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Therapeutic Photobiomodulation Before Strenuous Exercise Attenuates Shoulder Muscle Fatigue

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Context: Photobiomodulation therapy (PBMT) applied as a preconditioning treatment before exercise has been shown to attenuate fatigue and improve skeletal muscle contractile function during high-intensity resistance exercise. Practical implications for preconditioning muscles with PBMT before fatiguing exercise include a safe and noninvasive means to enhance performance and reduce the risk of musculoskeletal injury.

Objective: To examine the muscle fatigue–attenuating effects of PBMT on performance of the shoulder external-rotator muscle group when applied as a preconditioning treatment before high-intensity, high-volume resistance exercise.

Design: Sham-controlled, crossover design.

Setting: Laboratory.

Patients or Other Participants: Twenty healthy men (n = 8) and women (n = 12) between the ages of 18 and 30 years.

Intervention(s): Photobiomodulation therapy was administered using a near-infrared laser (λ = 810/980 N·m, 1.8 W/cm^2, treatment area = 80–120 cm^2) to the shoulder external-rotator muscles at a radiant exposure of 10 J/cm^2. Participants performed 12 sets of isokinetic shoulder exercise. Each set consisted of 21 concentric contractions of internal and external rotation at 60°/s. The sets were subdivided into 3 blocks of exercise (block 1: sets 1–4; block 2: sets 5–8; block 3: sets 9–12).

Main Outcome Measure(s): Normalized peak torque (N·m/kg), average peak torque (N·m), total work (N·m), and average power (W).

Results: During the last block of exercise (sets 9–12), all performance measures for the active PBMT condition were 6.2% to 10% greater than the sham PBMT values ($P < .02$ to $P < .001$).

Conclusions: Photobiomodulation therapy attenuated fatigue and improved muscular performance of the shoulder external rotators in the latter stages of strenuous resistance exercise.

Key Words: near-infrared, isokinetic, skeletal muscle

Key Points

- Preconditioning shoulder musculature with photobiomodulation therapy attenuates fatigue and maintains muscle performance of the external rotators throughout high-intensity and high-volume resistance exercise.
- Photobiomodulation therapy is safe, noninvasive, and may be an effective muscle fatigue–reducing aid for athletes who rely upon high-intensity and high-volume shoulder mechanics.

Skeletal muscle fatigue is a rate-limiting factor for athletes who participate and compete in sports that require muscular endurance and sustained levels of strength. Acutely, fatigue impairs muscular force output and motor control and reduces a muscle's capacity to perform work over a designated period of time.[1,2] Athletes involved in overhead-throwing sports such as baseball, volleyball, and tennis require protracted strength and endurance of the rotator cuff muscles, and as a consequence, the athlete's likelihood of experiencing exercise-induced fatigue as well as fatigue-induced musculoskeletal injury may increase.[3–5] As a result, strength and conditioning coaches and athletic trainers are developing and implementing prevention strategies aimed at mitigating the effects of exercise-induced fatigue and the risk for fatigue-induced injury during both training and performance. One strategy that is garnering interest in the sports medicine community is the use of photobiomodulation therapy (PBMT) as a preconditioning treatment for skeletal muscle.

Photobiomodulation is a form of light therapy that uses nonionizing forms of light sources (eg, lasers, light-emitting diodes [LEDs], and broadband light) in the visible and infrared spectrum.[6] Photobiomodulation therapy works at the cellular level, specifically targeting the mitochondria.[7–9] Photons penetrating the cell membrane, primarily in the red and infrared wavelengths, may stimulate photo-acceptors within the mitochondria, producing biochemical changes in the respiratory

