BMJ Open Sport & Exercise Medicine

Comparison of the effects of static stretching on range of motion and jump height between quadriceps, hamstrings and triceps surae in collegiate basketball players

Kosuke Takeuchi ,[1] Fumiko Tsukuda[2]

To cite: Takeuchi K, Tsukuda F. 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 & Exercise Medicine* 2019;**5**:e000631. doi:10.1136/bmjsem-2019-000631

Accepted 11 December 2019

Check for updates

© Author(s) (or their employer(s)) 2019. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

[1]Kobe International University, Faculty of Rehabilitation, Department of Physical Therapy, Kobe, Hyogo, Japan
[2]Biwako Seikei Sport College, Faculty of Sport, Department of Sport, Otsu, Shiga, Japan

Correspondence to
Dr Kosuke Takeuchi;
tkousuke413@yahoo.co.jp

ABSTRACT

Objectives The purpose of the present study was to compare the effects of static stretching (SS) on the range of motion and vertical jump height between the quadriceps, hamstrings and triceps surae in collegiate basketball players.

Methods Fourteen male collegiate basketball players (20.2±0.7 years, 179.0±5.0 cm, 71.9±8.3 kg) underwent 5 min of SS for the quadriceps, hamstrings and triceps surae, in random order. Before and after each stretch, the range of motion (ROM) and vertical jump height were measured.

Results ROM of the quadriceps, hamstrings and triceps surae were increased without any difference of relative change in the range. The vertical jump height showed no change after SS of the quadriceps and hamstrings, while it decreased after SS of the triceps surae ($p<0.05$).

Conclusion These results suggested that SS for the triceps surae may have a large impact on jump performance.

INTRODUCTION

Static stretching (SS) is commonly used as a part of a warm-up routine to increase flexibility and prevent sports-related injuries.[1] Increasing range of motion (ROM) is essential to prevent the occurrence of sports-related injuries.[2–4] Previous studies reported that SS increased ROM[5] and is effective in the prevention of muscle–tendon injuries, such as muscle strain.[6] There is a high occurrence of muscle strain in the rectus femoris muscle, hamstrings and gastrocnemius muscle, which are the major extensor muscles of the lower extremities.[7 8] Previous studies have also examined the effective duration of SS on these muscles,[9–11] and reported that the effective methods of SS to increase flexibility differ depending on the targeted muscles, but there is no study comparing the effects of SS between the muscles.

What are the new findings?

- This is the first study to compare the effects of static stretching between the quadriceps, hamstrings and triceps surae.
- Range of motion increased without significant difference between the muscles.
- Vertical jump height decreased after static stretching of the triceps surae.

Some previous studies reported that SS before sports activity should be avoided because jump performance decreased immediately after SS.[12] Jumping is a movement that involves the lower limb extensor muscles in a co-ordinated manner.[11] Some studies found that jump performance was decreased immediately after SS for the main lower extremity extensor muscles (quadriceps, hamstrings and triceps surae).[13 14] However, it is not clear whether SS for single muscles influences jump performance. Guissard and Reiles[15] reported that squat jump height was not changed after 6 min of SS of the quadriceps. On the other hand, Cornwell *et al*[16] reported that squat jump height was decreased after 6 min of SS of the triceps surae. Therefore, it is possible that there is a muscle, or more than one, that has a decisive influence on the decrement in jumping performance after SS.

The purpose of the present study was to compare the effects of SS on ROM and vertical jump height between the quadriceps, hamstrings and triceps surae in collegiate basketball players.

METHODS

Subjects

Fourteen collegiate basketball players (14 men, 20.2±0.7 years, 179.0±5.0 cm, 71.9±8.3 kg) were recruited for this study because they have a higher level of proficiency

BMJ Open Sport Exerc Med: first published as 10.1136/bmjsem-2019-000631 on 22 December 2019. Downloaded from http://bmjopensem.bmj.com/ on April 16, 2024 by guest. Protected by copyright.

