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Comparison of the Effect of Passive and Active Recovery, and Self-Myofascial Release Exercises on Lactate Removal and Total Quality of Recovery

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Abstract

Recovery from exercise-induced fatigue is crucial for subsequent performance. Self-myofascial release (SMR) using a foam roller is an alternative to active recovery (AR). This study aims to compare the effects of passive recovery (PR), AR, and SMR on blood lactate [La^-] removal and total quality of recovery (TQR). Twenty-two well trained male athletes (age: 22.6±2.9 years) underwent three testing sessions conducted 72 hours apart but at the same time of each day in a randomized order. After determining resting [La^-] and heart rate (HR), the subjects completed a Wingate anaerobic test (WAnT), triggering muscular fatigue. HR and [La^-] were measured three minutes after the WAnT, following which the subjects underwent one of the three different recovery interventions over 15 minutes: PR (lying supine), AR (cycling at 40% of the estimated maximum HR of the respective subject), and SMR (using foam roller on lower extremity muscles). After each recovery intervention, [La^-], HR, and TQR were measured. There was no statistically significant difference in [La^-] and HR values obtained before the WAnT test ($p=0.368$, $p=0.691$, respectively) and right after the WAnT test (0.264, $p=0.629$) Both AR and SMR were more effective than PR for [La^-] removal and obtaining a higher TQR ($p<0.001$). However, SMR and AR were not superior to one another for blood [La^-] removal ($p>0.05$). In contrast, a significantly higher TQR was observed with SMR than AR and PR ($p<0.001$). Athletes can apply AR or SMR to recover from strenuous exercise. SMR can be an alternative to PR and AR as a recovery tool.

Keywords: active recovery, passive recovery, self-myofascial release, blood lactate, total quality of recovery

1. Introduction

Exercise-induced muscle fatigue is defined as the decreased ability to generate appropriate amounts of muscle force or power during on-going contractile activity (Finsterer, 2012). However, the basic mechanism underlying muscle fatigue has not been firmly established (Potvin and Fuglevand, 2017). Muscle fatigue is generally attributable to peripheral and central factors (Wan et al., 2017; Allen et al., 2008). Peripheral fatigue is produced by changes at or distal to the neuromuscular junction (depletion of creatine phosphate or accumulation of inorganic phosphate) (Allen et al., 2008). Central fatigue originates at the central nervous system, which decreases the neural drive to the muscle (Wan et al., 2017). Exercise-induced alterations in muscle homeostasis, including hydrogen ion (H^+) accumulation, potassium loss, depletion of high-energy phosphates (ATP and creatine phosphate) and glycogen, loss of calcium homeostasis, or local ischemia, may be some of the causative factors associated with disruption of the muscle excitation-contraction cycle during intense exercise and in post-exercise muscle fatigue (Mika et al, 2007; Steele et al., 2003). It has been known that high-intensity exercise results in increased levels of both intramuscular and circulating levels of lactate [La^-] (Connolly et al., 2003). This increase in [La^-], reflecting H^+ concentration, has been shown to inhibit contractile performance and cause premature fatigue (Connolly et al., 2003; Corder et al., 2000).

Blood [La^-] concentration is the most widely used marker of muscular fatigue (Barnett, 2006) occurring during exercise and sports. Fast muscle recovery is necessary for better muscle performance in sports with short inter-bout rest periods (Mika et al., 2007; Hinzpeter et al., 2010). Recovery is defined as the normalization of the pH within muscle (Lattier et al., 2004). Researchers reported that examples of active and passive recovery (PR) methods used for recovery are

massage, active recovery (AR), cryotherapy, contrast temperature water immersion therapy, hyperbaric oxygen therapy, nonsteroidal anti-inflammatory drugs, compression garments, stretching, electromyostimulation, and combination modalities (Barnett, 2006). Numerous studies have reported that AR is more effective than PR in removal of [La^-] (Connolly et al., 2003; Corder et al., 2000; White and Wells 2015; Menzies et al., 2010; Heyman et al., 2009; Baldari et al., 2005; Spierer et al., 2004).

