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RESEARCH

Influence of different durations of lower limb static stretching on the performance of long jump athletes: a randomized controlled trial

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Abstract

Purpose To evaluate the influence of different durations of lower limb static stretching (SS) on the performance of long jump (LJ) athletes.

Methods A crossover randomized controlled trial was conducted with 20 athletes, submitted to 4 conditions: 3 experimental conditions, performing the usual warm-up plus SS of quadriceps, hamstrings, gastrocnemius and tibialis anterior during 30 s, 1 min or 3 min; and a control condition, of only the usual warm-up. LJ performance was assessed before and immediately after the interventions/control.

Results There was a significant change after the 3 min SS, with an improvement in the distance achieved ($p = 0.012$). However, there were no differences between the 4 conditions ($p = 0.154$).

Conclusion Results suggest that SS performed for 30 s, 1 min or 3 min, seem not to influence the LJ performance, since despite an improvement in the distance reached after the 3 min SS, there were no significant differences between conditions.

Keywords Static stretching · Performance · Long jump

Introduction

Long Jump is an athletic (track and field) event that combines speed, strength and agility in an attempt to land as far away from the take-off point [1], being performed in 4 different phases: the run-up, take-off, flight and landing [2]. The athlete starts by sprinting, jumps up from a take-off board, and flies through the air before landing in a box of sand [2]. Previous research describing the biomechanics and electromyographic analysis of the long jump has shown the contribution of lower limb muscles during the different phases, especially the quadriceps muscles, the hamstrings, the gastrocnemius and the tibialis anterior [3, 4].

Warm-up prior to athletic events is considered essential to optimize performance. Traditional warm-up programs are typically composed of aerobic activity, sport-specific exercises and stretching. Specifically stretching, is considered an essential component of warm-up routines in athletic settings, as an increased flexibility has been linked to an increased range of motion and decreased incidence of injury, particularly of muscle injuries [5–8]. This might be related to the viscoelastic effects of stretching. Indeed, previous investigations describe that an increase in joint range of motion is

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associated with a decrease in passive resistance to stretch, as a result of a reduction in muscle stiffness or an increase in muscle compliance [5, 9].

Static stretching (SS) involves lengthening a muscle until a stretch sensation or point of discomfort is reached, holding the muscle in a lengthened position for a period of time [7]. Despite the evidence regarding the effect of stretching on muscle injury prevention, several studies have been investigating the potential harms of SS on the performance of many athletes, with controversial results [5–7, 10–13]. On one hand, several adverse effects of SS have been pointed, such as a decrease in maximal strength, torque production and muscle activation [11, 14, 15]; and impaired sprint [6] and jump height performance [16]. On the other hand, other studies have described no detrimental effects on sprint or jump performance associated with prior SS in trained healthy athletes [12, 17]. However, the lack of impairment may be related to different factors like possible short durations of the SS, and stretches performed with an intensity less than the point of discomfort [10].

The effects of SS have been largely investigated in many sports and in different types of vertical jumps. Nevertheless, to date, no studies have described neither the effects of lower limb SS specifically on long jump athletes' performance nor assessed the effects of different durations of SS. In this sense, this study aims to evaluate the influence of different durations of lower limb SS on the performance of long jump athletes.

Methods

Participants

In this crossover randomized controlled trial, a convenience sample of 20 professional track and field athletes (11 male and 9 female) participated in the study. A block randomization was performed using an online platform, to assure equal sample sizes across the study conditions. Participants were included if they were track and field athletes for at least 1 year, and excluded if any injury in the lower limbs or trunk occurred in the previous 6 months. Furthermore, the eligible participants were asked not to consume alcohol or coffee in the 48 h prior to the assessments of the study. The study was approved by the Ethical Committee of Fernando Pessoa's University. All athletes gave their written consent to participate in the study and all procedures were according to the Declaration of Helsinki.