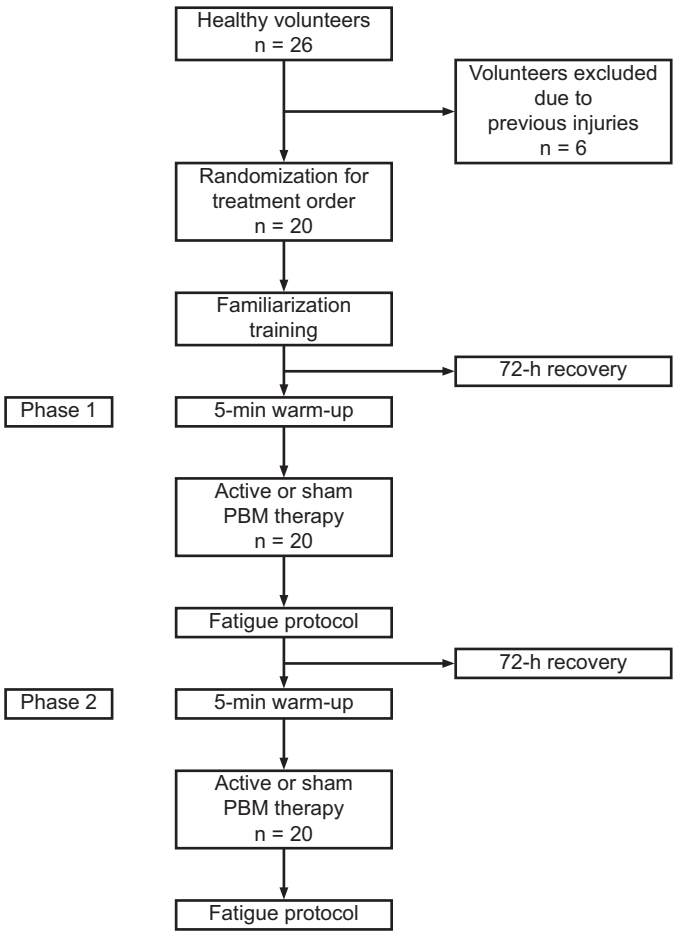

Figure 1. Flowchart demonstrating the timeline for the study. Participants received a 72-hour recovery between familiarization training and the start of phase 1 and between phases 1 and 2. All participants completed both phases of the study. Abbreviation: PBM photobiomodulation.

chain, and improve mitochondrial function.[8–10] These functional improvements include increased mitochondrial membrane potential and enhanced synthesis of cytochrome c oxidase and adenosine triphosphate (ATP).[9–14] Evidence suggests that photobiomodulation can prevent muscle damage and improve functional and biochemical recovery in rodents.[11,13,15–23] In addition to preclinical findings, PBMT has also been investigated as a preconditioning treatment to delay the onset of skeletal muscle fatigue and increase physical strength in human participants.[13,18,20,24]

No researchers to date have measured the effects of PBMT on performance of the muscles that assist in shoulder function. A preconditioning treatment administered before practices or games to muscles involved in overhead-throwing sports that would delay the onset and extent of fatigue and improve muscular endurance would be beneficial to athletes. For athletes involved in overhead-throwing sports such as baseball, tennis, and volleyball, the external rotators of the shoulder would be a suitable target for PBMT due to their high demand during sport performance. Therefore, our objective was to compare the effects of active PBMT and sham PBMT on contractile function and fatigue resistance of the shoulder external-rotator muscle group when applied as a preconditioning treatment before high-volume and high-intensity isokinetic resistance exercise.

Table 1. Participant Characteristics[a]

	Men (n = 8)	Women (n = 12)
Height, cm	176.3 ± 3.6	164.8 ± 4.9
Body mass, kg	80.1 ± 6.9	66.2 ± 9.1
Body mass index, kg/m^2	25.8 ± 4.4	24.4 ± 3.5
Age, y	23.3 ± 1.6	24.9 ± 2.0

[a] Values are listed as mean ± SD.

METHODS

Study Design

We used a double-blind, repeated-measures, placebo-controlled, crossover design in this study to compare the preconditioning effects of PBMT on torque and work output of the shoulder external rotators (infraspinatus and teres minor). Each participant received both active and sham PBMT followed by the completion of a fatigue protocol consisting of high-intensity and high-volume isokinetic resistance exercise. The order of PBMT treatment was randomized (Figure 1).

