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Research Article

Pneumatic Compression Massage Decreases Effects of Delayed Onset Muscle Soreness in Active Females

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Abstract

Background: Eccentric exercise often results in Delayed Onset Muscle Soreness (DOMS) which causes decreases in muscle strength and power with accompanying prolonged pain.

Objectives: The study examined the effectiveness of Pneumatic Compression Massage (PCM) on changes in leg power following DOMS-inducing eccentric hamstring exercises. Pain levels and perceived efficacy of PCM as a recovery method for exercise-induced DOMS was also examined.

Methods: Twenty-one active college-aged female volunteers were randomly assigned to PCM or control groups after performing 4-rounds of eccentric Nordic hamstring exercises to failure after which control subjects sat quietly for 10 minutes while the PCM-assigned subjects wore pneumatic compression massage (PCM) leggings for 10 minutes. All variables were evaluated at baseline and at 1-, 24-, 48-, and 72-hours after the exercise sets.

Results: Movement economy was significantly greater as PCM had significantly faster ground contact time (GCT) at 24-hrs (p=0.01), 48-hrs (p=0.04), and 72-hrs (p=0.03) compared to control subjects. Leg muscle power output was significantly higher in PCM at 24-hrs (p=0.04), 48-hrs (p=0.05), and 72-hrs (p=0.01), while control subjects had significantly more pain at 72-hrs (p=0.02).

Conclusion: PCM applied for 10-minutes every 24-hours following DOMS-inducing eccentric exercise resulted in greater improvements in movement economy, reaction time, jump height, lower limb power, pain, and other DOMS-related symptoms.

Keywords: Recovery; Lower limb power; Pain; Vertical jump height.

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Introduction

Delayed Onset Muscle Soreness (DOMS) can be a common side effect of many athletes' and recreational exercisers' training regimen. It is often experienced by individuals who have recently started a new exercise program, increased the intensity or duration of their workouts, or performed eccentric exercises (where the muscle lengthens under tension) as it is an exercise-induced muscle injury generally occurring after unaccustomed or strenuous exercise [1].

The exact cause of DOMS is not fully understood, but it is believed to be a result of microscopic damage to muscle fibers and the surrounding connective tissues. When muscles are subjected to unfamiliar or intense exercise, such as eccentric contractions, it can lead to tiny tears in the muscle fibers. The damage triggers an inflammatory response and activates pain receptors, resulting in the characteristic symptoms of DOMS.

The temporary agitation to the muscles can lead to temporary decreases in physical performance and strength [2-7], joint range of motion (ROM) [8-10], stretch tolerance [11], and increased passive muscle stiffness [11-12]. Recovery from exercise-induced injuries and general workout fatigue have shown the efficacy of massage [13,14]. Pneumatic compression massage (PCM) is a type of massage therapy that uses circumferential sleeves to massage limbs with pressurized air in a computer-controlled wave-like motion. PCM has been shown to improve flexibility and range of motion [14].

However, PCM has not be studied in an exclusive female population nor has power output, vertical jump height, and other performance indicators have not been studied in females to-date.

The purpose of the study was to evaluate the efficacy of a PCM for the change in leg strength and power output, and the prevention of or reduction of DOMS.

The primary outcome was changes in lower limb maximal strength including ground contact time (GCT), jump height, and power factor examined at 1-, 24-, 48-, and 72-hours following a DOMS-inducing eccentric hamstring workout. Secondary outcomes were self-reported pain levels and perceived efficacy.

Methods

Participants

Twenty-one people were recruited to participated, and ages ranged from 18 years to 30 years old. Participants self-reported as female, healthy, and active individuals with no lower limb injuries in the previous 6-months.

Characteristics	Control (n=10)	PCM (n=11)	p-value
Age (years) Race [n (%)]	21.5 ± 3.5	24.1 ± 3.9	0.13
White	5 (50%)	5 (45%)	0.88

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Asian	4 (40%)	3 (27%)	
Pacific Islander	1 (10%)	3 (27%)	
Height (cm)	174.3 ± 5.2	173.1 ± 6.8	0.45
Weight (kg)	75.1 ± 8.9	77.6 ± 7.2	0.29

Table 1: Characteristics of the participants values are expressed in mean ± standard deviation except for race.