Experimental design and procedures

Participants were all submitted to the following 4 conditions, whose order was randomized, and with one week of the interval between them [6]. The flowchart describing the experimental design of the study is illustrated in Fig. 1:

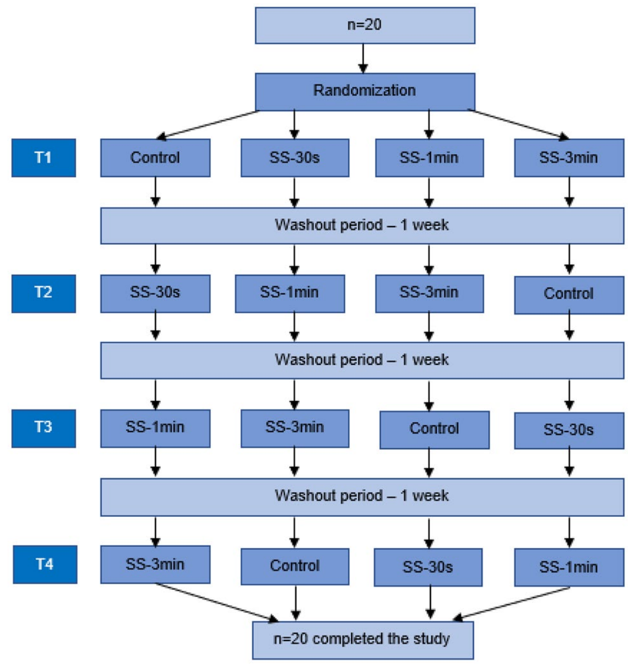

Fig. 1 Flowchart of the experimental design

- Experimental condition 1 (SS-30 s): usual warm-up + 30-s static stretching [18];
- Experimental condition 2 (SS-1 min): usual warm-up + 1-min static stretching [19];
- Experimental condition 3 (SS-3 min): usual warm-up + 3-min static stretching [20];
- Control condition (CON): usual warm-up.

The usual warm-up performed in all conditions consisted of 10 min of continuously controlled running and general mobility exercises.

For each condition, 3 jump attempts were measured before and immediately after the warm-up and the stretching protocol inherent to the defined condition. In the control condition, only the 3 jump attempts were measured before and immediately after the warm-up. According to the specifications of the modality, the best jump attempt (the one in which the greatest distance has been reached) was considered.

During the interval period until the next condition to be performed, the athletes maintained their usual routine and training plans.

For the four conditions, all participants were assessed in the afternoon period, and in the same time points.

Stretching protocols

In the 3 experimental conditions, athletes were submitted to a static stretching protocol that involved the following 4 muscle groups:

1. Quadriceps: in a prone position, the athletes flexed the knee, holding the foot, to reach the limit of the range of motion [21];
2. Hamstrings: athletes sat on the floor with one leg extended forward and the other leg to the side. Then, the arms were extended to try to reach the foot of the extended leg [22]
3. Gastrocnemius: with the hands on the wall, the leg to be stretched took a step back holding the heel on the floor, and maintaining extension at the knee [23];
4. Tibialis anterior: participants were facing the wall, with the entire foot flat on the ground and toes pointed forward. Then, they secured themselves to a handrail and then projected their hips back [24].

All stretches were maintained during the stipulated time of the conditions under study, and were performed bilaterally.

Statistical analysis

Data analysis was performed using the Statistical Package for the Social Sciences Software v. 26 for Windows, considering a significance level of 5%. A new variable was computed (Diff_jump), calculated as the difference in the long jump after intervention (measurement after – measurement before). Descriptive analysis of the variables was described in Median and Interquartile Range (Mdn; IQR). Shapiro–Wilk test was used to assess the normality of the distribution of variables. Non-parametric test of Wilcoxon was used for intragroup comparisons regarding the analysis of the distance achieved in the long jump before and after the interventions or control. Effect size of the interventions was assessed through the rank-biserial correlation, which represents the difference between the proportion of favourable and unfavourable pairs [25]. In this test, values range between -1 (the totality of the values of the second sample are larger than the values of the first sample) and + 1 (the totality of the values of the second sample are smaller than the values of the first sample). The Friedman test was used for intergroup comparisons to verify differences between conditions in the long jump performance before and after the intervention.