Participants

Twenty-six healthy individuals (16 women, 10 men) volunteered to participate in the study. Participants were screened for eligibility based on the following inclusion criteria: 18 to 30 years of age and physically active in a sport or exercise at least 1 day per week. All participants indicated that they engaged in physical activity on a regular basis (approximately 3 to 5 days a week, primarily running, but also biking, swimming, etc). None of the participants reported engaging in regular strenuous resistance exercise (more than once per week, on average) for the upper extremity. Institutional regulations prevented the recruitment of current intercollegiate athletes, limiting the sample to only those who had competed up to and including the intramural level. Exclusion criteria were as follows: current or past musculoskeletal injury to their dominant shoulder, history of neuromuscular disease, upper extremity injury within the past 6 months, cardiovascular disorder, use of dietary supplements or pharmacologic agents for the purpose of building muscle mass, or an intention to begin or modify their exercise training while enrolled in the study. Six individuals screened (4 women, 2 men) were excluded due to past dominant-shoulder injuries. Twenty individuals participated in all test sessions of the study (Table 1). All participants provided signed informed consent, and the study was approved by the Institutional Review Board of the University of Tennessee at Chattanooga (IRB 13-071). All experimental procedures followed in this study conformed to the World Medical Association International Code of Medical Ethics (Helsinki Declaration of 1975).

Procedures

Participants initially completed a familiarization training protocol for shoulder internal and external rotation before being entered into the exercise-testing phase of the study to eliminate a possible training effect. The familiarization protocol was identical in design to the fatigue protocol (described below). Participants were entered into the exercise-testing phase of the study when peak torque values between familiarization training sessions had less than a 10% difference.

Table 2. Treatment Parameters

Parameter	Value or Description
Diodes	2 near infrared
Wavelengths, N·m	810 and 980
Combined output power, W	10 W (20% at 810 N·m, 80% at 980 N·m)
Frequency	Continuous wave
Irradiance at target, W/cm^2	1.8
Exposure duration, s	80–120
Radiant exposure, J/cm^2	10
Area irradiated, cm^2	80–120
Application technique	Scanning with rollerball
Total radiant energy, J	800–1200

Treatment. Before receiving PBMT (active or sham), each participant performed a 5-minute upper extremity warm-up on a Schwinn Airdyne cycle ergometer at an intensity of 3 (*moderate*) of 10 (*maximal*) using the modified Borg category-ratio scale of perceived exertion. After the warm-up, each participant received a PBMT treatment (active or sham) pre-exercise while lying in the prone position with their shoulder at 90° of abduction and external rotation and their elbow at 90° of flexion. Photobiomodulation therapy was administered using a commercially available, Food and Drug Administration–approved, class IV high-power therapeutic laser. The therapeutic laser (LCT-1000, LiteCure Medical, LLC) emitted photonic wavelengths at 810 and 980 N·m. The laser had a combined output power of 10 W (20% 810 N·m, 80% 980 N·m, and 1.8 W/cm^2 irradiance). The infraspinatus and teres minor were located by palpating the spine of the scapula, the inferior angle of the scapula, and the medial and lateral borders. To deliver a uniform energy density to the tissues, a paper template, separately sized for men (larger) and women (smaller), was placed over the muscles to isolate the treatment area. The treatment area ranged from 80 to 120 cm^2, and the dosage was then calculated (10 J/cm^2 × treatment area). The calculated dose was applied using a scanning technique in a continuous wave output mode with a rollerball in contact with the skin. Total dosages ranged from 800 to 1200 J applied immediately before completing the fatigue protocol. The treatment times ranged from 80 to 120 seconds (Table 2). The sham therapy was identical in treatment time and application technique with the exception that the output power of the laser was disabled and only the aiming beam (red light) was active. The aiming beam delivered a single wavelength of 650 N·m with an output power of 4 mW. There was an approximately 5-minute time lapse between the end of the PBMT and the start of the fatigue protocol.

