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RESEARCH

Acute effects of dynamic stretching exercises on vertical jump performance and flexibility

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Abstract

Purpose This study was conducted to examine the acute effects of dynamic stretching exercises (DSE) on vertical jump height (VJH), muscle strength (MS), and flexibility in athletes and sedentary individuals.

Methods The study included 28 athletes and 28 sedentary. Athlete and sedentary groups were equally distributed into two groups DSE group of 3 and 6 min. At the beginning of the trial, VJH, MS, and flexibility were measured. VJH was measured using the Vertimetric Vertical Jump, was assessed using the Lafayette Manual Muscle Tester, and flexibility was evaluated using a sit-and-reach bench. Both groups jogged for 5 min. One group performed a 3-min DSE, while the other group performed a 6-min DSE. Then, all measurements were repeated immediately after, at 5 min, 10 min, and 15 min (MS was measured only before and immediately after stretching sessions).

Results In our study comparing athletes and sedentary participants, athletes exhibited significant differences in flexibility and VJH, regardless of the duration of stretching. For the 3-min DSE group, flexibility increased immediately after stretching and remained consistent. In the 6-min DSE group, flexibility continued to increase for up to 5 min after DSE, and then it plateaued. When comparing the VJH of athletes in the 3-min and 6-min DSE groups, significant differences were found at 5 and 15 min after DSE.

Conclusions It is thought that including DSE in warm-up protocols will positively affect VJH and flexibility. Six-minute DSE increased strength in sedentary but did not affect strength in athletes.

Keywords Dynamic stretching exercise · Vertical jump height · Muscle strength · Flexibility

Introduction

Stretching exercises are commonly used as pre- and/or post-activity routines to improve range of motion, improve muscle performance, facilitate recovery after vigorous exercise, or reduce the risk of activity-related injury [1]. It has been proven that long-term (> 30–60 s) static stretching exercises can have detrimental effects on muscle performance [2]. Dynamic stretching is preferred rather than static stretching as part of a comprehensive warm-up routine that includes both aerobic and sport-specific activities [3]. Dynamic stretching is preferred because it imitates exercise movements, improves nerve conduction, muscle compliance, and energy production, while maintaining central drive [4].

Dynamic stretching is associated with performance enhancement through increased metabolic factors such as heart rate, core temperature, and blood flow [5]. The acute effects of dynamic stretching exercises (DSE) have been shown to increase vertical jump height, joint range of motion, hamstring flexibility, and isometric/isotonic muscle strength [6–10]. But, there are studies in the literature that report a decline in performance following dynamic stretching [5, 11, 12]. This is attributed to factors such

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as the stretching duration, intensity, velocity, and type of contraction employed in the studies [13, 14].

In the literature, stretching time plays a key role in the effect of DSE on performance. Studies that report positive effects on performance have employed short-duration DSE [15–17]. Although a study showed a decrease in hamstring eccentric-concentric muscle strength after prolonged stretching (16 min) [11], another study found that short-term dynamic stretching was more effective in improving isokinetic strength and power than stretching for more than 90 s [13]. Ryan et al. compared 6-min and 12-min dynamic stretching and reported that 6-min stretching was the most appropriate time for performance and muscular endurance [18]. But, a recent review found an insufficient level of evidence [19]. Therefore, the purpose of our study is to investigate the effects of DSE, applied at different durations, on vertical jump, muscle strength, and flexibility in both athletic and sedentary individuals. It was hypothesized that 6 min of DSE would increase vertical jump height, flexibility, and muscle strength greater than 3 min of DSE.

Methods

Procedure

Participants who agreed to participate after the purpose of the study was explained were informed of the exercises and test protocols defined for their respective groups. It was stated that the exercises and measurements would take 30–40 min in total. They were also informed about the potential risks of DSE exercises and possible effects such as mild fatigue.

Participants' sociodemographic characteristics and dominant extremity were recorded. The leg used for kicking was defined as the dominant foot, while the supporting leg was identified as the non-dominant foot (Fig. 1). Ethical approval for the study was obtained from Sivas Cumhuriyet University Non-Interventional Clinical Research Ethics Committee on March 10, 2021 (2021-03/23).

