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Original Article

Recovery strategies for cycling and mountain biking athletes after a fatigue protocol: A randomized crossover controlled trial

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Abstract

Muscle recovery in athletes has been a progressively investigated topic and there has been growing concern about it. Due to more and more dense race calendars, using the best recovery method between training and events is crucial to the athlete's performance. The massage gun is an instrument that is becoming increasingly popular. Research has followed this growth trend, however the available information is still scarce with the need to explore the topic for different protocols and populations, namely in the cycling community. Therefore, the study aimed to evaluate the effects of a massage gun protocol and a static stretching protocol on fatigue parameters in experienced road cycling and mountain biking athletes. Sixteen cyclists performed two fatigue in-session protocols in which two random experimental recovery protocols (massage guns and static stretching), were applied between the fatigue protocols. Data relating to Heart rate, Power, Lactate concentration, VO_2max, and Rate of perceived exertion were collected in four moments (M1 - baseline; M2 - after fatigue protocol; M3 - after the recovery protocol; M4 - after a second fatigue protocol). The athletes repeated the tests two weeks apart performing the other recovery protocol. From the collected data, it was found that the use of the massage gun and static stretching protocols causes positive effects in fatigue-related outcomes (Lactate concentration and Rate of perceived exertion). However, no statistically significant differences were found between the groups ($p > 0.05$). Therefore, although massage guns could be an effective instrument in decreasing fatigue related outcomes, they are not superior to others more commonly used and established recovery methods, such as static stretching.

Keywords

Recovery; Fatigue; Cyclists, Massage guns; Static Stretching

1 Introduction

Cycling is a sport that encompasses different types of bicycles and environments, such as road cycling, MTB, BMX, track cycling, among others. Nowadays there are cycling competitions spread across numerous corners of the world and competitions, from recreative youth to elite professional sport. A cyclist who belongs to this elite of the sport, travels an average of 35,000 km per year in the "World Tour" events (Lucía, Hoyos, & Chicharro, 2001). Being about 90 days in competition, on average, during which there is a high probability that in these 90 days, the participation in at least one Grand Tour (Giro D'Italia, Tour de France or Vuelta) will be included, a competition with a duration of 3 weeks, in which athletes race through the most diverse terrains (Sanders & Heijboer, 2019).

The olympic discipline of MTB, the Cross-Country Olympic (XCO), in turn, does not have such a dense competitive calendar, however its competitions are held at a much higher level of intensity. XCO is designated as an endurance discipline, however, given the layout style with practically constant uphill and downhill loads, this discipline can also be described as an intermittent high-intensity activity (Prinz, Simon, Tschan & Nimmerichter, 2021). XCO competitions are held in a circuit format, where the racing time varies between 80 and 100 minutes (UCI) and the competition intensity corresponds, on average, to 84% of VO_2max, and 80% of the race is spent above the lactate threshold (Impellizzeri & Marcora, 2007).

The VO_2max values for Elite Road cyclists are quite high, usually between 70-85 ml/kg/min, reflecting the great aerobic capacity required to sustain high Intensities during long races (Lounana, Campion, Noakes & Medelli, 2007; Lucia et al., 2006; Sitko, Cirer-Sastre, Corbi & López-Laval, 2021). Generally, a road race is held below 70% of the VO_2max on average (Elbert, Martin, Stephens & Withers, 2006). However, in an uphill time trial this value may go up to ~90% (Peinado et al., 2018) and in races like criteriums, which involve frequent high-intensity efforts, leading to high and variable VO_2 max usage, or in sprints or attacks in the mountains, it is expected to reach average values as high as 95% of the VO_2max (Faria, Parker and Faria, 2005a, 2005b). The anaerobic threshold in well-trained athletes is usually between 85-90% of VO_2max, and the time spent above this threshold can be 10 to 20% of the total race time, depending on the intensity of the competition (Coyle, 2005; Faria, Parker and Faria, 2005a, 2005b).

Such high training and competition loads, result in high levels of accumulated fatigue. Fatigue appears in the literature as a difficult term to define, but it is commonly designated as a risk factor that leads to decreased muscle power or strength, as well as cognitive ability, during exercise, because of the chronic increase (accumulation) of physical and/or mental loads (Bestwick-Stevenson, Toone, Neupert, Edwards, & Kluzek, 2022). Thus, it is essential to have an organized program that combines training with recovery strategies, which has been found to be the key to success (Dupuy, Douzi, Theurot, Bosquet, & Dugué, 2018). In the case of endurance athletes, such as cyclists, the loads and volumes of training to which they are subjected lead to high levels of fatigue established in the body. Therefore, the lack of a recovery program between workouts can eventually lead to overtraining or muscle injury (Davis, Alabed, & Chico, 2020).

The concept of recovery appears in literature as a process in which it is possible to restore the resources invested during physical activity, both at a physiological and mental level (Kellmann, M. et al., 2018). The search for effective recovery programs has become intense, leading several authors to seek answers regarding the search for the best recovery method. In the Dupuy et al. (2018) study, the authors identified several methods being massage the most effective one. This recovery method is shown to be the most impactful in reducing muscle soreness and the athlete's subjective perception of fatigue, with its effects being felt up to about 96 hours after physical exercise. The reduction in the feeling of fatigue after massage is explained by the reduction in cortisol levels and increased circulation of beta-endorphins (Field, Hernandez-Reif, Diego, Schanberg, & Kuhn, 2005).

