive neuromuscular facilitation (PNF) stretching on shoulder flexion and extension ROM.

**Design:** This study used a crossover design.

**Methods:** Twelve women, recreationally trained in FR and SE, were recruited. Participants performed 2 FR, SS, and PNF stretching sessions each for the quadriceps and hamstrings: FR (FR60 and FR120), SS (SS60 and SS120), and PNF (PNF60 and PNF120). For each experimental condition, 2 baselines measurements were collected, and the mean baseline was used as the resting value. There were 6 postintervention measurements: immediately (Post-0), 10 min (Post-10), 20 min (Post-20), 30 min (Post-30), 24 h (Post-24), and 48 h (Post-48).

**Statistical Analysis:** A 3-way repeated-measures ANOVA (2 volumes × 3 conditions × 6 times) was used to compare the shoulder flexion and extension ROM. Eta-squared (eta²) and Cohen’s d effect sizes minimum detectable change (MDC) scores were calculated.

**Results:** Following FR or stretching of the quadriceps and hamstrings, there was a statistical increase ($P < 0.05$) in shoulder flexion ROM at Post-0 and Post-10 for all protocols; however, SS120 and PNF120 did not exceed the minimum detectable change at Post-10. Similarly, shoulder extension ROM increased ($P < 0.05$) at Post-0, Post-10, Post-20, and Post-30, but it did not exceed the minimum detectable change at Post-10 and Post-20 for SS120 and PNF60, respectively, and Post-20 for PNF120.

**Conclusion:** In conclusion, both stretching techniques and FR increased the ROM of a nonstretched joint (shoulder), which can have practical implications for both training and rehabilitation.

**Clinical Applications:** During immobilization or rehabilitation, rolling of nonlocal or distant muscles could help contribute to the acute improvement of the injured joints’ ROM.

---

**Background:** Roller massage (RM) can be painful and induce muscle activity during application. Acute increases in pain pressure threshold (PPT) and range of motion (ROM) have been previously reported following RM. It is unclear whether the RM-induced increases in PPT and ROM can be attributed to changes in neural or muscle responses. To help determine if neural pain pathways are affected by roller massage, transcutaneous electrical nerve stimulation (TENS) was used as a form of electroanalgesia during RM with PPT and ROM tested on the affected and contralateral quadriceps.

**Purpose:** The purpose of this study was to evaluate in both quadriceps, the effect of brief intense TENS on PPT and ROM following unilateral RM of the quadriceps.

**Design:** This study used a randomized, within-subjects’ design.

**Methods:** Local and nonlocal effects of TENS and roller massage versus a control condition (rolling without TENS application) were examined. Four 30-s bouts of RM of the dominant quadriceps were implemented with 30 s of rest. The researcher applied the RM using a constant pressure device with $\sim 70\%$ of the maximum tolerable load. Perceived pain was monitored using a visual analog scale (VAS) during RM. Ipsilateral and contralateral quadriceps ROM and PPT were measured immediately following RM.

**Statistical Analysis:** A $4 \times 3$ repeated-measures ANOVA was used to analyze the ROM and pain tolerance of the dominant and nondominant quadriceps during the 4 interventions (RM, TENS, BOTH, control) and 3 testing times (baseline, preintervention, postintervention). A $2 \times 4$ within-subjects ANOVA was used to analyze the pain perception associated with RM during the 2 interventions involving RM (RM and BOTH) and 4 RM bouts during each intervention.

**Results:** Significant main effects for time showed increased PPT and ROM in both the treated and contralateral quadriceps, with no significant main effects or interactions for intervention and time. Moderate to large effect sizes and meaningful clinically important differences (MCID) were detected when comparing baseline to pre- and postintervention, respectively. VAS scores were significantly (main effect for intervention) and near significantly (interactions) reduced with MCID when TENS was applied during rolling.

**Conclusion:** The addition of TENS to rolling did not increase PPT or ROM in the affected or contralateral quadriceps, likely because of a repeated testing effect.

