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Effect of Self-Myofascial Release on Physical Performance in Young Basketball Players

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Abstract

The aim of this study is to determine the effect of self-myofascial release (SMR) applied immediately after intense exercise on physical performance parameters such as joint range of motion (ROM), flexibility, agility, and balance. One of the popular methods today to reduce the negative effects on the body after fatigue is self-myofascial release. Myofascial release is a targeted, directional, low-load mechanical force application aimed at restoring optimum tissue length and improving function. The study involved 12 male basketball players (mean age 16,42±0,52 years) who actively played basketball and were randomly divided into two groups (SMR Group, n=6; CNT Group, n=6) The participants performed a self-myofascial release application for 30 seconds immediately after basketball training (3 days per week) for 8 weeks. The flexibility, agility, balance, and joint range of motion values of the participants were measured before and after the 8-week period (Pre Test and Post Test). The statistical analysis of within-group time differences and inter-group differences was performed using a mixed design (2x2) ANOVA test (SPSS 23). Significant results in favor of the SMR group were found only for hip adduction ROM values ($p<0,05$), while improvements in other ROM values, flexibility, and agility parameters were detected within the SMR groups, though not statistically significant between Pre Test and Post Test. As a result, it was not possible to establish evidence that SMR applications after training could significantly help in increasing joint range of motion, improving balance performance, enhancing muscle flexibility, or decreasing agility values in basketball players. However, improvements, albeit at low levels, in all parameters suggest that self-myofascial release may contribute to the recovery phase of athletes. Therefore, clinicians, sports scientists, coaches, and athletic performance specialists should provide athletes with the most appropriate recovery strategies for higher performance, readiness, and competition.

Keyword: Range of Motion, Balance, Flexibility, Agility, Myofascial Release.

Özet

Genç Basketbolcularda Kendi Kendine Miyofasyal Gevşemenin Fiziksel Performans Üzerine Etkisi

Bu çalışmanın amacı, yoğun bir egzersizin hemen sonrasında uygulanan köpük rulo ile kendi kendine miyofasyal gevşemenin, fiziksel performans parametrelerinden eklem hareket açıklığı, esneklik, çeviklik ve denge performansları üzerine etkisini belirlemektir. Yorgunluk sonrası vücutta oluşan olumsuzlukların azaltılmasına yönelik günümüz popüler yöntemlerden birisi kendi kendine myofasyal gevşemedir. Miyofasyal gevşeme, optimum doku uzunluğunu geri kazandırmayı ve işlevi iyileştirmeyi amaçlayan hedefli, yönlü, düşük yüklemeli mekanik kuvvet içeren bir uygulamadır. Çalışmaya faal olarak basketbol oynayan ve rasgele yöntemle iki gruba ayrılan (SMR Grup, n=6; KNT Grup, n=6) 16,42± 0,52 yıl yaş ortalaması olan 12 erkek basketbolcu katılmıştır. Katılımcılara 8 hafta süren basketbol antrenmanlarının hemen sonrası (haftada 3 gün) 30 sn'lik sürelerle kendi kendine myofasyal gevşeme uygulaması yapılmıştır. Katılımcıların esneklik, çeviklik, denge ve eklem hareket açıklığı değerleri, 8 haftalık sürenin öncesinde ve sonrasında (Ön Test ve Son Test) ölçülmüştür. Grup içi zaman farklılıkları ve gruplar arası farklılıkların istatistiksel analizinde Karma Desen (2x2) ANOVA" testi (SPSS 23) kullanılmıştır. Gruplar arasında yalnızca kalça adduksiyon ROM değerlerinde SMR grubu lehine anlamlı sonuç (p<0,05) bulunurken, diğer ROM değerleri, esneklik ve çeviklik parametrelerinde sadece grup içi Ön Test ve Son Test ölçümleri arasında SMR gruplarında anlamlı düzeyde olmasa da iyileşmelerin olduğu tespit edilmiştir. Sonuç olarak, basketbolcularda antrenman sonrası SMR uygulamalarının eklem hareket açıklıklarının artırılmasında, denge performanslarının yükseltilmesinde, kas esneklik düzeyinin arttırılmasında ve çeviklik değerlerinin aşağı çekilmesinde yüksek düzeyde bir etkiye yardımcı olabileceği yönünde bir göstergeye ulaşılamamıştır. Fakat tüm parametrelerde düşük düzeyde de olsa iyileşmelerin görülmesi, oyuncuların toparlanma aşamasında katkılar sağlayabileceğini düşündürmektedir. Bu nedenle, klinisyenler, spor bilimciler, antrenörler ve atletik performansçılar sporcuların daha yüksek performans, hazır bulunuşluk ve rekabet için en uygun toparlanma stratejilerini sağlamalıdırlar.