Over time, new massage methods were developed (such as massage guns) and transformed the way massage was administered, with the aim of maximizing its effects. The use of vibratory or percussive therapies dates to ancient Greek times, when these methods were used to obtain therapeutic health benefits (Cochrane, 2011). Currently, thanks to scientific and technological evolution, the use of these methods has evolved to a level where it is possible to utilize in treatment and recovery (Alavinia et al., 2021; Cochrane, 2011; Moggio et al., 2022). Ferreira et al. (2023), presented in their systematic review, the effects that the use of percussive massage therapies have on sports recovery. The authors analyzed, in the included studies, the effects of the therapeutic method in terms of performance, recovery and in terms of physiological mechanisms, such as neural, vascular and mechanical, with the use of different times of action and frequency used in massage instruments. The results of this study revealed that, in the short-term, there are positive changes in terms of range of motion, flexibility levels, and in factors related to muscle recovery. On the other hand, in terms of strength, agility, acceleration and explosiveness, there were no positive changes, and in some studies analyzed, there was a decrease in these sports' performance factors. The authors revealed that the results found were useful for the development of this topic, but there are still many doubts regarding it. Thus, the authors end up advising the continuation of the exploration of this theme, with varied samples, execution times, and frequencies of use different from those described, with the aim of achieving different results.

As for flexibility programs in the post-exercise period, it is presented in the literature as an effective method for reducing muscle soreness, by the elimination of lactic acid through microcirculation in the muscles (Afonso et al., 2021), as well as being presented as an effective method for increasing range of motion. The term flexibility is commonly used as a synonym for the term stretching but, in the study by Dantas and Conceição (2017), the authors define the term flexibility as a physical capacity, while the term stretching is described as the technique or exercise that aims to develop flexibility. There are three types of flexibility that are frequently addressed in the literature: static, dynamic, and isometric. The most traditional and common type is static stretching, which consists of maintaining an elongated position for a period without movement. Static stretching can still be subdivided into active and passive, the difference between the two is the presence of assistance from an external (passive) force. Within dynamic flexibility, we can find two types of stretches: active and ballistic. Active stretches consist of the ability to move a joint through its entire range of motion in a controlled and repeated manner. Ballistics, on the other hand, are performed through rapid and repetitive movements, in great amplitude. However, due to the high risk of injury, this practice has been discouraged (Page, 2012). Isometric flexibility involves stretching the muscles while doing an isometric contraction, i.e., without movement of the joints. This method is often used in Proprioceptive Neuromuscular Facilitation (PNF) techniques, which combines muscle contractions and relaxations to increase range of motion. However, in literature there are still many doubts regarding the subject, and it is possible to find studies that reveal improvements in the recovery levels of athletes, other studies without significant differences in the pre- and post-intervention, and even studies that reveal a decrease in the performance and recovery outcomes.

Thus, due to the great importance that this topic represents in sports performance and recovery, there is the need to add information to the existing literature and to provide more effective methods to improve the outcomes. Therefore, this study aims to compare the two recovery methods (static stretching and massage guns) and evaluate their effects on the athletes´ recovery and performance.

2 Material and Methods

2.1 Study Design

This study followed a randomized crossover-controlled trial design and adhered to the CONSORT guidelines (Schulz, Altman & Moher, 2010). In this study, cycling athletes were subjected to a fatigue protocol (with conditions similar to those found in competition) followed by a randomly assigned recovery method (static stretching or massage gun - according to the Randomizer computer program [www.randomizer.org]). Two weeks after the first randomization, the athletes performed the other protocol (Figure 2).

To ensure that for all athletes the procedures were followed in the same way, in the same order, a plan was designed. Thus:

- First, a collection of the cyclists' socio-demographic data (using a short questionnaire, with closed questions) were retrieved;
- Then, the randomization of participants was performed (participants were randomized into two groups - the massage gun group and the static stretching);
- Before performing the fatigue protocol, rate of perceived exertion, heart rate and blood lactate values were taken (M1);
- Next, the fatigue protocol was carried out, where heart rate and power values were monitored and the VO_2max was indirectly calculated;
- Immediately after the fatigue protocol, the rate of perceived exertion, lactate, power and heart rate values (average and maximum during the protocol) were collected (M2);
- Then, the cyclists performed the recovery protocol to which they were randomized (massage gun or static stretching);
- Immediately after the recovery protocol, lactate, rate of perceived exertion and heart rate values were retrieved (M3);
- Next, a second fatigue protocol was applied, where the values of average and maximum heart rate, VO_2max, power, were monitored once again;
- Immediately after finalizing the second fatigue protocol, lactate, rate of perceived exertion and heart rate values were retrieved (M4);

Below is a diagram of the procedures carried out (Figure 1).

