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Comparison of the acute effects of static and dynamic stretching exercises on flexibility, agility and anaerobic performance in professional football players

Profesyonel futbolcularda statik ve dinamik germe egzersizlerinin esneklik, çeviklik ve anaerobik performans üzerindeki akut etkilerinin karşılaştırılması

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ABSTRACT

Objectives: In this study, we compared the acute effects of static and dynamic stretching exercises on flexibility, agility, fatigue index and anaerobic performance in professional football players.

Patients and methods: Between August 2013 and September 2013, a total of 20 professional football players (mean age, 25.3±4.3 years; height, 1.83±0.03 m; body mass, 79.1±4.1 kg; football experience, 11.1±2.2 years) completed three different warm-up sessions at 24-hour intervals. First, second and third warm-up sessions were named as "aerobic running", "aerobic running combined with static stretching" and "aerobic running combined with dynamic stretching", respectively. After each session, the athletes were evaluated in terms of stand and reach flexibility, Illinois agility, and running-based anaerobic sprint tests, respectively.

Results: Analysis of variance indicated that "aerobic running combined with static stretching" increased agility ($p \leq 0.05$) and decreased relative average power, and relative maximum power ($p \leq 0.05$). However, no significant effect of static stretching on minimum power was detected ($p > 0.05$). The fatigue index score was greater following "aerobic running" and "aerobic running combined with dynamic stretching" than following "aerobic running combined with static stretching". We observed that aerobic running combined with static or dynamic stretching increased the flexibility more effectively than aerobic running alone ($p \leq 0.05$).

Conclusion: The results of this study demonstrated that football players could prevent possible decreases in anaerobic performance by removing static stretching exercises from warm-up routines used before training and/or competitions. On the other hand, static and/or dynamic stretching exercises can be applied in addition to aerobic running to enhance flexibility.

Keywords: Agility; anaerobic performance; dynamic stretching; fatigue index; flexibility; football, static stretching.

ÖZ

Amaç: Bu çalışmada, profesyonel futbolcularda statik ve dinamik germe egzersizlerinin esneklik, çeviklik, yorgunluk indeksi ve anaerobik performans üzerindeki akut etkileri karşılaştırıldı.

Hastalar ve yöntemler: Ağustos 2013 - Eylül 2013 tarihleri arasında, toplam 20 profesyonel futbolcu (ort. yaş 25.3±4.3 yıl; boy uzunluğu, 1.83±0.03 m; vücut kütlesi, 79.1±4.1 kg; futbol deneyimi, 11.1±2.2 yıl), 24 saatlik aralıklarla uygulanan üç farklı ısınma seansını tamamladı. Birinci, ikinci ve üçüncü seanslar sırasıyla "aerobik koşu", "aerobik koşu ile birlikte statik germe" ve "aerobik koşu ile birlikte dinamik germe" seansı olarak adlandırıldı. Her bir seansın sonunda sporcular sırasıyla durarak uzanma esneklik, Illinois çeviklik ve koşuya dayalı anaerobik sprint testleri açısından değerlendirildi

Bulgular: Varyans analizi, "aerobik koşu ile birlikte statik germe"nin çeviklik performansını artırdığını ($p \leq 0.05$), bağıl maksimum güç ve bağıl ortalama gücü ise azalttığını gösterdi ($p \leq 0.05$). Bununla birlikte, statik germenin bağıl minimum güç üzerinde anlamlı bir etkisi olmadığı belirlendi ($p > 0.05$). Yorgunluk indeks skoru ise, "aerobik koşu"da ve "aerobik koşu ile birlikte dinamik germe"de, "aerobik koşu ile birlikte statik germe"ye kıyasla daha yüksek bulundu. Aerobik koşu ile birlikte statik germe veya dinamik germenin, esnekliği tek başına uygulanan aerobik koşudan daha etkili artırdığı belirlendi ($p \leq 0.05$).