Anahtar Kelimeler: Eklem hareket açıklığı, denge, esneklik, çeviklik, myofasyal gevşeme.

INTRODUCTION

It is very important for athlete performance to eliminate the effects such as fatigue and delayed onset muscle soreness (DOMS) that occur in athletes after exercise as soon as possible (1, 8, 15, 17). Failure to recover in a short period of time can also negatively affect players' performance and general well-being (19). Furthermore, players at all levels of competition are exposed to intense training and match programmes, which can lead to fatigue accumulation (12, 19). In order to determine effective strategies to eliminate these negative effects, various researches have been conducted and are still being conducted by many researchers. Post-exercise recovery strategies such as self-myofascial relaxation (SMR) applications (8, 16, 24, 26, 42) are common methods applied to reduce fatigue and muscle soreness. The main goal of SMR is to reduce the tension between the muscles and the surrounding fascia tissue and increase mobility. Fascial tissue is a structure whose presence is determined in every region and every part of the human body, wrapping the body like a spider web, and whose value and benefits are understood more and more every day. The fascial system penetrates and surrounds all organs, muscles, bones and nerve fibres; it gives the body a functional structure and provides an environment that allows all body systems to work in an integrated manner (2). The myofascial system and its physiological effects on the human body have been widely studied in the field of physical activity and sports strength and conditioning in the last decade (20, 28, 34, 50). Although scientific evidence is limited, 'myofascial release' (MFR) and 'self-myofascial release' (SMR) applications are quite common today in gyms and sports centres by individuals of all ages (4, 39) and are even used by athletes and coaches in the fields of sports performance and physiotherapy (8).

Myofascial release is a therapeutic intervention to loosen soft tissue from areas of abnormally tight fascia (36). Myofascial release therapy involves targeted, directional, low-loading mechanical forces aimed at restoring optimal tissue length and improving function (3). It is suggested that high or sustained pressure applied through myofascial release causes the golgi tendon organs to sense sensations of varying tension in the musculature and induce relaxation of muscle fibres (36). A popular approach to self-myofascial release (SMR) has emerged as a technique in which individuals apply pressurised rolling forces with a foam roller along the targeted musculature using their own body mass and follow the orientation of the mobilised muscle (41). SMR has become a popular method that affects muscle and myofascial structures by increasing fascia compliance and extensibility (37) and reducing passive muscle stiffness (38). The best known positive effect of SMR is the increase in ROM values (23, 32, 49). Beardsley and Scarabot (5) positively commented that myofascial release studies increased the range of motion by relaxing the fascia.

Studies examining the possible effects of SMR on the body mention that there may be fascial restrictions that may prevent normal muscle function after physical exertion (2, 45, 54). They state that this situation may affect the musculoskeletal system, which is the basis for sports performance (45) and the physical conditions (strength, speed, endurance, flexibility) arising from it (11). The idea that SMR exercises can be an alternative to recovery methods for soft tissue regeneration attracts the attention of athletes, coaches, fitness participants and physiotherapists (32, 41). Despite its popularity, the physiological effects of many SMR tools on the body are still unclear. As a result, a consensus regarding the specific use of SMR in an optimal programme to enhance physical capacity, accelerate recovery processes and improve overall athletic performance has yet to be established (6, 22). Given that SMR is emerging as a trend in the field of physical conditioning (52), it is important to determine the conceptual meaning of the myofascial system in order to reach a broader understanding of the effects of SMR on the human body and how these effects can affect athletes' performance (34).

Considering that the effects of myofascial release on athletes are still unclear in the literature, an answer to the following question was sought. After an intense exercise session, does self-myofascial release with a foam roller accelerate muscle recovery, increase range of motion and improve balance, flexibility and agility performances that affect athletic performance?

METHOD

The study is a quantitative study and was carried out in experimental research type. The ethics committee approval for this experimental study was obtained from Selçuk University, Faculty of Sport Sciences, Non-interventional Clinical Research Ethics Committee (03.24.2023; 37).