Fatigue Protocol. Isokinetic dynamometry has been used to measure and evaluate fatigue resistance and muscle performance in several PBMT preconditioning studies and is considered to be the gold standard for measuring skeletal muscle contractile function in clinical and laboratory settings.[11,15–17,23,25] The isokinetic exercise and testing protocols are controlled by angular velocity and range of motion, and the work performed can be quantified in a reliable and valid manner.[25,26] Furthermore, numerous studies have been performed that compared active PBMT with sham PBMT for the biceps and quadriceps muscle groups using isometric, isotonic, and isokinetic resistance exercise to measure muscle performance.[15–17,19,21–23] The BIODEX System 3 Pro isokinetic dynamometer (Biodex Medical Systems) was used for exercise testing. The dynamometer was calibrated before conducting data collection. Participants had their dominant arm positioned at 30° of shoulder horizontal adduction and 45° of shoulder abduction. Shoulder position was confirmed using a Baseline plastic goniometer. This position was chosen as it has been previously examined and is reliable for internal and external rotation strength assessment.[25,26] The arc of motion for internal and external rotation ranged from 45° to 90° of external rotation (45° of total range of motion).

Participants averaged 2.6 training sessions, and all participants had at least 2 training sessions. All familiarization training and exercise testing sessions were held a minimum of 72 hours apart. If the participant self-reported symptoms of muscle soreness (≥2 of 10), they received an additional day of rest until their score dropped below 2. No participants in the current study required this protocol modification.

The fatigue protocol required participants to perform a total of 12 sets of isokinetic exercise. Each set consisted of 21 continuous concentric contractions of internal and external rotation with the angular velocity set at 60°/s (total of 252 repetitions). The sets were subdivided into 3 separate blocks of exercise (block 1: sets 1–4; block 2: sets 5–8; and block 3: sets 9–12). Twenty seconds of recovery was provided between sets, and 5 minutes of recovery was provided between blocks. Each participant was instructed to provide maximal effort during external rotation contractions, whereas submaximal effort was used during internal rotation. Torque and work output values were recorded for the external rotation component of the fatigue protocol because the external rotators were the focus of the study. All torque and work output values were averaged over each bout of exercise.

The recorded isokinetic performance measures included normalized peak torque (NPT), average torque (AT), total work, and average power. Peak torque is the maximum torque produced during a set of isokinetic resistance exercise (N·m), and NPT is relative to body mass (N·m/kg). Average torque is the peak torque from every repetition averaged across the number of repetitions per set. Total work is the cumulative amount of work (or torque) produced by the participant during a set of resistance exercise (N·m), also referred to as the area under the torque curve. Average power is the total work divided by time (W). This measure represents how quickly a muscle can produce torque.[25]

Blinding. The therapist administering PBMT was separate from the exercise scientist who conducted and supervised the fatigue protocol. The participants and exercise scientist were blinded to the treatment order (active or sham PBMT). The therapist was aware of the treatment order but was blinded to the outcome of the performance measures. Photobiomodulation therapy treatments were administered in a consistent manner in order to eliminate any potential bias on the part of the therapist.

Statistical Analysis

All statistical procedures were performed with PASW Statistics 18.0 statistical package (IBM SPSS Inc). A 2 conditions (active PBMT versus sham PBMT) × 3 times (block of exercise) analysis of variance with repeated measures on the last variable (time) was used to compare active PBMT with sham PBMT for shoulder external rotation for NPT (N·m/kg), average peak torque (N·m), total work (N·m), and average power (W) over the course of 3 blocks of resistance exercise. Raw values within each block were compared to calculate percentage

Table 3. Performance Measures for the 3 Blocks of Exercise

Measure	Block 1	Block 2	Block 3
Normalized peak torque, N·m/kg			
Active PBMT	12.5 ± 2.9	12.0 ± 2.6	12.4 ± 2.7
Sham PBMT	12.5 ± 2.8	12.1 ± 2.9	11.6 ± 2.6
Average peak torque, N·m			
Active PBMT	15.5 ± 5.5	14.8 ± 4.3	15.2 ± 3.9
Sham PBMT	15.4 ± 4.8	14.7 ± 4.4	14.2 ± 4.3
Total work, N·m			
Active PBMT	184.3 ± 62.7	169.6 ± 47.3	169.4 ± 38.3
Sham PBMT	181.7 ± 52.9	166.3 ± 42.0	152.3 ± 34.1
Average power, W			
Active PBMT	13.7 ± 5.9	12.7 ± 4.3	12.9 ± 3.6
Sham PBMT	13.5 ± 4.8	12.5 ± 4.3	11.6 ± 3.5