Sonuç: Bu çalışmanın sonuçları, futbolcuların antrenman veya müsabakalar öncesinde ısınma programlarından statik germeleri çıkararak olası anaerobik performans düşüşlerini önleyebileceklerini göstermektedir. Diğer taraftan esneklik artımı için, aerobik koşuya ek olarak statik veya dinamik germeler uygulanabilir.

Anahtar sözcükler: Çeviklik; anaerobik performans; dinamik germe; yorgunluk indeksi; esneklik; futbol, statik germe.

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Pre-exercise warm-up routines typically consist of a submaximal aerobic activity (e.g., jogging, cycling) and stretching exercises. The submaximal aerobic activity is performed to increase body temperature, as such increases in body and muscle temperature have been found to increase nerve conduction velocity, enzymatic cycling, and muscle compliance.[1] The second component of warm-up consists of different types of stretching exercises such as static stretching (SS), dynamic stretching (DS), ballistic stretching (BS) and proprioceptive neuromuscular facilitation.[2]

Stretching is believed to enhance physical performance, prevent injury, alleviate muscle soreness and increase flexibility.[3] Traditionally, SS exercise is preferred when compared to other types of stretching exercises in many athletic events.[4] However, some researchers report that acute SS exercises have detrimental effects on isometric and isokinetic force, jump height, sprint time, balance, reaction times and agility performance.[5]

Avela et al.[6] reported that these negative effects of SS are attributable to mechanical and neuromuscular factors such as tendon slack, decreased motor unit activation and altered reflex sensitivity. Some authors stated that these negative effects of SS exercise depend on the duration and intensity of stretching.[7]

Ogura et al.[8] found that 30 s of SS did not affect muscular performance; however, 60 s of SS caused a significant decrease in strength. In light of this result, we can speculate that the duration of stretching may be a significant factor. Since SS has negative effects on physical performance; coaches, trainers and athletes have recently tended to prefer DS to SS. Because of this change, DS exercise is being more commonly performed in recent years. Some authors reported that DS exercise has positive effects on power, sprint, and jump performance.[9] These positive effects of DS are attributable mainly to elevated muscle and body temperature, post-activation potentiation (PAP) in the stretched muscle caused by voluntary contractions of the agonist, stimulation of the nervous system and decreased inhibition of antagonist muscles.[1]

Therefore, based on our review of the literature, the use of DS exercises such as those performed in the above-mentioned studies seems to be a more effective preparation method for athletic performance than traditional SS exercises. However, more research studies are needed to determine the extent to which this method is valid for improving the performance of professional football players. Therefore, we aimed to compare the acute effects of SS and DS exercises on flexibility, agility, fatigue index and anaerobic performance in professional football players.

The primary hypothesis of the present study was that anaerobic performance and agility would be affected negatively after SS exercise. The secondary hypothesis was that DS exercise would more effectively enhance flexibility.

PATIENTS AND METHODS

Before the start of the investigation, all procedures were approved by the Trakya University Ethics Committee (GOKAEK 2013/140). In addition, all volunteers provided written informed consent before participating in this study. The study was conducted in accordance with the principles of the Declaration of Helsinki. Twenty professional football players (mean age 25.3±4.3 years; height 1.83±0.03 m; body mass 79.1±4.2 kg; football experience 11.1±2.2 years; training volume 5.95±0.82 days/week) were recruited for this study. For inclusion in this study, the following participation characteristics were necessary: *(i)* possession of a professional footballer license and at least five years of experience in playing football, *(ii)* did not have any functional limitation that could interfere in the test performance and *(iii)* had no medical conditions that could influence test results.

Procedures

Subjects performed one of the three different warm up protocols for an equal duration in each session. Subjects performed aerobic running (AR), AR combined with SS (AR+SS), and AR combined with DS (AR+DS) in the first, second and third session, respectively. Research protocols were completed on three consecutive days with 24 hours interval. The same researcher group performed all tests at the same time of day (13:00 to 16:00) to avoid the effect of circadian rhythms on the study results. Details of the three warm-up protocols are explained below, and the contents of each warm-up protocol are presented in Table 1.