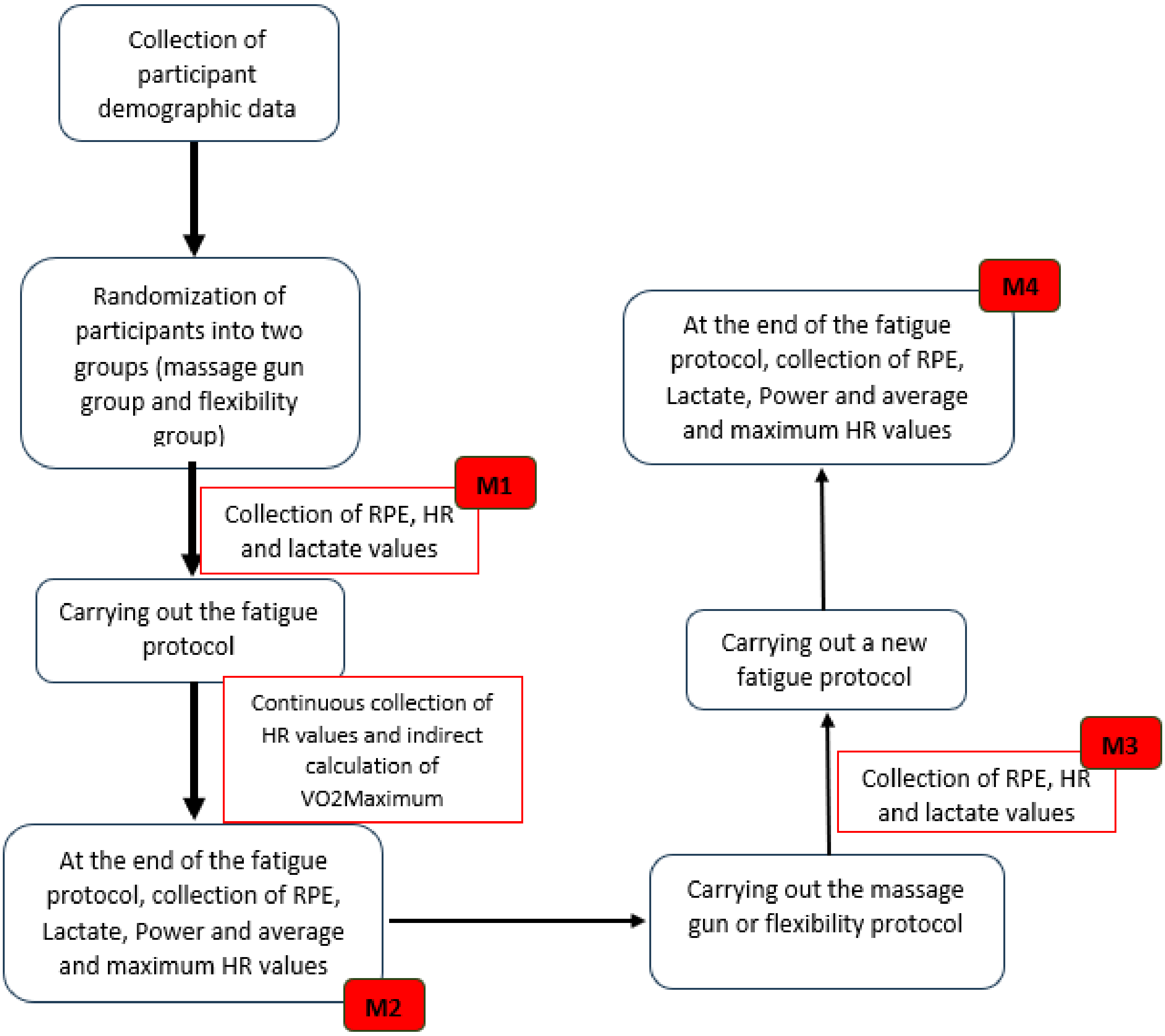

Figure 1. Summary of procedures.

2.2 Participants

This study features a sample of cycling athletes. Within this sample, they were from two different cycling disciplines, XCO and road cycling. The number of athletes recruited for this study was 20, calculated with G-Power, according to an alpha of 0.05, a power = 0.80, and an effect size = 0.8.

To obtain the desired sample, eligibility criteria were defined.

- Inclusion:
  - be between 18 and 35 years old;
  - participate in competitive official cycling for at least 5 years;
  - have a weekly training load of at least 300 minutes.
- Exclusion:
  - have some type of motor or intellectual disability;
  - have suffered an acute injury to the lower limbs less than 6 months ago;
  - have surgery or some chronic injury to the lower limbs;
  - suffer from any type of hormonal, liver, kidney, gastrointestinal, cardiovascular or respiratory disorder;
  - have consumed alcohol or some stimulant, such as caffeine, in the last 72 hours;
  - be a smoker, drugs or other doping substances user;

- take some type of medication;
- have prior knowledge of both massage guns and the static stretching protocol of the Portuguese Cycling Federation;
- in case of female athletes, they were excluded during menstruation.

2.3 Fatigue protocol

For this study, a fatigue protocol was carried out in a controlled laboratory setting, using a professional cycling roller with power measurement (TACX NEO II). Factors such as heart rate, blood lactate values and rate of perceived exertion (RPE) were analyzed. Regarding the variables to be analyzed, these were chosen based on the information found in the literature that point to these outcomes as being reliable methods of assessing an athlete's fatigue and recovery (Bestwick-Stevenson et al., 2022).

Some premises for carrying out this study were:

- The need to perform a warm-up;
- The load was individualized, set at a certain percentage of the athlete's maximum aerobic power (MAP);
- The load was representative of the discipline/discipline that the athlete practices;
- Use of a fixed cadence so that there are no load fluctuations and the accumulation of undesirable fatigue.

