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Comparative Effects of SMR Rolling and Dynamic Stretching on Forward Flexion and Jump Height in U14–U15 Football Players

SMR henger és dinamikus nyújtás összehasonlító vizsgálata az előrehajlásra és a felugrási magasságra U14-U15 labdarúgóknál.

Szerzők: **Mónika Szigethy** [1], **Enikő Hurtik-Tóth** [2]

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Sectioneditor / Rovatszerkesztő:
Katalin Nagyváradi
ELTE Eötvös Loránd Tudományegyetem
Pedagógiai és Pszichológiai Kar,
nagyvaradi.katalin@ppk.elte.hu

Szigethy Mónika [1]
ELTE Eötvös Loránd Tudományegyetem
Pedagógiai és Pszichológiai Kar,
Sporttudományi Intézet - Szombathely
szigethy.monika@ppk.elte.hu

Hurtik-Tóth Enikő [2]
ELTE Eötvös Loránd Tudományegyetem
Pedagógiai és Pszichológiai Kar,
Sporttudományi Intézet - Szombathely
toth.eniko@ppk.elte.hu

Absztrakt: A tanulmány célja az SMR-hengerezés (self-myofascial release) és a dinamikus nyújtás hatásának vizsgálata volt az alsó végtagi rugalmasságra és a felugrási magasságra U14–U15 korosztályú labdarúgók körében. A kutatásban a Király SE két utánpótláscsapata vett részt (U14: n=17; U15: n=19). A sportolók három különböző bemelegítési protokollt alkalmaztak: kizárólag SMR, kizárólag dinamikus nyújtás, illetve a kettő kombinációja. A teljesítménymutatókat a Finger Floor Test és a Vertical Jump teszt segítségével mértük, a bemelegítés előtt és után is. A nem paraméteres statisztikai elemzés (Wilcoxon- és Kruskal-Wallis-próbák) szignifikáns javulást mutatott az előrehajlás-teszt eredményeiben mindkét korcsoportban: az U14-es csoportban az első mérés 16,96 ± 10,45 cm, a második mérés 15,21 ± 9,77 cm (p <0,001), míg az U15-ös csoportban az első mérés 11,92 ± 11,06 cm, a második mérés pedig 10,52 ± 10,06 cm (p <0,001) volt. A felugrási magasság tekintetében nem mutatkozott statisztikailag szignifikáns változás. A kutatás megerősítette, hogy már egy rövid bemelegítő beavatkozás is javíthatja a hajlékonyságot, de a teljesítményfokozás érdekében nem elegendő önmagában az SMR vagy dinamikus nyújtás alkalmazása. A vizsgálat felhívja a figyelmet a fasciarendszer célzott aktiválásának jelentőségére a modern sportedzésben.
Kulcsszavak: SMR, dinamikus nyújtás, fascia, hajlékonyság, felugrási magasság, U14–U15 labdarúgók

Abstract: The aim of this study was to examine the effects of SMR (self-myofascial release) rolling and dynamic stretching on lower limb flexibility and vertical jump height among U14–U15 football players. Two youth teams from Király SE participated in the research (U14: n=17; U15: n=19). The athletes followed three different warm-up protocols: SMR only, dynamic stretching only, and a combination of both. Performance indicators were measured by using the Finger Floor Test and the Vertical Jump Test, both before and after the warm-up. Non-parametric statistical analysis (Wilcoxon and Kruskal-Wallis tests) revealed a significant improvement in the forward flexion test in both age groups: in the U14 group the first measurement was 16.96 ± 10.45 cm and the second measurement was 15.21 ± 9.77 cm ($p < 0.001$), while in the U15 group the first measurement was 11.92 ± 11.06 cm and the second measurement was 10.52 ± 10.06 cm ($p < 0.001$). No statistically significant change was observed in jump height. The study confirmed that even a short warm-up intervention can improve flexibility, but using SMR or dynamic stretching alone is not sufficient for performance enhancement. The findings highlight the importance of targeted activation of the fascial system in modern athletic training.
Keywords: SMR, dynamic stretching, fascia, flexibility, jump height, U14–U15 football players