1. AR: As a warm-up, a 20 m shuttle run test was completed. The players completed the test at level 5 (approximately 42 shuttles, 840 m), with an aim towards standardizing each warm-up session. This session was completed in approximately 5 min.
2. AR+SS: This session consisted of 5 min of AR plus 5 min of SS (6 different unilateral SS exercises [1×20 s hold for each extremity, 10 s interval between exercises] and one bilateral

Table 1. Contents of each warm up protocol

AR protocol (First session)	AR+SS protocol (Second session)	AR+DS protocol (Third session)
Aerobic running	Aerobic running	Aerobic running
Two min of resting	Two min of resting	Two min of resting
S&R test	Static stretching exercises	Dynamic stretching exercises
Two min of resting	Two min of resting	Two min of resting
Illinois agility test	S&R test	S&R test
Five min of resting	Two min of resting	Two min of resting
RAST	Illinois agility test	Illinois agility test
	Five min of resting	Five min of resting
	RAST	RAST

AR: Aerobic running; SS: Static stretching; DS: Dynamic stretching; S&R: Stand and reach; RAST: Running-based anaerobic sprint test.

exercise [2×20 s hold]). The SS exercises used in the study were the standing quadriceps stretch, standing hamstring stretch, standing hip flexor stretch, standing piriformis stretch, standing calf stretch, seated spinal twist, and sitting groin straddle (spread eagle).

3. AR+DS: This session consisted of 5 min of AR plus 5 min of DS [7 different DS exercises (2×20 s, with 10 s between exercises)]. The DS exercises used in the study were walking hamstring kicks, walking lunges, lateral walking lunges, power high knee, dynamic hip flexor, leg swing towards the opposite side and explosive hip flexion mobility.

Performance tests

At the end of each session, the players performed the stand-and-reach (S&R) test (Standing Trunk Flexion Meter, Takei Physical Fitness Test, TKK 5103, made in PRC), Illinois agility test and running-based anaerobic sprint test (RAST).

Stand and reach flexibility test: In this study, the S&R test was chosen as a static flexibility measure, as experts agree that it has been used extensively as an indirect measure to simultaneously assess the hamstring and low back flexibility.[10]

During the test, subjects held one hand exactly on the other one and flexed their trunk slowly (Figure 1). Measurements were based on the maximum distance reached and held for two s.[10] The test was performed twice with a 30 second interval between trials, and the best score of the two trials was included in the statistical analysis.

Illinois agility test (IAT): The IAT, which is commonly used in measuring agility in soccer players, was used in this study for that purpose.[11,12] The IAT was performed once maximally.

Implementation of the IAT: The length of the field was 10 m, while the width (distance between the start and finish points) was 5 m four cones were placed at the center of the testing area at a distance of 3.3 m from one another. The four cones were used to mark the start, finish and two turning points (Figure 2). The subjects performed the test while lying face down, with their hands at shoulder level. The trial started on the "go" command, and in response, the subjects ran as fast as possible. The trial was completed when the players crossed the finish line without having knocked over any cones.[11]

Running based anaerobic sprint test: The RAST involves six 35 m sprints separated by 10 second recovery trials. Anaerobic performance and FI were determined by using an equation developed by Keir et al.[13] The RAST was used in this study to assess the anaerobic performance of the soccer players because the distances and recovery time characteristic of the

Figure 1. Stand and reach test.