Once these premises are met, the protocol will be ready to be carried out. Being an adaptation of the study by Menard et al., the intensity described in their study was intended for XCO athletes, where competitions have an average intensity of 84% of the athletes' MAP, thus, this will be the load target used. For road cycling athletes, we considered the intensities of a Time Trial race, according to Støren, Ø., et al (2013), of approximately 84% of the MAP. Regarding track cycling riders, and according to Mujica et al (2012), the considered race intensity would be above 80% of VO_2max. The target load was pre-determined and individualized for each athlete by a previous exploratory analysis using a similar protocol in the same conditions (with a 1-week previous visit to the facilities). The VO_2max was estimated by the power of a 5-minute maximal effort and calculated: $VO_2max = 16.6 + (8.87 \times$ 5-min relative power output [W/Kg]) (Seitko et al., 2021). Therefore, the fatigue protocol design consisted in:

- The protocol started with a 10-minute activation; this activation starts with 5 minutes at 50% of the target load, followed by increments of 10% load every minute, until reaching the target load at 10 minutes;
- 5 minutes on target load (84% MAP);
- Data collection: during the protocol, the values of HR, power and the estimated value of the athlete's maximum VO_2max are continuously collected. At the end of the protocol, HR values (mean and median), average power output, blood lactate and RPE (Borg (1990) adapted scale, CR 10) were taken.

2.4 Outcomes

2.4.1 Heart rate (HR)

The athlete was properly equipped with a Garmin heart rate sensor, and the corresponding data was collected on a cycle computer from the same brand Garmin 830 (Garmin Ltd., Kansas, USA). HR data were taken at strategic moments to evaluate the changes caused by the protocols. The values were taken at 4 key moments: before any intervention to record the athlete's HR at rest; immediately after the application of the first fatigue protocol; immediately after the application of the recovery protocol; and immediately after the second performance of the fatigue protocol.

2.4.2 Lactate

To assess lactate concentration, a lactate measuring instrument Lactate Scout Pro (EFK, Cardiff, UK) was used, which analyzed a drop of the athlete's blood, placed on a reactive strip. Lactate assessment was performed at the same time as HR.

2.4.3 Rate or perceived exertion (RPE)

Of the various existing scales for athletes to self-evaluate fatigue, the chosen one for this study was the Borg CR-10 RPE adapted scale. The fatigue protocol to be used is an adaptation of Menard et al. (2018) study. RPE assessment was performed at the same time as lactate.

2.5 Recovery methods

2.5.1 Static stretching protocol

The chosen static stretching protocol, to be carried out after the fatigue protocol, was developed by the National Technical Department of the Portuguese Cycling Federation, which included the participation of Pedro Castro Vigário, Gabriel Mendes, and José Luís Algarra. This protocol lasted 20 minutes and was designed for performing static stretching exercises, along with some general guidelines for carrying them out safely and effectively. The guidelines given were:

- Stretching must occur at maximum or submaximal amplitude, maintaining this position for 30 seconds, without forcing or causing significant pain or discomfort (moderate: 3 (0-10 VAS));
- Breathe deeply and naturally during stretching not blocking the breathing during stretching.

Regarding the muscle groups addressed in the static stretching protocol, it was decided to apply only to the muscle groups of the lower limbs, which are mostly involved in the technical action of pedaling. As such, the protocol provides a total of four specific lower limb static stretching exercises. During the exercises, the athletes were supervised by a certified sports professional with experience in cycling and in this type of stretching. The professional's objective was to monitor the exercises to ensure that they were being carried out properly and according to the guidelines stipulated and explored previously. Each exercise was repeated four times.

- Exercise 1 - Heel to glute (Quadriceps): With support of one hand on a table or wall, pointing the knee towards the floor of the flexed leg, holding the hand on the instep and gently pull towards the buttocks. Feeling a slight discomfort in the quadriceps area, hold the position for 30 seconds, change lower limbs and repeat 4 times (total time 2 minutes).
- Exercise 2 - Butterfly (Thigh adductors): Starting from a sitting position, bring the feet plantar together. While holding the feet, gently move the knees toward the floor. If necessary, it could help the movement with the hands, pushing the knees toward the ground. Always maintaining the spine straight. Feeling a slight discomfort in the adductor area of the thigh, hold the position for 30 seconds, rest 30 seconds and repeat again (4 times) (total time 4 minutes – 2 minutes execution + 2 minutes rest).
- Exercise 3 - Hands to feet (Hamstrings and gastrocnemius): Starting from a sitting position, gently extend one leg and keep the foot relaxed. Flex the torso forward as much as possible, trying to keep the spine straight. Feeling slight discomfort in the hamstring area, hold the position for 30 seconds, change the lower limb and repeat 4 times (total time 2 minutes). Then, repeat the same form of exercise, changing only the position of the foot, asking the athlete to have the foot in dorsal flexion throughout the execution. Feeling a slight discomfort in the gastrocnemius area, hold the position for 30

seconds, change the lower limbs and repeat 4 times (total time 2 minutes).

- Exercise 4 - Knee to chest (Glutes): In supine position, holding the leg below the knee, move the knee toward the chest. Feeling a slight discomfort in the gluteal area, hold the position for 30 seconds, change legs and repeat 4 times (total time 2 minutes).

2.5.2 *Massage guns*

For the massage gun protocol, the "Fascial Gun®" was used with the characteristics of 6 mm amplitude and 3600 rpm frequency. Specifically, for this protocol, a time of 2 minutes per muscle group was chosen, with a frequency of 46 Hz, using the round head. Always applying at a 90º angle, the massage gun was passed above and below the muscle belly, trying to orient it according to the direction of the fibers. The massage gun was applied by an experienced clinician, who always tried to follow the same rate (1 second) and pressure during its application (discomfort up to 3 [0-10; VAS] and paying attention to changes in sound and tissue response). For the gluteal, hamstring and gastrocnemius muscle groups, the athlete was relaxed, in a neutral position, in the prone position. For the quadriceps and thigh adductors, the athlete was relaxed, in a neutral position, in the supine position.

