Dynamic Compression Enhances Pressure-to-Pain Threshold in Elite Athlete Recovery: Exploratory Study

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Abstract

Sands, WA, McNeal, JR, Murray, SR, and Stone, MH. Dynamic compression enhances pressure-to-pain threshold in elite athlete recovery: exploratory study. *J Strength Cond Res* 29(5): 1263–1272, 2015—Athlete recovery-adaptation is crucial to the progress and performance of highly trained athletes. The purpose of this study was to assess peristaltic pulse dynamic compression (PPDC) in reducing short-term pressure-to-pain threshold (PPT) among Olympic Training Center athletes after morning training. Muscular tenderness and stiffness are common symptoms of fatigue and exercise-induced muscle microtrauma and edema. Twenty-four highly trained athletes (men = 12 and women = 12) volunteered to participate in this study. The athletes were randomly assigned to experimental ($n = 12$) and control ($n = 12$) groups. Pressure-to-pain threshold measurements were conducted with a manual algometer on 3 lower extremity muscles. Experimental group athletes underwent PPDC on both legs through computer-controlled circumferential inflated leggings that used a peristaltic-like pressure pattern from feet to groin. Pressures in each cell were set to factory defaults. Treatment time was 15 minutes. The control group performed the same procedures except that the inflation pump to the leggings was off. The experimental timeline included a morning training session, followed by a PPT pretest, treatment application (PPDC or control), an immediate post-test (PPT), and a delayed post-test (PPT) after the afternoon practice session. Difference score results showed that the experimental group's PPT threshold improved after PPDC treatment immediately and persisted the remainder of the day after afternoon practice. The control group showed no statistical change. We conclude that PPDC is a promising means of accelerating and enhancing recovery after the normal aggressive training that occurs in Olympic and aspiring Olympic athletes.

Key Words muscle microtrauma, training adaptation, elite athletes, muscle tenderness

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Introduction

Athletes have always looked for advantages in training and competition to obtain an "edge" on their opponents. Highly trained athletes undergo rigorous training that results in muscle microtrauma (3,20) and exercise-induced inflammation (13,31,41). Avoiding, reducing, and recovering from the small- and large-body traumas from training and competition are a crucial aspect of athlete training, one that has received widespread interest only recently. Diverse scientific and medical areas have begun collaboration in athlete recovery, including physical therapy, athletic training, massage therapy, and nutrition. The goals of these collaborations are to enhance performance of athletes by reduction of fatigue and soreness and enhancing and accelerating specific training adaptations (49). As an indication of the seriousness of these trends, training terminology and methodology have embraced the concept of "recovery-adaptation" as central to the modern understanding of high-performance athletic training (52). Moreover, national Olympic, business entities, and other organizations have built expensive facilities designed to centralize the implementation of recovery modalities and methods to enhance recovery-adaptation (9).

Recovery is defined as returning something that was lost. Athletes need more than to return to a state before a training stress; athletes also need to adapt to the stress by increasing their sport- or task-specific fitness. There is a natural unity of training stress, recovery, and adaptation that coaches and athletes strive to exploit for performance enhancement (27) (pp. 65–66). Training stress results in exercise-induced injury and inflammation. These symptoms are commonly observed as muscle tenderness, swelling, and movement impairment (10). Moreover,

athletes and coaches often simply refer to these symptoms as fatigue, overtraining, or overreaching–the price of high-performance sport. The sport world is rapidly embracing the therapeutic arts and sciences to obtain the benefits of recovery methods designed to combat the entire spectrum of fatigue-related performance impairments. One method that has received attention is muscle and limb compression. The use of compression to reduce hemorrhage, cell necrosis, ischemia, impaired function, local tenderness, and proteolytic enzyme action dates from the time of the gladiators (37) (pp. 4–5). Modern approaches have included static compression through specific garments designed to compress the limbs and torso. Dynamic compression has involved manual compression (e.g., massage) and mechanical compression using special devices such as garments that envelop the limbs and inflatable circumferential fabric cells.

Forms of static and dynamic compression have shown promise in edema reduction, enhanced lymphatic return, increased blood flow, and pain reduction (15). Compression may be a beneficial adjunct for athlete recovery (17,19). However, information on the practical aspects of recovery modalities and their effectiveness has been equivocal. Writing about fatigue management after the Beijing Olympic Games, Australian sport scientists wrote: "We conclude that well-accepted methods such as sufficient nutrition, hydration, and rest seem to be the most effective strategies for optimizing recovery in Olympic athletes." (46) (pp. 1409). The previous statement is paradoxical based on Australia's recognized leadership in the implementation of special recovery methods and facilities (46). Moreover, modern recovery methods and technologies are relatively new and merit continued investigation.