Typically, 15–25 minutes of resting is thought to be the optimal time for returning pH levels to normal after performing moderate intensity exercise (Bond et al., 1991). PR is simple resting, often in the form of sitting, lying down, or stretching (Warren et al., 2015). AR, wherein athletes participate in low to moderate intensity active movement (exercise intensity of 30–60% of the estimated maximum HR [HR_{max}] of the person who is exercising), is often cardiovascular in nature in an effort to increase vasodilatation, increase oxygen-rich blood flow to the muscle, and remove blood [La-] (Corder et al., 2000; Monedero and Donne 2000). AR has been shown to enhance [La^-] clearance from type II skeletal muscle fibers through facilitating its oxidation by adjacent type I fibers (Baldari et al., 2005).

The aim of this study was to compare AR, PR , and SMR with a foam roller on [La^-] removal and total quality of recovery (TQR). We hypothesized that 1) AR and SMR are more effective than PR in removal of [La^-]; 2) SMR is superior to AR in removal of [La^-] and obtaining a higher TQR score.

2. Method

Twenty-two well trained male athletes from team sports (basketball, soccer, etc.) volunteered to participate in this study. Descriptive data of the subjects are presented in Table 1. The inclusion criteria were: a) aged ≥18 years, b) having an active team sports license c) had no pre-existing injury or muscular soreness. Subjects who were using an ergogenic aid and had an active lower extremity injury or muscle soreness were excluded from the study. Each subject was instructed to refrain from strenuous physical activity for 24 hours prior to testing. They were also informed to abstain from caffeine or alcohol consumption for 12 hours and otherwise continue their regular dietary habits. All subjects were verbally informed of the procedures, the potential risk and benefits of the study, and if willing to participate, were required to provide their written informed consent prior to their enrollment in the study. This study was approved by the ethics committee of the Eskisehir Osmangazi University (protocol number: 80558721/53) in accordance with the Declaration of Helsinki.

Table 1. Descriptive statistics of participants

	Participants (n=22)
	Mean ±SD
Age (y)	22.6 ±2.9
Height (cm)	182.0 ±9.5
Mass (kg)	78.9 ±12.4
General training age (m)	139.6 ±20.1
Training frequency (h/w)	9.6 ±0.6

SD: standard deviation; w: week; m: month; y: year.

2.1 Data Collection Procedure

The detailed experimental design flowchart is shown in Figure 1. Each recovery session started with the subject lying in the supine position for 15 minutes. During this period, resting heart rate (HR) was followed and at the end of this period, resting blood [La^-] was measured and right after this, the subject warmed up (5 minute warming up with light cycling resistance and 5 second of sprint cycling at the end of every consecutive minute). After two minutes resting, subjects completed a standardized WAnT and average mean power (R-AP). Right after the WAnT, the rating of perceived exertion (RPE) score was recorded and after 3 minutes of the WAnT, HR, and [La-] were recorded. After this, the subject began one of the recovery interventions (passive, active, or SMR). One minute after the recovery, HR, [La-] and TQR points (TQR) were recorded. In this study, there were three testing sessions, with each session performed at the same time of the day with a 72-hour interval.

DAY 1		DAY 2		DAY 3
Lying in a supine position during 15 minute. Recording resting HR and resting [La^-]	72 Hours	Lying in a supine position during 15 minute. Recording resting HR and resting [La^-]	72 Hours	Lying in a supine position during 15 minute. Recording resting HR and resting [La^-]
5 minute warming up with light cycling resistance and 5 second of sprint cycling at the end of every consecutive minute		5 minute warming up with light cycling resistance and 5 second of sprint cycling at the end of every consecutive minute		5 minute warming up with light cycling resistance and 5 second of sprint cycling at the end of every consecutive minute
WAnT, R-AP (W/kg)		WAnT, R-AP (W/kg)		WAnT, R-AP (W/kg)
3^{rd} minute after WAnT, recording HR and [La^-]		3^{rd} minute after WAnT, recording HR and [La^-]		3^{rd} minute after WAnT, recording HR and [La^-]
RANDOMIZED INTERVENTION		**RANDOMIZED INTERVENTION**		**RANDOMIZED INTERVENTION**
Lying in a supine position for 15 minute		Cycling in intensity of 40 % of estimated HR_{max} of the subject for 15 minutes		Foam rolling to each side of the hip, iliotibial band, quadriceps, hamstring, gastrocnemius ,tibialis anterior for 15 minutes (3×30 sec with 10 sec rest).
Recording HR, [La^-] and TQR		Recording HR, [La^-] and TQR		Recording HR, [La^-] and TQR

Figure 1. Flowchart of experimental design

PR: passive recovery; AR: active recovery; SMR: self-myofascial release; R-AP: relative average power; W: watt; [La^-]: blood lactate; HR: heart rate; TQR: total quality recovery; RPE: rating of perceived exertion.