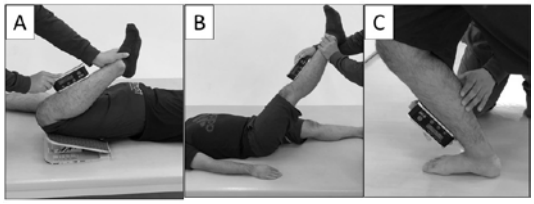

Figure 1 Range of motion (ROM) measurement. A: Measurement of ROM for the quadriceps was performed in a prone position with the hip joint of the dominant leg extended at 15 degrees by using a wedge-shaped device. The knee of the dominant leg was passively flexed from 0 degrees to a maximally tolerable angle without pain. B: Measurement of ROM for the hamstrings was performed in a supine position. The hip joint of the dominant leg was passively flexed from 0 degrees to a maximally tolerable angle without pain with the knee in full extension. C: Measurement of ROM for the triceps surae was performed by using a weight-bearing lunge method.[17] The participant leaned forward until a maximum stretch was felt in the posterior dominant leg while keeping the knee fully extended and the heel in contact with the ground.

of jumping than athletes of other sports. Subjects with a history of lower-limb injuries within 1 year were excluded. All subjects were informed of the requirements and risks associated with their involvement in this study.

Experimental approach to the problem

The study was conducted on three separate days with all participants undergoing one of three different conditions each day, and the participants received the three different SS in random order. The targeted muscles of the SS were the quadriceps, hamstrings and triceps surae. Before and after each session of SS, ROM and vertical jump height were measured. All experiments were completed in the same room, in which the temperature was maintained at 25°C.

Measurement of ROM

ROM was measured by using the dominant leg. The dominant leg was determined by asking which leg they use to kick a ball as fast as possible.[16] ROM was defined as one at which the participants were able to have a maximally tolerable angle without pain. A digital inclinometer (DL164V; Survey Techno-Science, Japan) was used to measure ROM. The digital inclinometer was placed at the mid-point of the anterior tibial border, between the tibial tuberosity and the anterior joint line of the ankle.[17] The methods of measuring ROM are shown in figure 1.

Measurement of vertical jump height

After measurement of ROM, the participants performed three submaximal vertical jump trials as warm-ups. After the submaximal trials, the participants performed three maximal effort vertical jump trials, with a 30 s rest interval between each trial. The greatest value of the three maximum trials was used for the analyses.

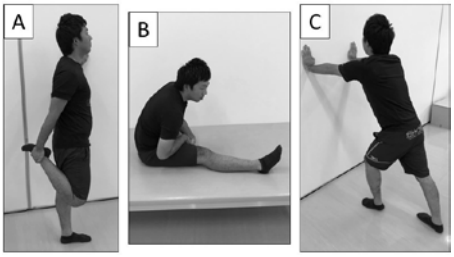

Figure 2 Posture of each stretch. A: Stretching of the quadriceps. The participants then flexed their knee joint to the maximal angle without pain. If the knee joint was flexed maximally and the stretching was insufficient, the hip joint was extended. B: Stretching of hamstrings. The participants reached forward to the toes of the extended leg. C: Stretching of triceps surae. The participants leaned while bending the front leg at the maximal angle without pain and keeping the other leg fully extended behind the body. The heel of the back leg remained in contact with the floor at all times.

Static stretching

All SS was performed in 1 set of 5 min on each of the dominant and non-dominant legs, in random order, because the minimum time for an increase in flexibility differs between the muscles (hamstrings need 3 min, triceps surae needs 2 min, quadriceps is unknown) and 5 min of SS may increase the flexibility of the three muscles. The participants were instructed to be relaxed during SS. The posture of each stretch is shown in figure 2.

Statistical analyses

All data were described as mean±SD. Before using parametric tests, the assumption of normality was verified using the Kolmogorov-Smirnov test. A paired t-test was used to compare the difference of ROM and vertical jump height between before and after values for each muscle. A one-way analysis of variance was used to examine the difference of relative change in ROM and vertical jump height between muscles. When a significant difference was found, post hoc analyses using Tukey's test was performed. SPSS statistics V.25 was used for all statistical analyses. Differences were considered statistically significant at an alpha level of $p<0.05$.

RESULTS

Range of motion

ROM was increased in all muscles (all $p<0.05$) (table 1). There was no significant difference in the relative change in ROM ($p<0.05$) (table 1).

Vertical jump height

In the quadriceps ($p=0.35$) and hamstrings ($p=0.22$), the vertical jump height indicated no change, while it decreased in the triceps surae ($p<0.01$) (table 2). There was a significant difference in the relative change of the vertical jump height ($p<0.05$, partial $\eta^2=0.28$), and post hoc analyses indicated that the change in the triceps

BMJ Open Sport Exerc Med: first published as 10.1136/bmjsem-2019-000631 on 22 December 2019. Downloaded from http://bmjopensem.bmj.com/ on April 16, 2024 by guest. Protected by copyright.