Protocol

Screening

All potential participants completed an informed consent (IC), and all protocol were approved by the Institutional Review Board of Brigham Young University-Hawaii. Following the IC, all subject completed a Physical Activity Readiness Questionnaire to screen for possible risk factors of physical activity based on health history and current symptoms.

Participants were excluded if patients had a history of leg musculoskeletal injury in the last 6 months or any other health problems that would prevent them from safely completing the study protocol.

Subjects were also excluded if patients had done a strenuous leg exercise training session in the last 3 days, and patients were asked to do no resistance or cardiovascular training for the duration of the study.

Active warm-up

The subjects walked for 5-minutes on the treadmill at a self-determine moderate pace followed by 5-minutes of dynamic hamstring stretches to activate and warm-up the hamstrings (Figure 1) for the study protocol and timeline. Immediately after the dynamic stretches, the subjects completed the following assessments on the right leg:

Explosive Leg Power tests (ground contact time and jump height tests).

The subjects performed a vertical max jump test using the Just Jump System (Probiotics Inc., Fredonia, NY) using the 4-jump mode. The mean ground contact time and jump height of the four jumps were calculated. The power factor is calculated by the device and displayed with the other measurements following the final of the four jumps. Subjects jumped and landed on both legs for all jump tests. Ground contact time (GCT) is a metric commonly used in sports and fitness tracking to measure the amount of time your foot spends in contact with the ground during a specific movement, such as running or jumping. It refers to the duration between the moment your foot first contacts the ground and the moment it lifts off again.

GCT can provide valuable insights into various aspects of athletic performance with shorter ground contact times generally associated with better performance and efficiency. Jump height correlates to leg

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muscle strength with greater jump heights indicating greater muscle strength. The power factor is not a separate test, but is a calculation derived by dividing the airtime by the ground contact time. It provides a straightforward measurement that combines leg strength and quickness, effectively capturing the desired evaluation of both factors in a single, user-friendly numerical value. The Just Jump System manufacturer does not provide a unit of measurement for the variable; however, a larger power factor indicates a greater amount of available muscle force.

Pain

A 10-point visual analogue scale (VAS) was used to assess pain levels. A lower VAS score indicated a lower level of pain.

Perceived efficacy

A 5-point Likert scale was used to examine subjects' perceived efficacy of PCM or sitting quietly to reduce their exercise-induced DOMS. Answer options ranged from "5-Extremely effect" to "1-Not effective at all" with a higher score indicating a greater perceived efficacy. The test was only given on the final day of the study to assess the subjects' overall subjective experience with their randomly assigned study intervention.

Eccentric workout

Subject performed 4 sets to failure of Nordic hamstring exercises. Patients were given a 2-second rest between repetitions and a 2-minute rest between sets.