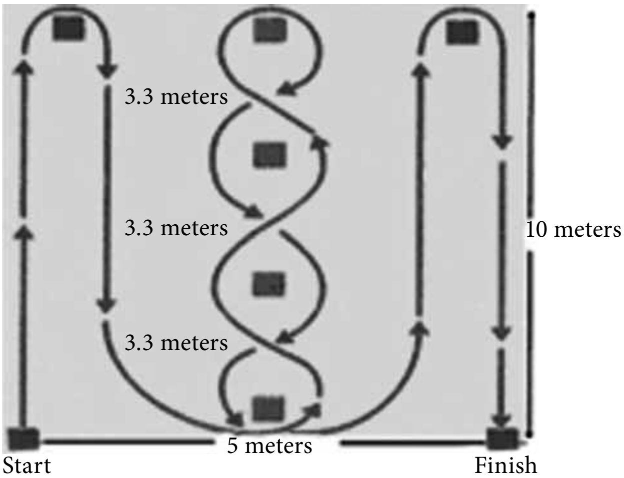

Figure 2. Illinois agility test.

RAST protocol suggest that it might be an ideal test to evaluate the anaerobic performance of field-based team-sport athletes.[13]

The participants were permitted a 2 min rest period between the S&R and IATs, and a 5 min rest period between the IAT and RAST.

Statistical analysis

Study data were analyzed using the IBM SPSS Statistics for Windows version 20.0 software program (IBM Corporation, Armonk, NY USA). The result of the Shapiro-Wilk test and skewness and kurtosis values illustrated that the study data met the assumption of normality. Possible differences in dependent variables between protocols were assessed using one-way repeated-measures analysis of variance (ANOVA). Mauchly's sphericity test was used to check for the sphericity assumption. In the case of a significant F-ratio in ANOVA, Bonferroni post hoc test was used to perform pairwise comparisons. Unbiased effect sizes of the differences (Hedge's d, effect size: d <0.2, trivial; 0.2 ≤ d <0.5; small; 0.5 ≤ d ≤0.8, moderate; d> 0.8, large) were also reported. A p value of ≤0.05 indicated statistical significance in all analyses.

RESULTS

Measures of performance variables after each warm up protocol were demonstrated in Table 2. Flexibility was found to be significantly greater after AR+SS and AR+DS than after AR (p≤0.05). However, the difference between AR+SS and AR+DS was insignificant. Moreover, the results indicated that AR+SS more effectively enhanced agility than AR+DS. The FI was greater after AR and AR+DS than after AR+SS. Maximum and average power were significantly greater after AR than after AR+SS. The participants displayed significantly greater maximum and average power after AR+DS than after AR+SS. There was no statistically significant difference in minimum power between the three protocols. The results of statistical analysis are presented in Table 3a, b.

Table 2. Measures of dependent variables after each warm up protocol

Variable	Warm up protocol	Mean±SD	%Δ from AR
Flexibility (cm)	AR	11.8±3.9	
	AR+SS	12.8±4.2	−9.98
	AR+DS	12.9±3.7	−11.9
Agility (s)	AR	16.2±0.7	
	AR+SS	16.3±0.7	−0.945
	AR+DS	16.1±0.7	−0.559
Fatigue index	AR	6.0±2.7	
	AR+SS	4.1±1.8	−23.6
	AR+DS	5.9±2.7	−9.44
Peak power (w/kg)	AR	9.5±1.8	
	AR+SS	8.4±1.6	−10.9
	AR+DS	9.2±1.6	−2.50
Average power (w/kg)	AR	8.3±1.6	
	AR+SS	7.4±1.4	−9.14
	AR+DS	8.0±1.4	−2.72
Minimum power (w/kg)	AR	7.1±1.4	
	AR+SS	6.7±1.2	−4.96
	AR+DS	6.8±1.4	−3.29

SD: Standard deviation; AR: Aerobic running; SS: Static stretching; DS: Dynamic stretching; "%Δ from AR" indicates percentage difference from AR warm up protocol and negative percentages indicate decrement, positive percentages indicate increment. "%Δ from AR" values were calculated using individual change scores.