2.2 Body Mass and Height

Body mass and height of the subjects were measured with a digital device (SECA,769-Turkey).

Heart rate and blood lactate. HR and blood [La^-] were measured three times in the study, prior to the WAnT, at the 3^{rd} minute after the WAnT, and the 1^{st} minute after the recovery protocol. During the study, the HR of the subject was followed with a telemetric HR monitor (Polar S810i-Finland). [La^-] was determined from fingerstick blood samples (EKF Lactate Scout Analyzer-USA). Blood samples were taken from the ring finger of the subject.

2.3 The Wingate Anaerobic Test

The WAnT test was used to trigger muscular fatigue and stimulate [La^-] production. None of our subjects were accustomed to competing in high-intensity activities which continued for 30 seconds (non-intermittent). Therefore, we hypothesized that the WAnT might trigger muscular fatigue. The WAnT began with a 5-minute warm-up period with light cycling resistance and 5 seconds of sprint cycling at the end of every consecutive minute (Atanasov et al., 2015). After a 2-minute rest period, the subject pedaled as fast as possible on a cycle ergometer (Monark Ergometer, 874 E-Sweden) set at a resistance of 0.075 $kp.kg^{-1}$ body mass (BM) (Finsterer, 2012; Ramírez et al., 2016). Strong verbal encouragements were provided equally to all subjects during each WAnT. At the end of the WAnT, MP and R-AP were recorded by the computer software of the Monark Ergometer.

2.4 Rating of Perceived Exertion (RPE)

The RPE from the WAnT was assessed by the Borg scale (scale ranging from "no exertion at all" (6 points) to "maximal effort" (20 points) (Borg et al., 1985).

2.5 Passive Recovery (PR)

Subjects quietly laid in a supine position for 15 minutes for the PR (Pinar et al., 2012).

2.6 Active Recovery (AR)

Subjects cycled for 15 minutes at an intensity of 40% of their own estimated HR_{max} (Warren et al., 2015). The target HR for AR was determined by the Karvonen formula (Hansen et al., 2012). During cycling, the subject was verbally encouraged to keep his/her own target HR and HR was followed on a telemetric HR monitor.

2.7 Self-Myofascial Release Exercise With Foam Roller (SMR)

The subject rolled a grid foam roller cylinder (height: 13 inches, diameter: 5.5 inches; Trigger Point-USA) from the top of the selected muscle to the bottom and then returned to the starting position (Healey et al., 204). Rolling cadence was

set as 50 beats per minute (bpm) with an online metronome (Pearcey et al., 2015). SMR exercises were applied to each side of the hamstrings, quadriceps, hip, iliotibial band, gastrocnemius, and tibialis anterior as 3 × 30 seconds with a 10-second inter-set passive rest. The subject was allowed a 30-second rest between exercises. Because there is no consensus on how much pressure is needed during SMR, we encouraged our subjects to apply as much pressure as they could during SMR.

2.8 Total Quality of Recovery

After each recovery intervention, the subject evaluated the recovery quality of their own recovery by the TQR scale (scale ranging from "very poor recovery" (6 points) to "very good recovery" (20 points) (Pinar et al., 2012).

3. Results

3.1 Statistics and Data Analysis

IBM® SPSS® Statistics for Windows version 23 software (IBM® Corp., 2016, Armonk, NY) was used for the data analysis. Normal distribution of residuals of related data was tested using the Shapiro-Wilk test. The effectiveness of each recovery intervention for 15 minutes was assessed using one-factor repeated measures analysis of variance with the post hoc Bonferroni method for pairwise comparisons for significant results. Mauchly's Sphericity test was used to check for sphericity assumption. When the normality condition was not provided, the Friedman Test was used for variance analysis and the Wilcoxon signed-rank test was performed for paired comparisons. Since factorial ANOVA assumptions were met only for [La^-] variable, 3 × 2 two way repeated measures ANOVA test was performed just on the [La^-] variable to reveal possible interaction effect between factors (Intervention × Time). Therefore, differences in other variables between interventions were examined using Wilcoxon signed rank test after a significant Friedman test result. The statistical significance level was set at $p<0.05$ for all analyses.