Table 1 Changes in ROM

	Pre (degree)	Post (degree)	Relative change (%)
Quadriceps	128.0±9.1	130.2±8.0*	101.8±1.7
Hamstrings	57.5±9.0	62.5±10.3*	108.9±9.1
Triceps surae	44.2±6.1	46.6±6.4*	105.7±9.0

Values were described as mean±SD.
*P<0.05 vs pre value in the same muscle.

surae was a lower value than those of other muscles (p<0.05) (table 2).

In the present study, the sample size was not evaluated in advance. Therefore, we calculated the actual power from the effect size of the relative change of vertical jump height using G*power[18] at a setting of α=0.05 and a sample size of 14. The results indicated that the statistical power was sufficient (0.98).

DISCUSSION

Changes in ROM

The present study showed that ROM increased without any difference between the muscles, while vertical jump height significantly decreased after SS of only the triceps surae. The effective duration of SS required to decrease passive properties differs between each muscle.[9–11] Nakamura *et al* reported that SS for more than 2 min is effective in increasing the extensibility of the gastrocnemius muscle.[10] Matsuo *et al*[9] and Nakamura *et al*[11] reported that more than 3 min of SS is effective on decrement in passive stiffness of the hamstrings. To our best knowledge, the effective duration of SS for the quadriceps is unclear. Therefore, the present study used SS for 5 min because it may increase muscle extensibility in these three muscles. Kataura *et al*[19] reported that the intensity of SS is related to the relative change in muscle–tendon unit stiffness, which indicated that the intensity of SS has an impact on its effects. Because the three muscles targeted in the present study have different characteristics in volume, cross-sectional area and shape, it is very difficult to perform SS at the same intensity. Therefore, in this study, the intensity of SS was decided as the maximum angle at which the participants felt no pain. In this study, ROM of the three muscles was increased after 5 min of SS without significant difference in relative changes in ROM between the muscles. These data indicated that SS for 5 min at the maximum angle increased ROM, regardless of the muscle.

Table 2 Changes in vertical jump height

	Pre (cm)	Post (cm)	Relative change (%)
Quadriceps	68.2±8.4	67.8±9.2	99.2±2.5
Hamstrings	66.0±7.8	65.4±7.2	99.3±2.4
Triceps surae	66.5±6.3	64.3±6.6*	96.7±3.1†

Values were described as mean±SD.
*P<0.05 vs pre value in the same muscle.
†P<0.05 vs relative change in other muscles.

Changes in vertical jump height

In this study, 5 min of SS of the triceps surae decreased vertical jump height by 3.3%, while it showed no change in the quadriceps and hamstrings. Behm and Chaouachi[12] reported that a decrement in jump performance after SS was affected by the duration of SS, and SS for more than 90 s decreases jump performance by 3.3%. These results indicated that the results of the present study are consistent with the previous study. There are limited studies that have examined the effects of SS for single muscles on the alteration of jump performance. Guissard and Reiles[15] showed vertical jump height indicated no change after SS of the quadriceps for 6 min. On the other hand, Cornwell *et al*[16] and Fletcher and Jones[20] reported that vertical jump height was decreased after SS of the triceps surae for 6 and 1.5 min, respectively. To our best knowledge, there is no study that has examined the effects of SS of the hamstrings on jump performance. However, Lim and Park[21] reported that a foam roller exercise on the hamstrings increased ROM, but vertical jump performance showed no change. The elasticity of the Achilles tendon plays an important role in jump performance.[22] A previous study showed that tendon stiffness decreased after 5 min of SS for the triceps surae.[23] These findings suggested that it is possible that SS for the triceps surae decreased vertical jump height because of decrement in Achilles tendon stiffness.

Jump height is very important for basketball players, but they need various types of performance, such as sprinting and agility. The muscles required for each movement are different. Therefore, it is necessary to show the effects of SS on various types of performance.

CONCLUSION

The ROM of the quadriceps, hamstrings and triceps surae were significantly increased without any difference of relative change in the range. Vertical jump height was significantly decreased after SS of only the triceps surae.