**Clinical Applications:** The finding that TENS decreases the relative amount of perceived pain during RM could decrease the discomfort associated with the RM technique.

---

**The addition of transcutaneous nerve stimulation with roller massage did not increase pain tolerance or range of motion**

James Douglas Young, Alyssa-Joy Spence, Gerard Power, and David George Behm

*Memorial University of Newfoundland, St. John’s, Newfoundland, Canada*
with rolling, which could increase the desire or frequency of use.

The effects of vibration and foam rolling on subsequent performance

James D. Young, Alyssa-Joy Spence, Camila D. Lima, Jonathan L. Low, Emily Colwell, and David G. Behm

Memorial University of Newfoundland, St, John’s, Newfoundland, Canada

Background: Vibration has been shown to improve performance and is known to affect the processing of sensory information. Research has shown that rolling can improve range of motion (ROM) and decrease the pain associated with muscle soreness. There are few studies investigating the integration of both vibration and rolling on subsequent ROM and performance measures.

Purpose: The purpose of the study was to investigate the effects of different frequencies of a vibrating foam roller on ROM and performance.

Design: This study used a randomized within-subjects’ design.

Methods: The protocol incorporated three 30-s bouts of foam rolling on both the quadriceps and hamstrings of the dominant and nondominant leg. Experimental conditions included 3 intensities of vibration and foam rolling, traditional foam rolling without vibration, and a control session. Measures included knee extension (KE) and knee flexion (KF) maximal voluntary isometric contractions (MVICs), vertical jump (VJ), and range of motion (ROM) using the modified Thomas test (MTT) and sit and reach test. Measures were collected preintervention and postintervention. Both the ipsilateral and contralateral limbs were assessed.

Statistical Analysis: Separate repeated-measures, within-subjects ANOVAs (5 conditions x 2 times) were used to analyze the testing variables for the dominant and nondominant limbs.

Results: Significant main effects for time were evident for all variables with the exception of VJ and KF MVIC. Sit and reach and MTT ROM for the dominant and nondominant legs increased by 2.5%, 4.8%, and 3.2%, respectively. KE MVIC for the dominant leg, nondominant leg, and the dominant KF MVIC decreased by 4.2%, 4.1%, and 4.8%, respectively. Significant interactions showed that the lowest vibrating frequency had a 6.2% near significantly ($P = 0.078$) greater nondominant MMT ROM than the nonvibrating foam rolling, whereas the highest vibrating frequency showed a significantly ($P = 0.02$) higher posttest KE MVIC than the control condition. Sit and reach scores increased for the lowest ($P = 0.002$) and highest ($P = 0.078$) vibrating rolling frequencies by 6.5% and 2.5%, respectively.

Conclusions: The vibrating foam roller did provide some additional benefits for KE MVIC force versus the control condition, and MTT ROM versus nonvibrating foam rolling. In addition, the lowest and highest vibrating frequencies showed only significant increases in sit and reach scores. However, in general, the effect of repeated testing generated more pervasive increases in ROM and decreases in MVIC force than the interventions for both the affected and contralateral legs. In the present study, vibrating foam rolling provided sporadic ROM advantages over traditional foam rolling.

Clinical Applications: A vibrating foam roller does not seem to provide consistently greater benefits to ROM or force than a traditional foam roller.

Acute effects of combined strengthening and roller massage exercises on twitch torque, muscle activation, and maximal voluntary contraction in young adults

Helmi Chaabene, Olaf Prieske, Fridolin Zinke, David G. Behm, and Urs Granacher

University of Potsdam, Potsdam, Germany

Memorial University of Newfoundland, St, John’s, Newfoundland, Canada

Background: Contractile responses are significantly affected by the history of voluntary muscle activation. Performance can be augmented through the mechanism of postactivation potentiation (PAP). Self-massage rolling technique have been effective in improving joint range of motion maximal voluntary contraction force and power, speed, and agility performances in a variety of studies.

Purpose: The purpose of this study is to examine and compare the effects of a combined strength and roller massager versus a single-mode strength conditioning activity or a single-mode roller massage condition on twitch contractile properties, maximal voluntary strength, and muscle activation in young athletes.