Literature on the effects of static compression use in recovery is unclear (17). In contrast, the dynamic compression literature is nearly uniformly favorable, indicating that this modality may provide an optimized recovery tool that may enhance lymphatic drainage with less risk to distal lymphatic valves than thermal applications, massage, active recovery, and passive recovery. As such, dynamic compression may accelerate recovery by the aforementioned mechanisms (28,35,38). Research to assess the effectiveness and potentially optimize the modes, methods, timing, and other aspects of dynamic compression is necessary to determine the efficacy of peristaltic pulse dynamic compression (PPDC) with high-performance athletics.

The purpose of this study was to assess the efficacy of PPDC on pressure-to-pain threshold (PPT) with highly trained, international level athletes undergoing normal aggressive training. Efficacy of the PPDC was operationalized as an increase in the level of pressure required to elicit a pain stimulus. Pressure-to-pain threshold served as the means of measuring exercise-induced muscle trauma. Peristaltic pulse dynamic compression was compared with a control treatment.

Methods

Experimental Approach to the Problem

Fatigue is a ubiquitous aspect of athlete training. Fatigue can be categorized as central or peripheral (47) and is measured through performance decrements as seen in the inability to attain a previous maximal force or torque or an inability to avoid task failure in multiple repetitions of an exercise (56). However, fatigue mechanisms and symptoms are also seen in: metabolism (55), muscle activation (42), thermal extremes (11), and pain (8). Moreover, the expression of fatigue may be systemic or local (55), sport- or task-specific (26), dominant fiber-type–specific (55), tension-type–specific (44), and technique- and time-dependent (25). Figure 1 shows an example of muscle soreness from recovery monitoring among Olympic level track cyclists. As such, PPT was chosen as the criterion measure for this study for the following reasons:

1. Fatigue is often measured by physical performance decrements such as maximal force changes and task failure (56). However, fatigue is manifested and measurable in a variety of other ways. Using maximal force or task failure methods with this intact, multisport population was not possible because the athletes and coaches would not permit a sport scientist to influence ongoing training by using an arbitrary fatigue test that could contaminate the athlete's physical status (40).
2. Maximal force and task failure tests will not be sport-specific for all sports in this study. Therefore, PPT was chosen because pain tends to permeate all sports and sport fatigue states. High-performance athletes express their soreness and fatigue in muscle-specific ways (40) (Figure 1).
3. Athletes and coaches protect their time jealously and thoroughly. A fatigue-related test could not involve more than a few minutes if the athletes and coaches were going to participate and could not serve as a fitness or fatigue stimulus that could disturb current training (48,52).
4. Pain, discomfort, and muscular tenderness manifests across most forms of fatigue (2,10,39,43), pain tends to be idiosyncratic (4,6) and muscle, but not muscle region, specific (6).

The primary common means of measuring PPT is through an algometer. Algometers have been used in many investigations of muscular pain and DOMS and found to be both reliable and valid across a number of populations, muscles, and conditions (2,34).

Subjects

The population of interest was highly trained men and women internationally competitive athletes from the US Olympic Training Center (USOTC) in Colorado Springs, CO, USA. The population of resident athletes at the USOTC includes more than a dozen sports and over 100 highly trained athletes. Moreover, the USOTC had recently constructed a recovery center that served as the facility dedicated to investigating the means of accelerating athlete recovery. Thus, this experiment used athletes from several