Introduction

The use of SMR (self-myofascial release) devices began to spread widely in the 2000s, first in fitness and sports rehabilitation, and later in recreational exercise. Ultrasound diagnostics opened new doors to exploring its significance in movement, as its function in the living human body had previously remained hidden: during autopsies, it appeared to be merely unnecessary connective tissue that needed to be removed. However, living fascia is like freshly kneaded dough—flexible and malleable, while the fascia observed in a dead body is more like dry dough: stiff and parched.

This change in perspective is particularly important from a practical point of view, as the true function of fascia can only be understood and effectively influenced by interpreting it as a living, dynamic system. In my work, however, I often find that athletes do not have accurate knowledge about the physiological effects of various warm-up protocols, such as dynamic stretching, what physiological effects they have, or what tissue structures SMR rolling targets, what systemic approach underlies the techniques used, and what methodological considerations should be taken into account when applying them to enhance performance or promote regeneration. The effect of rolling with SMR tools on myofascia is based on a holistic approach to modern training methods, so instead of local treatments, a global approach based on fascial chains has come to the fore (Myers, 2001; Earls & Myers, 2017). The term "fascia" is currently used in two different ways in the literature: on the one hand, in a narrow sense, to refer to tissue parts that can be separated by dissection, and on the other hand, in a broader sense, to refer to a functionally connected connective tissue system that networks the entire body.

Due to the duality of the concept, the Fascia Nomenclature Committee proposed a new definition that encompasses both approaches to more accurately reflect the interdisciplinary meaning of fascia (Adstrum et al., 2017; Stecco & Schleip, 2016). As a resulttissues andplex approach, fascia has been defined with the following comprehensive formulation: The fascial system is a network that interweaves, connects, supports, and suspends the entire body, which is continuously present, three-dimensional, collagen-based, viscoelastic loose and dense fibrous connective tissues, and ensures the stability and mobility of the body through its constant state of tension. It includes anatomical structures such as deep and superficial fasciae, joint capsules, ligaments, tendons, aponeuroses, membranes, meninges, visceral fasciae, and other tissues functionally connected to them (Stecco & Schleip, 2016). Its functional structure ensures the integrated functioning of the body's organ systems with the help of the nervous system.

Its mechanism of action is unquestionable, as 5-10 minutes of rolling with an SMR device significantly improves range of motion, which has been confirmed by several systematic reviews and meta-analyses: even a short 3-5 minute rolling session can result in a significant increase in joint range of motion without a decrease in muscle strength (MacDonald et al., 2013; Sullivan et al., 2013; Konrad et al., 2021). Since then, several review studies and meta-analyses have confirmed this finding (e.g., Cheatham et al., 2015; Konrad et al., 2022), but research on the mechanism and long-term effects of rolling is still ongoing. Krause et al. (2019) compared the effects of SMR rolling (2×60 seconds on the front of the thigh), static stretching, and control on knee flexion range of motion in a randomized study. SMR significantly improved range of motion without reducing muscle stiffness but increased the sensory threshold and reduced sliding between fascial layers. According to their results, the effect of SMR may be partly neurosensory in origin. Isa et al. (2020) found in their study of adolescent boys that a single session of SMR with a manual roller bar 3×30 seconds of SMR per muscle group significantly increased flexibility, resulting in an average improvement of 2.25 cm on the Sit and Reach test. Su et al. (2017) compared the acute effects of SMR rolling, static stretching, and dynamic stretching on the flexibility and muscle strength of 30 young adults. All methods improved quadriceps and hamstring flexibility, but SMR rolling resulted in the greatest improvement. Knee extensor muscle strength increased significantly after rolling and dynamic stretching, while static stretching had no effect. According to the authors, rolling increases flexibility without reducing muscle strength. Based on four studies summarized by Anderson et al. (2020), combining dynamic stretching and rolling may have a beneficial effect on muscle strength and agility, especially in healthy, active adults. The rolling protocols used in the studies targeted the major lower limb muscle groups (e.g., quadriceps, hamstrings, gluteus, gastrocnemius) for 30–90 seconds. However, changes in flexibility were not consistently significant, so in terms of acute performance enhancement, SMR and dynamic stretching together may have an effect on strength and movement speed abilities.