Design: This study used a randomized within-subjects’ design.
Methods: In total, 15 healthy physical education students (male students, 8; female students, 7) with no previous experience in roller massaging volunteered to participate in this study. Following a standardized warm-up, pretests consisted of twitch torques of the triceps surae, plantar flexors’ maximal isokinetic torque, and electromyography (EMG) of the lateral gastrocnemius, tibialis anterior, and soleus muscles. The 4 conditioning interventions involved (1) Strength: 3 × 10 isokinetic-concentric plantarflexion/dorsiflexion contractions (80% MVC, 35°/s); (2) 1-min roller massage of the plantar flexors, at a visual analogue pain scale of 7/10; (3) combination of the strength and roller massage conditioning protocols; and (4) control. Posttests were conducted 7 min after the conditioning interventions.

Statistical Analysis: Repeated-measures ANOVA were used to detect differences between the 4 conditions. Effect sizes (Cohen’s d) were calculated as a measure of practical relevance of performance changes.

Conclusions: There was no individual or additive effects of foam rolling with a strength conditioning exercise on subsequent evoked twitch contractile properties.

Design: This study used a cross-sectional clinical measurements by using digital instrumented grip and pinch dynamometers (Jamar Plus™).

Methods: The study was reviewed and approved by a university institutional review board (IRB#638). Dominant hand (“handedness”) was assessed at the outset by 3 questions related to participants preferred hand use for writing, eating with a utensil, and throwing a ball. The protocol used was modified and adapted from the American Society of Hand Therapy (ASHT). A single practice trial at less than full force and 1 maximal test trial were completed with each hand for grip and for the following standardized pinch tests: tip to tip (i.e., thumb with index finger), lateral key pinch (i.e., thumb with middle phalanx of index finger), and palmar pinch (i.e., pad to pad pressure between thumb, index, and long/middle finger). Digital readings of force production were recorded in pounds.

Statistical Analysis: Strength performance for grip and pinch was categorized by age (decade) and gender with descriptive statistics and 2 × 2 ANOVA for age group by gender.

Results: In total, 171 normal volunteers (61% female volunteers; age range, 18 and 90 [36 ± 19.8] years; BMI, 26 (± 5.5) kg/m²) participated in the study. The right hand was determined to be dominant in 76% of the male volunteers and 92% of female volunteers. Generally, male volunteers had greater hand grip and pinch strength than female volunteers across the age groups. Strength peaked in the 30’s and decreased over time, with a marked decrease in strength noted in the sixth decade. Both the hand grip and pinch strength values obtained in the current study were found to be consistently lower (from 5% up to 40%) than the classic reference values reported by Mathiowetz et.al. The differences were the most notable in the younger age groups (under 50 years).

Conclusions: Normative hand grip and pinch strength values need to be further assessed in a larger study to update normative reference standards for use in clinical practice.

Clinical Application: Hand grip strength has been used to characterize total body strength and predict mortality, postsurgical complications, and future disability. Muscle strength often declines with age and has been associated with increased risk of falls, hip fractures, loss of bone mineral density, long-term survival in severe congestive heart failure, functional dependence in older adults (>75 years), prediction of hospital length of stay, and loss of functional status in hospitalized patients. The Jamar Plus (digital) hand and pinch gauge dynamometers are simple, cost-effective, and easy to use. Health-care providers

Jamar Plus™ normative hand grip and pinch strength values in an adult population: pilot findings

J.A. Brosky, 1 L. Miller, 1 N. Ayotte, 1 S. Quinn, 1 R.V. Topp, 2 T. Williams, 1 and I. Haas 1

1Bellarmine University, Louisville, KY
2University of San Diego School of Nursing and Health Science, San Diego, CA

Background: Adequate hand grip and pinch strength are important for everyday functional tasks. These measures of function have been used by health professionals to determine progress of rehabilitation programs following upper extremity injury or surgery and safe return to work or sports, or as a component of physical examinations. Hand grip strength has also been used to as an indicator of fragility, predictor of hospital length of stay, postoperative complications, and cardiovascular mortality in older adults. Commonly used normative reference values were developed over 30 years ago, and contemporary normative value tables are needed as new and improved digital instrumentation has been introduced.