Table 1 Sample characterization

Variable	Mdn; IQR
Age (years)	21; 8
Weight (kg)	64.5; 20
Height (m)	1.70; 0.17
BMI (kg/m^2)	22.7; 2.4
Years of practice	5; 2
Weekly trainings	5; 2

Results

The sample characterization regarding the variables age, weight, height, body mass index (BMI), years of track and field practice and the number of weekly training is described in Table 1.

Table 2 describes the intra- and inter-group comparisons of the athletes' performance in the long jump (in meters) before and after the 4 conditions of the study.

A significant change was observed only in the SS-3 min condition, showing an improvement in the distance achieved in the long jump ($p = 0.012$) between the two assessments. However, there were no significant differences between conditions both before ($p = 0.284$) and after the intervention ($p = 0.154$).

A raincloud plot illustrating the distribution of the differences in long jump performance can be seen in Fig. 2. It is possible to note that the group of SS-3 min was the only where most of the subjects had a positive influence after stretching. In the other groups, several subjects evidenced mostly a decrease in jump performance.

Discussion

The aim of this study was to evaluate the influence of different durations of lower limb SS on the performance of long jump athletes, with 3 different durations being studied (30 s, 1 min and 3 min).

Some mechanical and viscoelastic properties of muscles can be affected by SS. In a previous investigation with track and field athletes, it was demonstrated that after hamstrings SS, muscle elasticity worsened [26]. The authors suggested that the changes in elasticity caused a disturbance in the optimal distance between actin and myosin chains, affecting the ability to generate strength, speed and explosive power [26], which may justify the decreased performance in jump height described in the study. Indeed, an adequate muscle elasticity plays an important role in stretch–shortening cycle activities such as jumping, as it results in better energy conservation and in an enhanced released propulsive force [27]. Muscle stiffness also seems to be relevant in jump performance. Previous research has shown that higher stiffness favors fast

Table 2 Intra- ($p^{\uparrow}$) and intergroup ($p^{\downarrow}$) comparisons

Condition	Before Mdn; IQR	After Mdn; IQR	Effect size¥ (95% CI)	$p^{\uparrow}$	Diff_jump Mdn; IQR
Control	3.95; 0.80	3.74; 0.98	− 0.400 (− 0.728; 0.076)	0.117	0.09; 0.45
SS-30 s	3.98; 1.05	3.88; 0.91	− 0.090 (− 0.530; 0.388)	0.737	− 0.03; 0.37
SS-1 min	4.05; 0.93	4.08; 1.21	− 0.390 (− 0.722; − 0.087)	0.121	0.23; 0.69
SS-3 min	4.18; 0.79	4.44; 0.92	− 0.633 (-0.847; − 0.242)	0.012*	0.24; 0.33
$p^{\downarrow}$	0.202	0.286			0.410

*$p<0.05$; ¥: Rank-biserial correlation, *CI* confidence Interval, *Diff_jump* difference in the long jump performance between the assessment before and after conditions, *IQR* interquartile range, *Mdn* median, *SS-30 s* static stretching 30 s, *SS-1 min* static stretching 1 min, *SS-3 min* static stretching 3 min