The role of modern warm-up protocols in sports

For our daily three-dimensional movements to be performed smoothly and with optimal performance, according to modern training theory, fascial chain-based thinking and preventive preparation based on it are essential for movement quality, performance, and injury prevention. The purpose of preventive warm-up is to prepare the skeletal, muscular, nervous, and fascial systems for exercise.

This complex approach has become indispensable in sports today, as the spatial interpretation of joint movement (sagittal, frontal, and transverse) is also necessary for the correct execution of exercises (Biróné & Hurtik-Tóth, 2024). The fascial system plays a key role in this system: as a connecting and mediating network, it ensures the harmonious cooperation of the different segments of the body and contributes to maintaining an optimal balance between stability and mobility. In athletes, the effectiveness of pre-exercise tone enhancement and regeneration processes (e.g., waste removal) depends largely on the condition of the fascia layers. The elasticity of the fascia is primarily provided by elastin, while collagen is responsible for the strength and tensile strength of the tissue. If collagen production outweighs elastin production, the fascia becomes stiffer and loses its flexible, adaptable structure (Trębacz & Barzycka, 2023). For athletes, optimal movement and outstanding performance require adequate lubrication of the fascial layers, which is largely provided by hyaluronic acid (HA). According to research, the amount of HA varies anatomically: in regions where there is greater slippage between the fascia layers—such as the ankle retinaculum—the HA content is significantly higher, which plays a key role in pain-free, injury-free movement (Fede et al., 2018; Pratt, 2021). The pressure exerted during rolling changes the viscoelastic properties of the hyaluronic acid between the fascial layers: due to the thixotropic phenomenon, viscosity decreases, i.e., the resistance of hyaluronic acid molecules to flow decreases, thus improving the sliding between the layers and the lubricity of the tissues. The sliding mechanism described above ensures the athlete's smooth movements.

The aim of the research

The aim of the research was to examine the extent of change brought about by SMR rolling, dynamic stretching, and a combination of these in the flexibility and jump height of U14 and U15 soccer players, based on a comparison of their condition before and after warm-up. In addition, we aimed to compare the effectiveness of each warm-up protocol in terms of performance changes, separated by age group.

Hypotheses

H1: I hypothesize that the forward bend and jump values of the U14 and U15 teams will show significant differences as a result of the different warm-up protocols.

H2: I hypothesize that athletes who received both muscle relaxation (SMR) and muscle activation (dynamic stretching) stimuli during warm-up will show greater improvement in their flexibility indicators than those who used only one of the methods.

Materials and methods

Research participants

The study involved soccer players from the Király SE U14 (n = 17) and U15 (n = 19) age groups. The average age of the U14 group was 13.8 ± 0.3 years, their body weight was 52.1 ± 9.7 kg, their height was 168.3 ± 9.0 cm, and muscle mass was 25.8 ± 5.0 kg. The average age of the U15 group was 15.2 ± 0.3 years, with a body weight of 58.2 ± 8.6 kg, a height of 174.0 ± 7.0 cm, and a muscle mass of 29.5 ± 5.2 kg.

The participating athletes used three different protocols during the warm-up: SMR rolling only, dynamic stretching only, or a combination of the two. Among the U14 players, 5 (31.25%) used a combination of SMR rolling and dynamic stretching, 5 (31.25%) used only SMR rolling, and 6 (37.5%) used only dynamic stretching. We observed similar proportions in the U15 age group: 6 players (31.58%) performed a combined warm-up, 6 players (31.58%) used only rolling, while 7 players (36.84%) used only dynamic stretching.