Purpose: The purpose of this study was to evaluate grip and pinch strength in adults using the Jamar Plus™ (digital) hand and pinch gauge dynamometers and to compare these results to previous normative tables.
should consider incorporating regular grip and pinch assessments into all physical examinations, as these evaluations can be simple yet important physiological measures of vitality similar to heart rate and blood pressure.

---

**The effect of progressing ankle brace restriction on walking and running gait characteristics in healthy individuals**

Jena Etnoyer-Slaski,¹ Jay Greenstein,¹ Barton N. Bishop,¹ and Robert Topp²

¹Sport and Spine Rehab Clinical Research Foundation, Rockville, MD
²University of San Diego School of Nursing and Health Science, San Diego, CA

**Background:** In 2010, the nationwide incidence of ankle sprains has been estimated to be 1,016,282, with a greater incidence in female individuals and individuals of age ≥25 years. Among individuals with a history of ankle sprains, 32%–74% report chronic symptoms, recurrent ankle sprains, and/or perceived instability. Ankle braces are used both prophylactically to prevent first time injuries among athletes participating in sports considered high risk for ankle sprains (e.g., volleyball, basketball, soccer) and more commonly to prevent recurrent ankle sprains. Ankle braces have been found to restrict ankle joint range of motion during activity while not negatively affecting performance. There is a large selection of ankle braces in the market offering varying levels of support. This makes it difficult for an individual to know what brace is needed for their condition that also meets their satisfaction for comfort.

**Purpose:** The purpose of this study is to determine the differences in gait characteristics and user satisfaction when walking and running while wearing 4 different ankle braces in a healthy population.

**Methods:** A total of 20 healthy individuals, ≥18 years (average age, 31.1 years), comprised this convenience sample. Participants were excluded if they reported being pregnant or being treated for a musculoskeletal injury. After providing explanation of the study and obtaining consent, each participant completed background information and the Cumberland Ankle Instability Tool (CAIT). Participants then completed a 1-min, 3-mpg walking gait assessment unbraced, followed by a 2-min, 6-mpg unbraced running assessment. Following the unbraced condition, participants were randomly assigned into 1 of the following 4 conditions: (1) 329 Ankle Sleeve, (2) AS1Pro, (3) Eclipse 1, or (4) Eclipse 2. Participants placed an assigned brace on each ankle and then repeated the walking and running assessments. Next, the participants filled out a 10-item satisfaction questionnaire, and were randomly assigned a second brace. The protocol was repeated until they completed the walking, running, and satisfaction survey in all 4 brace conditions.

**Outcome Measures:** The last 30 s of the walk and run assessments were used as the data collection periods. Data collected were averaged over the 30 s and included knee (flexion/extension), ankle (dorsiflexion/plantarflexion), and foot (inversion/eversion), and bilateral step length. Brace satisfaction scores questionnaire consisted of 10 items using a 7-point Likert scale ranging from 1 (extremely dissatisfied) to 7 (extremely satisfied) and included characteristics of appearance, ease of application, fit, comfort while walking and running, stability, interference with ability to move, ability of brace to prevent ankle injury, and overall satisfaction.

**Statistical Analysis:** Descriptive statistics were calculated to determine if the assumptions of parametric statistics were met. Once the data were validated and the assumptions were met, a series of repeated-measures ANOVA statistics were calculated. Each measure of walking and running gait characteristics were tested in the model over 5 conditions (4 braces and 1 unbraced condition). If any of these statistics showed a significant main effect (P < 0.05), the means across the 5 data collection points were further evaluated with Tukey post hoc comparisons. The same model was used to examine each of the 10-satisfaction questions separately and then when these 10 scores are summed to a total satisfaction score.