Research Group: Twelve male basketball players aged 16-18 years actively playing basketball participated in the study. Before the study, participants were provided with a verbal explanation of the procedures and signed informed consent. All procedures were in accordance with the Declaration of Helsinki. Two groups were formed from the participants, the SMR group (6 athletes) and the CNT group (6 athletes). Descriptive information (Age, Body Weight (BW), Height, Body Fat Percentage (BFP), Lean Body Mass (LBM) and Body Mass Index (BMI) were measured/calculated and tabulated (see Table 1).

Data Collection

For body composition measurements of the participants, a scale (DESİS) with an accuracy of ±50 g, a stadiometer (SECA) with an accuracy of ±1 mm, and a skinfold caliper (HOLTAİN) with an accuracy of ±0.2 mm were used.

Agility measurements were performed with the Ilionis test. It was performed twice with 5 min intervals and the best test result was recorded.

Flexibility measurements were performed using a standard sit-stand test table and the higher value of the 2 measurements was recorded.

Balance measurements were performed using a multiaxial balance measurement device (BBS, Biodex Medical Systems Inc, Shirley, USA). With the balance measurements performed within 10 seconds with eyes open (GA), a total of 3 measurement results including swing limits, medial-lateral index, anterior-posterior index and overall stability index were obtained and recorded.

Range of Motion (ROM) was measured from 5 regions including shoulder (flexion, extension, abduction), hip (flexion, extension, abduction, adduction), knee (flexion), elbow (flexion) joints by means of HALO inc. (USA) digital goniometer (Correll et al 2018).

Figure 1. Range of Motion (ROM) Measurements of the Participants with Digital Goniometer.

Implementation Procedure

Type and Duration of Training; Both groups were ensured to continue their classical basketball training in their teams for 8 weeks and not to participate in any other physical activity. This process started with the 2nd half of the 2024-2025 season.

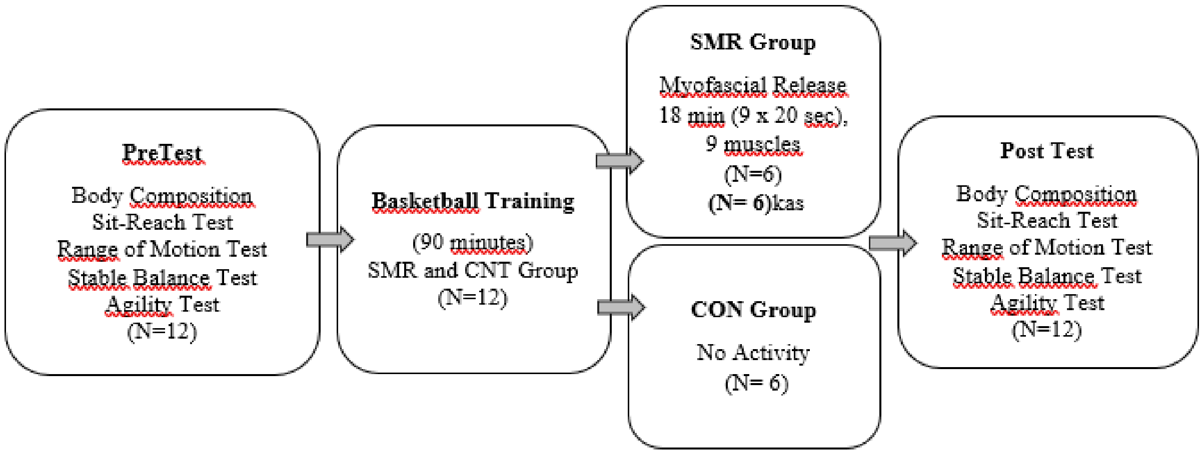

Figure 2. Study Design Diyagram

Content and duration of SMR applications; SMR application training was given by an expert trainer so that SMR applications could be performed by the athletes themselves. SMR application; Planter Facia, Gastrocneminius, Adductors, Tensor Fascia Latae, Hamstring, Gluteuses, Quadriceps, Priformis, Thoracic Spine, Latissimus Dorci, Pectoralis Major muscle groups were applied. In this study, a 90 cm long and 15 cm diameter high density (ACTIFOAM) foam cylinder with a smooth surface (without serrations) was used, and an 8 cm diameter ball of the same hardness (ACTIFOAM) was used for underfoot Planter Facia application.