Participants

Twenty-eight football players who played in the Premiere League and 28 healthy male volunteers participated in the study. Our inclusion criteria were being voluntary to participate, being male, being aged between 15 and 21 years, having no lower extremity injury in the past year, and absence of any neuromuscular problems.

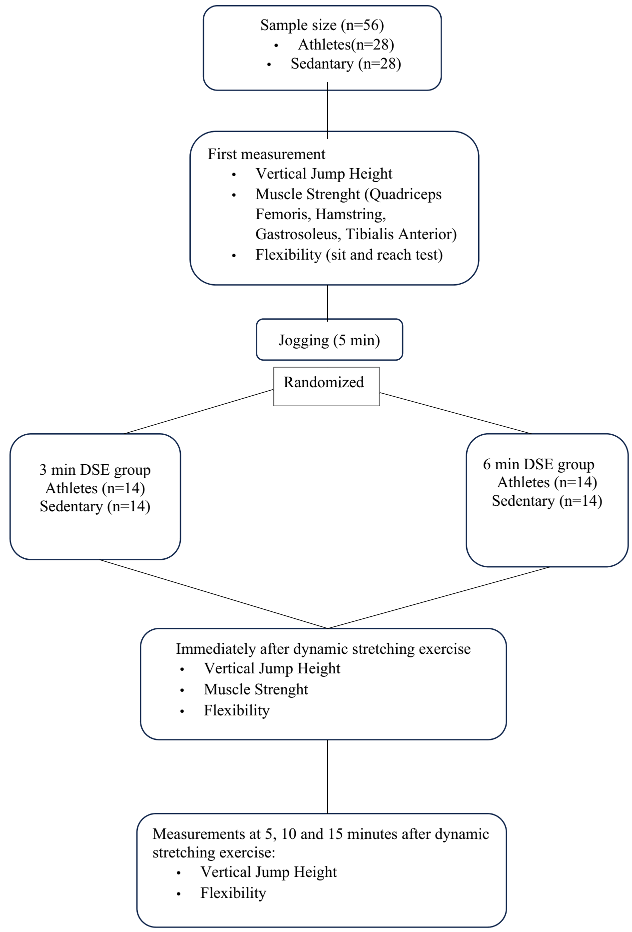

Fig. 1 Study flowchart

Intervention

Dynamic stretching exercises Participants were given practical explanations and demonstrations before the exercises were carried out. Participants jogged for 5 min and then performed the DSE. Only set-1 exercises were applied to one of the groups and set-1 and set-2 were applied together to the other group. The group that only performed the set-1 group exercises took an average of 3–4 min, while the other group performed 6–7 min. In the implementation of each movement, the stretching position was held for 2 s and then continued by walking. A rest interval of 10 s was given between exercises, and each was repeated 14 times. Set-1 exercises included standing quadriceps femoris stretching, standing heel pulling to hips, standing hamstring and posterior leg muscles stretching, and standing forward reaching. Set-2 exercises included forward lunge and opposite upper extremity elevation movement, lateral lunge movement, running with high knee pull, and running with backward heel pull.

Outcome measurement

Vertical jump test Measurements were made using the Vertimetric Vertical Jump and Leg Strength Measurement Device Lafayette USA. VertiMetric is a wireless device that measures vertical jump height (VJH) and leg power. The intervisit relative reliability of the VertiMetric device ranged from 0.91 to 0.93 [20]. The time to stay in the air and the jump height are measured by attaching a foot band to the ankle of the participant, asking them to bend their both knees and then jump in the vertical direction. This was done by giving the command: "Can you perform a vertical jump to maximum height, keeping your arms loose and extended at the sides of your body without any swinging motion". Since the instrument could not measure if the knees were flexed while performing the jump, the participants were asked not to bend their knees during the jump while the measurement was being made.