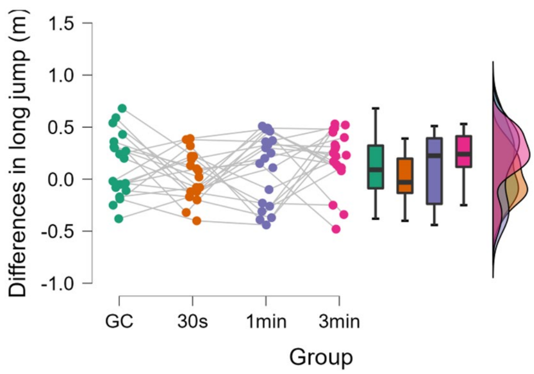

Fig. 2 Differences in long jump performance in the study groups

stretch–shortening cycle activities and enhances explosive athletic performance in trained individuals [28], as muscle stiffness is positively related to the vertical ground reaction force [28]. Evidence from the investigations of Nakamura, Ikezoe [29] and Caliskan, Akkoc [30] shows a decrease in muscle stiffness after 5 min of SS of the gastrocnemius and rectus femoris, respectively, proposing that SS may impair jumping performance by also decreasing muscle stiffness.

The results of the present study are not in line with the previous evidence since it was revealed that in the conditions of SS of 30 s and 1 min there were no significant changes in performance. On the contrary, in the 3-min SS condition, there was even a significant improvement in the distance achieved in the long jump. However, considering the final assessment and the difference between the final and initial assessments, there were no differences between the 4 conditions of the study, including the control condition where no stretching was performed. These findings suggest that the improvement in performance after SS of lower limbs muscle groups for 3 min, may not be attributed to the stretching intervention. More likely, this improvement in performance can be attributed to the effect of warm-up. Indeed, the investigations of Holt and Lambourne [31] and Pagaduan, Pojskić [32] registered an improvement in jump performance after general warm-ups aiming to increase blood flow, heart rate and temperature in the muscles. In fact, previous evidence suggests that an increase in temperature can induce lower viscous resistance improving muscle contractility, and consequently, performance [33, 34].

A review from Behm and Chaouachi [10] aimed to investigate the negative, null or positive responses to stretching on performance. The authors reported impairments in studies who performed SS for different moderate durations, such as 90 s, 2 min, 3 min and over 5 min, whereas the mean percentage of impairments in strength and force was − 6.9%, exceeding the jump (− 2.7%) and sprint (− 2.4%) performance decrements. Specifically in vertical jump height, significantly higher impairments were also detected when performing SS for more than 90 s when compared to less than 90 s. In that sense, most of the included studies in this review let the authors to conclude that, in general, shorter durations of SS within a warm-up may not negatively impact performance in highly trained individuals, while durations longer than 90 s seem to introduce impairments.

Regarding the 30 s and 1 min SS, the conclusions of the review of Behm and Chaouachi [10] are in line with the results of the present study where, similarly, no detrimental effects on jump performance were detected for these conditions. On the other hand, conflicting results were found for the condition of 3 min of SS, since there was no loss of performance, and there was even an improvement in the jump distance, which is contradictory to the conclusions of Behm and Chaouachi [10] that SS longer than 90 s impairs jump performance. However, it should be noted that in this review, the focus was on vertical jumps and not on long jump performance, therefore, the factors or mechanisms that may contribute to the decrease in performance after SS in the vertical jump may be different from those for the long jump. Furthermore, most of the studies involved in the revision perform the SS in one muscle group, while the present study involved four lower limb's muscle groups, which may also produce distinct effects. Nevertheless, as previously indicated, the improvement achieved after the 3-min SS, may not be attributed to SS, since no differences between conditions were noted.

The study of de Oliveira and Rama [12] used a wider stretching protocol with more muscle groups (triceps surae, quadriceps, hamstrings, gluteus maximus and quadratus lumborum). Although countermovement jumps were performed in this study, similar to our results, the authors reported no impairments in jump performance in healthy trained athletes after 30 s of SS.