Table 3. Statistical comparison of dependent variables between the warm up protocols

(a)	Flexibility						
	Δ (cm)	95%	CI of Δ	*p*	d	95%	CI of d
AR - AR+SS	-0.990	-1.68	-0.297	0.004*	0.240	0.387	0.093
AR - AR+DS	-1.05	-1.76	-0.330	0.003*	0.269	0.431	0.108
AR+SS - AR+DS	-0.055	-0.468	-0.578	1.000*	0.014	-0.097	0.070
	Agility						
	Δ (%)	95%	CI of Δ	*p*	d	95%	CI of d
AR - AR+SS	-0.140	-0.566	0.287	1.000*	0.193	0.647	0.260
AR - AR+DS	0.098	-0.188	0.383	1.000*	0.141	-0.177	0.458
AR+SS - AR+DS	0.237	0.030	0.471	0.047*	0.328	0.062	0.595
	Fatigue index						
	Δ (w/kg)	95%	CI of Δ	*p*	d	95%	CI of d
AR - AR+SS	1.85	0.164	3.53	0.029*	0.782	0.192	1.373
AR - AR+DS	0.071	-1.86	2.00	1.000*	0.026	-0.503	0.554
AR+SS - AR+DS	-1.78	-3.48	-0.08	0.039*	0.755	1.350	0.160

(b)	Maximum power						
	Δ (cm)	95%	CI of Δ	*p*	d	95%	CI of d
AR - AR+SS	1.12	0.296	1.95	0.006*	0.647	0.230	1.063
AR - AR+DS	0.285	-0.212	0.781	0.446*	0.163	-0.057	0.382
AR+SS - AR+DS	-0.840	-1.37	-0.308	0.002*	0.506	0.798	0.214
	Average power						
	Δ (%)	95%	CI of Δ	*p*	d	95%	CI of d
AR - AR+SS	0.838	0.208	1.47	0.007*	0.564	0.198	0.930
AR - AR+DS	0.268	-0.094	0.629	0.201*	0.177	-0.009	0.363
AR+SS - AR+DS	-0.570	-1.12	-0.025	0.038*	0.405	0.726	0.084
	Minimum power						
	Δ (w/kg)	95%	CI of Δ	*p*	d	95%	CI of d
AR - AR+SS	0.419	-0.044	0.883	0.084	0.315	0.036	0.595
AR - AR+DS	0.291	-0.344	0.926	0.243*	0.204	-0.140	0.548
AR+SS - AR+DS	-0.128	-0.646	0.902	1.000*	0.094	-0.340	0.528

CI: Confidence interval; * p≤0.05; Δ: Change; AR: Aerobic running; SS: Static stretching; DS: Dynamic stretching; d: Unbiased effect size of the difference (Hedge's d, effect size: d <0.2, trivial; 0.2≤ d <0.5, small; 0.5≤ d≤ 0.8, moderate; d >0.8, large).

DISCUSSION

The results of this study revealed that *(i)* AR combined with SS exercise more effectively enhanced agility than did AR combined with DS exercise; *(ii)* AR combined with SS or DS more effectively increased flexibility than AR alone; *(iii)* AR combined with SS led to a reduction in relative average power, and relative maximum power, however no significant effect on minimum power was detected; *(iv)* the fatigue index was greater following "AR" and "AR combined with DS" than following "ARcombined with SS".

The modern football game is characterized by fast movements, which have become prominent in short and long sprints, explosive reactions (jumping) and quick changes in direction.[14] Therefore, agility is one of the main determinants of performance in football.[11]

The first finding of this study was that SS exercise more effectively enhanced agility than DS exercise. Contrary to this finding, Chatzopoulos et al.[9] found that DS exercise more effectively improved agility than SS exercise. In addition, McMillian et al.[4] reported that DS exercise moderately enhanced agility compared with SS exercise. However, a study reported no significant difference between SS and DS in terms of agility.[15] These contradictory results may be because of methodological discrepancies such as the volume and intensity of stretching, type of SS exercise, targeted muscle groups, the training status of the subjects, sports experience level and age of the participants.[1]