Abbreviation: PBMT, photobiomodulation therapy.
[a] All values are displayed as mean ± SD.

differences in mean ± SD among the aforementioned isokinetic measures. The significance level was set a priori at .05, and all significant interactions were followed by post hoc analyses. Planned comparisons in the form of multiple paired *t* tests were performed to identify significant between-conditions and within-times differences. To control for inflated α levels resulting from repeated comparisons, we adjusted the level of significance by dividing the original α of .05 by the number of comparisons per dependent variable (c = 3). Thus, our adjusted α was set at .017 (.05/3). After completion of each PBMT session, participants were asked what type of treatment they thought they had received (active or sham PBMT). A χ^2 analysis of their responses indicated that the sham treatment was not distinguishable from the active treatment ($\chi^2 = 18.2$, $P = .63$).

RESULTS

Contractile function attenuated over the course of the fatigue protocol. For the sham PBMT condition, NPT and AT measures declined between 3.3% and 7.8% ($P < .013$), work measures declined between 8.4% and 16.2% ($P < .02$), and average power declined between 7.4% and 14% ($P < .001$). For the active PBMT condition, torque and work output declined minimally (0.1%–4.0%, $P > .05$) over the course of the fatigue protocol.

Although there were no significant differences in performance between the active and sham PBMT conditions during the first 2 blocks of exercise (sets 1–8), torque and work output measures diminished significantly for the sham PBMT condition during the last block of exercise (sets 9–12; Table 3).

After receiving active PBMT, participants produced 6.2% greater NPT (N·m/kg; $F_{2,\ 237} = 6.83$, $P = .001$, $\eta^2 = 0.92$) compared with the sham PBMT condition during the last block of exercise (Figure 2). Similarly, participants produced 6.7% more average peak torque ($F_{2,\ 237} = 5.22$, $P = .006$, $\eta^2 = 0.83$) after receiving active PBMT compared with the sham PBMT condition during the last block of exercise (Figure 3).

Participants produced 10% more total work (N·m; $F_{2,\ 237} = 7.16$, $P = .001$, $\eta^2 = 0.93$) and average power (W; $F_{2,\ 237} = 5.25$, $P = .006$, $\eta^2 = 0.90$) after receiving active PBMT compared with the sham PBMT during the last block of exercise (Figures 4 and 5).

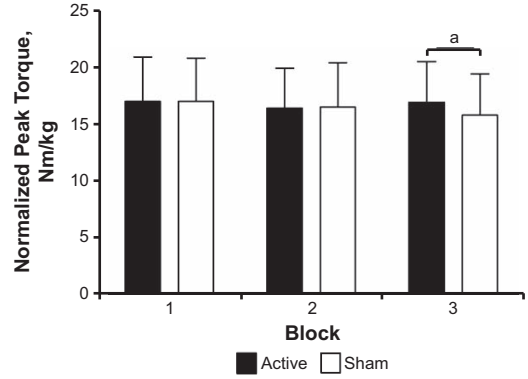

Figure 2. Normalized peak torque (NPT) for the 3 blocks of exercise. During the third block of exercise (sets 9–12), participants produced higher levels of NPT after receiving active phototherapy compared with sham phototherapy. [a] Difference ($P \leq .01$).

DISCUSSION

The efficacy of PBMT on improving skeletal muscle contractile function has been examined in numerous studies with healthy and/or athletic populations.[11,15–19,21–23] Previous researchers studying PBMT's preconditioning effect on skeletal muscle before high-intensity resistance exercise have found significant increases in the number of repetitions or elapsed time to volitional fatigue and pre-exercise to postexercise torque output compared with a sham control PBMT condition, indicating a fatigue resistance effect of PBMT.[15,18,19,21–23] Our objective was to compare the effects of active and sham PBMT on contractile function and fatigue resistance of the shoulder external-rotator muscle group using a high-volume and high-intensity muscle-fatiguing resistance exercise protocol.