SMR was applied by means of foam cylinders along the muscle fibres, from the proximal to the distal muscle insertion and vice versa, at a constant pressure and a speed of 2.5 cm/sec into the muscle tissue only. The participant was monitored by the researcher while applying the SMR technique, intervened when necessary and ensured that it was performed in the correct form. SMR was applied only to muscle tissue for an average of 20 seconds, avoiding pressure on bones, joints or tendons.

Figure 3. Self-Myofascial Release Practice and Foam Roller and Foam Ball Used.

Statistical Analysis

SPSS version 23.0.0 (SPSS Inc., Chicago IL, USA) was used in the analysis of all data and alpha levels were evaluated at 0.05 for significance. In data table presentations, values are expressed as mean (X) and standard deviation (SD). For the normal distribution analysis of the data, Skewnew-Kurtasis test and skewness and kurtosis values (51, 21) and then Shapiro-Wilk test values were taken into consideration. 'Box' test for the equality of Covariance Matrices and then "Levene" test results for the equality of Error Covariances were taken into consideration. 'Mauchly' test was performed for the sphericity condition, and in cases where the sphericity assumption was not met, the results were determined and used with Greenhouse-Geisser correction. 'Mixed Design (2x2) ANOVA' test was used in the pretest and posttest comparisons of the experimental and control groups of all the data obtained. The 'Eta Square (ηp2)' values were calculated and interpreted for the effect size of the significant differences obtained. Eta square (η2) values were considered as small effect size if equal to 0,01, medium effect size if equal to 0.05, and large effect size if equal to 0,14 (10).

FINDINGS

Table 1. Pretest Values Regarding Body Composition Parameters of Participants

N=12	Min.	Max.	$\bar{x}$	SD
Age (years)	16,00	17,00	16,42	0,52
Height (cm)	1,72	2,07	1,89	8,93
Body Weight (kg)	60,00	110,00	80,75	12,93
Body Fat Percentage (%)	9,43	20,15	13,86	3,16
Body Mass Index (kg/cm)	18,60	29,84	22,53	3,03

Table 2. Mixed Design Anova Test Results of Participants' Range of Motion (ROM) Values

	Groups	N	Pre Test	Post Test	F Time	F Group	F GroupxTime
			$\bar{x}$ ± SD				
SHOULDER (flexion)	SMR Group	6	167,67±23,27	186,50±19,77	9,08*	0,01	1,19
	CNT Group	6	171,50±17,46	180,33±17,36			
	Total	12	169,58±19,71	183,42±18,03			
SHOULDER (extension)	SMR Group	6	46,83±12,23	50,50±13,90	0,95	0,76	0,01
	CNT Group	6	40,00±17,42	44,67±14,56			
	Total	12	43,42±14,71	47,58±13,91			
SHOULDER (abduction)	SMR Group	6	150,00±21,71	165,83±18,08	4,18	1,91	0,43
	CNT Group	6	141,50±16,83	149,67±16,91			
	Total	12	145,75±19,04	157,75±18,70			
HIP (flexion)	SMR Grubu	6	81,67±8,02	88,83±5,27	4,19	3,49	1,47
	SMR Group	6	71,00±11,82	72,83±5,27			
	CNT Group	12	76,33±11,12	80,83±16,77			
HIP (extension)	SMR Group	6	18,50±2,88	19,83±2,40	0,25	0,57	0,70
	CNT Group	6	19,67±2,94	19,33±3,56			
	Total	12	19,08±2,84	19,58±2,91			
HIP (adduction)	SMR Group	6	22,67±6,53	30,83±11,30	5,17*	0,44	5,17*
	CNT Group	6	29,67±8,29	29,67±5,47			
	Total	12	26,17±8,00	30,25±8,49			
HIP (abduction)	SMR Group	6	41,17±5,49	49,17±9,50	4,84*	3,99	1,59
	CNT Group	6	34,83±9,93	37,00±10,14			
	Total	12	38,00±8,33	43,08±11,32			
KNEE (flexion)	SMR Group	6	143,83±22,85	141,33±11,18	0,49	3,82	0,45
	CNT Group	6	126,67±21,40	122,00±15,96			
	Total	12	135,25±22,93	131,67±16,57			
ELBOW (flexion)	SMR Group	6	148,33±4,84	150,50±5,82	0,70	0,14	2,92
	CNT Group	6	153,33±7,15	147,00±3,63			
	Total	12	150,83±6,38	148,75±4,98			