Static flexibility is defined as the range of motion (ROM) of a joint or series of joints.[16] Flexibility is a major component of physical fitness.[17] Stretching prior to exercise has been suggested to improve muscle flexibility and prevent muscle injury.[18] Some of the techniques used to increase muscle flexibility include BS, SS and proprioceptive neuromuscular facilitation.[19] It has been accepted that SS exercise produces a greater acute improvement in flexibility than other types of stretching exercise.[5,8,18] Some researchers reported that DS and BS exercises enhance flexibility to a similar extent as SS exercise.[20,21] whereas other researchers stated that DS exercise is less effective than SS exercise for improving flexibility.[22]

Similar to the results of Herman and Smith[20] as well as those of Beedle and Mann,[21] the results of this study illustrated that hamstring flexibility was significantly increased by both SS and DS exercises at a similar rate. The lack of a clear superiority between the SS and DS exercises in terms of hamstring flexibility may be attributable to the duration of SS in this study, as this duration may have been too short to enhance hamstring flexibility.

Although Bandy et al.[23] argued that 30 or 60 s of SS is more effective than 15 s of SS. Odunaiya et al.[24] reported that 15 s of SS is as effective as a 30, 60, 90, or 120 s of SS in terms of enhancing hamstring flexibility. According to Magnusson and Renström,[25] acute increases in flexibility after SS exercise may be related to “stretch tolerance.” The acute improvement of flexibility may be attributed to changes in the length and stiffness of the musculotendinous unit (MTU) of the affected limb, which have been classified as elastic changes temporarily.[1]

Football performance depends upon a myriad of factors such as technical/biomechanical, tactical, mental and physiological areas.[26] Muscular power is an important factor in football.[26] Elite football players perform 150-250 brief intense movements during a game, which indicates that the rate of anaerobic energy turnover is high at certain times.[27]

Before exercise and athletic performance SS is often performed because this is widely believed to decrease the risk of injury and improve performance.[28] However, there is a growing body of evidence advocating that SS exercise has detrimental effects on anaerobic power performance.[3,4,29-31] These negative effects of SS exercise are attributable to mechanical and neurological mechanisms such as reduced MTU stiffness, altered reflex sensitivity and decreased muscle activation.[1,3]

In contrast to SS exercise, DS exercise has proven to significantly improve anaerobic power.[4,9,29,30,32] The acute improvement of anaerobic power after DS exercise is attributed to postactivation potentiation (PAP), which may be results of increased phosphorylation of myosin light chains, increasing the calcium sensitivity of the myofilaments. Also an increase in muscle temperature and muscle blood flow as a result of DS exercise may induce a more forceful and quicker muscle contraction by increasing speed of nerve impulses and the force-generating capacity of muscle cell.[4,25,30]

Kay and Blazevich[33] argued that SS for less than 30 s per muscle group might not be detrimental to anaerobic muscle power. On the contrary, Pinto et al.[31] argued that stretching for no more than 60 s per muscle group did not appear to impair muscle performance. Holt and Lambourne[34] also found no change in vertical jump performance after 15 s (3×5 s) of SS. These findings are inconsistent with our findings, as we found that 20 s of stretching resulted in the impairment of anaerobic power parameters such as peak power and average power. The reasons for these disparate findings are unknown,[31] but they could be related to the duration and intensity of SS exercise, the anaerobic power test used in the study, and experience level of the subjects.[28] Based on our literature search, we realized that anaerobic power has previously been measured using the counter movement jump test, squat jump test and 20 m sprint test. In this study, anaerobic muscle power was measured using the RAST.[13]

One important finding in the current study is the fatigue index was greater after AR alone than after AR combine with SS. Participants exhibited greater fatigue index scores after AR combine with DS than after AR combine with SS. Since it is known that the fatigue index indicates the rate at which power output declines for an athlete,[35] this index can provide coaches with information about an athlete’s anaerobic capacity or endurance. Athletes with a high fatigue index may need to focus on improving their anaerobic capacity. However, it is difficult to explain the possible physiological mechanisms related to this issue, as no knowledge is currently available in the literature.