The protocol execution time was 10 minutes per lower limb, totaling 20 minutes (gluteus maximus 2 minutes + vastus medialis 30 seconds + vastus lateralis 30 seconds + vastus intermedius and rectus femoris 1 minute + gracilis, adductor longus, adductor brevis 2 minutes + biceps femoris 1 minute + semitendinosus and semimembranosus 1 minute + internal calf 1 minute + external calf 1 minute.

2.6 Statistical Analysis

The data were compiled in frequency tables in which the average values recorded at different moments of the protocol and in the two interventions carried out were analyzed, with the respective standard deviations. Statistical analysis of the data was then carried out in which normality was tested (Shapiro-Wilk) showing the variables were non-parametric. As such, to compare the two different recovery methods, the Mann-Whitney U statistical test was performed for independent samples. A p value < 0.05 was considered statistically significant. Additionally, the effect size was calculated using Cohen's d, and interpreted as follows: $0.0 \leq d < 0.2$ (very small); $0.2 \leq d < 0.5$ (small); $0.5 \leq d < 0.8$ (medium); $d \geq 0.8$ (large). Furthermore, comparisons were made between different moments of assessment of the same outcome with Friedman's non-parametric test and Durbin-Conove's post-hoc test (Cohen, 2013).

3 Results

The study began with 17 selected athletes, and ended with 16 athletes, since one of the cyclists (athlete 7) was excluded for not complying with one of the elements of inclusion in the project, namely for using doping substances (for more information see Figure 2).

The study population was 16 male athletes practicing road cycling and mountain biking, with a mean age of 22.75 ± 3.61 years, an average weight of 69.53 ± 7.73 kg and an average height of 177.56 ± 4.59 cm. Regarding the cyclists' experience, the sample had on average 6.44 ± 2.26 years of practice. Concerning the weekly training time, the sample reported an average of 11.63 ± 3.26 hours per week. Finally, the sample was composed of 31.25% road cyclists (n = 5) and 68.75% mountain bikers (n = 11) (Table 1).

