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Does Static Stretching Compromise Jump Performance in Diurnal Variation?

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Abstract: The purpose of the study was to investigate the effect of static stretching on squat jump (SJ) and countermovement jump (CMJ) in diurnal variation. Fifty-three male collegiate athletes (age=21.9±2.6 years; height=179.7±8.1cm; body-mass=75.3±8.6kg; mean±SD) completed the SJ and CMJ tests either after static stretching or no stretching protocols at two times of the day (07:00h and 17:00h) in random order on non-consecutive days. After warming-up for 5 minutes with low-intensity jogging, participants walked for 2 minutes before performing one of the two stretching protocols (static stretching or no stretching) then 4-5 minutes of additional rest was given before SJ and CMJ performances were measured. Jump heights were analyzed using the two-way ANOVA with repeated measures (2[stretching]×2[time-of-day]). No stretching protocol caused better jump heights in both SJ and CMJ ($p < .01$). SJ heights were higher at 17:00 compared to 07:00 in both static stretching (8.8%) and no stretching (9.1%) protocols ($p < .01$). Similarly, CMJ heights were higher at 17:00 compared to 07:00 in both static stretching (10.6%) and no stretching (5.8%) protocols ($p < .01$). Static stretching adversely influenced jump heights both in the morning and evening. However, it caused less negative effect in the evening.

Keywords: Circadian Variation, Warm-up, Muscle Power, Jump Height

1. Introduction

Warm-up routines are important in sports. Warm-ups are usually performed to stimulate physiological responses such as increasing blood flow to active muscles, metabolic reactions, nerve conduction velocity, enzymatic activity, body temperature, and power output (Erkut, Gelen, & Sunar, 2017; Hoffman, 2014; Jeffreys, 2007). The role of stretching is important for warm-up. Even if there are various types of stretching method, they are mainly categorized as static and dynamic stretching (Sue Falsone, 2014). Previous studies indicate that dynamic stretching should be preferred due to the fact that it does not compromise acute performance pre-activity (Amiri-Khorasani, Abu Osman, & Yusof, 2011; Behm & Chaouachi, 2011; Hough, Ross, & Howatson, 2009; Opplert & Babault, 2018; Richman, Tyo, & Nicks, 2019). On the other hand, static stretching is preferable to increase range of motion and prevent from injuries (Herbert & Gabriel, 2002; Jeffreys, 2007; Samson, Button, Chaouachi, & Behm, 2012). Studies have indicated that static stretching compromises jumping performance (Jeffreys, 2007; Samuel, M. N., Holcomb, W. R., Guadagnoli, M. A., Rubley, M. D., & Wallmann, 2008;

Unick, Kieffer, Cheesman, & Feeney, 2005). However, static stretching is commonly used in training sessions and programs and there are also a few studies indicating that static stretching has no adverse effect on acute performance (Bazett-Jones, Gibson, & Mcbride, 2008; De Oliveira & Rama, 2016; Unick et al., 2005). This uncertainty still demands to have a better understanding of stretching methods.

Diurnal rhythm is a cycle of 24 hours and diurnal variation indicates fluctuation in daytime (Greg Atkinson & Reilly, 1996). Many college players' training programs are scheduled at early hours of the day (Hatfield, Nicoll, & Kraemer, 2016). There are many different abilities that athletes need to improve and practice in their training programs. It's important to know what's the best time for each specific ability to be performed during the day.

A study investigated the effect of static and dynamic stretching on squat jump and countermovement jump at two different times of the day (morning 07:00, evening 17:00 h) and concluded that dynamic stretching induced better results. However, static stretching performance differed from morning to evening and reached better result in the evening (Chtourou, H., Aloui, A., Hammouda, O., Chaouachi, A., Chamari, K., & Souissi, 2013). Another study was not specified the type of the stretching routine showed that there was no significant difference in squat jump and 40m sprint performance during morning and afternoon measurements (09:00-15:00 h). However, generally other studies' findings showed anaerobic power outputs were higher in the evening (G Atkinson, Coldwells, Reilly, & Waterhouse, 1994; Greg Atkinson & Reilly, 1996; Hill & Smith, 1991; Reilly & Down, 1992; Souissi, N., Gauthier, A., Sesboüé, B., Larue, J., & Davenne, 2004). So, there is a lack of information whether the most important thing is the time of the day or type of stretching method for performance.