The primary hypothesis in the current study was that anaerobic performance and agility would be negatively affected by SS exercise. After SS exercise, significant negative changes in anaerobic performance were observed, whereas agility was enhanced. The secondary hypothesis was that DS exercise would more effectively enhance flexibility. The results of the current study partially verified the primary hypothesis, but the second hypothesis could not be verified.

There are limitations to this study, owing to the study design, we could not determine whether DS or SS is superior in terms of effect on flexibility. The small sample size limited the conclusions that could be made. Thus, further larger studies are needed. The sample size was, however, similar to those in previous similar trials.[3,5,7,8,32] Moreover, we assumed that all of the players showed maximal effort during performance tests. Similar studies used various warm-up procedures. These procedures consist of many stretching exercises and techniques. Among these stretching exercises, we assumed that the stretching exercises chosen in this study were the most appropriate for our subjects.

In conclusion, the results of the present study demonstrated that DS exercise before competitions or training sessions was more effective than SS exercise in preventing possible impairments in anaerobic performance. The football players who performed DS and/or SS exercise in addition to light AR showed enhanced flexibility. With regard to the positive effects of SS exercise on agility and the fatigue index, our findings need to be confirmed in future studies. Replication of this study in a larger sample population will be helpful to more reliably explain the effects of SS and DS on flexibility, agility, fatigue index and anaerobic performance in professional football players.

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REFERENCES

1. Behm DG, Chaouachi A. A review of the acute effects of static and dynamic stretching on performance. Eur J Appl Physiol 2011;111:2633-51.
2. Franco BL, Signorelli GR, Trajano GS, Costa PB, de Oliveira CG. Acute effects of three different stretching protocols on the wingate test performance. J Sports Sci Med 2012;11:1-7.
3. Bradley PS, Olsen PD, Portas MD. The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. J Strength Cond Res 2007;2:223-6.
4. McMillian DJ, Moore JH, Hatler BS, Taylor DC. Dynamic vs. static-stretching warm up: the effect on power and agility performance. J Strength Cond Res 2006;20:492-9.
5. Murphy JR, Di Santo MC, Alkanani T, Behm DG. Aerobic activity before and following short-duration static stretching improves range of motion and performance vs. a traditional warm-up. Appl Physiol Nutr Metab 2010;35:679-90.
6. Avela J, Finni T, Liikavainio T, Niemelä E, Komi PV. Neural and mechanical responses of the triceps surae muscle group after 1 h of repeated fast passive stretches. J Appl Physiol (1985) 2004;96:2325-32.
7. Donti O, Tsolakis C, Bogdanis GC. Effects of baseline levels of flexibility and vertical jump ability on performance following different volumes of static stretching and potentiating exercises in elite gymnasts. J Sports Sci Med 2014;13:105-13.
8. Ogura Y, Miyahara Y, Naito H, Katamoto S, Aoki J. Duration of static stretching influences muscle force production in hamstring muscles. J Strength Cond Res 2007;21:788-92.
9. Chatzopoulos D, Galazoulas C, Patikas D, Kotzamanidis C. Acute effects of static and dynamic stretching on balance, agility, reaction time and movement time. J Sports Sci Med 2014;13:403-9.
10. Holt LE, Pelham TW, Burke DG. Modifications to the Standard Sit-and-Reach Flexibility Protocol. J Athl Train 1999;34:43-7.
11. Göral K. Examination of agility performance of soccer players according to their playing position. The Sport Journal 2015;51. Available from: http://thesportjournal.org/article/examination-of-agility-performances-of-soccer-players-according-to-their-playing-positions/
12. Váczi M, Tollár J, Meszler B, Juhász I, Karsai I. Short-term high intensity plyometric training program improves strength, power and agility in male soccer players. J Hum Kinet 2013;36:17-26.
13. Keir DA, Thériault F, Serresse O. Evaluation of the running-based anaerobic sprint test as a measure of repeated sprint ability in collegiate-level soccer players. J Strength Cond Res 2013;27:1671-8.
14. Kapidzic A, Pojskic H, Muratovic M, Uzicanin E, Bilalic, J. Correlation of tests for evaluating explosive strength and agility of football players. Sport SPA 2011;8:29-34.
15. Faigenbaum AD, Kang J, McFarland J, Bloom JM, Magnatta J ,Ratamess NA, et al. Acute effects of different warm-up protocols on anaerobic performance in teenage athletes. PES 2006;17:64-75.
16. Gleim GW, McHugh MP. Flexibility and its effects on sports injury and performance. Sports Med 1997;24:289-99.
17. Magnusson SP. Passive properties of human skeletal muscle during stretch maneuvers. A review. Scand J Med Sci Sports 1998;8:65-77.
18. O'Sullivan K, Murray E, Sainsbury D. The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. BMC Musculoskelet Disord 2009;10:37.