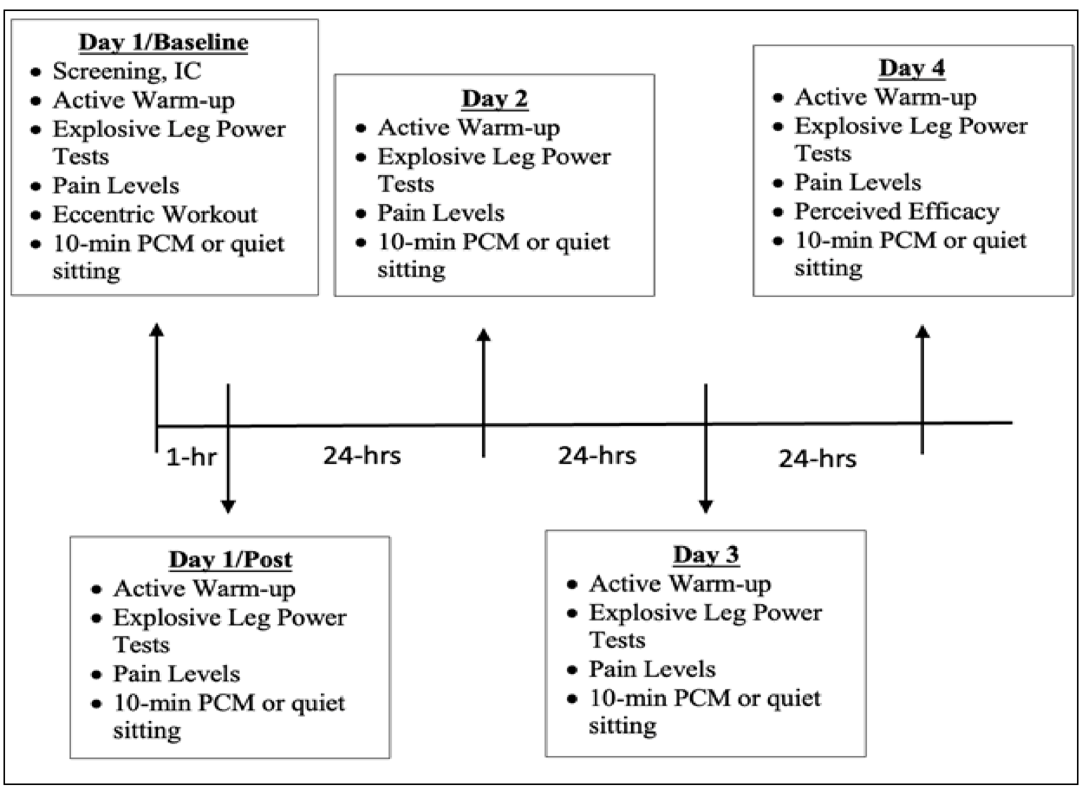

Figure 1: Study protocol timeline of events.

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Post-workout assessments and therapy

At 1-hour, 24-hours, 48-hours, and 72-hours following the eccentric workout, each subject returned for post-workout testing. Subject completed a brief survey asking about their muscle pain and soreness using 10-point visual analogue scales (VAS). The subjects then performed the same dynamic warmup and testing previously done for the baseline assessment-GCT and jump heigh tests. PCM-assigned subjects did a 10-minute PCM session and control subjects sat quietly for 10-minutes.

Pneumatic Compressive Massage (PCM)

Subjects randomized to the treatment group were seated in a reclining chair and wore the PCM device (Classic Boot System, Rapid Reboot, Linden, UT). The device control was set to Program A for 10-minutes at 120mmHg.

Control subjects

Subjects assigned to the control group sat quietly in a reclining chair for 10 min.

Statistical analysis

Descriptive statistics are displayed as means, standard deviations, and frequencies. Analysis of Variance (ANOVA) tests were used to compare group means across study intervals. Fisher's Exact Tests was used to compare categorical data of perceived efficacy. Paired t-tests were used to determine differences between age, height, weight as well as between control and PCM variables of GCT, power factor, jump height, pain, and perceived efficacy.

The alpha level of significance was set at $p \leq 0.05$ and all analyses were conducted using Jamovi version 2.3 (Sydney, Australia).

Results

There were no significant differences in baseline study variables between the control and PCM subjects however, here were significant differences found when examining the study variables over time (Table 1).

Variable	**Time from DOMS-inducing exercise**				
GCT (ms)	**Baseline (0-hrs)**	**1-hr**	**24-hrs**	**48-hrs**	**72-hrs**
Control	60.2 ± 3.0	89.1 ± 4.5	95.6 ± 5.3*	77.8 ± 4.4*	75.9 ± 3.9*
PCM	62.5 ± 3.1	82.8 ± 4.1	82.5 ± 4.4	71.3 ± 4.0	66.8 ± 3.4
Jump Height (in)	0-hrs	1-hr	24-hrs	48-hrs	72-hrs
Control	13.0 ± 0.7	10.1 ± 0.5	8.2 ± 0.5*	10.4 ± 0.5	11.2 ± 0.6
PCM	12.8 ± 0.7	9.7 ± 0.6	8.9 ± 0.4	10.9 ± 0.6	11 ± 0.6
Power Factor	0-hrs	1-hr	24-hrs	48-hrs	72-hrs
Control	1.8 ± 0.19	1.2 ± 0.11	1.1 ± 0.10*	1.3 ± 0.6*	1.3 ± 0.15*
PCM	1.7 ± 0.18	1.3 ± 0.07	1.2 ± 0.09	1.4 ± 0.7	1.5 ± 0.13
Pain (VAS)	0-hrs	1-hr	24-hrs	48-hrs	72-hrs
Control	0.4 ± 0.02	2.5 ± 0.09	2.6 ± 0.13	3.2 ± 0.16	3.4 ± 0.17*
PCM	1 ± 0.05	2.6 ± 0.11	2.4 ± 0.12	2.9 ± 0.15	2.7 ± 0.12

