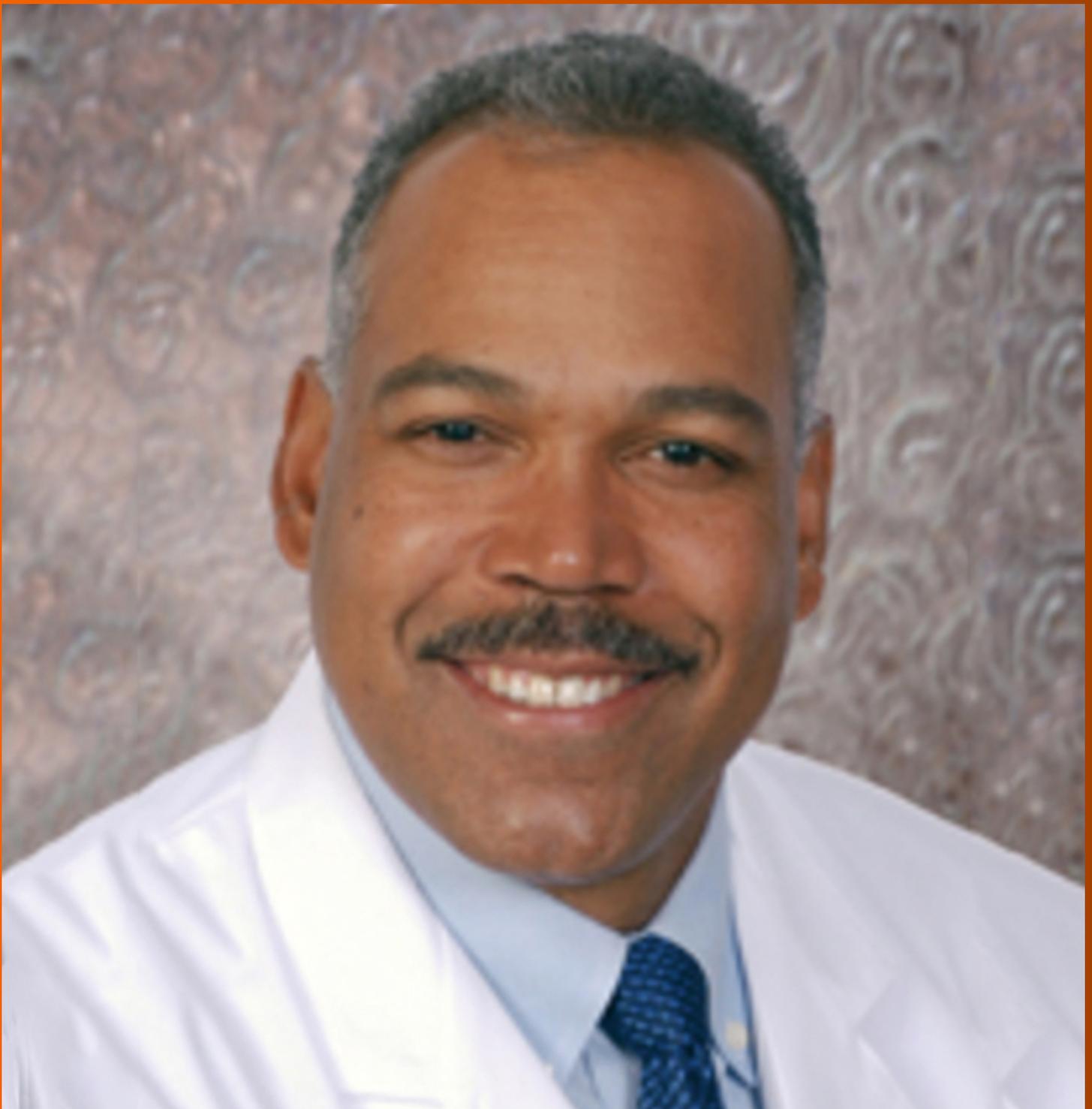


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Randomized Controlled Trial

Effect of deep transverse friction massage vs stretching on football players' performance

Mohammed Ali Fakhro, Hussein Chahine, Hassan Srour, Kasim Hijazi

ORCID number: Mohammed Ali Fakhro (0000-0001-7324-6253); Hussein Chahine (0000-0002-6439-4307); Hassan Srour (0000-0002-9318-0842); Kasim Hijazi (0000-0003-0664-0984).