Data collection tools

The demographic data of the players were obtained using the InBody 770 body composition analyzer, which operates on the principle of bioelectrical impedance.The SMR rolling technique used during data collection followed the sequence of the fascial chain, specifically the Superficial Back Line, based on Myers' (2001) theory. Accordingly, the rolling sequence was uniform for all muscle areas and lasted one minute each: plantar fascia, Achilles tendon, gastrocnemius, hamstrings, and finally the gluteus muscle group. Lower limb explosiveness was measured using the Vertical Jump test, in which each player performed two repetitions, and the better value was recorded. The jump height was recorded using a measuring device developed for this purpose.

To measure flexibility, we used a standardized version of the Finger Floor Test. During the test, participants stood with their feet shoulder-width apart, knees straight, and torso straight, and attempted to reach the floor with their fingertips. The degree of flexibility was recorded based on the distance (in cm) between the fingers and the floor. The measurement was taken while standing on a 23 cm high stool so that the changes resulting from the warm-up protocol could be easily monitored even in hypermobile athletes. In the Finger Floor Test, a lower value means a better result, as the fingers are closer to the ground. Three types of warm-up protocols were used in the study. The first group followed a combined protocol consisting of 8 minutes of rolling followed by 8 minutes of dynamic stretching, for a total of nine standard exercises. The second group performed only SMR rolling warm-up for 8 minutes. The third group performed dynamic stretching exercises led by a trainer, also for 8 minutes, using 9 different exercises.

Statistical methods

We calculated descriptive statistics (mean, standard deviation) for demographic variables (age, height, weight). We examined the distribution of the main performance indicators—the jump height and forward bend test—using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Based on the results, most of the variables did not show a normal distribution, so we used non-parametric statistical tests.

We used the Wilcoxon test to compare the two measurement times (before and after warm-up) separately for the U14 and U15 age groups for both tests (jump height and forward bend).

To compare the effects of the individual warm-up protocols (SMR, dynamic stretching, combined), we used the Kruskal-Wallis test, based only on the changes in the forward bend test results, separately for the U14 and U15 groups.

We did not perform a separate protocol comparison for jump height, as it did not show a significant change based on the pooled Wilcoxon test.

We used IBM SPSS Statistics for Windows version 27.0 (IBM Corp., Armonk, NY, 2017) to process the data.

Results

The forward bend test and jump height results of the athletes participating in the study were analyzed separately by age (U14 N=16 and U15 N=19). The basic statistical indicators for each measurement time point are presented below.

For athletes in the U14 age group, the average performance in the first forward bend test measurement was 16.96 cm (SD = 10.45), while in the second measurement this value decreased to 15.21 cm (SD = 9.77). The median was 19 cm and 16 cm, respectively. The variation in the variables is relatively large, as indicated by the high standard deviation values and the range of 38–39 cm.

For the U15 age group, the average of the first measurement of the forward bend test was 11.92 cm (SD = 11.06), while the second measurement was 10.52 cm (SD = 10.06). The median values were 13 cm and 11 cm, respectively. The range was similarly large, between 41 and 43 cm, with a positive skew, indicating a slight shift to the right in the distribution.

In terms of jump height, the average of the first and second measurements in the U14 group was almost identical (196.74 cm and 195.48 cm), but the standard deviation values above 101 cm show extreme dispersion. The median value was 245 cm, which suggests that several athletes produced outstanding results.