The findings of the present study suggest no potential harms of SS when applied to the proposed lower limb muscles for 30 s, 1 min or 3 min to each muscle group. Nevertheless, some limitations should be recognized. First, the reduced sample size. Second, the fact that only the acute effects of SS on performance were assessed. Since the available literature is scarce, future research with more robust samples, and with more than one intervention session, should address the effects of more SS durations on long jump performance, and measure for how long possible changes in performance are maintained. Likewise, additional electromyographic analysis of the muscles submitted to SS would be important to understand which mechanisms or muscle changes SS cause.

Conclusion

The results of the present study suggest that SS performed for 30 s, 1 min or 3 min seem not to significantly influence the long jump performance in track and field athletes, since despite an improvement in the distance reached after the 3 min SS, there were no significant differences between conditions, including compared to control.

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Author contributions SR and JA conceived the experimental design of the study; SR collected the data and JA and AS drafted the manuscript; JA and AS analysed the data; AS, IMS, RC and NV assisted in revising and editing the manuscript. All authors read and approved the final version of the manuscript, and agreed with the order of the presentation of the authors.

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Data availability The authors confirm that the data supporting the findings of this study are available within the article.

Declarations

Conflict of interest Authors state no conflict of interest.

Ethical approval and Informed consent The study was approved by the Ethical Committee of Fernando Pessoa's University. All athletes gave their written consent to participate in the study and all procedures were according to the Declaration of Helsinki.

References

1. Yadav M, Saroj M (2015) Biomechanical analysis of long jump: the hitch Kick. Inter J Phys Education, Sports Health 1(6):164–166
2. Linthorne NP (2008) Biomechanics of the long jump. In: Hong Y, Bartlett R (eds) Routledge handbook of biomechanics and human movement science. Routledge, London, pp 352–365
3. Kakihana W, Suzuki S (2001) The EMG activity and mechanics of the running jump as a function of takeoff angle. J Electromyogr Kinesiol 11(5):365–372
4. Mackala K, Stodólka J, Siemienski A, Coh M (2013) Biomechanical analysis of standing long jump from varying starting positions. J Strength Conditioning Res 27(10):2674–2684
5. McHugh MP, Cosgrave C (2010) To stretch or not to stretch: the role of stretching in injury prevention and performance. Scand J Med Sci Sports 20(2):169–181
6. Winchester JB, Nelson AG, Landin D, Young MA, Schexnayder IC (2008) Static stretching impairs sprint performance in collegiate track and field athletes. J Strength Conditioning Res 22(1):13–19
7. Behm DG, Blazevich AJ, Kay AD, McHugh M (2016) Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. Appl Physiol Nutr Metab 41(1):1–11
8. Rahman MH, Islam MS (2020) Stretching and flexibility: a range of motion for games and sports. Eur J Physical Edu Sport Scie 6(8):22–36
9. McHugh MP, Nesse M (2008) Effect of stretching on strength loss and pain after eccentric exercise. Med Sci Sports Exerc 40(3):566–573
10. Behm DG, Chaouachi A (2011) A review of the acute effects of static and dynamic stretching on performance. Eur J Appl Physiol 111(11):2633–2651
11. Costa EC, dos Santos CM, Prestes J, da Silva JB, Knackfuss MI (2009) Acute effect of static stretching on the strength performance of jiu-jitsu athletes in horizontal bench press. Fitness Performance J 8(3):212–217
12. de Oliveira FCL, Rama LMPL (2016) Static stretching does not reduce variability, jump and speed performance. Int J Sports Phys Ther 11(2):237–246
13. Behm DG, Kay AD, Trajano GS, Blazevich AJ (2021) Mechanisms underlying performance impairments following prolonged static stretching without a comprehensive warm-up. Eur J Appl Physiol 121(1):67–94