Table 2: Subjects changes in study factors over time. Values are expressed in mean ± standard deviation. *Indicates p>.05 between interventions.

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GCT

PCM had significantly lower GCT times compared to control at 24-hrs (p=0.01), 48-hrs (p=0.04), and 72-hrs (p=0.03) post exercise indicating increased reaction time, improved muscle power, and lower limb movement efficiency (Figure 2).

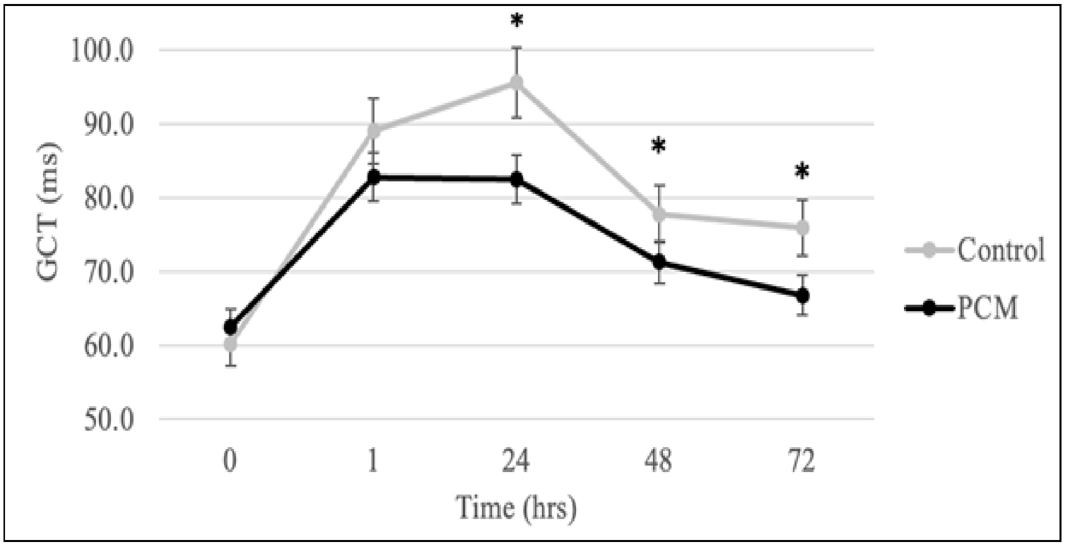

Figure 2: Mean ground contact time (GCT) of control and PCM subjects over time.

Jump Height

(Figure 3) shows the changes in jump height over time with PCM showing significantly greater leg strength (p=0.05) at 24-hrs.