In the U15 age group, the average jump height was also almost identical in the first (165.03 cm) and second measurements (165.17 cm), but the standard deviation was even

Age Group	Test	Mean	Standard Deviation	Median	Minimum	Maximum	Range
U14	Forward Bending Test 1	16,96	10,448	19	0	39	39
	Forward Bending Test 2	15,21	9,772	16	0	38	38
	Vertical Jump 1	196,74	101,218	245	0	274	274
	Vertical Jump 2	195,48	102,105	245	0	276	276
U15	Forward Bending Test 1	11,92	11,062	13	0	43	43
	Forward Bending Test 2	10,52	10,062	11	0	41	41
	Vertical Jump 1	165,03	125,387	251	0	284	284
	Vertical Jump 2	165,17	125,462	251	0	283	283

Table 1: Descriptive statistics for the U14 and U15 teams before and after the protocols

Team	Tests	N (Sample Size)	Test Statistic	Standard Error	Standardized Test Statistic (Z)	Asymptotic Significance
U14	Forward Bending	16	196,500	246,809	-7,500	<0,001
	Vertical Jump		1863,000	219,045	0,548	0,584
U15	Forward Bending	19	312,500	230,972	-6,745	<0,001
	Vertical Jump		1582,000	192,358	0,619	0,536

Table 2: Results of the Wilcoxon test for the effects of warm-up protocols on forward bend and jump tests in the U14 and U15 age groups

higher (above 125 cm), indicating greater variability in performance. These results are shown in Table 1.

To check the distribution of the sample, we used the Kolmogorov–Smirnov and Shapiro–Wilk tests, considering the latter to be primary for small and medium-sized samples. For both the U14 and U15 age groups, all variables examined—i.e., forward bend test measurements 1 and 2, and jump height measurements 1 and 2—showed significant deviations from the normal distribution ($p < 0.001$). Therefore, we used the non-parametric Wilcoxon test in subsequent analyses.

Non-parametric statistical analysis

Based on the results of the Wilcoxon test, there was a significant improvement in the forward bend test in both the U14 and U15 age groups as a result of the warm-up protocol (U14: $Z = -7.500$, $p < 0.001$; U15: $Z = -6.745$, $p < 0.001$). In contrast, there was no significant change in jump height in either age group (U14: $Z = 0.548$, $p = 0.584$; U15: $Z = 0.619$, $p = 0.536$), suggesting that the warm-up used did not significantly affect jumping performance. These results are presented in Table 2.

During statistical analysis, we used the Kruskal–Wallis test to determine whether the effects of the different warm-up protocols (combined SMR + dynamic stretching, SMR only, and dynamic stretching only) differed based on changes in the forward bend test results of U14 players. Since the normality test justified the use of a non-parametric method, this procedure was suitable for comparing the median differences between the three independent groups.

Based on the results of the test, the statistical value of the test was $\chi^2 = 1.04$, with 2 degrees of freedom, and the significance level was $p = 0.949$. This value is well above the accepted threshold of 0.05, so the null hypothesis cannot be rejected. Accordingly, no statistically significant difference can be demonstrated in the effect of the individual warm-up protocols based on the change in the forward bend performance of the U14 athletes. The average differences in the forward bend test as a result of the three warm-up protocols were 1.68 cm for the combined protocol (SMR+DN), 1.82 cm for SMR rolling, and 1.77 cm for dynamic stretching in the U14 team, as shown in Figure 1.

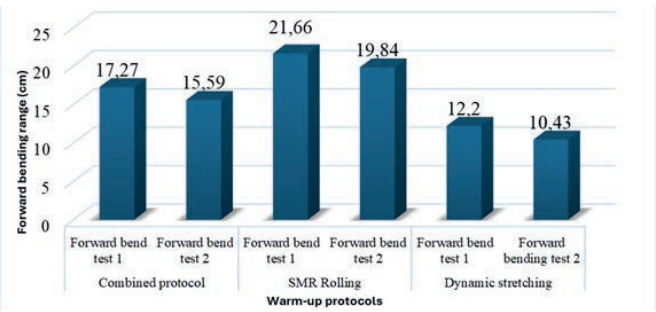

Figure 1: Forward bend indicators for the U14 team before and after the protocols