14. Cramer J, Housh T, Weir J, Johnson G, Coburn J, Beck T (2005) The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. Eur J Appl Physiol 93(5):530–539
15. Nelson AG, Allen JD, Cornwell A, Kokkonen J (2001) Inhibition of maximal voluntary isometric torque production by acute stretching is joint-angle specific. Res Q Exerc Sport 72(1):68–70
16. Behm DG, Kibele A (2007) Effects of differing intensities of static stretching on jump performance. Eur J Appl Physiol 101(5):587–594
17. Stafilidis S, Tilp M (2015) Effects of short duration static stretching on jump performance, maximum voluntary contraction, and various mechanical and morphological parameters of the muscle–tendon unit of the lower extremities. Eur J Appl Physiol 115(3):607–617
18. Brandenburg J (2006) Duration of stretch does not influence the degree of force loss following static stretching. J Sports Med Phys Fitness 46(4):526–534
19. Mohr AR, Long BC, Goad CL (2014) Effect of foam rolling and static stretching on passive hip-flexion range of motion. J Sport Rehabil 23(4):296–299
20. Hobara H, Inoue K, Kato E, Kanosue K (2011) Acute effects of static stretching on leg-spring behavior during hopping. Eur J Appl Physiol 111(9):2115–2121
21. Lee JH, Jang K-M, Kim E, Rhim HC, Kim H-D (2021) Static and Dynamic quadriceps stretching exercises in patients with patellofemoral pain: a randomized controlled trial. Sports Health 13(5):482–489
22. Chan S, Hong Y, Robinson P (2001) Flexibility and passive resistance of the hamstrings of young adults using two different static stretching protocols. Scand J Med Sci Sports 11(2):81–86
23. Takeuchi K, Tsukuda F (2019) Comparison of the effects of static stretching on range of motion and jump height between quadriceps, hamstrings and triceps surae in collegiate basketball players. BMJ Open Sport Exerc Med 5(1):e000631
24. Kearney R, Hunter I (1984) System identification of human stretch reflex dynamics: Tibialis anterior. Exp Brain Res 56(1):40–49
25. Kerby DS (2014) The simple difference formula: an approach to teaching nonparametric correlation. Comprehensive Psychology 3(1):11
26. Meerits T, Bacchieri S, Pääsuke M, Ereline J, Cicchella A, Gapeyeva H (2014) Acute effect of static and dynamic stretching on tone and elasticity of hamstring muscle and on vertical jump performance in track-and-field athletes. Acta Kinesiologiae Universitatis Tartuensis 20:48–59
27. Turner AN, Jeffreys I (2010) The stretch-shortening cycle: proposed mechanisms and methods for enhancement. Strength Conditioning J 32(4):87–99
28. Ando R, Sato S, Hirata N, Tanimoto H, Imaizumi N, Suzuki Y et al (2021) Relationship between resting medial gastrocnemius stiffness and drop jump performance. J Electromyogr Kinesiol 58:102549
29. Nakamura M, Ikezoe T, Takeno Y, Ichihashi N (2011) Acute and prolonged effect of static stretching on the passive stiffness of the human gastrocnemius muscle tendon unit in vivo. J Orthop Res 29(11):1759–1763
30. Caliskan E, Akkoc O, Bayramoglu Z, Gozubuyuk OB, Kural D, Azamat S et al (2019) Effects of static stretching duration on muscle stiffness and blood flow in the rectus femoris in adolescents. Med Ultrason 21(2):136–143
31. Holt BW, Lambourne K (2008) The impact of different warm-Up protocols on vertical jump performance in male collegiate athletes. J Strength Conditioning Res 22(1):226–229
32. Pagaduan JC, Pojskić H, Užičanin E, Babajić F (2012) Effect of various warm-up protocols on jump performance in college football players. J Hum Kinet 35(1):127–132
33. Bishop D (2003) Warm up I: potential mechanisms and the effects of passive warm up on exercise performance. Sports Medicine (Auckland, NZ) 33(6):439–454
34. Herda TJ, Herda ND, Costa PB, Walter-Herda AA, Valdez AM, Cramer JT (2013) The effects of dynamic stretching on the passive properties of the muscle-tendon unit. J Sports Sci 31(5):479–487