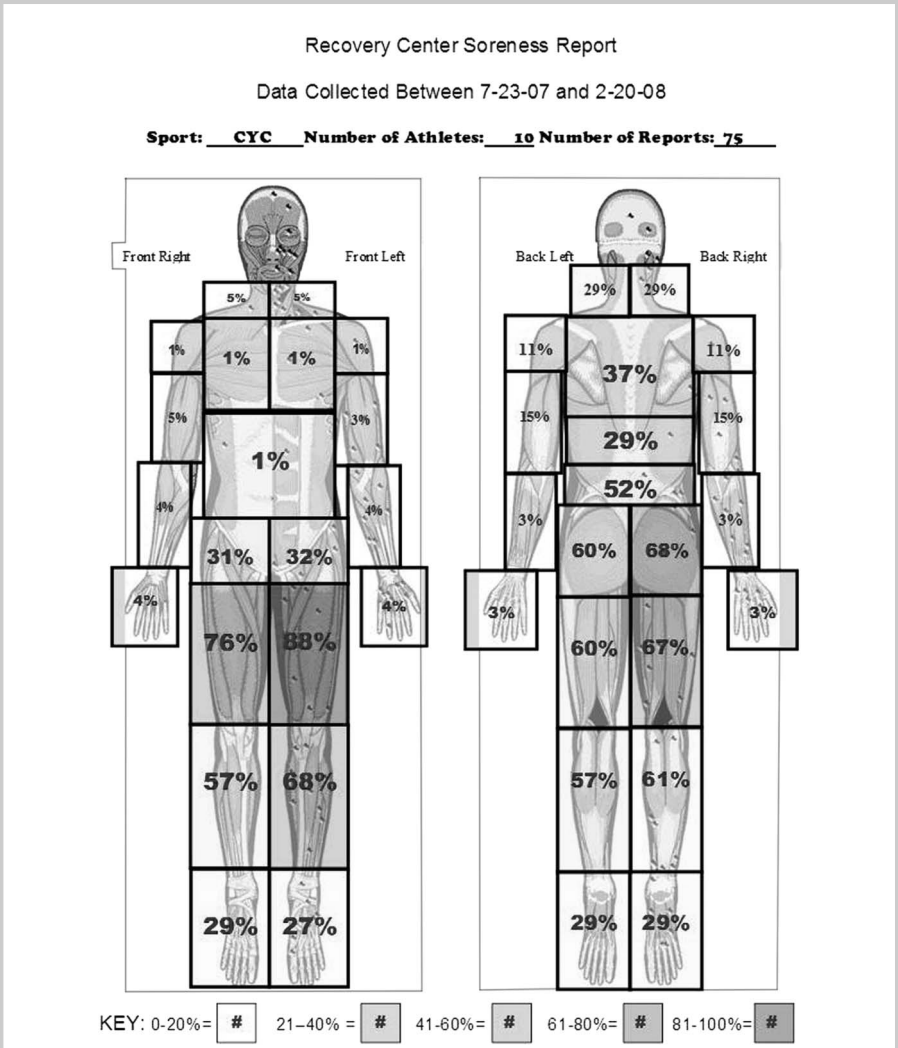

Figure 1. Athlete soreness report. Note the percentages of reports for specific muscles and the lack of bilateral symmetry in these reports. The figure shows that muscle soreness may be expressed in different levels by different muscles. The primary reason for the lack of bilateral symmetry in this report figure is because track cyclists are constantly turning left stressing the left leg.

sports. All subjects were resident athletes living and training at the USOTC, with regular access to the USOC Recovery Center. Consequently, a comparable control group for such a unique population was nearly impossible to obtain, and sample sizes were modest (51).

Subjects ($N = 24$; Table 1) were a volunteer convenience sample of resident national team athletes from multiple sports training at the USOTC in Colorado Springs, CO. Female subjects were between the ages of 18 and 36 years. Male subjects were between the ages of 23 and 40 years. Treatment and testing were conducted at the Recovery Center on the U.S. Olympic Committee complex. Sports represented were (sport, number of athletes) freestyle wrestling, 3; Greco-Roman wrestling, 3; triathlon, 3; track cycling, 1; weightlifting, 8; gymnastics, 4; modern pentathlon, 1; and shooting, 1. The athletes were regular attendees of the Recovery Center. Athletes were randomly assigned to one of 4 groups by sex and condition (PPDC vs. control). This investigation was approved by the Colorado Mesa University and East Tennessee State University Institutional Review Boards on the Study of Human Subjects. Athlete characteristics are shown in Table 1. After agreeing to participate in the study, the athletes were asked to return on a day of their convenience that involved 2 training sessions, morning and afternoon.

Study participants were active national team athletes participating in aggressive training in their respective sports. Despite training at the U.S. Olympic Training Center, training loads were not monitored and training diary records were not maintained by most of these athletes and coaches. Furthermore, these athletes faced enormous time demands occupied by multiple training sessions, school, work, competitions, and other commitments. Therefore, this study was designed and implemented such that training time intrusions were minimized.