We were able to show that active PBMT administered just before resistance exercise significantly attenuated muscular fatigue and improved muscular performance of the shoulder external rotators during the latter stages of the fatigue protocol. The enhancements in contractile function and fatigue resistance were best demonstrated by the significant increases in torque and work output after active PBMT compared with sham PBMT on all performance measures during the third block of resistance exercise. Interestingly, there were no significant differences in muscle performance between the active and sham PBMT treatments during the first 2 blocks of exercise

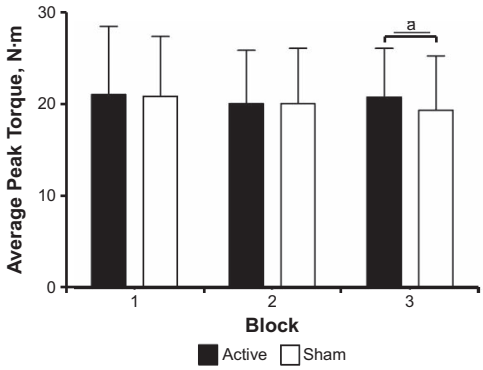

Figure 3. Average torque (AT) for the 3 blocks of exercise. During the third block of exercise (sets 9–12), participants produced higher levels of AT after receiving active phototherapy compared with sham phototherapy. [a] Difference ($P \leq .01$).

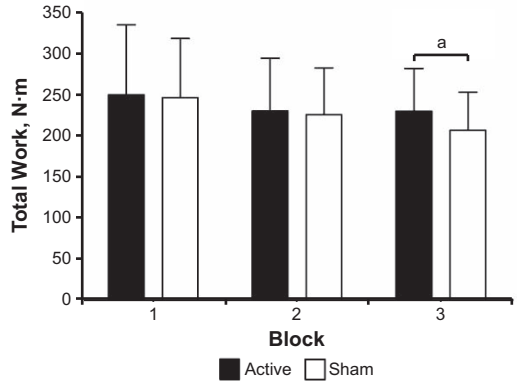

Figure 4. Total work (TW) for the 3 blocks of exercise. During the third block of exercise (sets 9–12), participants produced more TW after receiving active phototherapy compared with sham phototherapy. [a] Difference ($P \leq .002$).

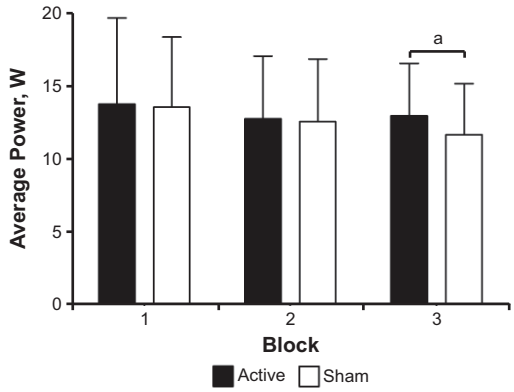

Figure 5. Average power (AP) for the 3 blocks of exercise. During the third block of exercise (sets 9–12), participants produced more AP after receiving active phototherapy compared with sham phototherapy. [a] Difference ($P = .001$).

(sets 1 to 8). The significant differences in fatigue resistance between the active and sham PBMT treatments during the third block of exercise (sets 9–12) occurred approximately 20 minutes into the fatigue protocol. This is a novel finding when compared with other published studies that used fatigue protocols to investigate the effects of PBMT on delaying the onset of skeletal muscle fatigue.