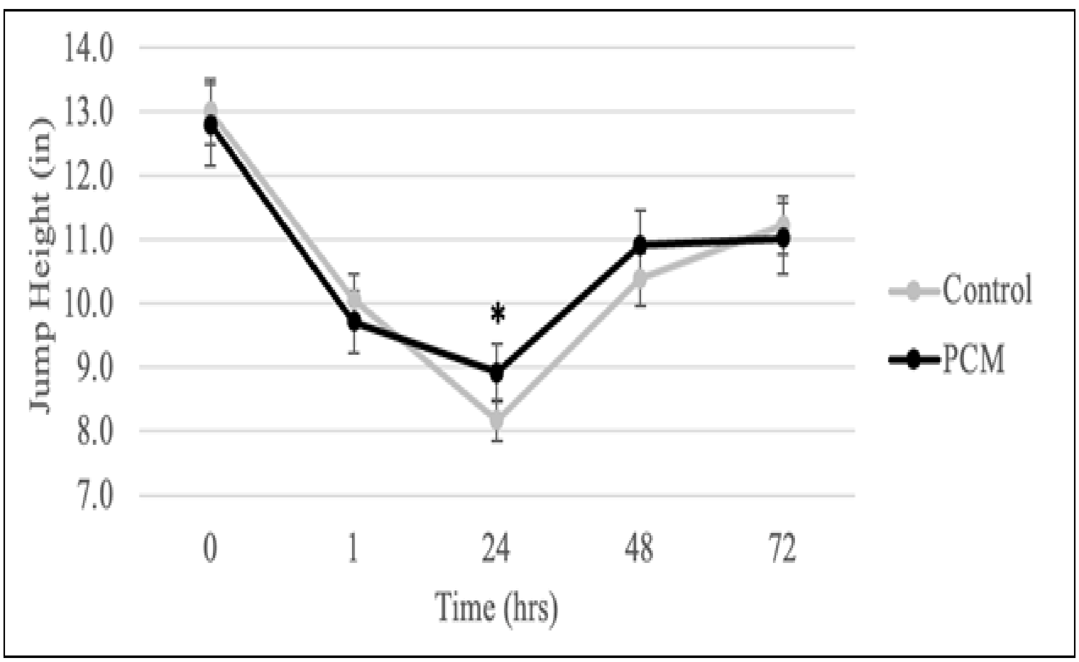

Figure 3: Mean jump height of control and PCM subjects over time.

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Power factor

Control had significantly lower leg strength and quickness as indicated by lower power factor calculations at 24-hrs (p=0.04), 48-hrs (p=0.05), and 72-hrs (p=0.01) (Figure 4). It consistent with the decreased jump heights and increased GCT results seen in the control group.

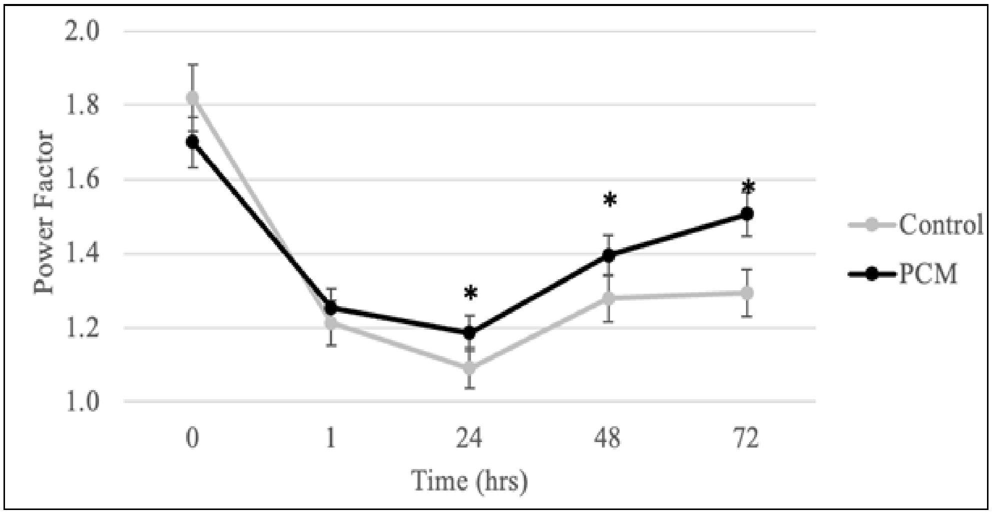

Figure 4: Mean power factor of control and PCM subjects over time.

Pain

The pain levels following the DOMS-inducing exercise caused an increase in pain for both groups as seen in (Figure 5). Only at 72-hrs post exercise was the pain significantly different between the groups with PCM reporting a statistically lower VAS (p=0.02).