CONSORT Flow Diagram

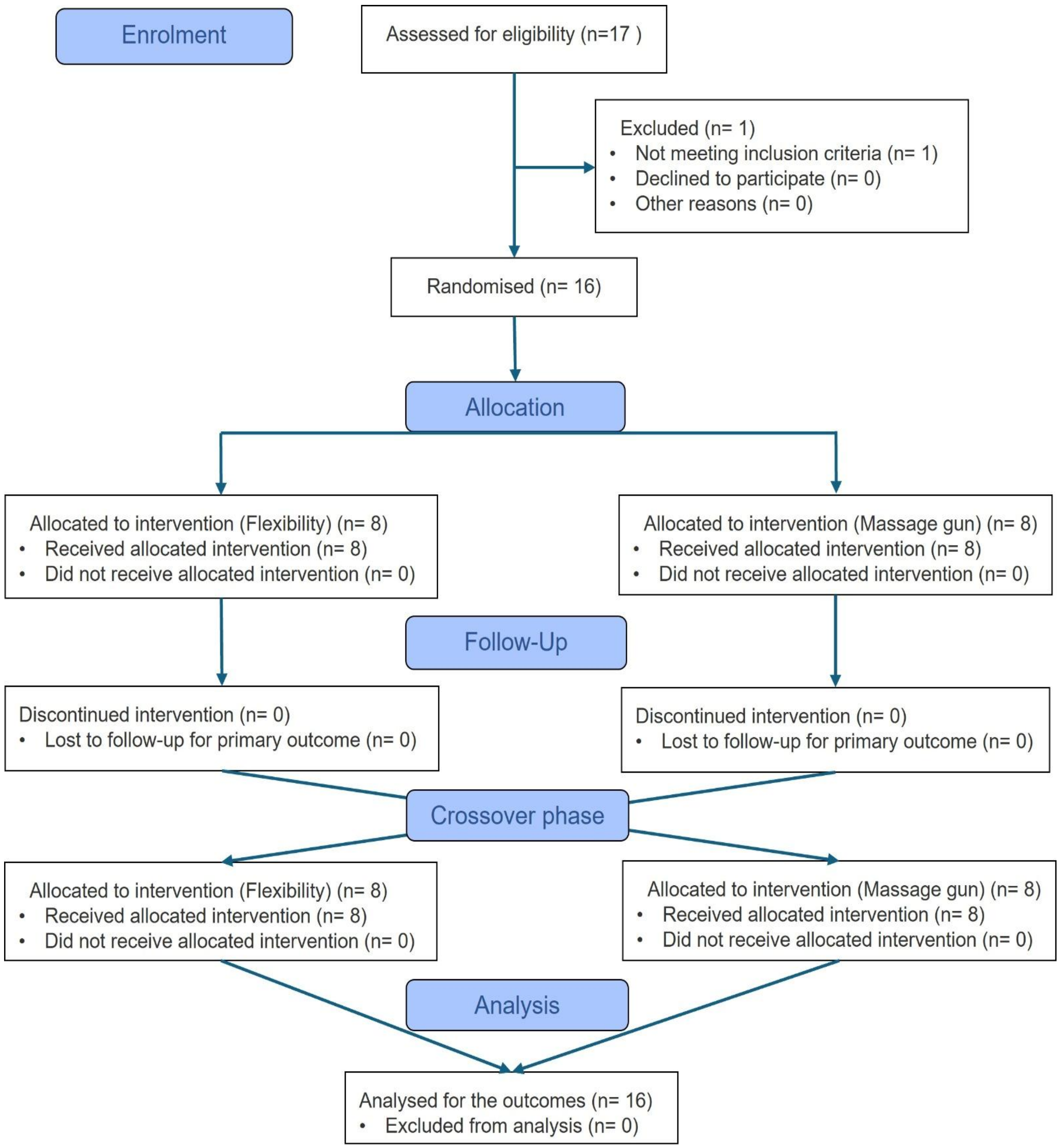

Figure 2. Study diagram.

Both interventions caused significant changes in RPE over time ($p < 0.001$). Regarding the values obtained at different moments and interventions, in M1 the initial RPE was low (average of 0.56) and similar (d = 0.21) for both interventions, not showing statistically different ($p = 0.49$). In M2, both interventions showed an increase in RPE values (average of 8.34), not showing statistical differences between the groups ($p = 0.05$) and a medium effect size (d = 0.66). In M3, RPE the values decreased again (average of 1.69) in both groups, showing no statistically significant differences between the groups (p =

0.16) and a small effect size (d = 0.47). Finally, in M4 the RPE increased again (mean 8.47) and was very close between groups (d = 0.11) with a non-significant p value (0.74). For a better perception of the results obtained in the RPE in the two interventions and in the four evaluation moments, see Table 2.

Regarding the Lactate concentration outcome, the interventions resulted in significant changes over time ($p < 0.001$). Their behavior was like the previous outcome, **i.e.**, low in M1 and M3 (average of 1.07 and 5.51, respectively), and higher in M2 and M4 (average of 9.05 and 8.29, respectively). However, no differences ($p > 0.05$) were found between static stretching and massage gun at specific times. Specifically, very small effect sizes were found in M1 and M4 (0.02 and 0.12, respectively), and small effect sizes in M2 and M3 (0.28 and 0.32, respectively). For a better perception of the results obtained in the Lactate in the two interventions and in the four evaluation moments, see Table 3.

Regarding the control of the fatigue protocol and the physiological responses of the interventions, at the beginning of the protocol (M1), the static stretching and massage gun interventions present very similar values of HR and VO_2. In M2, physiological responses, including average HR, max HR, power and VO_2, are practically identical between the two interventions, indicating a similar response to exercise. In M3, HR continued to be similar between interventions. In the final phase (M4), the interventions maintain almost identical results in terms of average HR, HR max, power and VO_2. For more details, see Table 4.

Table 1. Sample characterization.

ID	AGE (YEARS)	WEIGHT (KG)	HEIGHT (CM)	PRATICE TIME (YEARS)	WEEK TRAINING TIME (HOURS)	Discipline
1	21	72	181	10	12	Road
2	18	60.5	180	6	8	MTB
3	24	63	178	4	16	Road
4	20	76	175	6	8	MTB
5	20	63	173	6	10	MTB
6	20	64	183	8	14	MTB
7	22	69	172	11	12	MTB
8	22	65	174	6	14	Road
9	19	61	169	9	12	MTB
10	25	81	180	2	12	MTB
11	25	77	178	7	8	MTB
12	25	68	177	8	10	MTB
13	24	72	178	5	10	MTB
14	23	63	175	4	16	Road
15	34	89	188	5	6	MTB
16	22	62	179	6	18	Road
Mean±SD; n(%)	22.75±3.61	69.53±7.73	177.56±4.59	6.44±2.26	11.63±3.26	Road - 5 (31.25%) MTB - 11 (68.75%)

Table 2. RPE Results

Intervention	M1	M2	M3	M4	P
Static stretching	0.50 (◎0.52)	8.90 (◎0.79)	1.50 (◎0.63)	8.29 (◎0.84)	< 0.001
Massage Gun	0.63 (±0.50)	9.15 (±0.77)	1.88 (±0.81)	8.36 (±0.48)	<0.001
P	0.49	0.05	0.16	0.74	
d	0.21	0.66	0.47	0.11	

M1 - baseline; M2 - after first fatigue protocol; M3 - after recovery protocol; M4 - after second fatigue protocol

Table 3. Lactate Results.

Intervention	M1	M2	M3	M4	P
Static stretching	1.09 (±0.26)	8.13 (±0.62)	5.41 (±0.83)	8.47 (±0.57)	< 0.001
Massage Gun	1.05 (±0.21)	8.56 (±0.51)	5.61 (±0.67)	8.44 (±0.51)	< 0.001
P	0.97	0.44	0.38	0.75	
d	0.02	0.28	0.32	0.12	

M1 - baseline; M2 - after first fatigue protocol; M3 - after recovery protocol; M4 - after second fatigue protocol