The results of the Friedman test showed that there was no statistically significant difference in [La^-] and HR values obtained before the WAnT test (p=0.368, p=0.691, respectively) and rigth after the WAnT test (0.264, p=0.629) According to this result, it can be said that evaluated fatigue levels of participants were similar when they came to the laboratory and they were affected similarly by exhaustive effect generated up by WAnT test before the recovery intervention (see Table 2). R-AP values obtained from the WAnT tests performed in order to create muscular fatigue were not found to be statistically different from each other (see Table 2). In this case, it was concluded that the training loads made up of the WAnT tests were at similar levels.

However, the RPE values obtained right after the WAnT tests were statistically significantly different between SMR and other recovery interventions and the maximum statistical difference was observed in between the RPE values after the WAnT test which was performed before the SMR and PR interventions ($p<0.001$). Therefore, it was determined that the WAnT tests performed in this study were perceived at different exertional levels by the participants. Mean percentage change and pairwise comparison values related to the test are shown in Table 3. It was determined that the three different 15-minute recovery methods have a statistically significant effect on perceived recovery related to the TQR score; the biggest statistically significant effect in pairwise comparison was found between the SMR and PR methods ($p<0.01$) (Table 3).

Table 2. Statistical values of R-AP, baseline of La and HR, TQR and RPE related to different intervention days

	Recovery Intervention Day					
	PR	AR	SMR	F or χ^2	p	η_p^2
R-AP ($W \cdot kg^{-1}$)	7.06 ± 0.69	7.14 ± 0.73	6.96 ± 0.48	1.59 (F)	0.215	0.071
Baseline [La^-] (mM/L)	1.45 [0.98–1.70]	1.40 [1.20–1.85]	1.50 [1.40–1.85]	2.00 (χ^2)	0.368	-
Baseline HR (bpm)	68.5 [59.5–82.5]	73.0 [67.3–80.3]	69.0 [62.8–76.5]	0.74 (χ^2)	0.691	-
[La^-] right after WAnT (mM/L)	10.5 ± 2.3	11.3 ± 2.5	10.5 ± 2.5	1.37 (F)	0.264	0.061
HR right after WAnT (bpm)	109 [80–128]	110 [77–136]	110 [73–124]	0.93 (χ^2)	0.629	-
TQR	10.0 [9.0–12.0]	13.0 [13.0–14.0]	15.0 [15.0–17.0]	21.2 (χ^2)	<0.001*	-
RPE	13.0 [14.0–15.0]	13.8 [15.0–15.5]	15.0 [17.0–18.0]	32.0 (χ^2)	<0.001*	-

Descriptive statistics are reported as either mean ± standard deviation or median [25 percentile – 75 percentile]; PR: passive recovery; AR: active recovery; SMR: self-myofascial release; F: F value in ANOVA; χ^2: chi-square, η_p^2 partial eta square, R-AP: relative average power; W: watt; [La^-]: blood lactate; HR: heart rate; bpm: beat per minute; TQR: total quality recovery; RPE: rating of perceived exertion.

*$p < 0.05$

Table 3. Comparison of TQR and RPE scores

	Pairwise Comparison	Δ	p	Z	ES
RPE	PR−AR	– 1.00 [– 2.00 - – 0.25]	0.033*	−2.13	0.32
	PR−SMR	– 3.00 [– 4.00 - – 1.75]	<0.001*	−3.94	0.59
	AR−SMR	– 2.00 [– 3.00 - – 1.75]	<0.001*	−3.96	0.60
TQR	PR−AR	– 3.00 [– 4.00 - – 1.00]	<0.001*	−3.77	0.57
	PR−SMR	– 6.00 [– 7.00 - – 3.00]	<0.001*	−3.83	0.58
	AR−SMR	– 3.00 [– 4.00 - – 1.75]	<0.001*	−3.74	0.56

Descriptive statistics are reported as median [25 percentile – 75 percentile]; PR: passive recovery; AR: active recovery; SMR: self-myofascial release; RPE: rating of perceived exertion; TQR: total quality of recovery; Δ: difference; ES: effect size for Wilcoxon signed rank test (*r*; 0.1 = small, 0.3 = medium, 0.5 = large effect size); Z: Z value in Wilcoxon signed rank test

*p < 0.05

Two way repeated measures ANOVA results revealed that there was a significant interaction ($F[2, 42] = 13.3$, $p < 0.001$, $\eta_p^2 = 0.387$) between RI and Time indicating that change patterns in [La^-] over 15 minutes were different between RIs. Also significant main effects were found for both RI ($F[2, 42] = 6.43$, $p = 0.004$, $\eta_p^2 = 0.234$) and Time ($F[1, 21] = 263.2$, $p < 0.001$, $\eta_p^2 = 0.926$). Lactate reductions (Δ) were significantly greater after AR ($p < 0.001$) and SMR ($p < 0.001$) interventions when compared to PR (Table 4). However, no significant difference were found in lactate reductions between AR and SMR ($p = 1.00$). According to this result, it was found that SMR and AR are more effective than PR to cope with fatigue related to [La^-] caused by the WAnT but SMR and AR were not superior to one another.