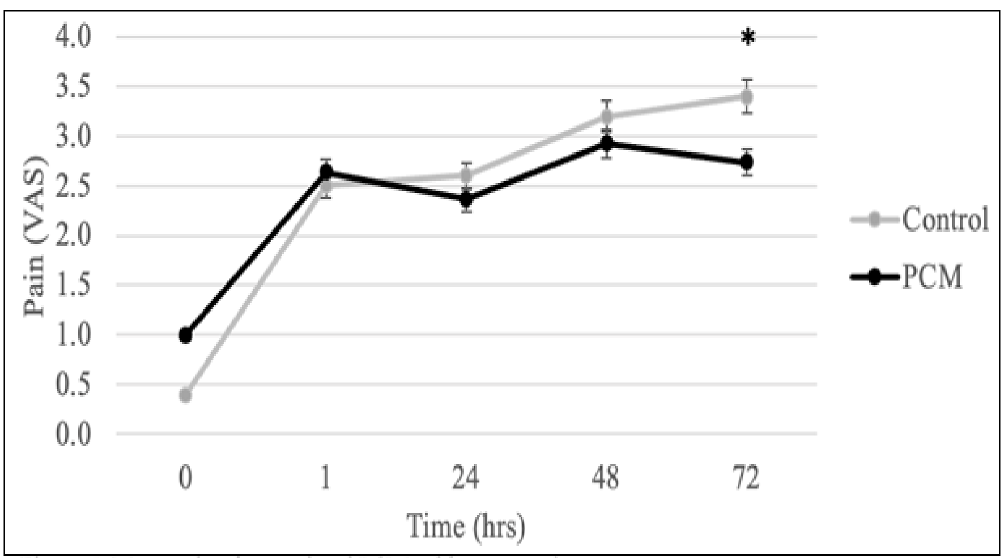

Figure 5: Mean pain of control and PCM subjects over time.

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Perceived efficacy

When asked the rate their subjective experience with sitting quietly or wearing PCM leggings every day for 10-minutes, control subjects' median rating of their intervention was "neither effective nor ineffective" while PCM reported significantly higher subjective satisfaction and perceived efficacy with PCM to reduce their DOMS as demonstrated with their median response of "very effective" (2.5 ± 0.1 vs 4.3 ± 0.3, $p=0.009$).

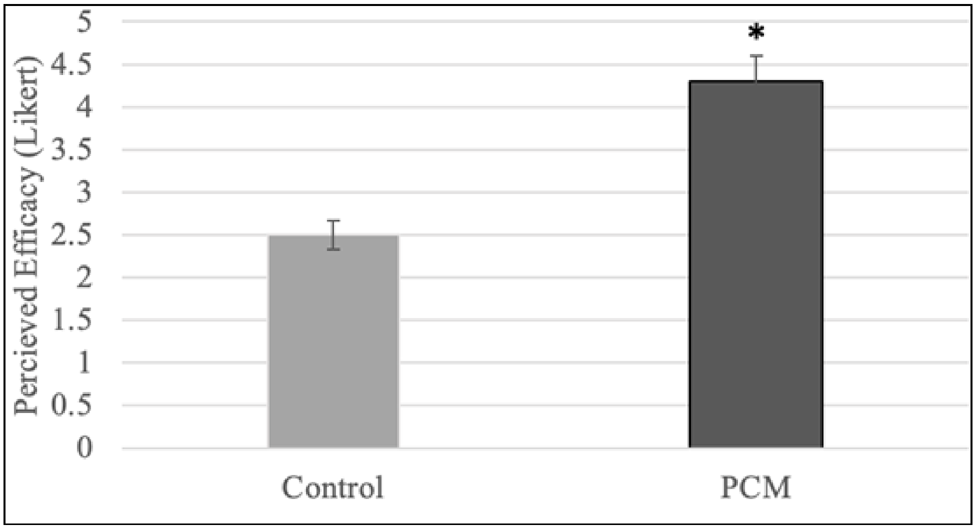

Figure 6: Perceived efficacy of randomly-assigned intervention.