Procedures

Pressure-to-pain threshold was measured using a manual algometer (Force One, FDIX 50; Wagner Instruments, Greenwich, CT, USA). The algometer is a handheld device with an integral load cell that transduces the pressure applied to the subject through a 0.11-cm diameter round solid contact surface. The algometer had a capacity of 222.4 N (50 lb), mass 0.4 kg, and dimensions of 70 × 100 × 30 mm. Sampling was 100 Hz. The accuracy and linearity of the algometer were tested by comparison with a small 1-dimensional force platform (PASCO, CI-6461, Roseville, CA. USA). The algometer was placed vertically and manually pressed against the center of the force platform. The force platform sampled at 100 Hz. Sampling

Table 1. Subject characteristics.*

Group	Age (y)	*SD*	Height (cm)	*SD*	Mass (kg)	*SD*	*N*
Sex–condition							
Male–PPDC	23.3	2.0	176.7	10.4	77.8	9.1	6
Female–PPDC	23.5	6.8	159.8	9.1	69.5	17.2	6
Male–control	26.2	7.1	174.5	10.5	75.9	17.7	6
Female–control	23.3	2.6	162.5	6.5	59.6	5.2	6

*PPDC = peristaltic pulse dynamic compression.

began when the algometer was held in a still position. The correlation for the paired forces from the algometer and the force platform over 100 samples was $r = 0.99+$ (standard error of estimate = 0.32 N). The algometer was considered reliable and valid (12,36).

Peristaltic pulse dynamic compression (NormaTec, Newton Center, MA, USA) was used for compression treatments of the lower extremities of the subjects. Peristaltic pulse dynamic compression is used primarily for the reduction of edema, enhancement of lymph and blood flow, and subsequent wound healing in the extremities (53). The device consisted of 2 separate "pant legs" or "leggings," with 5 circumferential inflatable chambers encircling the legs and covering the legs from feet to groin. Total length of each pant leg was approximately 85 cm. The different chambers, when laid flat had the following dimensions, proceeding from the foot to the crotch: 17 × 17 cm, 32 × 17 cm, 37 × 17 cm, 42 × 17 cm, and 42 × 17 cm. Peristaltic pulse dynamic compression cells inflation pressures and durations were controlled by a computerized air pump. A single 180-cm hose from the pump unit bifurcated to attach separately to each compression legging followed by smaller hoses going to each of the 5 leg chambers. While the pressure and rest periods of each cell can be programmed, factory defaults were used in this investigation for all chamber pressures. The foot chamber used a pressure of 70 mm Hg, whereas all the remaining chambers were inflated to 80 mm Hg. Pulse times were constant at 30 seconds in each chamber. Rest times per chamber were 30 seconds. Each total PPDC treatment session was programmed to last 15 minutes. The computerized pump controlled all cell pressures and durations. The PPDC device produced a patented and proprietary peristaltic-like waveform for intracell and intercell pressures. The peristaltic pulse dynamic compression devices were untested in an athlete recovery setting before this study (Figure 2).

Participating athletes reported to the USOTC Recovery Center after morning training for their first testing and treatment session. On arrival, the athletes were measured for height, mass, and queried for age. Familiarization with the algometer test procedure followed. The thenar muscle of the right hand was used as the example muscle for familiarization of the athlete with the PPT procedures. Athletes were shown the digital display of the algometer as increasing pressure was applied so that the athlete could see the change in force as the pressure on the muscle was manually increased. The athletes were asked to pay close attention to the pressure sensation experienced from the thenar muscle. When the pressure sensation shifted to a pain sensation, the athletes were asked to announce "stop." Athletes were told that this was not a test of "guts" to reduce the athletes' motivations to "compete" and unduly attempt to withstand pain. Athletes underwent 3 trials of the initial familiarization with the algometer and PPT.

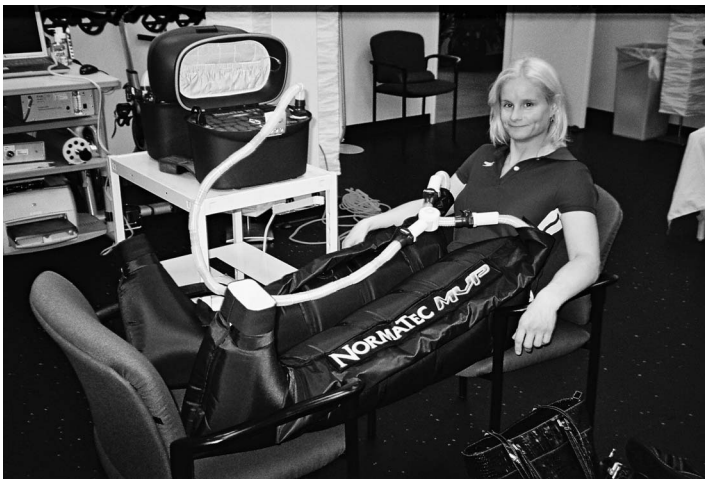

Figure 2. Peristaltic pulse dynamic compression leggings.