19. Bandy WD, Irion JM, Briggler M. The effect of time and frequency of static stretching on flexibility of the hamstring muscles. Phys Ther 1997;77:1090-6.
20. Herman SL, Smith DT. Four-week dynamic stretching warm-up intervention elicits longer-term performance benefits. J Strength Cond Res 2008;22:1286-97.
21. Beedle BB, Mann CL. A comparison of two warm-ups on joint range of motion. J Strength Cond Res 2007;21:776-9.
22. Covert CA, Alexander MP, Petronis JJ, Davis DS. Comparison of ballistic and static stretching on hamstring muscle length using an equal stretching dose. J Strength Cond Res 2010;24:3008-14.
23. Bandy WD, Irion JM, Briggler M. The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. J Orthop Sports Phys Ther 1998;27:295-300.
24. Odunaiya NA, Hamzat TK, Ajayi OF. The effect of static stretch duration on the flexibility of hamstring muscle. AJBR 2005;8:79-82.
25. Magnusson P, Renström P. European College of Sports Sciences Position statement: The role of stretching in sports. Eur J Sport Sci 2006;6:87-91.
26. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. Sports Med 2005;35:501-36.
27. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. J Sports Sci 2006;24:665-74.
28. Amiri-Khorasani M, Sahebozamani M, Tabrizi KG, Yusof AB. Acute effect of different stretching methods on Illinois agility test in soccer players. J Strength Cond Res 2010;24:2698-704.
29. Hough PA, Ross EZ, Howatson G. Effects of dynamic and static stretching on vertical jump performance and electromyographic activity. J Strength Cond Res 2009;23:507-12.
30. Needham RA, Morse CI, Degens H. The acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players. J Strength Cond Res 2009;23:2614-20.
31. Pinto MD, Wilhelm EN, Tricoli V, Pinto RS, Blazevich AJ. Differential effects of 30- vs. 60-second static muscle stretching on vertical jump performance. J Strength Cond Res 2014;28:3440-6.
32. Carvalho FL, Carvalho MC, Simão R, Gomes TM, Costa PB, Neto LB, et al. Acute effects of a warm-up including active, passive, and dynamic stretching on vertical jump performance. J Strength Cond Res 2012;26:2447-52.
33. Kay AD, Blazevich AJ. Effect of acute static stretch on maximal muscle performance: a systematic review. Med Sci Sports Exerc 2012;44:154-64.
34. Holt BW, Lambourne K. The impact of different warm-up protocols on vertical jump performance in male collegiate athletes. J Strength Cond Res 2008;22:226-9.
35. Lopez EI, Smoliga JM, Zavorsky GS. The effect of passive versus active recovery on power output over six repeated wingate sprints. Res Q Exerc Sport 2014;85:519-26.