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Clinical trial registration statement:

This trial was registered in ClinicalTrials.gov under the trial registration number (NCT03540888).

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Mohammed Ali Fakhro, Hussein Chahine, Hassan Srour, Kasim Hijazi, Faculty of Public Health, Department of Physical Therapy, Lebanese German University, Sahel Alma, Jounieh 00961, Keserwan, Lebanon

Corresponding author: Mohammed Ali Fakhro, PT, DPT, Coordinator, Department of Physical Therapy, Faculty of Public Health, Lebanese German University, Sahel Alma, P.O Box 206, Jounieh 00961, Keserwan, Lebanon. m.fakhro@lgu.edu.lb

Abstract**BACKGROUND**

Flexibility, agility and muscle strength are key factors to either win or lose a game. Recently the effect of a new technique, deep transverse friction massage (DTFM) on muscle extensibility as compared to traditional stretching techniques has been examined.

AIM

To compare the effect of DTFM *vs* static and dynamic stretching techniques on the hamstring's extensibility, agility, and strength amongst Lebanese and Syrian football players. Recording the incidence of non-contact hamstring muscle injury was a secondary objective.

METHODS

This study is a single-blinded prospective longitudinal randomized controlled trial. The experiment took place over a period of four weeks. Football players were randomized into three intervention groups (static stretching; dynamic stretching; DTFM). Participants of each group were followed-up carefully by assessors during their intervention sessions three times per week, for a total of 12 sessions and during the data collection. Extensibility, agility, and strength were compared between intervention groups at (baseline; acute; and chronic) phases. Straight leg raise and 1 repetition maximum tests were used to measure the dominant leg hamstring muscle extensibility and maximal strength respectively. T-drill test was used to assess the lower extremities agility.

RESULTS

Of 103 Lebanese and Syrian male football players aged between 18 and 35 were sampled from Damascus-Syria and South of Lebanon to participate in this study. Between-groups measures of acute strength ($P = 0.011$) and chronic extensibility ($P = 0.000$) solely showed a significant difference, and the static group showed to be superior as compared to the other groups. No loss to follow-up or protocol violation was recorded.

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CONCLUSION

Static stretching is showing to be superior to the other techniques used, regarding gaining long-term extensibility and short-term maximal muscle strength. In addition, DTFM showed improvements but did not outweigh the effects on footballers' performance when comparing it to static and dynamic techniques. Finally, no difference between the interventions is recorded regarding the rate of muscle injuries incidence.

Key words: Football; Massage; Prevention; Athletic injuries; Sports injury; Static stretching; Dynamic stretching

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Core tip: Static stretching may be used for male football players aged between 18 and 35 for 30 min before exercises for its positive effect on short-term muscle strength and after exercises for its beneficial effect on long-term extensibility.

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INTRODUCTION

In the professional field of sports, injuries can have serious repercussions on a team's entire season, and on a particular individual's health, future, and surroundings^[1]. According to the American College Football League statistics, injuries were prevalent between the year 2004 and 2009, where 51.3% of injuries of muscular and ligamentous origin were recorded during training and matches. Hamstring tears alone accounted for 5.5% of these injuries^[2]. In addition, hamstring muscle injuries showed to be common in sports requiring running^[3]. They were usually caused by a muscle imbalance between the quadriceps muscle which was strong while the hamstring muscle was weak and inflexible. This imbalance puts a great deal of pressure on the hamstring leading to injury and tear^[3].

The high incidence and prevalence of muscular injuries led coaches, medical teams and researchers from around the world to seek modalities to prevent these events from happening^[4,5]. Moreover, previous studies highlighted the effect of various stretching techniques on optimizing athletic performance while reducing the incidence of muscle injury^[6]. In the literature, stretching was defined as "an exercise in which a muscle or a muscle group is intentionally flexed or stretched in order to improve the muscle's extensibility"^[7]. In addition, static stretching proved to be the best technique to increase extensibility^[8], while it decreased performance and lead to an increase in the risk of injury when performed immediately before an exercise^[9,10]. Additionally, only 2 min of static stretching per muscle group during warm-up, could negatively alter muscle strength^[11].