The algometer pretests were followed with marking a "dot" on 3 muscle bellies (6) with a permanent marker (lateral gastrocnemius, biceps femoris, and vastus lateralis) at the center of the skin depression circle. Algometry proceeded in a randomly selected order and on a randomly selected leg (6).

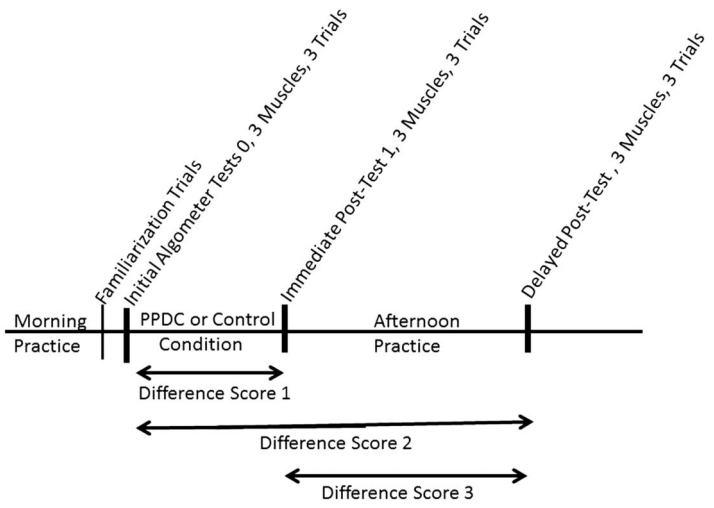

Figure 3. Experimental timeline showing the sequence of experimental activities.

Three measurement trials per muscle were performed. Algometer measurements have been shown to be stable intraclass correlation coefficients with internal consistency values (ICCs) ranging from 0.70 to 0.94 (22). Testing was performed with the participant lying prone and supine on a massage table. The athlete and the investigator were blinded to the results as testing proceeded by turning the digital display away from the view of both athlete and investigator. The same tester performed all algometer assessments (2).

After the pretest, each athlete underwent a treatment that consisted of PPDC in a seated position for 15-minutes with legs held horizontally and supported by a chair or a control treatment where the subject donned the compression pant legs and sat in the chair with legs horizontal for 15 minutes. Thus, the control condition mimicked the PPDC condition except the inflation pump was not turned on. After the 15-minute use of the PPDC leggings, the participants underwent an immediate post-test as described in the previous paragraph. The athletes were dismissed and did their normal daily activities until their afternoon practice. After their afternoon practice, the

Table 2. Descriptive statistics: PtPT, test session × sex × muscle ($N \cdot cm^{-2}$).

	Control condition $n = 12$	Female Mean	$n = 6$ *SD*	Male Mean	$n = 6$ *SD*
Initial test	Lateral gastrocnemius	49.3	9.9	73.4	21.2
	Biceps femoris	64.3	18.5	86.7	31.4
	Vastus lateralis	55.0	23.3	68.7	21.5
Immediate post-test	Lateral gastrocnemius	49.6	8.9	64.5	16.4
	Biceps femoris	56.2	13.7	79.2	20.9
	Vastus lateralis	45.9	15.4	64.4	24.6
Delayed post-test	Lateral gastrocnemius	48.0	10.4	65.2	13.4
	Biceps femoris	55.4	16.8	74.1	10.5
	Vastus lateralis	44.1	15.1	67.9	16.0
	PPDC condition $n = 12$	Female Mean	$n = 6$ *SD*	Male Mean	$n = 6$ *SD*
Initial test	Lateral gastrocnemius	53.5	17.4	58.1	16.7
	Biceps femoris	52.9	13.4	64.4	13.4
	Vastus lateralis	46.2	8.3	52.9	9.9
Immediate post-test	Lateral gastrocnemius	59.5	12.3	69.5	17.6
	Biceps femoris	61.2	13.3	86.0	15.5
	Vastus lateralis	57.6	7.1	67.5	14.8
Delayed post-test	Lateral gastrocnemius	61.5	14.1	76.5	9.3
	Biceps femoris	61.1	12.7	78.2	10.3
	Vastus lateralis	60.5	8.1	58.2	11.2

Table 3. Descriptive statistics: difference scores, difference × sex × muscle ($N \cdot cm^{-2}$).