Flexibility Participants flexibility was evaluated with the sit and reach bench, a widely used, valid, and reliable test [21]. The sit and reach bench was fixed to the wall and the participants were asked to place the soles of their feet on the bench. The participants sat on the floor with their legs straight under the test bench. In the long sitting position with the trunk upright, the point of the fingertip of the participant was noted. The difference between the point where they could reach the maximum with their fingertips and the point where they first reached out was accepted as the longest flexibility value. The test was repeated 3 times and the highest score was recorded in cm. Knees should not be bent while lying down.

Muscle strength Muscle strength was measured with a Lafayette Manual Muscle Tester (Muscle Measurement System 01165, USA digital hand dynamometer). Knee extension, knee flexion, plantar flexion, and dorsiflexion strengths were measured. In this test, the practitioner measures the maximum force required to overcome the isometric contraction by applying force with the device. During the measurement, it is requested to maintain the isometric contraction for 5 s. Three measurements were made and the average was recorded in Newtons.

Statistical analysis

The sample size was determined with the G-Power program. The effect size of the study was 0.68, the power was 80%, and the clinical significance (margin of error) was accepted as $p = 0.05$ [22]. The total sample size was calculated as 56 people, with 28 people in each group. Data were analyzed with the IBM SPSS Statistics program (version 23.0; Illinois, USA). Normal data distribution was evaluated by analytical (Shapiro–Wilk test) and visual methods (histogram). Since the normal distribution was achieved, the independent sample *t* test was used in the comparison between groups, and the paired *t* test was used within the group. Analysis of variance in repeated measurements with the Bonferroni test was applied in repeated measurements for four different times after treatment. Statistical significance was accepted as $p < 0.05$. Cohen's d coefficient was used to calculate the effect size. Cohen d categorized effect sizes as small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$) [23].

Results

The mean age of the athlete group was 17.6 ± 1.1 and the sedentary group was 18.5 ± 2.0 years. The body mass index of the athlete group was 22.6 ± 1.4, and 22.3 ± 3.0 in the sedentary group. Table 1 includes the VJH and flexibility values before and after the dynamic stretching exercise, with values less than $p < 0.005$ in bold.

When the VJH of the athlete group was compared between the 3-min and 6-min exercise groups, significant differences were found at 5-min and 15-min after the DSE ($p = 0.018$, $p = 0.018$, respectively). When the flexibility and VJH were compared, athletes had statistically significant differences from sedentary participants, regardless of stretching duration, in all measured parameters ($p < 0.05$).

In the 3-min DSE group, a post-stretching increase was observed for flexibility, which remained consistent over time. In the 6-min DSE group, flexibility values continued to increase up to 5 min after dynamic stretching and then plateaued. In the sedentary group, a statistically significant correlation was found between the duration of DSE and the time parameter ($p = 0.049$) (Table 1).

Before 3-min DSE, a statistically significant difference was found in the average muscle strengths of the right quadriceps femoris, left quadriceps femoris, and left gastrosoleus between the athlete and sedentary groups. Immediately after the exercise, a statistically significant difference was observed in the average muscle strengths of the right quadriceps femoris, left quadriceps femoris, right hamstring, and left hamstring ($p < 0.05$). A statistically significant difference was found for the right quadriceps femoris and right gastrosoleus before dynamic stretching, and only for the right quadriceps femoris immediately after exercise 6-min DSE group ($p < 0.05$). When the mean muscle strength difference before and after dynamic stretching was compared, a statistically significant difference was found in the right hamstring in the 3-min DSE group and in the left gastrosoleus in the 6-min DSE group ($p < 0.05$) (Table 2).

Table 1 Vertical jump height and flexibility values before and after dynamic stretching exercise