On the other hand, the literature on the dynamic stretching was conflicting. Some studies reported that an acute bout of dynamic stretching induced either a similar or higher increase in extensibility as compared to static stretching, whereas many other studies reject this statement^[12]. Dynamic stretching mimics sports movements and showed to have positive effects on performance and on the reduction of injury rates.

However, lesser gains in extensibility were recorded when compared to static stretching^[4]. Dynamic stretching should be chosen over static stretching during the warm-up phase, which usually requires a high level of strength and explosive muscular power. Troumbley^[13] recommends the use of the dynamic stretching technique as the main stretching technique before agility-related sports, where it induced the greatest performance in agility movements proved by a reduction T-Drill time. This was further supported by Fletcher and Jones^[14], who contend that dynamic stretching elicits the best performance in power and high-speed activities.

Herbert and Gabriel^[15] reviewed the literature on the effects of stretching on performance and suggested that more research is needed to truly understand the effects of stretching on agility-related performance. Moreover, more studies are

needed to clearly understand the mechanism and effect of the static stretching technique on the risk of muscle injury^[16]. Recently, researchers confirmed that deep transverse friction massage (DTFM) on the musculotendinous junction (MTJ) increased muscle extensibility^[17,18].

DTFM involved the application of manual pressure directly to the MTJ which, when sufficient, will stimulate Golgi tendon organs and inhibit muscle tension^[17,18]. However, no studies have been conducted to compare the effects of DTFM to other stretching techniques on agility, muscle strength and rate of muscle injury occurrence. For this reason, the aim of this study was to check the effect of DTFM on performance as compared to static and dynamic stretching techniques amongst Lebanese and Syrian football players. Moreover, recording the incidence of non-contact hamstring muscle injury was the secondary objective.

MATERIAL AND METHODS

Design

This study is a single-blinded longitudinal randomized controlled trial. In order to compare the effects of DTFM to static and dynamic stretching techniques, participants were randomly assigned to one of three groups: (1) DTFM group; (2) Dynamic stretching group; and (3) Static stretching group. They were followed-up over a period of four weeks.

Ethical approval was obtained from the Lebanese German University's Institutional Review Board (Ref No.:1EC/2017) and this study is registered in ClinicalTrials.gov under the trial registration number (NCT03540888). Upon the confirmation of the footballer's eligibility, each participant signed an informed consent form and fill in a separate form for personal data collection. To ensure confidentiality, sheets were kept in a file in a concealed place, and only the principal investigators of this study were able to access data when it was needed.

Participants and selection criteria

In order to recruit the participants, gyms and football clubs across Damascus-Syria and South of Lebanon were visited and information sheets were distributed. These sheets: (1) Explained the purpose of the study; (2) Emphasized on voluntary participation; (3) Described the experiment process and its duration; (4) Stated possible risks and benefits; (5) Emphasized confidentiality; and (6) Provided investigators means of contact. 103 Lebanese and Syrian male football players aged between 18 and 35 were sampled to participate in this study. For a participant to be considered eligible he supposed to be: (1) Male; (2) A football player; and (3) Physically active (1 to 3 hours of football per week)^[19]. Participants under the age of 18 and over 35 years and ones who had an existing injury to the musculoskeletal system were excluded.

After applying the selection criteria, 96 remaining football players were the final participants of this study, with no loss to follow-up (participation rate: 100%), or any protocol violation being recorded (Figure 1).

Procedure

To start the experiment, each enrolled participant signed a consent form. Then, an independent examiner who was not involved in the enrollment process systematically allocated participants into one of the three intervention groups by withdrawing names randomly out of a bowl. The first draw assigned the participant into the static stretching group; the second draw to the dynamic stretching group; the third draw to the DTFM group. This was repeated until all eligible participants were assigned to groups. The investigator who entered eligible participants in the study was not aware of which group they were allocated to.