Friedman test results showed that there was no significant difference in HR changes between recovery interventions (p=0.185). But it can be said that the biggest value obtained from SMR intervention (see) Table 5).

Table 4. Pairwise comparison of [la^-] values between different recovery interventions

				RM ANOVA for %Δ			Pairwise Comparison		
RI	Time	[La^-] (mM/L) Mean ± SD	%Δ Mean ± SD	F	p	η_p^2		p	ES
PR	Post-WAnT	11.0 ± 2.5	−27.7 ± 17.8				ΔPR−ΔAR:	<0.001	3.60
	Post-RI	7.9 ± 2.4							
AR	Post-WAnT	11.3 ± 2.5	−52.5 ± 14.9	28.3	<0.001	0.574	ΔPR−ΔSMR:	<0.001	2.41
	Post-RI	5.3 ± 1.8							
SMR	Post-WAnT	10.5 ± 2.0	−51.1 ± 11.3				ΔAR−ΔSMR:	1.00	0.20
	Post-RI	5.1 ± 1.6							

PR: passive recovery; AR: active recovery; SMR: self-myofascial release; RI: recovery intervention; WAnT: Wingate anaerobic test; [La^-]: blood lactate; %Δ: percentage change; RM: Repeated Measures; F: F value in ANOVA; η_p^2 partial eta square; ES: effect size (Cohen *d*; 0.2 = small, 0.5 = medium, 0.8 = large effect size)

*p < 0.05

Table 5. HR changes between different recovery interventions

				Friedman Test for %Δ	
RI	Time	HR (bpm)	%Δ	χ^2	p
PR	Post-WAnT	108.5 [98.0 – 119.3]	−9.0 [−14.9 - −3.9]		
	Post-RI	97.5 [84.0 – 105.3]			
AR	Post-WAnT	109.5 [100.8 – 125.3]	−12.5 [−17.0 - −4.3]	3.38	0.185
	Post-RI	99.0 [84.0 – 110.0]			
SMR	Post-WAnT	110.0 [99.3 – 115.0]	−17.8 [−20.6 - −10.8]		
	Post-RI	90.5 [86.3 – 96.0]			

Descriptive statistics are reported as median [25 percentile – 75 percentile]; RI: recovery intervention; PR: passive recovery; AR: active recovery; SMR: self-myofascial release; HR: heart rate; bpm: beat per minute; %Δ: percentage change; χ^2: chi-squared test

*$p < 0.05$

4. Discussion

This study primarily aimed to investigate if SMR might be an alternative to AR for removal of blood [La^-], which is an accepted physiological indicator for recovery, and getting a higher TQR score, which is an accepted psychological indicator of recovery. The results from the present study indicated that: a) both AR and SMR were more effective than PR in terms of removal of [La^-] and obtaining a higher TQR score; b) however, SMR and AR were not superior to one another in terms of removal of [La^-]; c) moreover, a higher TQR score was observed with SMR when compared to AR and PR. In view of these results, our first hypothesis was verified; however, the second hypothesis was only partially verified, since SMR was not superior to AR in removal of [La^-].

Nédélec et al. (2013) reported that 81% of the French Professional soccer team performed AR immediately after the match and/or on the following days. Numerous researchers argued that AR is more effective than PR in removal of [La^-] and decreased muscle soreness (Corder et al., 2000; Hinzpeter et al., 2014; Menzies et al., 2010; Mika et al., 2016; Ali et al., 2012; Dorado et al., 2004; Sairyo et al., 2003; Bogdanis et al., 1996;). The positive effects of AR associated with blood flow to recovering muscle are from phosphocreatine (PCr) resynthesis and pH recovery (Quistorff et al., 1993). It has been well known that adequate blood flow to the recovering muscle will increase oxygen delivery and, therefore, enhance PCr resynthesis (Sahlin et al., 1979), while at the same time [La^-] and H^+ will be removed faster due to the greater [La^-] and H^+ gradients between the muscle and blood (Bogdanis et al., 1996). An increased muscle [La^-] and H^+ removal has been shown to result in a faster recovery of muscle performance (Renaud, 1989).