Contributors KT designed the study. FT helped with the implementation.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval The study was performed in accordance with the Declaration of Helsinki and was approved by the ethical committee of Biwako Seikei Sport College (No. 133).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is

BMJ Open Sport Exerc Med: first published as 10.1136/bmjsem-2019-000631 on 22 December 2019. Downloaded from http://bmjopensem.bmj.com/ on April 16, 2024 by guest. Protected by copyright.

properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iD
Kosuke Takeuchi http://orcid.org/0000-0002-7433-4148

REFERENCES

1 Takeuchi K, Nakamura M, Kakihana H, *et al*. A survey of static and dynamic stretching protocol. *Int J Sport Heal Sci* 2019;17:72–9.
2 Hubbard TJ, Carpenter EM, Cordova ML. Contributing factors to medial tibial stress syndrome: a prospective investigation. *Med Sci Sports Exerc* 2009;41:490–6.
3 Kaufman KR, Brodine SK, Shaffer RA, *et al*. The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med* 1999;27:585–93.
4 Mahieu NN, Witvrouw E, Stevens V, *et al*. Intrinsic risk factors for the development of Achilles tendon overuse injury. *Am J Sports Med* 2006;34:226–35.
5 Nakamura M, Ikezoe T, Takeno Y, *et al*. Effects of a 4-week static stretch training program on passive stiffness of human gastrocnemius muscle–tendon unit in vivo. *Eur J Appl Physiol* 2012;112:2749–55.
6 Hadala M, Barrios C. Different strategies for sports injury prevention in an America's Cup yachting crew. *Med Sci Sports Exerc* 2009;41:1587–96.
7 Abrams GD, Renstrom PA, Safran MR. Epidemiology of musculoskeletal injury in the tennis player. *Br J Sports Med* 2012;46:492–8.
8 Nhan DT, Klyce W, Lee RJ. Epidemiological patterns of alternative racquet-sport injuries in the United States, 1997–2016. *Orthop J Sport Med* 2018;6.
9 Matsuo S, Suzuki S, Iwata M, *et al*. Acute effects of different stretching durations on passive torque, mobility, and isometric muscle force. *J Strength Cond Res* 2013;27:3367–76.
10 Nakamura M, Ikezoe T, Takeno Y, *et al*. Time course of changes in passive properties of the gastrocnemius muscle–tendon unit during 5 min of static stretching. *Man Ther* 2013;18:211–5.
11 Nakamura M, Ikezoe T, Nishishita S, *et al*. Static stretching duration needed to decrease passive stiffness of hamstring muscle–tendon unit. *J Phys Fit Sport Med* 2019;8:113–6.
12 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.
13 Haddad M, Dridi A, Chtara M, *et al*. Static stretching can impair explosive performance for at least 24 hours. *J Strength Cond Res* 2014;28:140–6.
14 Robbins JW, Scheuermann BW. Varying amounts of acute static stretching and its effect on vertical jump performance. *J Strength Cond Res* 2008;22:781–6.
15 Guissard N, Reiles F. Effects of static stretching and contract relax methods on the force production and jump performance. *Comput Methods Biomech Biomed Engin* 2005;8:127–8.
16 Cornwell A, Nelson AG, Gary Heise BS. Acute effects of passive muscle stretching on vertical jump performance. *J Hum Mov Stud* 2001;40:307–24.
17 Munteanu SE, Strawhorn AB, Landorf KB, *et al*. A weightbearing technique for the measurement of ankle joint dorsiflexion with the knee extended is reliable. *J Sci Med Sport* 2009;12:54–9.
18 Faul F, Erdfelder E, Lang A-G, *et al*. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods* 2007;39:175–91.
19 Kataura S, Suzuki S, Matsuo S, *et al*. Acute effects of the different intensity of static stretching on flexibility and isometric muscle force. *J Strength Cond Res* 2017;31:3403–10.
20 Fletcher IM, Jones B. The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *J Strength Cond Res* 2004;18:885–8.
21 Lim J-H, Park C-B. The immediate effects of foam roller with vibration on hamstring flexibility and jump performance in healthy adults. *J Exerc Rehabil* 2019;15:50–4.
22 Kubo K, Morimoto M, Komuro T, *et al*. Influences of tendon stiffness, joint stiffness, and electromyographic activity on jump performances using single joint. *Eur J Appl Physiol* 2007;99:235–43.
23 Kubo K, Kanehisa H, Fukunaga T. Effects of transient muscle contractions and stretching on the tendon structures in vivo. *Acta Physiol Scand* 2002;175:157–64.

BMJ Open Sport Exerc Med: first published as 10.1136/bmjsem-2019-000631 on 22 December 2019. Downloaded from http://bmjopensem.bmj.com/ on April 16, 2024 by guest. Protected by copyright.