For the 15-year-old players, we also used the Kruskal–Wallis test to examine whether there was a significant difference in the change in forward bend test results due to the different warm-up protocols (SMR, dynamic stretching, or a combination of these). During the study, the statistical value of the test was $\chi^2 = 3.583$, with 2 degrees of freedom, and the asymptotic significance value was $p = 0.167$. Since this value is greater than the statistical significance threshold of 0.05, the null hypothesis cannot be rejected. The average differences in forward bend test results for the three warm-up protocols were 1.73 cm for the combined protocol (SMR+DN), 1.39 cm for SMR rolling, and 1.11 cm for dynamic stretching in the U14 team, which means that the use of the three different warm-up protocols did not result in a statistically significant difference in the improvement of forward bend in U15 athletes. This means that the use of the three different warm-up protocols did not result in a statistically significant difference in the improvement of forward bend in U15 athletes. Based on the results, the various interventions had a similar effect on the development of flexibility in this age group, as illustrated in Figure 2.

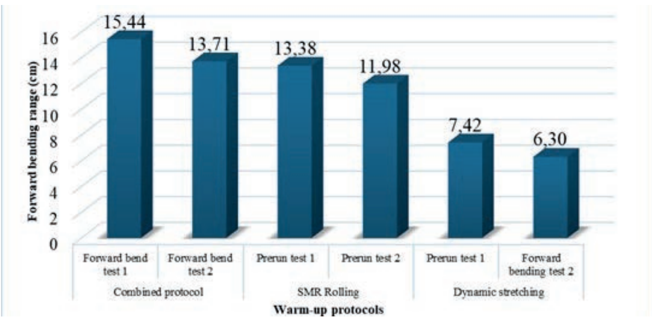

Figure 2: Forward bend indicators for the U15 team before and after the protocols

Verification of hypotheses

The hypothesis that the warm-up protocol would result in significant differences in the jump height and forward bend tests of the U14 and U15 age groups was only partially confirmed. Based on the research results of Pandey and Kulkarni (2021), the changes in range of motion observed in our own study can be attributed to the use of the SMR roller, which can improve the thixotropic properties of the fascia through the heat generated by friction, thereby increasing the range of motion (ROM) of the joints. In addition, dynamic stretching exercises also work through a similar mechanism of action, as confirmed by our results. The improvement in flexibility was significant in both groups, while the change in jump height was not statistically significant. The hypothesis regarding the three warm-up protocols was not confirmed, as the statistical analysis showed no significant difference between the groups. In both groups, we observed an increase in range of motion of less than two centimeters as a result of the three different protocols.

Conclusion and outlook

The aim of the study was to investigate the effects of self-massage with an SMR roller and dynamic stretching, both in combination and separately, on flexibility development in the U14 and U15 age groups.

The results of the study are consistent with previous research, which suggests that even short-term SMR use can have a positive effect on range of motion without causing a decrease in muscle strength (MacDonald et al., 2013; Cheatham et al., 2015; Konrad et al., 2021). In addition, the interpretation of the fascial system as a dynamic, living tissue opens up new perspectives in the development of training theory and warm-up protocols. Furthermore, Isa's 2020 study confirmed that short-term use of rolling greatly increased flexibility, as verified by the Sit and Reach test.

Stretching is a routine part of warm-ups for athletes, especially when their goal is to support maximum performance in competitive situations (Gerdijan et al., 2021). In addition, the use of self-massage, also known as self-myofascial release (SMR), is becoming increasingly common as part of warm-up protocols (Popelka & Pivovarniček, 2022). However, the combination of SMR and dynamic stretching shows significant methodological differences: due to the type of techniques used, the duration of the treatments, and the differences in the targeted muscle groups, the results of scientific research are diverse and not always clear. Among the limitations of the research, I would mention that the results only applied to two teams from one association, and it would be worthwhile to analyze the data in the form of a follow-up study, taking into account the match loads.

One limitation of our study is the relatively small sample size, which restricts the generalizability of the findings. Future research should therefore replicate the investigation in the same age group (U14–U15) with a larger number of participants to draw more reliable conclusions about the effects of different warm-up protocols. A larger sample would also allow for more advanced statistical analyses, thereby increasing the validity of the results.

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