*p=0,05

When the participants' Shoulder extension and abduction, Hıp flexion and extension, Knee flexion and Elbow flexion ROM values were examined, it was found that there were no significant differences in any of the time, group and group x time effect factors (p>0,05). It was observed that the effect of the time factor was statistically significant in Shoulder flexion (F(1,9)=9.08, p=0,01, η2=0,48) and Hip abduction ROM values (F(1,9)=4,84, p=0,05, η2=0,33). It was determined that there were significant differences in Hip adduction ROM values (F(1,9)=4,84, p=0,05, η2=0,33) in all effect factors, time (F(1,9)=5,17, p=0,04, η2=0,34), group (F(1,9)=0,44, p=0,05, η2=0,04) and group x time (F(1,9)=5,17, p=0,04, η2=0,34).

Table 3. Mixed Design Anova Test Results of Participants' Open Eye Balance Parameters

	Groups	N	Pre Test $\bar{x}$ ± SD	Post Test	F Time	F Group	F GroupxTime
Right Foot (Anterior-Posterior Index)	SMR Group	6	1,40±0,77	1,12±0,48	1,67	2,15	0,16
	CNT Group	6	1,87±0,73	1,72±0,76			
	Total	12	1,63±0,76	1,42±0,68			
Right Foot (Inner-Outer Index)	SMR Group	6	1,57±0,72	1,65±0,69	0,88	0,16	0,15
	CNT Group	6	1,38±0,42	1,58±0,57			
	Total	12	1,47±0,57	1,61±0,60			
Right Foot (Total Index)	SMR Group	6	2,33±1,06	2,28±0,97	1,32	1,11	0,62
	CNT Group	6	2,63±0,97	2,37±1,13			
	Total	12	2,48±0,98	2,33±1,00			
Left Foot (Anterior-Posterior Index)	SMR Group	6	1,58±0,55	1,45±0,61	2,38	0,19	0,14
	CNT Group	6	1,47±0,91	1,25±0,52			
	Total	12	1,53±0,72	1,35±0,55			
Left Foot (Inner-Outer Index)	SMR Group	6	1,47±0,87	1,48±0,0,83	0,15	0,75	0,23
	CNT Group	6	1,25±0,36	1,08±0,62			
	Total	12	1,36±0,65	1,28±0,73			
Left Foot (Total Index)	SMR Group	6	2,35±1,01	2,45±1,18	0,61	0,29	2,24
	CNT Group	6	2,25±1,05	1,93±0,79			
	Total	12	2,30±0,98	2,19±0,99			

*p=0,05

When the participants' right foot front-back, inside-outside and total index values and the left foot front-back, inside-outside and total index values were examined, it was determined that there were no significant differences in any of the time, group and group x time effect factors (p>0,05), (see table 3).

Table 4. Mixed Design Anova Test Results of Participants' Flexibility and Agility Values.

	Groups	N	Pre Test $\bar{x}$ ± SD	Post Test	F Time	F Group	F GroupxTime
FLEXIBILITY (cm)	SMR Group	6	11,06±5,12	16,02±5,16	12,16*	0,41	1,16
	CNT Group	6	10,43±6,44	13,05±3,89			
	Total	12	10,75±5,56	14,53±4,62			
AGILITY (sec)	SMR Group	6	17,78±1,24	17,51±1,07	7,09*	0,51	3,37
	CNT Group	6	18,84±1,87	17,41±0,63			
	Total	12	18,31±1,61	17,46±0,84			

When the flexibility values of the participants (see table 2) were examined, it was seen that the effect of the time factor (F(1,9)=12,16, p=0,04, η2=0,55) was statistically significant, while no significant difference was found in the group and group x time factor (p>0,05). In the flexibility parameter, it was determined that the Post-Test values of both the SMR and CNT groups were higher than the Pre-Test values. Although this increase in the SMR group was not statistically significant, it was higher than the CNT group. Although the significance in this increase was a significance of p=0,54 between the groups, it was observed that there was a low-level effect when the effect size (η2=0,04) value was taken into account. When the agility values of the participants (see table 4) were examined, it was seen that the effect of the time factor (F(1,9)=7,091, p=0,02, η2=0,42) was statistically significant, while no significant difference was found in the group and group x time factor (p>0,05). When the Pre-Test and Post-Test agility mean values of the SMR and CNT groups were examined, it was determined that there were decreases in the Post-Test agility values in both groups compared to the Pre-Test values.