Difference score	Control condition $n = 12$	Female Mean	$n = 6$ SD	Male Mean	$n = 6$ SD
Initial test–immediate post-test	Lateral gastrocnemius	−0.30	10.41	8.89	7.49
	Biceps femoris	8.08	10.88	7.51	16.01
	Vastus lateralis	9.09	13.61	4.26	5.02
Initial test–delayed post-test	Lateral gastrocnemius	1.33	7.02	8.20	12.76
	Biceps femoris	8.08	10.88	7.51	16.01
	Vastus lateralis	10.89	11.60	0.74	11.62
Immediate post-test–delayed post-test	Lateral gastrocnemius	1.63	10.81	−0.69	8.34
	Biceps femoris	0.74	13.13	5.09	13.74
	Vastus lateralis	1.80	3.97	−3.51	12.27
	PPDC condition $n = 12$	Female Mean	$n = 6$ *SD*	Male Mean	$n = 6$ *SD*
Initial test–immediate post-test	Lateral gastrocnemius	−6.07	11.32	−11.39	10.78
	Biceps femoris	−8.22	9.28	−21.59	8.10
	Vastus lateralis	−11.46	5.99	−14.62	5.69
Initial test–delayed post-test	Lateral gastrocnemius	−7.98	17.70	−18.41	10.35
	Biceps femoris	−8.22	9.28	−21.59	8.10
	Vastus lateralis	−14.29	12.84	−5.31	10.64
Immediate post-test–delayed post-test	Lateral gastrocnemius	−1.91	13.70	−7.02	10.27
	Biceps femoris	0.03	6.74	7.73	5.89
	Vastus lateralis	−2.83	10.96	9.31	14.12

Table 4. Repeated measures analysis of variance–difference scores results.

Variable	*df*	*F*	Sig	$\eta^2_{partial}$	Power
Between subjects					
Sex	1	0.41	0.53	0.02	0.09
Condition	1	31.58	<0.001*	0.61†	1.00
Sex × condition	1	0.22	0.65	0.05	0.01
Error	20				
Within subjects					
Test difference	2	2.48	0.1	0.11	0.47
Test difference × sex	2	0.96	0.39	0.05	0.21
Test difference × Condition	2	13.55	<0.001*	0.40†	1.00
Test difference × sex × condition	2	1.6	0.21	0.07	0.32
Error	40				
Muscle	2	0.33	0.72	0.16†	0.10
Muscle × sex	2	0.14	0.87	0.01	0.07
Muscle × condition	2	0.53	0.59	0.03	0.13
Muscle × sex × condition	2	4.52	0.02*	0.18†	0.74
Error	40				
Test difference × muscle	4	1.87	0.12	0.09	0.54
Test difference × muscle × sex	4	3.68	0.008*	0.16†	0.86
Test difference × muscle × condition	4	3.00	0.023*	0.13†	0.78
Test difference × muscle × sex × condition	4	1.28	0.29	0.06	0.38
Error	80				

*$p \leq 0.05$.
†Large effect-size estimate.