	Before DS ($X \pm$ SD)	Immediately after DS ($X \pm$ SD)	DS 5-min later ($X \pm$ SD)	DS 10-min later ($X \pm$ SD)	DS 15-min later ($X \pm$ SD)	*F*	*p*
VJH (cm)							
Athletes							
3 min	**46.22 ± 3.61[a]**	**47.28 ± 5.26[a]**	**45.65 ± 3.37[a]**	**46.07 ± 3.57[a]**	**44.63 ± 3.92[a]**	1.95	0.137
6 min	**46.89 ± 6.83[a]**	**49.49 ± 4.75[a]**	**49.82 ± 5.07[a,b]**	**48.91 ± 4.56[a]**	**48.67 ± 4.54[a,b]**		
Sedentary							
3 min	38 ± 6.61	40.10 ± 6.11	38.41 ± 7.06	39.45 ± 6.56	38.77 ± 5.81	2.935	***0.049****
6 min	42.12 ± 3.58	42.29 ± 4.39	42.60 ± 4.22	42.00 ± 4.33	41.80 ± 3.50		
Flexibility (cm)							
Athletes							
3 min	**36.78 ± 5.97[a]**	**38.21 ± 5.91[a]**	**38.71 ± 5.49[a]**	**38.71 ± 5.73[a]**	**38.57 ± 6.02[a]**	0.97	0.406
6 min	**33.14 ± 11.25[a]**	**34.50 ± 10.55[a]**	**35.42 ± 9.83[a]**	**35.64 ± 9.88[a]**	**35.85 ± 10.58[a]**		
Sedentary							
3 min	26.57 ± 8.00	28.85 ± 7.61	30.14 ± 6.50	30.85 ± 6.56	30.71 ± 6.21	0.279	0.771
6 min	23.14 ± 6.44	25.92 ± 7.24	27.14 ± 7.19	27.21 ± 7.35	27.14 ± 7.50		

Independent *t* test—analysis of variance in repeated measures—Bonferroni test. Data are given as mean ± standard deviation

X mean, *SD* standard deviation, *DS* dynamic stretching, *VJH* vertical jump height, *cm* centimeter

*$p < 0.05$

[a]Statistically different from sedentary group

[b]Statistically different from 3 min group

Discussion

In this study, we hypothesized that 6-min DSE would lead to better improvements in vertical jump, flexibility, and muscle strength compared to 3-min DSE and that the increase in vertical jump and flexibility would last up to 15 min after stretching. According to our results, greater increases in VJH were observed in the athletes in the 6-min DSE and an increase in flexibility was observed in both DSE groups up to 15 min.

The intensity, volume, duration, and type of dynamic stretching routines are important components that can potentially influence post-stretching performance. Immediately after dynamic stretching in both athletes and sedentary individuals. Similar to the literature, we also found an increase [24, 25]. In athletes, 6-min DSE exercise showed better results in VJH compared to 3-min DSE, while they both showed similar effects in sedentary individuals. Ryan et al. demonstrated similar improvements in VJH in active males after 6-min and 12-min of DSE [18]. The effect of dynamic stretching on VJH lasted until immediately after stretching and then remained constant. Kruse et al. observed an increase in VJH after a short time (1 min) of dynamic stretching but concluded that the positive effects of DSE decreased if they waited up to 15 min [26]. Based on these studies the English Premier League Field Protection Policy states that the pre-match warm-up should end no later than 10 min before kick-off [26].

An increase in hamstring flexibility values was observed in both athletes and sedentary individuals after dynamic stretching and similar results have been reported in the literature [6, 7, 10]. One of the reasons for increased flexibility in dynamic stretching is that active and repetitive muscle contractions increase muscle temperature and increase tissue extensibility by reducing muscle viscosity [19]. In our study, similar increases were observed in both selected exercise durations. In the 3-min DSE group, flexibility increased immediately after stretching and remained constant at other times; increased until 5 min and then remained constant in the 6-min DSE group. We think the reason for this increase is that, as explained in the literature, stretching duration and intensity affect the passive stiffness of the muscle–tendon unit [14]. Iwata et al. show that high-intensity dynamic stretching results in a greater dose-dependent change in hamstring flexibility, which in turn results in a longer-lasting effect on passive stiffness [8]. Studies have found that the increase in flexibility after dynamic stretching decreased significantly after 15 min, but similar to our results, it remained larger than the initial values [27, 28]. Based on the findings from our study, we think that the effect time on flexibility is upon the individual's activity level, and we posit that engaging in an aerobic warm-up prior to stretching contributes to the enhancement of flexibility.