On the other hand, a considerable number of researchers proposed that AR was not superior to PR for recovery or that PR is more effective than AR in recovery, depending on [La^-] removal (Andersson et al., 2010; Dupont et al., 2007; Toubekis et al., 2006; Dupont et al., 2004; Fairchild et al., 2003). Choui et al. (1994) suggested that PR following intense exercise results in a greater amount of muscle glycogen resynthesis than AR over the same duration. Interestingly, Fairchild et al. (2003) reported that AR impairs glycogen repletion in skeletal muscle due to an unfavorable hormonal environment, such as higher plasma catecholamines and lower insulin levels. The positive effects of PR on performance were attributed to a slower decline in the oxyhemoglobin, suggesting that PR allows higher muscular reoxygenation than AR and, therefore a higher PCr resynthesis (Dupont et al., 2004). In the presence of equivocal results, the question arises as to which recovery is more effective in removal of [La^-]. The study by Dupont et al. (2007) revealed that the effect of the recovery type on performance might be linked to the exercise intensity performance criteria, recovery duration, and intensity of the recovery.

Regarding the effectiveness of SMR on recovery, several studies reported that SMR has an effect on recovery depending on decreased muscle soreness and increased pressure-pain threshold score following delayed-onset muscle soreness (Pearcey et al., 2015; Casanova et al., 2018). However, D'Amico and Gillis (2017) reported that SMR has no effect on the perception of muscle soreness score (by a Pain Test FPN 100 Algometer), but affects recovery of agility performance following exercise-induced muscle damage.

SMR is believed to have effects similar to massage according to the American Massage Therapy Association. Although the main mechanism is not known for recovery from muscular fatigue after SMR, it is generally attributed to decreased edema, enhanced blood [La^-] removal, and enhanced tissue healing, which are mainly due to the increase in muscular blood flow (Paolini, 2009). According to Pearcey et al. (2015) increased blood flow hinders the margination of neutrophils and reduces prostaglandin production, subsequently decreasing inflammation.

We could not find any studies other than the studies by D'amico and Paolone (2017) and Cè et al. (2013) which compared the effects of SMR and other recovery methods on recovery via [La^-] removal. In contrast to our study, D'amico and Paolone (2017) reported that SMR had no effect on the removal of [La^-]; this study also argued that light

exercise was a means of AR for minimizing fatigue-induced decrements in performance during successive exercise bouts. C è et al. (2013) also reported that neither massage (deep and superficial massage) nor passive stretching were effective alternatives to AR in accelerating [La^-] kinetics after a fatiguing exercise.

Okamoto et al. (2014) reported that SMR using a foam roller increases plasma nitric oxide concentration (NOC) and decreases arterial stiffness in healthy subjects aged 19.9 ± 0.3 years. We concluded that recovery from muscle fatigue may be attributed to increasing NOC, which is a known vasoactive substance. However, Casanova et al. (2018) argued that foam roller massage (target muscle gastrocnemius; 6 × 45 seconds with a 20-second rest) did not change the muscular oxygenation in young subjects' responses 48 hours after exercise-induced muscle damage.

Regarding TQR, previous studies have demonstrated strong inverse associations between TQR and biomarkers of muscle damage, such as creatine kinase (Osiecki et al., 2015). According to Osiecki et al. (2015) TQR may be a good predictor of the recovery state in team sports athletes. A study published by Rey et al. (2017) reported that post-training foam rolling exercises may help in restoring muscle soreness, players' perception of TQR, and agility on the following day in professional soccer players.

There were two main limitations in this study. First, the results of the study were limited to recovery from [La^-] following a WAnT. We could not apply several consecutive WAnT with the worry of medical problem which to be occurred after high-intensity exercise. Second, our subjects had no experience with using a foam roller. For experienced players using a foam roller for recovery, results may differ.

In conclusion, our study results show that using a foam roller for SMR seems to be as effective as AR as a recovery tool. Therefore, we suggest that SMR may be an alternative recovery tool after exercise-induced muscular fatigue. Due to contradictory results found in the literature for effects of SMR on recovery, further research is needed to explain this.

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4.2 Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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