The experiment took place in July 2017, over a period of four weeks. Participants of each group were followed-up carefully by assessors during their intervention sessions three times a week, for a total of 12 sessions and during data collection. Intervention sessions were scheduled on the same day as the players' training or matches. In addition, players and their coaches were told to make sure not to include any other stretching techniques during the entire intervention period. It is important to mention that stretching techniques were performed on both legs, but data were collected only from the dominant lower limb in the same manner across groups.

Static stretching group: Static stretching was chosen for its effectiveness in increasing both acute and chronic extensibility^[20]. All participants laid on the floor in a supine position with both feet pointing upwards. The tested limb was in full knee extension and the foot, in a relaxed position, was moved up passively by the assessor to a point

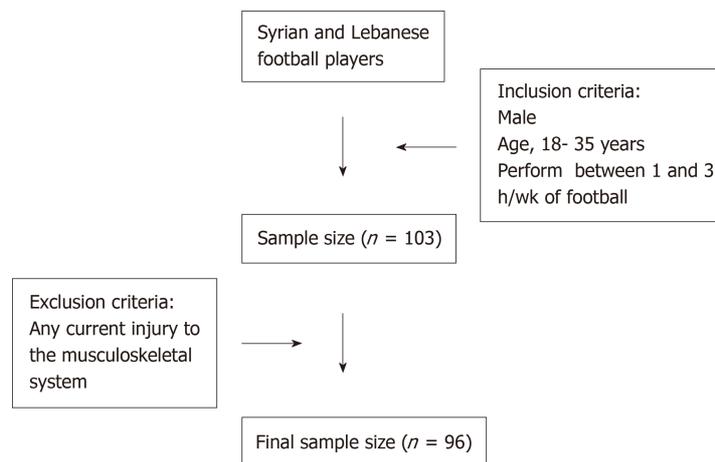


Figure 1 Flowchart representing the recruitment pool.

of slight pain or discomfort at the posterior aspect of the thigh. This technique puts the hamstring muscle at its greatest possible length. In accordance with the American College of Sports Medicine, this position was held for 30 s and was performed three times for a total of one minute and 30 s, 15 min after a match or training. The contralateral leg was stabilized by means of another collaborator in order to prevent compensation by rotation or elevation of the pelvis^[9,19].

Dynamic stretching group: The dynamic stretching technique was included for its positive effects on agility and muscle strength^[21]. Participants in this group swung their tested leg actively into hip flexion while keeping their knee fully extended and their ankle fully plantar flexed until a stretch was felt in the posterior thigh. This was repeated over 30 s at the end of the participant's warm-up phase^[12].

Deep transverse friction massage group: One of the examiners taught participants how to sit and perform pre-exercise self-massage on their tested leg MTJ. The procedure consisted of applying friction massage by fingertips transversely to the hamstrings tendon, in a sitting position. The tendon was located over four finger widths proximal to the medial and lateral epicondyles of the femur. One examiner carefully monitored how the technique was performed to assure the precision of the application. This massage technique was applied over a duration of 30 s at the end of the participants' warm-up phase^[18].

Data collection methods

Measurements took place once, on three occasions: (1) Baseline, at the first session; (2) 15 min, after the first intervention (acute phase); and (3) After four weeks (chronic phase). In addition, the (1) age; (2) height; (3) weight; and (4) injury incidence rate were recorded for each footballer. In addition, the statistical review of the study was performed by a biomedical statistician.

It is important to mention that stretching techniques were performed on both legs, but data was collected in the same manner across all three groups, only from the dominant lower limb to standardize the measurement between all participants. At the moment of data collection, the assessor was blind to the group to which participants belonged to. In addition, this assessor was not involved in the implementation of any of the techniques in this study.