**Results:** There was a significant difference in 7 of the 10 satisfaction questions where the 329 Ankle Sleeve had greater satisfaction than all of the bracing conditions. These satisfaction questions were appearance, ease of application, fit, walking comfort, running comfort, overall comfort, and overall satisfaction. During the walking phase of the study, there was significantly greater ROM, with both baseline and 329 Ankle Sleeve being greater than AS1Pro and E2 for left knee flexion (P = 0.000, baseline = 59.34, 329 Ankle Sleeve = 58.22, AS1Pro = 56.65, E2 = 56.645) and right knee flexion (P = 0.002, baseline = 58.45, 329 Ankle Sleeve = 58.63, AS1Pro = 56.155, E2 = 55.63). When running, the E2 brace was significantly less than baseline and 329 Ankle Sleeve for right (P = 0.004) and left (P = 0.004) foot supination/pronation at heel strike. Additionally, both the baseline (x = 8.79) and 329 Ankle Sleeve (x = 8.17) were significantly greater (P = 0.001) than the AS1Pro (x = 5.365) for left foot supination/pronation foot-off. The
E2 ($x = 3.735$) was significantly less ($P = 0.001$) than all other conditions (baseline = 8.79, 329 Ankle Sleeve = 8.17, AS1Pro = 5.365, E1 = 6.71) for left foot supination/pronation foot-off when running. **Clinical Relevance:** The use of ankle braces is common among many athletes. However, when faced with choosing what brace to use, many do not know the difference between the braces. The results of this study support previous literature in finding that the semi-rigid brace allows normal sagittal ankle motion while limiting frontal plane ankle range of motion when running. However, the 329 Ankle Sleeve provided greater satisfaction when walking and running among users than all other braces. Therefore, a brace should be chosen on the basis of the level of restriction needed as well as the comfort.

**Quadriceps femoris muscle force production using a portable neuromuscular electrical stimulation device**

I. Khuzeykin,¹ S. Coppinger,² M. Varnell,³ K.J. Silva,³ and J.A. Gallo³

¹North Reading High School, North Reading, MA, USA
²Lahey Hospital, Burlington, MA, USA
³Salem State University, Salem, MA, USA

**Background:** Previous literature indicates that neuromuscular electrical stimulation (NMES) devices capable of producing quadriceps femoris force of ≥50% of maximal volitional isometric contraction (MVIC) play an important adjunctive role in optimizing quadriceps strength during rehabilitation. The current evidence supporting force-generating capabilities of portable battery-powered NMES devices has been inconsistent.

**Purpose:** The purpose of this study was to test the force-generating capacity of a portable battery-powered NMES device.

**Design:** The research setting was an athletic training research laboratory. In total, 24 healthy individuals (women, 13; men, 13; age range, 18 to 35 years) were included in the study. The study was conducted at an experimental laboratory study using repeated measures.

**Methods:** An InTENSity Select Combo II Model DI2195 (Compass Health, Middleburg Heights, OH) was used to deliver NMES to the quadriceps femoris at maximum tolerable intensity. The device was set to a symmetrical biphasic waveform with a phase duration = 200 ms, frequency = 50 pps, ramp = 2 s, on-time = 10 s, and off-time = 60 s. A 2.75 × 5.0 inch Dura-Stick Plus self-adhesive electrode (DJO, Vista, CA) was placed over the vastus lateralis and vastus medialis oblique. A handheld manual muscle testing dynamometer (Lafayette Instrument, Lafayette, IN) was used to measure peak isometric force (kg) and average isometric force (kg). The peak isometric force (kg) produced over 3 trials was used to calculate % MVIC.

**Statistical Analysis:** Descriptive statistics were used for statistical analysis.

**Results:** The InTENSity Select Combo II produced an average peak isometric force of 54.1% ± 19.5% of the MVIC in 24 subjects. This was higher than the peak isometric force of 50% MVIC that was found to be effective in previous studies.

**Conclusions:** Based on the findings of this study, the InTENSity Select Combo II has the capacity to produce the necessary level of force to effectively deliver high intensity NMES to the quadriceps femoris.