DISCUSSION AND CONCLUSION

The aim of this study was to find an answer to the question whether self-myofascial release with a foam roller after an intensive exercise session helps to improve range of motion, balance, flexibility and agility performances which have effects on athletic performance.

When the findings of our study on active young basketball players were analysed, a significant difference between the groups (SMR and CNT) was found only in hip adduction ROM (see table 2) in favour of the SMR group. Significant differences were found in shoulder flexion and hip abduction ROM values in the intra-group time interaction, while no significant differences were found in other measured ROM values. However, improvements were observed in all ROM values in SMR groups compared to CNT groups.

It was determined that there were no significant differences between the groups in all parameters of balance measurements (see Table 3). On the other hand, in flexibility and agility variables, significant differences were found only between the pre-test and post-test values of the groups (SMR-CNT) (see table 4).

In all ROM values measured from nine regions in our study, increases were observed in both SMR and CNT groups in the pretest-posttest time parameters, but these increases were not significant in all except the hip adduction value. This significant increase in hip adduction value was 30.83 % in the SMR group and 29.67 % in the CNT group. Although we determined increases in all ROM values (between 2% and 15%), the lack of high level improvements in balance, flexibility and agility values suggested that the increases in ROM values were not sufficient to provide an increase in performance parameters. In a study conducted about 10 years before our study, Jay et al (25) applied SMR to one leg for 10 min after the stress they created in the hamstring muscles and did not determine a significant change in the ROM values of the leg with and without SMR as in our study.

Macdonald et al (33), who analysed post-exercise SMR application as in our study, reported that, contrary to the results of our study, there was an improvement in ROM values, muscle activation and vertical jump performance of the experimental groups compared to the control groups. In addition, in their systematic meta-analysis study on the use of SMR before and after exercise, Schroeder and Best (46) stated that increases in quadriceps and hamstring ROM values were detected depending on time factors, and as a result of their evaluation, they emphasised that foam roller SMR applications can be a valuable tool for exercising individuals and that individuals can eliminate the need for a massage therapist and allow individuals to self-treat themselves at a convenient time (immediately after exercise) and frequency (several times a day). Mauntel et al (35), in a review of 10 studies, Mauntel et al (35) found that a significant increase in ROM was observed in 8 of 10 studies and no significant changes in muscle function parameters were found in any of these 10 studies. Therefore, they recommended that clinicians use myofascial release applications before rehabilitation or physical activity.

The reason for this is that SMR applications effectively increase ROM without decreasing muscle function, and the increase in ROM increases the efficiency of movement and reduces the risk of injury. Martinez-Aranda et al (34), in their evaluation after a review of the literature on in-depth myofascial release involving a total of 25 articles and 517 athletes, stated that SMR applications are an effective and alternative application to improve the ROM values of the joints in both isolated and static and dynamic stretching without adversely affecting the athletes' performance in strength, speed and agility as well as muscle activities. They also emphasise that these improvements in ROM will provide higher performance in movement patterns and thus reduce the risk of skeletal muscle injuries. In addition to these explanations, they also stated that the most efficient and most appropriate SMR application time is approximately 1 minute 30 seconds.

In the limited literature studies in which the effects of SMR on static and dynamic balance were examined, there are studies in which improvements in balance performance were determined, as well as studies in which negative results were determined even if there was no improvement. The results of the study on the balance performance of SMR (23) and the subsequent studies (27, 53) and our study, in which we determined that SMR applied after basketball training did not have a positive effect on balance performance, are similar to these studies. In addition to these studies, Lee et al (30), one of the limited number of studies that determined the positive effects of SMR on balance performance, determined that foam rolling techniques showed an increase of 1.8% compared to static stretching techniques as a result of dynamic balance measurements with the Star

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Balance Test (YDT) after 2 different foam roller rolling and static stretching applications applied to 30 male university students. In another study, Zhang et al (55) determined that the performance of the SMR group was better than the CON group in the anterior axis and lateral axis at the end of the SMR applications in the balance values determined with the Star Balance Test and stated that the balance values of the SMR group improved up to 8%. In our study, no significant differences were detected in both right and left foot balance measurements, in both anterior-posterior and lateral-medial oscillations and in total balance evaluation, neither between the groups nor within-group time factors (pretest-posttest). The lack of improvement in balance performances in the present study suggests that the lack of improvement in ROM values is also related to the lack of improvement in ROM values.