Flexibility: Extensibility of the hamstrings muscle represented knee flexibility^[22]. Straight leg raise (SLR) is a widely used outcome measure used to assess the extensibility of the hamstring muscle. It is an easy and reliable method with intraclass correlation coefficients (ICCs) of 0.96, and high SEM values (2.2°) and MDD (6°)^[22]. SLR was first applied to all participants across the groups. All football players laid supine and were taught to relax during testing. A volunteer therapist raised the tested limb while maintaining the knee in full extension and the foot in a relaxed position. Another volunteer stabilized the other lower limb in neutral hip rotation and full knee extension. The test was stopped once the therapist felt a strong resistance, or when the pelvic rotation was noted. Then, the assessor placed the goniometer over the greater trochanter, with one arm aligning the lateral femoral condyle, and the other arm aligning parallel to the ground, in a direction to the mid-axillary line and recorded the hip angle. The scores were recorded as degrees of range of movement^[23].

Agility: Agility was chosen to represent the footballer's performance. This athletic event involves elements of speed, change of direction, and varying types of movement^[13]. After the measurement of the extensibility, agility was measured by the T-Drill test. The T-Drill has been proven to be a highly reliable testing measurement, ICC (0.95 with a 95% confidence interval)^[24,25]. Footballers were familiar with how to perform the T-Drill and were instructed on the test procedures. Then, they were instructed to jog for 2 min to warm-up. The participants performed the T-drill twice and the trial with the best time was taken for analysis by means of an alert assessor with a stopwatch. Results were measured in seconds^[13,25]. A diagram of the T-Drill with its dimensions is shown in (Figure 2).

Strength: Finally, maximal voluntary muscle strength of the hamstring muscle of the dominant leg was estimated by a one-repetition maximum (1RM) test. The ICC for 1-RM test-retest was (0.983, 95% confidence interval = 0.964-0.997)^[4]. After a rest time of 5 min, participants were guided to the knee flexors strengthening machine (hamstring curl machine). Resistance was placed just proximal to the posterior part of the calcaneus bone. At first, footballers performed a specific warm-up, consisting of a set of ten repetitions of knee flexion, with a light load. Afterward, for safety reasons, estimation of hamstring 1RM was calculated using the Brzycki formula: $\text{Weight lifted} / [1.0278 - (0.0278 \times \text{number of repetitions})]$. This formula exhibited a relatively low level of bias (1.6 to 0 kg) and had an ICC above 0.97. The lower end of the 95% confidence interval was above 0.94^[26]. Maximal voluntary strength was recorded in kilograms.

During the 4 wk trial period, only muscle-related non-contact sports injuries, confirmed by the team physicians during training or matches were collected. According to Marshall^[27] a non-contact injury is an injury sustained by an athlete without extrinsic contact by another player or object on the field.

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21.0 for Windows. Descriptive statistics (mean, standard deviation) were calculated to characterize participants' age, weight, and height. Means of the main key variables of the study were also calculated. The Shapiro-Wilk test was used to check the normality of the data distribution. A probability (P) value of > 0.05 means that there was no significant difference between groups.

To check for any difference in the incidence of muscle injury between each of the intervention groups, Fisher exact test was used because the expected cell count was less than 5. Dependent t -tests were used to determine any significant differences between the acute and chronic phases of extensibility, agility and muscle strength, and to check the difference between the baseline and chronic phases of these dependent variables.

Analysis of variance (ANOVA) test was used to check for any significant difference between the intervention groups and each of the extensibility, agility, and strength. This test was repeated for three different phases (baseline, acute and chronic). Moreover, after a statistically significant difference was shown between the variables, Tukey's Post Hoc test was used to show where the differences occurred between intervention groups.

RESULTS

Of 96 participants with a mean age of 24.7 ± 4.1 years were enrolled in the study. The footballers' mean weight and height recorded were respectively 74.9 ± 13.2 kg and 180.7 ± 6.5 cm. Within-group mean extensibility values comparison of both, the static stretching and DTFM groups, showed significant difference between the Baseline/Acute phases ($P = 0.000$, $P = 0.001$, respectively) and between the Baseline/Chronic phases ($P = 0.000$, $P = 0.000$, respectively) (Table 1). However, the between-groups comparison showed that only Chronic extensibility was significantly different ($P = 0.000$) (Table 2).

Regarding agility, within-groups mean values comparison showed a difference at both phases (Baseline/Acute; Baseline/Chronic), except for the Baseline/Chronic phases comparison of the dynamic stretching group where no significant difference was proven (0.078) (Table 3). Moreover, no significant difference was measured between the groups in all phases (Table 2).