Our isokinetic performance outcomes showed significant enhancements in 3 key areas of skeletal muscle contractile function: torque (normalized peak and average), work capacity, and average power. In the active PBMT condition, participants were able to maintain higher levels of torque output in the last block of exercise compared with the sham PBMT condition, especially during sets 10, 11, and 12. From the first block to the third block of exercise, NPT and AT, which are indicators of the muscle's maximal and average force generating capability, respectively, declined by only 0.6% for NPT and 2% for AT for the active PBMT condition, compared with a 7% (7.2% NPT and 7.8% AT) decline for the sham PBMT condition. Total work, which is a measure of the muscle's capability to maintain force generation over time, declined by 8% for the active PBMT condition compared with a 16% decline for the sham PBMT condition. Average power, which is a measure of work-rate intensity, declined by 5.8% for the active PBMT condition compared with a 13.5% decline for the sham PBMT condition.

Fatigue protocols used in previous studies were high intensity yet lacked the overall volume and duration of exercise of the current study. Our fatigue protocol consisted of 12 sets of 21 repetitions (252 total repetitions) and was sequenced into 3 blocks (4 sets of 21 repetitions for each block), with each exercise bout lasting 4 minutes with 5 minutes of recovery between blocks. The total elapsed time to complete the protocol was 22 minutes. The protocol used by Leal Junior et al involved performing repeated isotonic arm curls against a resistance of 75% of 1 repetition maximum until exhaustion (volitional fatigue), which usually lasted under 60 seconds.[21,22] The fatigue protocols used by Baroni et al and Larkin-Kaiser et al used isokinetic dynamometry that required repeated maximal concentric and/or eccentric contractions for a specified number of sets and repetitions.[15,16,23] These isokinetic protocols were considerably longer than the protocol used by Leal Junior et al, with durations of approximately 1 to 5 minutes, yet were significantly shorter in duration and lower in volume of exercise than the protocol used in the current study.[21,22]

From a mechanistic standpoint, improved contractile function and fatigue resistance after receiving active PBMT in our study may have resulted from enhanced mitochondrial activity and blood flow in the working muscles. Previous studies have provided evidence for the ability of PBMT, especially in the near-infrared wavelength spectrum, to activate the respiratory chain through the photo-acceptor cytochrome c oxidase and to enhance blood flow and microcirculation.[9,10,12,27–29] High-intensity and high-volume endurance exercise uses primarily oxidative pathways for energy production, which implicates mitochondrial activity of muscle as a likely source of ATP production. Respiratory-chain activation results in a cascade of enzymatic reactions leading to increased rates of ATP synthesis for sustained muscle function.[13,14] Increasing blood flow and microcirculation in muscle tissue exposed to PBMT would lead to an increase in the delivery of oxygen and other energy substrates to exercising muscles, thus leading to an increased ability for a muscle to perform work. Well-oxygenated muscle cells are better able to oxidize lactic acid to pyruvate, which is then used by the mitochondria to produce ATP via cellular respiration.[24,30]

Another potential mitigating factor that could have affected the biomodulatory effects of PBMT was the power output and amount of light energy delivered to the tissue or dose-response effects.[7,31] We used an output power of 10 W and a dose range of 800 to 1200 J per participant depending on the size of the muscle group (infraspinatus and teres minor) to achieve an energy density of 10 J/cm^2, which is substantially greater than that in other studies. Baroni et al used lower output powers ($\leq$200 mW) and applied doses (125 and 180 J) to the quadriceps muscle, and the isokinetic torque and work output were not significantly different between the active and sham PBMT.[15,16] The lack of performance enhancement in the Baroni et al studies may be due to the relatively low power and dosages delivered to the quadriceps muscle compared with our study.[15,16] The total doses in our study (800 and 1200 J) were delivered to the shoulder external rotators (infraspinatus and teres minor), which is a much smaller muscle group than the quadriceps. Dose response is currently not well defined in PBMT protocols and warrants further investigation.