Since the static stretching has not been left by the practitioners and there are few and limited studies investigating the effect of static stretching on jumping performance **in** diurnal variation, the current study was born. The purpose of the current study was to investigate the static stretching's effects on squat jump and countermovement jump performances in the morning and evening. It was hypothesized that static stretching in the morning has more adverse effects on jump performance compared to the evening.

2. Materials and Methods

Subjects — Fifty-three healthy male collegiate athletes (basketball=20, volleyball=19 and soccer=14) voluntarily participated in the study (age= 21,94 ± 2,6 years, height= 179,70 ± 8,1cm, body-mass= 75,38 ± 9,1kg). Participants had a minimum of five years of training experience and were active athletes who participate in their sports a minimum of four days a week, every session lasting an average of two hours. All measurements were taken during a competition season. Athletes who were injured or had suffered from an injury in the last six months did not participate in the study. The Declaration of Helsinki was followed in every step of the research and ethical committee approval was taken from Sakarya University of Applied Sciences.

Experimental Design — The study was designed in random order and crossover aiming to investigate the acute effect of static stretching on squat jump (SJ) and countermovement jump (CMJ) performance at different times of the day. The study consisted of one experimental group who performed static stretching (experimental group) and no stretching (control group) in a random order on non-consecutive days in both the morning (07:00 h) and evening (17:00 h). After every protocol was performed, they were assessed with the countermovement and squat jump test.

Two days before starting the data collection, participating athletes were informed about the study's tests and followed a familiarization session (they were quite experienced in static stretching, SJ and CMJ). All implementations and tests were instructed by the same trainer. Participants were split into groups and each group had a maximum of ten participants. After completion of the experimental procedure, participants passively rested (sitting) for approximately 4-5 minutes then their SJ and CMJ performances were measured (Figure 1.). Every protocol was randomly performed on non-consecutive days. All activities started with jogging to increase body temperature. However, body temperature was not measured. Athletes' running intensity was 40-60% of their maximal heart rate for 5 minutes running in the gym and it was monitored with a heart rate monitoring device (H10 sensor, Polar Electro Inc., Finland). They walked for 2 minutes after jogging (active rest).