Table 2 Muscle strength values before and after dynamic stretching

Muscle strength (kg)	Before ($X \pm SD$)			After ($X \pm SD$)			Mean difference ($X \pm SD$)		
	Athletes	Sedentary	*p*	Athletes	Sedentary	*p*	Athletes	Sedentary	*p* (ES)
Quadriceps									
Right									
3 min	27.22 ± 3.59	18.84 ± 3.06	***0.001****	23.66 ± 3.28	16.76 ± 3.0	***0.001****	– 3.56 ± 4.19	– 2.08 ± 1.63	0.22 (0.46)
6 min	26.93 ± 3.96	21.30 ± 3.77	***0.001****	**28.17 ± 4.12**[a]	**21.34 ± 4.83**[a]	***0.001****	1.23 ± 5.01	0.04 ± 3.66	0.47 (– 0.27)
Left									
3 min	23.13 ± 3.44	18.31 ± 3.24	***0.001****	22.47 ± 3.53	17.21 ± 4.28	***0.002****	– 0.66 ± 3.89	– 1.09 ± 2.31	0.72 (– 0.13)
6 min	24.69 ± 5.48	**20.98 ± 3.43**[a]	0.41	23.85 ± 3.46	**21.44 ± 4.27**[a]	0.11	– 0.83 ± 6.45	0.45 ± 3.41	0.51 (0.25)
Hamstring									
Right									
3 min	20.22 ± 3.11	18.74 ± 2.78	0.19	21.82 ± 3.80	17.37 ± 2.99	***0.002****	1.60 ± 2.86	– 1.37 ± 2.44	***0.007**** (**– 1.11**)
6 min	20.27 ± 3.37	**21.23 ± 2.94**[a]	0.43	21.08 ± 3.43	**20.68 ± 2.71**[a]	0.73	0.80 ± 3.48	– 0.54 ± 2.95	0.27 (– 0.42)
Left									
3 min	19.62 ± 3.28	17.71 ± 3.02	0.12	20.85 ± 3.32	17.29 ± 3.33	***0.009****	1.23 ± 3.21	– 0.41 ± 2.32	0.13 (– 0.53)
6 min	20.14 ± 3.38	**20.91 ± 3.96**[a]	0.58	19.5 ± 3.13	**20.35 ± 2.78**[a]	0.45	– 0.63 ± 4.22	0.55 ± 3.63	0.95 (0.02)
Gastrosoleus									
Right									
3 min	19.07 ± 4.92	17.23 ± 3.15	0.71	18.72 ± 4	18.45 ± 4.5	0.39	– 1.25 ± 3.93	1.22 ± 3.84	0.10 (0.63)
6 min	21.96 ± 5.44	18.2 ± 3.54	***0.04****	20.48 ± 6.71	20.63 ± 3.13	0.94	– 1.47 ± 7.23	2.42 ± 2.88	0.07 (0.7)
Left									
3 min	16.35 ± 2.78	16.83 ± 4.03	***0.002****	16.51 ± 3.04	17.91 ± 5.07	0.63	0.15 ± 2.06	1.08 ± 3.62	0.41 (0.31)
6 min	**21.02 ± 5.73**[a]	18.72 ± 4.46	0.24	18.53 ± 5.59	20.51 ± 4.65	0.31	2.49 ± 6.31	1.79 ± 4.35	***0.04*(0.78)***
Tibialis anterior									
Right									
3 min	14.99 ± 3.79	15.86 ± 2.72	0.32	17.07 ± 4.15	15.81 ± 3.47	0.87	2.07 ± 5.42	0.04 ± 2.61	0.19 (– 0.49)
6 min	17.51 ± 2.77	**19.63 ± 3.39**[a]	0.08	18.11 ± 4.27	**20.45 ± 4.65**[a]	0.31	0.60 ± 4.15	0.81 ± 3.27	0.88 (0.05)
Left									
3 min	14.64 ± 4.87	15.93 ± 2.58	0.19	15.41 ± 4.64	14.73 ± 2.52	0.38	0.76 ± 5.17	– 1.19 ± 1.60	0.18 (– 0.51)
6 min	16.68 ± 2.84	**19.15 ± 3.99**[a]	0.07	17.46 ± 4.9	**19.13 ± 2.87**[a]	0.28	0.78 ± 3.87	– 0.22 ± 3.66	0.57 (– 0.21)