**Clinical Application:** The InTENSity Select Combo II can be issued to patients undergoing postsurgical knee rehabilitation to overcome neural inhibition and enhance quadriceps strength recovery. This is especially important given that persistent quadriceps strength impairment is the single biggest impairment in the postsurgical knee. Previous literature has shown 15%–26% greater strength gain at 3–6 weeks postoperatively in patients who had high-intensity NMES added to standard postoperative knee rehabilitation. High-intensity NMES added to standard care in the first 6 weeks postoperatively appears to have the greatest impact on quadriceps strength recovery.

**Therapeutic ultrasound and short wave diathermy: dosing to induce vigorous heating prior to stretching, soft tissue mobilization, and joint mobilization techniques**

J.A. Gallo and K.J. Silva

Salem State University, Salem, MA, USA

**Background:** Preheating subcutaneous tissue immediately prior to stretching, joint mobilization, and soft tissue mobilization techniques have been common practice in the rehabilitation field. Superficial heating agents such as moist heat can only penetrate to within 1 cm of the surface of the skin, and are often not effective in elevating subcutaneous tissue temperature to the therapeutic level of vigorous heating (≥4°C above baseline). Therapeutic ultrasound and short wave diathermy have been advocated for
increasing intramuscular and intratendon tissue temperature from baseline temperature of \(\sim36^\circ C\) to absolute tissue temperatures of \(\geq40^\circ C\) (vigorous heating).

**Purpose:** The purpose of this study was to develop a clinical dosing model for the application of therapeutic ultrasound and short wave diathermy that will guide clinicians in selecting parameters that will produce vigorous heating levels in muscle and tendon. The dosing model will consider the size of the target tissue, tissue depth, tissue composition, and the stretching window post treatment.

**Design:** This study used a systematic literature review design.

**Methods:** The following databases were searched for original articles: MEDLINE, SportDiscus, and PEDro.

**Statistical Analysis:** Systematic literature review demonstrates the capacity of ultrasound and short-wave diathermy to elevate tissue temperatures to therapeutic levels.

**Results:** Properly dosed therapeutic ultrasound and short wave diathermy have the capacity to elevate intramuscular and intratendon tissue temperatures to \(4^\circ C\) above baseline temperature, yielding absolute temperatures of \(\geq40^\circ C\) (vigorous heating).

**Conclusions:** Sufficient therapeutic ultrasound and short wave diathermy data exist to guide parameter selection necessary to induce vigorous heating. The available data have been used to develop a clinical dosing model to guide parameter selection necessary to approximate the vigorous heating level that has been produced in research studies. Some variance between device manufactures should be expected.

**Clinical Application:** Effective heating with therapeutic ultrasound is limited to \(\sim2\) times the size of the ultrasound applicator head, making it best suited for smaller areas. Therapeutic ultrasound is an inefficient heater of deep muscle and can take up to 14 min of sonation to heat deep tissue (up to 5 cm in depth); 3 MHz of therapeutic ultrasound creates an efficiency of heating in superficial tissues within 2.5 cm for the surface of the skin. Collagen-rich tissues such as superficial tendons preferentially absorb ultrasound. Superficial tendons can reach vigorous heating within as little as 4 min of sonation. Short wave diathermy can effectively heat larger areas with up to 5-cm depth of penetration. Short wave diathermy is preferentially absorbed in muscle. Deep muscle tissue temperature can be elevated by \(4^\circ C\) within 15 min of treatment with properly dosed short wave diathermy. During thermotherapy treatments, it is important to begin the time at end-range stretching as the tissue temperature is approaching peak temperature toward the tail end of the treatment. It is also important to perform additional stretching, joint mobilization, and soft tissue techniques beginning immediately after the thermotherapy treatment. The stretching window after therapeutic ultrasound is 3.3 min for muscle and 5 min for tendon and ligament. Short wave diathermy extends these stretching windows. These stretching windows are increased by 3 times when thermotherapy is delivered with short wave diathermy.