Table 4. HR, VO_2max and Power (W) results

Intervention	M1 HR	M1 VO_2	M2 HR MEAN	M2 HR MAX	M2 WATTS	M2 VO_2	M3 HR	M4 HR MEAN	M4 HR MAX	M4 WATTS	M4 VO_2
Static streching	79.4 (±10.50)	60.5 (±9.38)	173 (±5.94)	175 (±5.71)	310 (±52.90)	60.5 (±9.38)	101 (±7.40)	172 (±5.12)	176 (±5.30)	313 (±51.8)	60.5 (±9.38)
Massage Gun	82.3 (±10.40)	60.5 (±9.38)	172 (±5.21)	174 (±5.35)	310 (±52.90)	60.5 (±9.38)	101 (±5.45)	172 (±4.08)	175 (±3.96)	313 (±5.18)	60.5 (±9.38)
Mean	80.8 (±10.40)	60.5 (±9.23)	172 (±5.52)	175 (±5.46)	310 (±52.90)	60.5 (±9.23)	101 (±6.40)	172 (±4.55)	175 (±4.62)	313 (±51.0)	60.5 (±9.23)

M1 - baseline; M2 - after first fatigue protocol; M3 - after recovery protocol; M4 - after second fatigue protocol; HR=heart rate; VO_2= oxygen consumption; Watts= power

4 Discussion

The objective of the present study was to compare two recovery methods (static stretching and massage guns) and evaluate their effects on the athlete's recovery and performance. Regarding the effectiveness of the protocols used, they showed positive results in recovery-related outcomes, as RPE, Lactate and HR reduced in the moment of application of the recovery protocol. Objectively, between the moments before and after the application of the recovery protocols, regarding the static stretching protocol, the mean RPE decreased from 8.90 (±0.79) to 1.50 (±0.63). In the massage gun protocol, the average values recorded decreased from 9.15 (±0.77) to 1.88 (±0.81), after application of the protocol. Regarding lactate, the average of the values recorded was 8.13 (±0.62) mmol·L−1 to 5.41 (±0.83) mmol·L−1 after the static stretching protocol, and 8.56 (±0.51) to 5.61 (±0.67) after applying the massage gun protocol. Regarding HR, the mean of the values recorded in the static stretching and massage gun protocol showed a reduction of 72 and 71 beats per minute, on average, after applying the respective protocols.

The goal of using recovery protocols is to assist and restore homeostasis in the body in the shortest possible period (Kellmann et al., 2018). In Lee, Sheridan, Ali, Sutanto and Wong (2021) study, it was found that post-exercise compression garments on cyclists benefit sports recovery. From a sample of 13 participants, the authors observed improvements in cardiovascular outcomes (HR and cardiac output), lactate, and muscle pain in the lower limbs. After the application of the fatigue protocol, they observed that the use of compression garments accelerated the removal of lactate, relative to the control group (lactate value after fatigue protocol: 12.5±1.7 mmol·L−1 (experimental group) and 12.4±1.4 mmol·L−1 (control group); Lactate value after 5 minutes of passive recovery: 6.4±1.7 mmol·L−1 and 8.7±1.8 mmol·L−1, respectively). In sports, other methods and protocols are described and used. Paoli et al. (2013) carried out a study in which they compared the effects of sports massage with and without ozonated oil on cyclists' performance and recovery. Sports massage is one of the most common methods to be applied due to the fact that it does not involve large investments and logistics, and because it is already a proven method by the literature to be valid for a better recovery of athletes, promoting an acceleration of lactate removal, reduction of muscle pain (Hilbert, Sforzo & Swensen, 2003) and helps to reduce the athlete's perception of fatigue. In the Paoli et al. (2013) study, it was concluded that the use of ozonated oil acts more favorably on the removal of lactate. The authors divided the recovery protocol into three phases (T1 - Beginning of the protocol; T2 - Medium of the protocol; T3 - End of the protocol) where then they evaluated the alterations and later compared the values obtained in the other methods (such as passive recovery and traditional sports massage). Regarding the massage with ozonated oil, there was a reduction of 52.5% between T1 and T3 compared to the 43.6% recorded in the application of oil-free sports massage. Similar results were found in the Bielik (2010) study in which authors sought to understand what differences would exist in the performance level of MTB athletes with the application of different recovery methods (control group, sports massage, and active recovery). In this study, the results obtained also revealed reductions in the level of blood lactate and perception of fatigue of the athlete. After the application of fatigue protocols, the values recorded for the different recovery protocols attribute an advantage to the use of active recovery as a more effective method. The values recorded for lactate were 13.31±2.9 vs. 7.49±3.9 mmol·L-1 (comparison between passive recovery and active recovery) and 14.68±3.0 vs. 7.49±3.9 mmol·L-1 (comparison between sports massage and active recovery).

Regarding the methods employed in this study, both techniques are widely used in sports to enhance recovery. Static stretching is one of the oldest and most commonly applied interventions in sports recovery, even though its results have been somewhat mixed. Both short-term and long-term improvements in mobility and flexibility may be observed (Afonso et al. 2021). It seems that static stretching has the potential to increase the tissues viscoelasticity and reduce its stiffness, which together enhances the range of motion (Bryant et al., 2023). Additionally, reductions in fatigue-related outcomes may also be encountered. However, some of these benefits may be more psychosocial than purely physiological, reflecting improved well-being and a sensation of relaxation rather than solely objective, measurable changes (Afonso et al. 2021). Although static stretching is expected to reduce pain and increase tolerance through mechanisms such as altered nociceptive signaling, parasympathetic activation, and modulation of the H-reflex, these physiological improvements are not always consistently detected in quantitative assessments (Bryant et al., 2023).