Discussion

The results from the study support the hypothesis that PCM increases the rate and quality of recovery following DOMS-inducing exercise. Those receiving the PCM treatment showcased a more significant improvement in leg strength, reaction time, movement efficiency, and pain. The higher mean jump height exhibited by the PCM group demonstrates the ability that PCM could be utilized to facilitate recovery from DOMS. After a single exhaustive strenuous eccentric exercise session, individuals receiving PCM saw decreased GCT indicating improved movement economy and a faster return to baseline performance levels. The findings indicated the utilization of PCM shows promise in mitigating the post-exercise soreness associated with DOMS and eccentric exercise, thereby contributing to enhanced muscular strength in the lower limbs. The improvement in leg strength is discernible through variables such as GCT, jump height, and the power factor, which collectively measure the amalgamation of strength and quickness. Notably, participants who received PCM treatment exhibited notable augmentation in lower limb muscular power generation when compared to subjects in the control group.

These results underscore the potential benefits of PCM in the rehabilitation of muscular power following rigorous eccentric resistance training.

The data suggests that PCM can be used to reduce soreness that typically develops from

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DOMS, leading to improved limb muscular strength after arduous exercise. Lower limb strength is exhibited through the GCT and jump height along with the power factor calculated as a metric to measure combined strength and quickness generated by the legs. Individuals receiving PCM demonstrated an increase in the generation of muscular power in the lower limbs compared to individuals in the control group. Thus, PCM is beneficial in the rehabilitation of muscle power after strenuous exercise.

Muscular stiffness refers to the resistance of a muscle to stretch or lengthen which can restrict the range of motion and limit the ability to generate force and power effectively [11]. The ability of PCM to combat muscle stiffness and increase range of motion serves as a beneficial aid for the training of athletes. An optimal amount of lower extremity stiffness is necessary for peak performance. If athletes are too stiff or not stiff enough, it can lead to underperformance or injury [15]. PCM can be used to ensure optimal muscle stiffness through its ability to combat DOMS as seen in the decreased pain levels and increased power factor data. PCM can be used to aid in training to achieve peak performance and prevent injury through the preservation and growth of range of motion as well as post-training and performance recovery for athletes and recreationally active exercisers.

The results highlight the importance of the PCM in preventing DOMS and advise that PCM can also be used to increase physical performance. The intervention is also beneficial in preventing injury and can be used as an aid in rehabilitation. As previously indicated, decreased muscle stiffness and stretching can assist in ensuring optimal lower extremity stiffness for peak performance. However, in competitive gymnasts stretching before activity lowered lower extremity power during performance [16]. Therefore, PCM can serve as a warmup method before performance. It can be used to prepare individuals for competition due to its ability to maintain lower limb power and strength while simultaneously preserving lower limb stiffness.

Like any study, certain limitations existed in the design and implementation of the research. Notably, there was no control over the use of prescription pain medication prior to or during the study. Furthermore, while subjects were instructed to abstain from resistance or cardiovascular training, a subset of participants engaged in occupations involving sustained physical activity, such as dancers, groundkeepers, and food service workers. Nonetheless, it is important to acknowledge that these individuals may have been accustomed to increased physical activity in comparison to subjects with more sedentary jobs and lifestyles. Future investigations could incorporate daily physical activity levels and step counts as factors to account for variations in energy expenditure and overall activity.

The study didn't control from the number of repetitions of the Nordic hamstring exercises completed. Future research could compare the outcomes of subjects with fewer versus greater completed DOMS-inducing exercise repetitions to determine if the duration and rigor of the exercise affected the rate of recovery to baseline levels. (The study was conducted within a 72-hour timeframe, which

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proved insufficient for assessing the speed at which both groups returned to baseline power and pain levels. Subsequent research should consider employing longer follow-up periods, ranging from 10 to 14 days, to ascertain the prolonged recovery rate. Moreover, the PCM intervention protocol only consisted of 10 minutes per day. It is worth noting that other studies have examined longer treatment durations of 20 to 30 minutes [15]. Finally, the sample size of 21 participants was relatively small, and future investigations would benefit from recruiting a larger cohort to enhance statistical power.

By addressing these limitations, future studies can provide more comprehensive insights into the effects of PCM interventions on various outcome measures related to power, pain, and recovery.

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