Independent *t* test

X mean, *SD* standard deviation, *ES* effect size, *kg* kilogram

*$p < 0.05$ significance level

[a]Statistically different from 3-min group

Immediately after dynamic stretching, athletes showed improvements in quadriceps, hamstring, and tibialis anterior isometric muscle strength compared to sedentary subjects. No change in isometric strength was observed in the ankle plantar flexors and dorsi flexors immediately after dynamic stretching. Mizuno measured isometric muscle strength with EMG and reported no change in isometric muscle strength [29]. There was a general increase in strength after dynamic stretching or no adverse effects, but a few studies showed a significant decrease in strength after dynamic stretching [19, 30]. In the literature, the increase in muscle strength after dynamic stretching is attributed to neural adaptation with more motor unit firing, whereas the decrease in muscle strength after stretching is explained by fatigue impairing recovery [9, 29]. When the difference in muscle strength averages was examined in our study, only the right quadriceps isometric muscle strength increased in the athletes compared to the 3-min DSE group group, while the others showed a decrease or non-significant small increases. When the strength averages were analyzed, an increase was observed in the hamstring, tibialis anterior, and left quadriceps in the 6-min DSE group compared to the sedentary group. However, reductions or minimal gains in other muscle groups highlight the specificity of such interventions and emphasize the need to tailor stretching exercises to effectively target specific muscle groups. when the 6-min and 3-min DSE groups were compared, muscle strength in except gastrosoleus muscles in the sedentary group was improved better in the 6-min DSE group. The reason for not seeing a gastrosoleus muscle strength effect may be due to the fact that DSE are mostly aimed at the hip and thigh muscles. As athletes have greater muscle thickness, the DSE might not have affected them similarly. We believe that when the DSE duration is longer than 6 min, there may be increases in muscle strength in athlete individuals.

Overall, these findings emphasize the importance of tailoring stretching routines to the specific needs and goals of athletes. The choice between static and dynamic stretching as well as the duration of stretching exercises should be carefully considered to optimize muscle strength gains in various muscle groups. Further research is needed to investigate the underlying mechanisms responsible for these effects and to provide athletes with evidence-based recommendations for their training regimen. In addition, individual variability and other potential factors affecting muscle strength should be considered when designing future interventions and exercise programs to ensure the most effective and safe practices for athletes.

The strengths of our study were similar physical structures and close age groups. Our study has several limitations. The male gender of our participants limited our ability to make comparisons between genders. In our investigation of isometric strength assessment using hand dynamometry, we acknowledge certain limitations in acquiring more objective data, as we were unable to conduct measurements of a more objective nature, such as isokinetic assessments.

Conclusion

6 min of DSE resulted in greater improvements in the VJH of athletes compared to a duration of 3 min. However, both durations had similar effects on sedentary individuals. Dynamic stretching resulted in increased hamstring flexibility in both athletes and sedentary individuals. The duration of stretching had an impact on the extent and duration of flexibility improvements, with longer durations resulting in sustained effects.

Six-minute DSE increased strength in sedentary people but did not affect strength in professional athletes. Longer stretching periods may be required to see a strength increase in football players. The duration of the dynamic stretching to be applied should vary depending on the sport performed.

The effects varied between different muscle groups and stretching times. The study emphasises the significance of customising stretching routines to meet individual needs and goals, taking into account factors such as the type of stretching, duration, and specificity of muscle groups. Understanding the effects of dynamic stretching on performance and muscle strength is essential for designing effective training programs for athletes. Further research is necessary to explore underlying mechanisms and provide evidence-based recommendations for optimal stretching practices.

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Author contributions All authors whose names appear on the submission made substantial contributions to the study conception or design. Data acquisition and analysis was performed, and the first draft of the manuscript was written by KÇG and ÖAG. AO revised the work and commented on the final version of the manuscript. All authors read and approved the final manuscript to be published.

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Data avaibility Data supporting the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest No potential conflict of interest was reported by the authors.

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