Another method employed in this study, massage gun, although its use in sports recovery is growing, the available evidence remains limited and occasionally contradictory. For example, in the systematic review of Ferreira et al. (2023), the authors concluded that the use of this method is beneficial for the recovery of flexibility and range of motion after exercise. However, the results found in the systematic review from the primary studies were poor in terms of the fatigue outcome, in which no statistically significant differences were observed, although there was a reduction in blood lactate. From the 11 studies included in the systematic review, only three had fatigue as outcome, which reveals the need for further study in this matter. In the study by Alonso-Calvete et al. (2022), the authors compared percussive therapy method with a passive recovery method and found no significant differences between the two methods regarding blood lactate and fatigue perception. Nevertheless, there was a reduction in lactate levels after the application of the protocols (difference of 9.6% vs 8.1% compared to passive recovery). Identical results are found in our study where it is possible to verify the effectiveness of the protocols used in the removal of lactate and perception of fatigue. However, it was not possible to determine significant differences already between protocols (effect size relative to the Lactate outcome at M3, d=0.32; effect size relative to the RPE outcome at M3, d=0.47). Also in the Ferreira et al. (2023) study, from the analyzed studies, the outcomes that appear most frequently are related to strength (Alvarado et al., 2022; García-Sillero et al., 2021; Hernandez, 2020; Konrad et al., 2020; Szymczyk et al., 2022; Trainer et al., 2022; Wang et al., 2022), range of motion (Alvarado et al., 2022; Hernandez, 2020; Konrad et al., 2020; Trainer et al., 2022) and fatigue (Alonso-Calvete et al., 2022; García-Sillero et al., 2021; Wang et al., 2022). Of these outcomes presented in the systematic review, the only one that the authors reveal to have shown positive differences after the application of the massage gun protocol was the range of motion and flexibility, proving to be a more effective method, compared to passive recovery (Konrad et al., 2020). Furthermore, in the Godemeche (2020) study, it was compared ultrasound to the massage gun, and massage gun showed to be more effective in gaining flexibility in the posterior chain muscles. Regarding the strength outcome, the massage gun is apparently ineffective in strength gains (Alvarado et al., 2022; Hernandez, 2020; Szymczyk et al., 2022; Wang et al., 2022). In terms of recovery, statistically significant results were found in the voluntary contraction of the upper trapezius after the application of a fatigue protocol followed by the application of the massage gun protocol, compared to a control group (passive recovery) (Wang et al., 2022). Our study also found some positive effects in fatigue-related outcomes (RPE and lactate). However, it was not possible to determine the best method to recover as no statistically significant differences were found between the two experimental recovery methods (massage guns and static stretching).

Although the use of massage guns is promising regarding the reduction of fatigue-related outcomes, its use is still a topic limitedly explored by the literature. Therefore, many of its effects are not yet fully understood. However, having access to studies with similar instruments, physiological responses found are expected to fall into three main categories: Neural, Vascular and Mechanical (Ferreira et al., 2023). In terms of neural alterations, when a vibratory stimulus is applied to the muscle (or muscle group), it will interrupt the natural frequency state of the tissues leading to alterations in neurophysiological functions (Wakeling, Nigg & Rozitis, 2002). The application of the massage gun for a long period of time, at low intensity, leads to a reduction in muscle tone and soreness via autogenic inhibition (Cochrane, 2011). Regarding changes at the vascular level, the literature shows that the shear stress caused by the vibratory protocol leads to changes in the concentrations of nitric oxide (Sackner, Gummels & Adams, 2005), acetylcholine (Tzen, Weinheimer-Haus, Corbiere & Koh, 2018) and prostaglandin (Mahbub et al., 2020), resulting in increased blood flow. With these changes, it is expected that a favorable environment for recovery will be created (Cochrane, 2011) with a decrease in muscle inflammation and an increase in oxygen supply and repair of muscle tissues. Finally, at a mechanical level, vibration causes a reduction in muscle tension and alters the viscoelastic connectivity of tissues, as well as mobility in general by increasing fluids and the temperature of the intervention area (Ferreira et al., 2022).

The available literature and our findings confirm that massage guns are a valid recovery method. The lack of significant differences between the two protocols likely arises because their effects are similar in the recovery-related outcomes. Static stretching is widely recognized as an effective method for reducing stiffness and muscle soreness, as well as for improving range of motion. However, its use may be limited due to potential adverse effects on strength outcomes, such as stretch-induced strength loss (Esposito, F. et al. 2009).

This study showed some limitations. One is the need for a larger specialized sample. Having access to a larger universe of data, we believe it is possible to obtain other types of more enlightening results on the topic. Also, if other types of massage gun protocols were tested, with different execution times and frequencies, the results may have been different. It may also be important to study and compare the effects with other interventions, namely massage, passive recovery or active recovery. Long-term effects should also be explored in similar future studies.

5 Practical Applications

Regarding the practical applications of this study, massage guns can be recommended as a valid recovery method in relation to fatigue parameters. The application of a massage gun protocol (such as the one used in this study) is therefore encouraged. However, we consider important to explore methods with different characteristics to evaluate the possibility of obtaining results even more favorable to the athlete's recovery.

6 Conclusions

The results show that the application of massage guns and static stretching protocols could be applied as a method of muscle recovery, mainly due to positive outcomes related to fatigue (reduction in blood lactate levels, RPE and reduction in HR and muscle pain). However, as no difference between the groups was found, it could not be determined the best method for the reduction of fatigue-related outcomes. Therefore, more studies need to be carried out with different populations, protocols, comparisons, and interventions.

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