When comparing the maximal hamstring muscle strength mean values of both, the static stretching group Baseline/Acute phase and the Baseline/Chronic phase, one could observe an extremely significant difference ($P = 0.000$) (Table 4). However, dynamic stretching within-group comparison showed an extremely significant

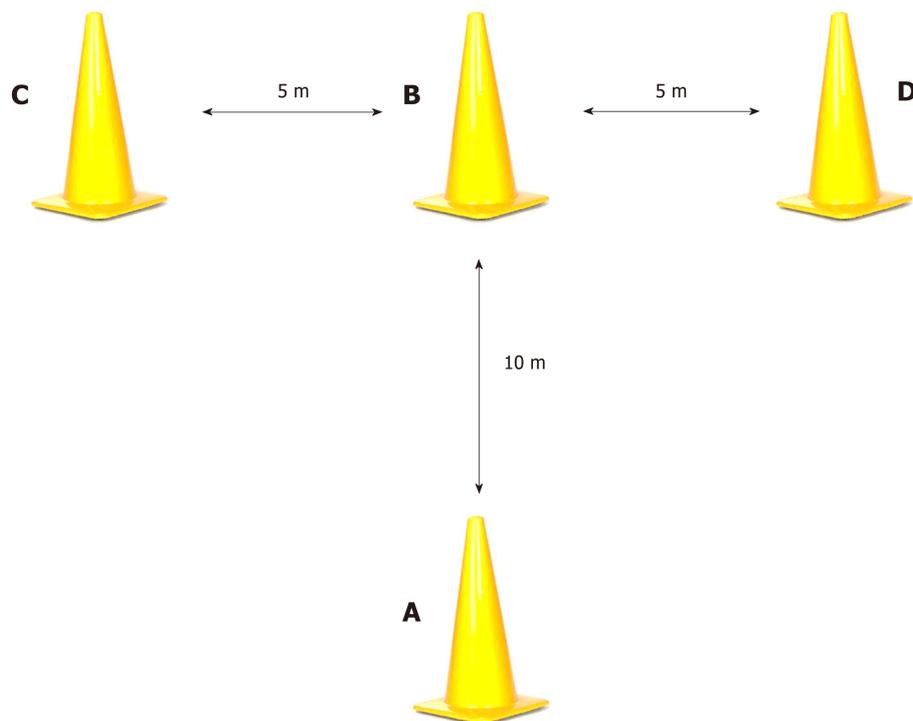


Figure 2 Diagram of the T-Drill test procedure.

difference between Baseline/Acute phases ($P = 0.000$), whereas, only a significant difference was recorded for the Baseline/Chronic phase ($P = 0.011$). Moreover, DTFM within-group comparison showed a very significant difference for the Baseline/Acute phases ($P = 0.001$) and an extremely significant difference for the Baseline/Chronic phases ($P = 0.000$). Between-groups means comparison showed only a significant difference in the acute strength phase ($P = 0.011$) (Table 2).

Muscle injury measures showed that the Dynamic stretching group scored the highest on muscle injury incidence (6%), while only 1 player (3%) was injured in the static group. No incidence of muscle injury was recorded in the DTFM group over the follow-up. Additionally, the comparison between the groups showed no significant difference ($P = 0.423$).

DISCUSSION

Sports injuries can have a serious negative impact on a player's health, future, and surroundings^[1]. Muscular injuries, in particular, were of high incidence and prevalence what led coaches, medical teams and researchers to seek modalities to prevent these events from happening^[4,5]. In this study, we primarily wanted to examine the effects of static stretching, dynamic stretching and DTFM on extensibility; agility, and maximal muscle strength. Non-contact hamstring muscle injury incidence was a secondary outcome.