It is a known fact that basketball players should have appropriate back and hamstring flexibility in order to reduce the risk of knee and ankle injuries with muscle strain and to increase their performance. Although the differences between the SMR group and the CNT group were not significant (p= 0,54), we observed an improvement of 44,85% in the SMR group and 25,12% in the CNT group in the pretest and posttest values of the groups. While these findings are compatible with the results reported by Casanova et al (2018), they contradict the study by Macdonald et al (33) in which they found significant effects of SMR in reducing the loss of knee flexion and hip flexion flexibility 48 and 72 hours after exercise. In addition, in a study using the same measurement method as our study, Sullivan et al (49) found a 4.3% increase in flexibility measurements before (31,32) and after (32,68) SMR (p=0,00), although there was no significant difference between the groups (p=0,07). In addition to these results, Zhang et al (55) stated that SMR provided a significant ($p<0.001$) interaction between flexibility variables and that the scores in SLR (11 ± 7%), TTT (50 ± 40%) and WBLT (22 ± 17%) increased and improved flexibility performance in the SMR group.

As a result of their study aiming to reveal the effects of SMR in more detail, Beardsley and Škarabot (5) reported that SMR acutely increased flexibility and reduced muscle soreness without negatively affecting athletic performance. However, they emphasised that it should be noted that there is conflicting evidence as to whether SMR improves flexibility in the long term. When the literature studies on the improvement of flexibility by SMR are evaluated, there are studies with significant differences (48, 29) as well as studies that do not find significant. In the literature, when traditional stretching methods (passive / static or dynamic) are compared with other methods (foam roller, pilates ball / circle, foam ball, etc.), it is stated that there are not many differences between them (9, 14, 40, 41, 43, 53) close values are determined and not much improvements are determined.

It was also stated that all the methods applied did not produce any negative effects. In a recent meta-analysis (34), it was reported that although the underlying causes of improved flexibility in general remain unclear for a number of reasons, from a more positive perspective, these positive effects may be explained by a temporary decrease in the connection between fascial tissue and muscle tissue or plasticity deformation of connective tissue (e.g. fascia, tendon, capsule). On the positive side, Martinez-Aranda et al (34) stated that a temporary reduction in pain perception may also lead to an improvement in short-term flexibility. Therefore, studies focussing on the short-term effects of SMR have argued that knee and hip flexibility improved mainly immediately after the application, and that this effect disappeared after 24 hours, with no permanent improvement. As a result, according to short-term interventions, in accordance with the temporal improvements mentioned above, they stated that the effects on flexibility lasted less than 10 minutes.

In addition, short-term improvements in flexibility values are based on evidence, but there are no clear statements about why there is no improvement. Although no significant improvement was observed in our study, the fact that the rate of increase determined in the SMR group was higher than the CNT group suggests that SMR application may have an additional contribution to the flexibility value.

We consider anaerobic performance as a basic requirement for playing basketball due to the high number and intensity of sprints, changes of direction and jumps that basketball players must perform during the competition. For this reason, agility performance measurement, which is one of the anaerobic data, was included in our study and we sought an answer to the question of how foam roller application after intensive basketball training affects agility performance. In our current study, there was no significant difference between the SMR group and the CNT group in the agility values of SMR, but significant improvements were observed between the Pre-Test and Post-Test values of both groups (time factor). This improvement was determined -1,52% in the SMR group and -7,59% in the CNT group, suggesting that the results were inconsistent. The fact that there was no difference between the groups in agility values, but that they differed over time in both groups, was interpreted as an indicator of a positive effect of 3 days of training and 1 day of competition per week on agility. Although there are massage-based applications on agility performance, the number of studies performed with normal foam rollers (without vibration, static/dynamic stretching) is limited. Rey et al. (42) examined the jump, sprint, flexibility, agility and recovery values as a result of SMR application after football training (n=18) and could not find a significant improvement in all parameters, but determined improvements in agility values in time ($\eta 2=0.27$) and time x group ($\eta 2=0.24$) values. The author commented on this result, stating that SMR has a positive effect in minimizing the decreases in agility test performance, providing a return close to pre-training values, and that this recovery mode can be one of the valuable aids for muscle recovery function in agility actions. Richman et al. (43) examined the effects of a 6-minute SMR protocol using a foam roller, combined with a general warm-up and sport-specific dynamic stretching (DS) session on flexibility and agility in a sample of 14 female university athletes, and reported that there were no significant differences between the groups, only improvements in flexibility values over time. When the studies that performed post-warm-up tests using vibrating foam roller and stretching applications were examined; studies that performed applications with different methods (vibrating foam roller, vibrating massage device and static/dynamic stretches) after warm-up training (not intense activity) (31, 9, 53) also determined significant differences in agility test results between the vibrating groups and the other groups, contrary to the results of the SMR study performed with a normal foam roller (our current study; Richman et al. (43)).