Because the most significant differences in fatigue attenuation were identified between active and sham PBMT at approximately 20 minutes into the exercise protocol, this observation may have strong practical implications for athletes who perform high-volume and high-intensity exercise tasks that involve durations of 20 minutes or longer. Our findings demonstrate a potential benefit for overhead-throwing athletes, such as baseball, softball, volleyball, and tennis players, for whom improved endurance of the rotator cuff musculature, in particular the external rotators, could potentially have a positive impact on a player's ability to pitch, strike, or serve with more force for extended periods of time (eg, innings in baseball and softball or sets for volleyball and tennis). Overhead-throwing sports often include high-volume, high-intensity muscle contractions separated by periods of recovery.[3] Our model of shoulder external-rotator muscle fatigue replicates this form of physical activity and the demands placed on these muscles. Studies have shown that the infraspinatus is particularly susceptible to exertional fatigue compared with other upper and lower extremity muscles.[32,33] If performance of the shoulder external rotators declines rapidly in overhead-throwing athletes due to fatigue associated with repeated bouts of strenuous activity, the shoulder can be placed at an increased risk of functional instability and injury.[3,34]

Another important issue with PBMT as a preconditioning treatment is the timing of the treatment before exercise begins. Most studies, including the current study, started the exercise or fatigue protocol within 5 minutes after the treatment. Our study identified improvements in skeletal muscle contractile function in the latter stage of the exercise protocol, thus raising an important clinical question of whether an optimal window for delivery of PBMT before exercise exists. In our study, if the PBMT had been administered an hour before the fatigue protocol instead of immediately before, would the participant's initial performance (eg, blocks 1 and 2) improve? Furthermore, does the body need a period of time for the PBMT to optimize its biomodulatory processes? Ferraresi et al investigated the timing of preconditioning skeletal muscle with PBMT using a mouse model of fatiguing exercise (inclined-ladder climbing). Mice were preconditioned with PBMT at 5 minutes, 3 hours, 6 hours, and 24 hours pre-exercise compared with a sham control condition.[13] Ferraresi et al were able to show that the groups that received the preconditioning treatment 3, 6, and 24 hours pre-exercise performed significantly more stair-climbing repetitions than the 5-minute and sham groups.[13] Most interesting was that the group that received the preconditioning treatment 6 hours pre-exercise completed the most stair-climbing repetitions, followed by the 3-hour and 24-hour groups.[13] Even though it would be difficult to translate these findings to human populations, these findings do indicate that further investigation is needed to determine optimal time-response curves for pre-exercise PBMT.

PRACTICAL APPLICATIONS AND LIMITATIONS

Preconditioning skeletal muscle with PBMT before fatiguing exercise is a rapidly growing area of investigation in the areas of sports medicine and exercise science. Our results are consistent with other research that has demonstrated a fatigue resistance effect of PBMT in skeletal muscle while performing strenuous exercise. The shoulder external rotators in overhead-throwing athletes are especially vulnerable to exertional fatigue due to the high demands for muscular endurance on those muscles. From an injury-prevention and performance-enhancement perspective, a preconditioning therapy using PBMT administered to the shoulder external rotators immediately before strenuous exercise that has the capability of attenuating muscle fatigue would be beneficial for an overhead-throwing athlete by improving the muscles' capacity to perform work while reducing the risk of functional instability and injury.

Limitations of this study include using a relatively small sample size and measuring muscle fatigue in a controlled research environment rather than in a sport-specific setting. Our fatigue protocol measured torque and work output only during the concentric phase of muscle contractions. Future studies may consider including torque and work output measurements from both phases (concentric and eccentric) of muscle contractions to capture a more comprehensive view of muscle contractile function. Future studies should be designed in a manner to better replicate real sports performance settings in highly competitive and/or elite athletes. Additionally, we used only a single PBMT session to measure our performance benefits, whereas a more longitudinal training study using multiple PBMT sessions over time would provide a more practical scenario for sports performance.

CONCLUSIONS

In conclusion, PBMT applied as a preconditioning treatment before high-intensity and high-volume resistance exercise significantly attenuated fatigue and maintained muscular performance of the shoulder external rotators in the latter stages of the exercise protocol. Preconditioning skeletal muscles with PBMT before fatiguing exercise may be a beneficial, noninvasive, and safe muscle fatigue–reducing aid for athletes who require high levels of muscular endurance.

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