Baseline/Acute within-groups comparison of extensibility revealed that only static stretching and DTFM groups had recorded a significant improvement. Huang *et al*^[18] similarly found out that when a self-petrissage massage was performed on the MTJ, this induced range of motion gains on recreationally active women. Additionally, a study by O'Sullivan, Murray, and Sainsbury^[28] showed that warm-up and static stretching was superior to dynamic stretching when tested for an increase in acute extensibility. Similarly, Baseline/Chronic phases within intervention groups comparison of extensibility showed that only static stretching and DTFM groups had recorded a significant difference. These findings are in accordance with those of the study conducted by Laureano *et al*^[29]. In addition, Akazawa *et al*^[17] concluded that performing DTFM on the MTJ showed a long-term increase in the muscle extensibility. However, the comparison of the intervention groups showed only a significant difference for chronic phase extensibility, where the static stretching group outweighed other techniques (mean = 100.0 ± 0.6 degrees) (Table 1). This can be

Table 1 Measure of intervention groups' extensibility at baseline, acute and chronic phases

	Baseline extensibility (Degrees)	Acute extensibility (Degrees)	Chronic extensibility (Degrees)	Baseline/acute extensibility (<i>P</i> value)	Baseline/chronic extensibility (<i>P</i> value)
Static stretching group	88.7 ± 1.5	94.0 ± 2.2	100.0 ± 0.6	0.000 ^{2c}	0.000 ^{2c}
Dynamic stretching group	91.2 ± 1.1	91.2 ± 2.6	92.1 ± 0.9	0.937	0.188
DTFM group	92.8 ± 1.2	94.6 ± 2.1	95.7 ± 0.7	0.001 ^{1c}	0.000 ^{2c}

¹Very significant difference;²Extremely significant difference.^c*P* < 0.001. DTFM: Deep transverse friction massage.

interpreted by the increase in muscle length noticed after chronic stretching rather than just an increase in short-term stretch tolerance^[25].

Regarding the agility mean measures, all groups showed a significant improvement at both Baseline/Acute and Baseline/Chronic phases, except for the dynamic stretching group measured between Baseline/Chronic phases. Moreover, all groups were similar when compared at the different phases (Baseline; Acute; Chronic) (Table 2). Our findings, contradict the results of Troumbley's^[13] study who recommend the use of dynamic stretching before agility-based exercises, and the results of studies that stated that static stretching had a negative effect on agility, and acceleration^[15,22].

When comparing the maximal hamstring muscle strength among all groups, all of them showed a significant improvement across phases (Baseline/Acute and Baseline/Chronic). However, the between-group comparison revealed that only a significant difference was found during the acute phase, and the static stretching group scored superior as compared to the other techniques (mean = 51.7 ± 1.6 kg) (Table 4). These results oppose other studies which concluded that static stretching had negative effects on muscle strength^[4,18,29,30]. On the other hand, the dynamic stretching group had recorded the highest incidence of muscle injuries (6%), however, no statistical difference was recorded regarding muscle injury occurrence among the intervention groups.

One of the limitations of the present study was the absence of pain tolerance measurement during static stretching. Recent studies have shown that improvements in short-term flexibility after static stretching training appear to be caused by changes in the perception of pain rather than the physical properties of the musculotendinous unit.¹⁷ Regarding agility, a laser time watch, which was considered as the gold standard for measuring the time during the T-drill would have replaced the regular stopwatch that was used in the study. Furthermore, optimal parameters to use DTFM on the MTJ are still lacking and might be considered in future studies. Moreover, to standardize the measures across the groups and players, we have collected data only from the dominant limb.

In conclusion, this study has demonstrated that no technique can be deemed to be better than the other regarding the short-term effects on extensibility and agility and the long-term effects on maximal voluntary muscle strength and agility. However, the static stretching technique showed the best outcomes on long-term extensibility and short-term maximal voluntary hamstring muscle strength. Finally, no difference between the interventions was recorded regarding its effects on the muscle injuries occurrence.