Since the use of different devices (vibration) and the implementation of the applications before exercise (after warming up) in these studies are different from our study method and their effects are thought to be different, it would be correct to evaluate such studies in different categories. Martinez-Aranda et al (34) stated that these inconsistencies determined in the literature can be explained by study designs, activities that induce fatigue, or differences between the samples. The low-value increase observed in agility performance after SMR application observed in our study, similar to what Martinez-Aranda at al (34) commented, may be due to decreased DOMS pain, increased voluntary activation, and decreased neural inhibition. Considering these different results in the literature, it is still unclear whether the use of SMR after training sessions will accelerate aerobic recovery and facilitate the improvement of repeated sprint performances. In order to transform this uncertainty into clear statements and to reveal the effect of SMR on recovery in every aspect, especially in team sports, more research needs to be done to definitely clarify the duration of SMR application and the intensity of pressure. It is also important that athletes are given meticulous training and reinforced with many repetitions so that they can apply SMR applications correctly.

The limitations of this study should definitely be taken into consideration when interpreting the results.

The first limitation is that the 8-week period during which SMR applications were performed in our study can be considered as a short period in terms of seeing improvements. When designed as a longitudinal application, it will facilitate the evaluation of the effectiveness of SMR on the level of fatigue that may occur after intense training and competition. In addition, SMR application is performed only once within the 24, 48 or 72 hours between two training sessions. SMR applications that can be repeated (more than once) between these training processes can facilitate fatigue level evaluations.

The second limitation is that the SMR trainings given to the athletes are created as a single repetition considering the time factor. Providing these trainings once before the study applications has ensured that the athletes cannot adjust the duration and intensity correctly, cannot clearly find the fascial trigger points or do not take the application seriously.

CONCLUSION AND RECOMMENDATIONS

In summary, the results of the current study did not show that SMR applications after training in basketball players could help to improve joint range of motion, increase balance performance, flexibility and agility performance at a high level. However, the fact that improvements were observed in all parameters, albeit at a low level, suggests that it may contribute to the recovery phase of the players. Therefore, clinicians, sports scientists, coaches and athletic performers should provide the most appropriate recovery strategies for athletes for higher performance, readiness and competition.

This study aimed to ensure that the use of SMR in basketball players during the recovery phase after intensive training and competition is beneficial to athletic performance by increasing joint range of motion, increasing stable balance performance, increasing muscle flexibility level and decreasing agility values. Considering the importance of how players feel, it can be thought that any action taken to increase the perception of recovery after exercise can help basketball players to train adequately, perform the planned workload or reach the expected performance level. Therefore, to minimize the negative effects of basketball training, coaches and athletic performers of all age categories, both amateur and professional, may consider prescribing 20 to 30 minutes of SMR practice to help enhance recovery between training and competition loads.

Limitations of the Study

This study has some methodological limitations.

First, the study was conducted with only 12 male basketball players between the ages of 16-18. This situation limits the generalizability of the findings to different age groups, genders or sports branches. The low number of participants may reduce statistical power and make it difficult to transfer the results to a larger population.

Second, the application period was limited to eight weeks. The effects of long-term applications are outside the scope of this study. In addition, since SMR applications are based on the principle that athletes perform them on their own, application differences between individuals and technical errors are another factor that may affect the reliability of the results.

However, although the participants were only asked to continue their basketball training, their physical activities outside of training could not be completely controlled. This factor has the potential to increase the effect of external variables on the results.

Finally, psychological, motivational or environmental factors were not evaluated in the study; only physical performance parameters were measured. Since these individual factors may indirectly affect performance, they should be carefully considered when interpreting the results.

In line with these limitations, the findings obtained should be interpreted carefully and should be considered as a reference for future studies. When evaluated within this framework, the results of the study provide important findings regarding the effects of SMR applications on physical performance in young athletes.

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