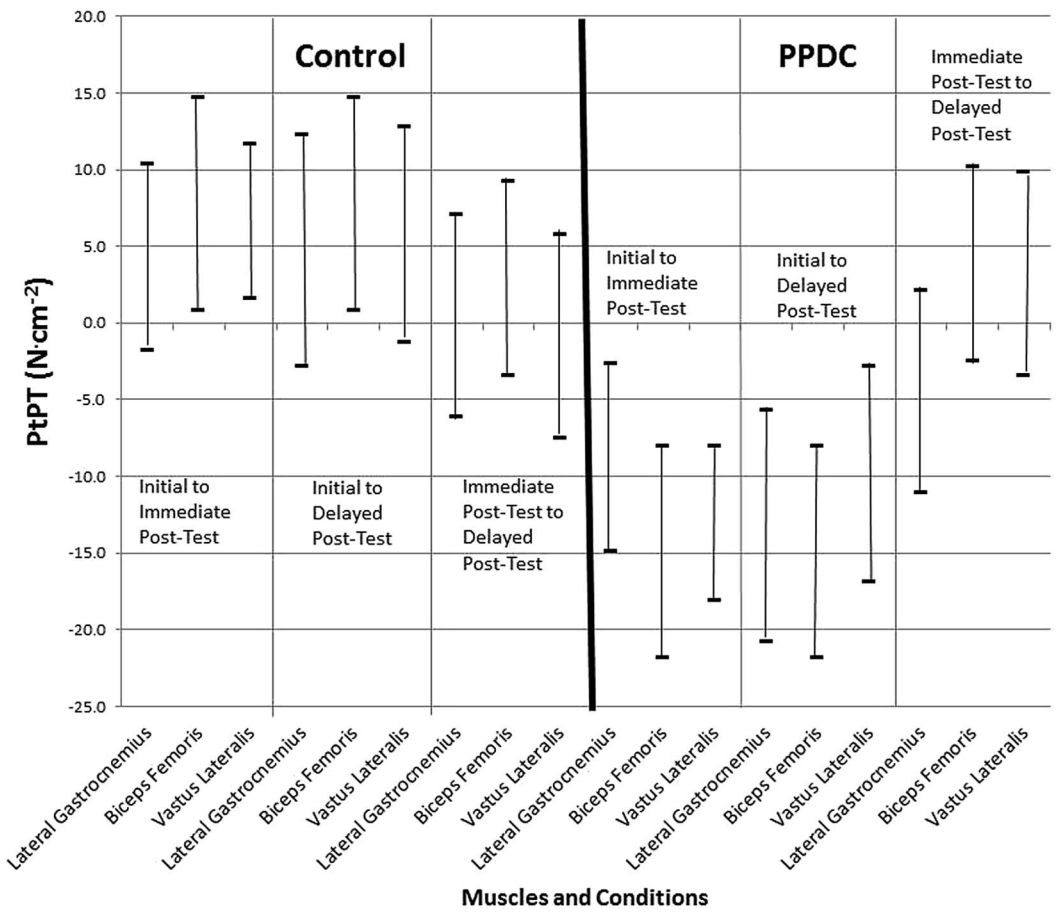

Figure 4. Ninety-five percent confidence intervals for all treatment and control conditions across muscles. Note that the peristaltic pulse dynamic compression condition shows confidence intervals that support the factorial analysis of variance and effect size statistics.

athletes returned to the USOTC Recovery Center and were retested in a delayed post-test duplicating the algometry methods as described above. The PPDC was used only after the morning practice and initial PPT test. In summary, Figure 3 shows the timeline of the activities, tests, and treatments. Athletes were never informed of their algometer force readings.

Statistical Analyses

Data were assessed for normality assumptions and analyzed for internal consistency (Cronbach's alpha), followed by calculation of the mean of the trend-free trials for further analyses. Descriptive statistics (mean and *SD*) and a 4-way factorial analysis of variance (ANOVA) with repeated measures on the last 2 dimensions (Sex[2] × Condition[2] × Difference Score[3] × Muscle[3]) were calculated. The difference scores were obtained by subtracting the immediate post-test 1 algometer PPT scores from the initial algometer PPT test 0 scores (difference score 1), subtracting the delayed post-test 2 scores from the initial algometer PPT test 0 (difference score 2), and subtracting the immediate post-test algometer test 2 scores from the second post-test algometer test 3 scores (difference score 3) (Figure 3). After the 4-way repeated measures ANOVA, post hoc analyses were conducted by examining the 95% confidence intervals of all PPT variables. Statistical significance was set at $p \leq 0.05$. Effect size estimates and statistical power values were included. Effect size estimates of $\eta^2_{partial}$ were interpreted as 0.01 = small; 0.06 = medium; and 0.13 = large (21). Given the importance of practical application of the results of this experiment, ecological validity and hypothesis generation were considered of paramount interest (49). Moreover, this study was the first of its kind and thereby serves as a hypothesis generating and exploratory study (32).

Results

Reliability and Sex Differences

All reliability values of PPT values across the 3 trials for all muscles and all test sessions ranged from $\alpha = 0.95$ to $\alpha = 0.98$,

indicating excellent internal consistency. After an initial analysis of the data for common statistical assumption violations and internal consistency, a 4-way repeated measures factorial ANOVA was calculated on the 4 dimensions listed above. Table 2 provides descriptive statistics of the PPT test data by test session, sex, and muscle.

Repeated Measures Analysis of Variance Results

Table 3 provides the descriptive statistics of the difference scores across test session comparisons, sex, and muscles. Table 4 shows the results of the 4-way repeated measures factorial ANOVA on the difference scores. The first, second, and third difference scores were computed across the 3 muscles.