Table 2 Comparison of extensibility, agility and maximal strength significance level between all intervention groups during baseline, acute, and chronic phases

Dependent variable	Significance between interventions
Baseline extensibility	0.078
Baseline agility	0.124
Baseline strength	0.0502
Acute extensibility	0.132
Acute agility	0.183
Acute strength	0.011 ^{1a}
Chronic extensibility	0.000 ^{2c}
Chronic agility	0.88
Chronic strength	0.07

¹Significant difference;²Extremely significant difference.^a $P < 0.05$,^c $P < 0.001$.**Table 3 Measure of intervention groups' agility at baseline, acute and chronic phases**

	Baseline agility (s)	Acute agility (s)	Chronic agility (s)	Baseline/acute agility (P value)	Baseline/chronic agility (P value)
Static stretching group	10.9 ± 0.3	10.4 ± 0.4	10.2 ± 0.4	0.001 ^{2c}	0.0001 ^{3c}
Dynamic stretching group	10.5 ± 0.4	9.9 ± 0.3	9.8 ± 0.5	0.000 ^{3c}	0.078
DTFM group	9.9 ± 0.7	10.1 ± 0.5	9.9 ± 0.5	0.0001 ^{3c}	0.023 ^{1a}

¹Significant difference;²Very significant difference;³Extremely significant difference.^a $P < 0.05$,^c $P < 0.001$. DTFM: Deep transverse friction massage.**Table 4 Measure of intervention groups' strength at baseline, acute and chronic phases**

	Baseline strength (kg)	Acute strength (kg)	Chronic strength (kg)	Baseline/acute strength (P value)	Baseline/chronic strength (P value)
Static stretching group	48.5 ± 2.1	51.7 ± 1.6	53.7 ± 1.3	0.000 ^{3c}	0.000 ^{3c}
Dynamic stretching group	48.4 ± 1.8	51.3 ± 1.4	50.9 ± 1.1	0.000 ³	0.011 ^{1a}
DTFM group	43.5 ± 1.2	45.5 ± 1.2	47.8 ± 0.9	0.001 ^{2c}	0.000 ^{3c}

¹Significant difference;²Very significant difference;³Extremely significant difference.^a $P < 0.05$,^c $P < 0.001$. DTFM: Deep transverse friction massage.

ARTICLE HIGHLIGHTS

Research background

Flexibility, agility and muscle strength are key factors to either win or lose a game. The high incidence and prevalence of muscular injuries led coaches, medical teams and researchers from around the world to seek modalities to prevent these events from happening. Recently, the effect of a new technique, deep transverse friction massage (DTFM) on muscle extensibility as compared to traditional stretching techniques has been examined.

Research motivation

This study compares the effect of DTFM to that of static and dynamic stretching techniques on

the hamstring's performance amongst Lebanese and Syrian football players. Sports injuries and more precisely muscular injuries can have a serious negative impact on a player's health, future, and surroundings. Therefore, seeking modalities to prevent these events from happening is needed.

Research objectives

This study primary objective was to compare the effect of DTFM vs static and dynamic stretching techniques on the hamstring's extensibility, agility, and strength amongst Lebanese and Syrian football players. Recording the incidence of non-contact hamstring muscle injury was a secondary objective. Optimizing the muscle-related parameters is important to decrease the incidence and impact of muscle injuries.

Research methods

A single-blinded prospective longitudinal randomized controlled trial was designed to realize the objectives of this study. The experiment took place over a period of four weeks, where Football players were randomized into three intervention groups (static stretching; dynamic stretching; DTFM). Participants were followed-up carefully three times per week, for a total of 12 sessions. Straight leg raise, and 1 repetition maximum tests were used to measure the dominant leg hamstring muscle extensibility and maximal strength respectively. T-drill test was used to assess the lower extremities agility at (baseline; acute; and chronic) phases.

Research results

Measures of acute strength ($P = 0.011$) and chronic extensibility ($P = 0.000$) showed solely a significant difference between the intervention groups, where the static group showed to be the superior. Moreover, no loss to follow-up or protocol violation was recorded. These findings reinforce the effect of static stretching on long-term flexibility and contradict that on strength.

Research conclusions

This study has shown that static stretching technique best outcomes on long-term extensibility and short-term maximal voluntary hamstring muscle strength. Finally, no difference between the interventions was recorded regarding its effects on the rate of muscle injuries occurrence.

Research perspectives

Future studies are required to test the effect of the DTFM as compared to the above-mentioned stretching techniques on muscle performance for a longer period of time. Moreover, the standardization of DTFM testing is needed.

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