Post Hoc Analysis

Post hoc analyses, 95% confidence intervals, are shown in Figure 4. Note the large differences in the control versus the PPDC analyses (score 1 and score 2), and that the comparisons between post-tests showed no obvious difference. As such, the PPDC resulted in increased PPT (negative values are due to the subtraction of the post-tests from the initial test) and that the post-tests (score 3) did not differ from each other.

Discussion

Algometry has been used successfully to determine the PPT as muscle tenderness in a variety of studies (1,23,30). The main results of interest in this experiment are shown in Table 4 and Figure 4. The PPT of athletes who underwent the PPDC treatment showed that a greater pressure was required to elicit the sensation of the transition from pressure-to-pain. In contrast, the PPT showed no statistical effect in the control condition. The statistical significance values Table 4 were mirrored by effect size estimates with the addition of a large effect size for muscle. Although the muscle effect did not reach statistical significance, the effect size indicated that a large effect was observed (21). Previous research has shown that scapular position influenced algometry measured regions of the trapezius muscle (5). However, different algometer measurement sites on the quadriceps did not show statistical differences (6). The information above seems to indicate that the PPT is stable across muscle locations in most applications and particularly when used on the thigh muscles of adults. Therefore, the PPDC condition treatment seems to be effective in reducing muscle tenderness as measured by PPT.

Sport practitioners rarely appreciate that exercise training results in an inflammatory process with associated edema. Moreover, the inflammation and edema do not have to rise to the level of an acute injury to detract from performance (37). Previous literature has shown that muscle and joint inflammation and edema are natural consequences of vigorous athletic training (10,14,18,24) and eccentric-dominant exercise (16). The inflammatory response can inhibit healing because of an "overshoot" phenomenon that may result in an imbalance of cytokines leading to physiologic fibrosis and the destruction of connective tissue (50). The early stage of edema after muscle microtrauma results in reduced tissue clearance because of the magnitude of extracellular fluid and compromised lymphatic vessel valves (38). Muscle contraction, acting as a local compression pump, has been considered the primary means of moving excess lymphatic fluid from extracellular spaces and venous return during recovery from exercise (28).

Muscle stiffness, tenderness, strength loss, and edema have been linked to exercise-induced muscle microtrauma (31). Enhancement of lymphatic return of proteins, immune cells, cellular debris, and fluid by an artificial means may accelerate recovery. A goal of dynamic compression is to reduce lymphatic obstruction and thereby enhance the removal of the protein- and debris-rich fluid that accumulates in the interstitial spaces after exercise-induced inflammation (29). Under normal conditions, about 10% of the blood plasma is transported to the interstitial space from local capillaries. During exercise, the amount of fluid moved by the lymphatic system can increase 3- to 6-fold (28). The 1-way nature of the lymphatic system results in the lymphatic vessels moving fluid to catchments and then upward to the subclavian veins for elimination of inflammatory debris through the kidneys. During removal of cellular debris from inflammation and lymph movement in general, the lymphatic vessels actively participate using smooth muscle contractions similar to peristalsis (54). However, the edema and collective debris of exercise-induced inflammation may obstruct the lymphatic vessels due to damage to lymphatic walls and fragile lymphatic valves prolonging the inflammatory response and return to normal athletic abilities (38,45). The "clogging" of the distal lymphatic vessels may respond to the peristaltic-like pressures applied in a PPDC treatment.

Peristaltic pulse dynamic compression seems to provide a means of enhancing recovery as shown in this study by the reduction of muscle tenderness obtained from pressure stimuli. Recovery modalities and the implementation of recovery activities may spell the difference between success and failure in modern elite sport. While sport-specific fitness is certainly noteworthy, at the highest levels of performance, amelioration of fatigue may play a larger role in discriminating between highly trained and highly fit athletes (7,33).

Practical Applications

Fatigue is usually defined by the inability to attain or maintain a force level or by task failure. Recovery is usually defined as the return to a previous force level or return of the ability to perform a task. Fatigue and recovery deserve broader definitions that include pain and discomfort. Fatigue may also be manifested by exercise-induced edema with associated pain and soreness. Recovery is promoted by the reduction of pain and discomfort. This initial and exploratory study showed that PPDC is a promising means of reducing PPT in highly trained national team athletes. The

reduction of PPT was coincident with reductions in muscle tenderness that manifested immediately after PPDC treatment and the PPT remained enhanced for several hours after the initial treatment and subsequent training session.

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