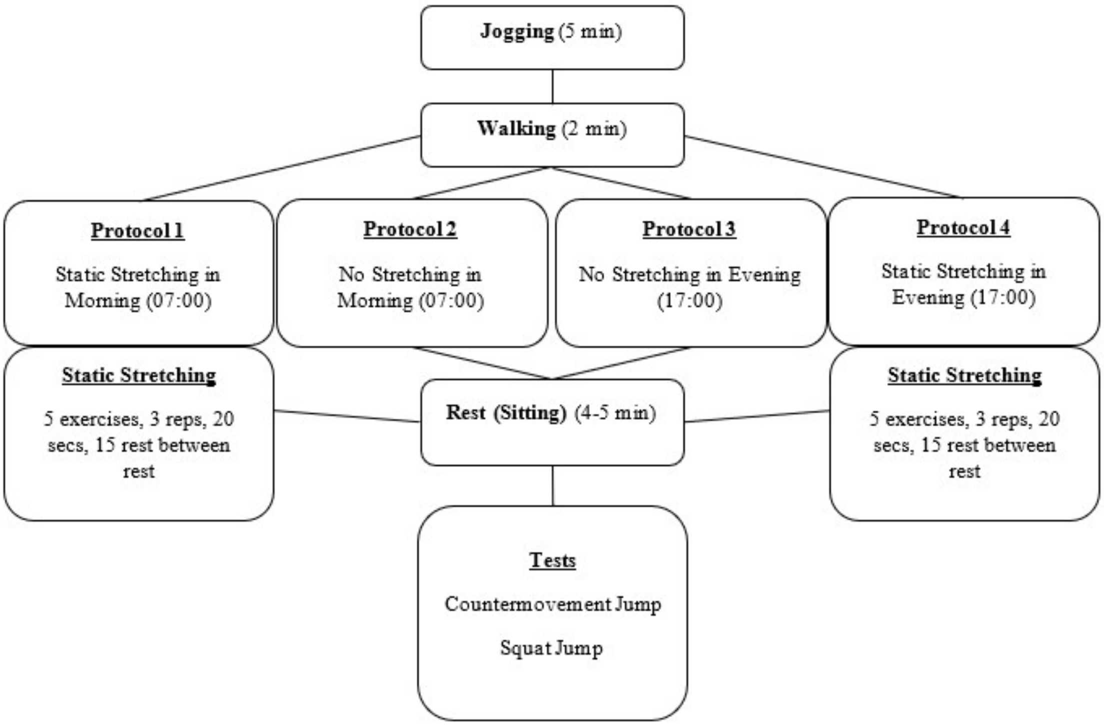


Figure 1. Summary of Experimental Procedure

Static stretching protocol — Participants stretched the muscle to the point of feeling mild discomfort (pain threshold) and performed 3 repetitions for 20 seconds and rested 15 seconds between repetitions. Static stretching implemented to certain muscle groups (1) (calves #21, quadriceps #91, adductors #64, hamstrings #46, and hip rotators #118) and it is outlined in (Table 1).

Measurement of jump performance — SJ and CMJ tests were used to determine jumping performance. The participants were asked to jump as high as possible on a 90x90 cm2 flat and solid surface and kept their hands on their waist with flexed knees up to 90◦ (knee flexion) during trials. In SJ, after reaching 90◦ knee flexion, they maintained their static positions for 2 seconds then jumped (full extension of the lower body). Participants followed the same jumping procedure with the SJ for CMJ. However, instead of maintaining the 90◦ knee flexion with a static position for 2 seconds, they immediately jumped. Participants performed 3 trials for each test and the best value was selected for analysis. After video captured in slow-motion (240 frames per second) with a smartphone (Apple Inc., iPhone 8) My Jump 2 app was used to analyze jumping height (Balsalobre-Fernández, Glaister, & Lockey, 2015; Turgut, Çoban, & Gelen, 2018). For each participant's take-off and contact frames were manually marked using the application to determine flight time.

Table 1. Static stretching exercises.

Calf stretch (#21). The participant stands two steps away from the wall. One leg is flexed (flexion) in the front, the other leg is extended (extension) in the back. Both two hands are on the wall for balance. During stretching, the foot should remain on the floor (rear foot maintains dorsiflexion). Then switches to the other side.
Quadriceps stretch (#91). The participant stands in front of the wall. One hand is on the wall for balance. One leg is flexed (flexion) and pulled through the hip with the other hand. Then switches to the other side.
Adductor stretch (#64). The participant stands straight on the floor. Knees are flexed (flexion), foot soles touch each other, and spine maintains neutral position (not bending). Knees are put apart with elbows.
Hamstring stretch (#46). The participant sits parallel to the floor. Both two knees are extended (extension). Hands are brought to toes (forward move) while maintaining the extension of the legs.
Hip rotator stretch (#118). The participant is on supine position. Knees are flexed (flexion). Left knee is hooked over to the right leg and pulled through floor (through right shoulder). Then switches to the other side.

Statistical analysis — All statistical data was analyzed with SPSS 20 program for Windows (SPSS, Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to determine the normality of the data. Means and standard deviations were calculated using standard statistical methods. Both two protocols were compared with repeated measures ANOVA test. Jump performance analyzed using the two-way ANOVA with repeated measures (2 [stretching]×2 [time-of-day]). When protocol × time interactions reached a statistical significance, post hoc paired t-tests were used to determine which protocol caused differences between protocols. The effect size was determined by converting the partial eta square to Cohen's d. Cohen (Cohen, 1969) classified effect sizes as small (0.00 - 0.49), medium (0.50 - 0.79), and large (d < 0.80). Intra-class correlation coefficient (ICC) and standard error measurement values (SEM) was used to measure reliability between trials. In all analyses, statistical significance value was accepted as p≤ .05.

3. Results

The findings of the jump performances after static stretching and no stretching protocols at different times of the day (7:00 and 17:00 h) is shown in figure 2 and figure 3.

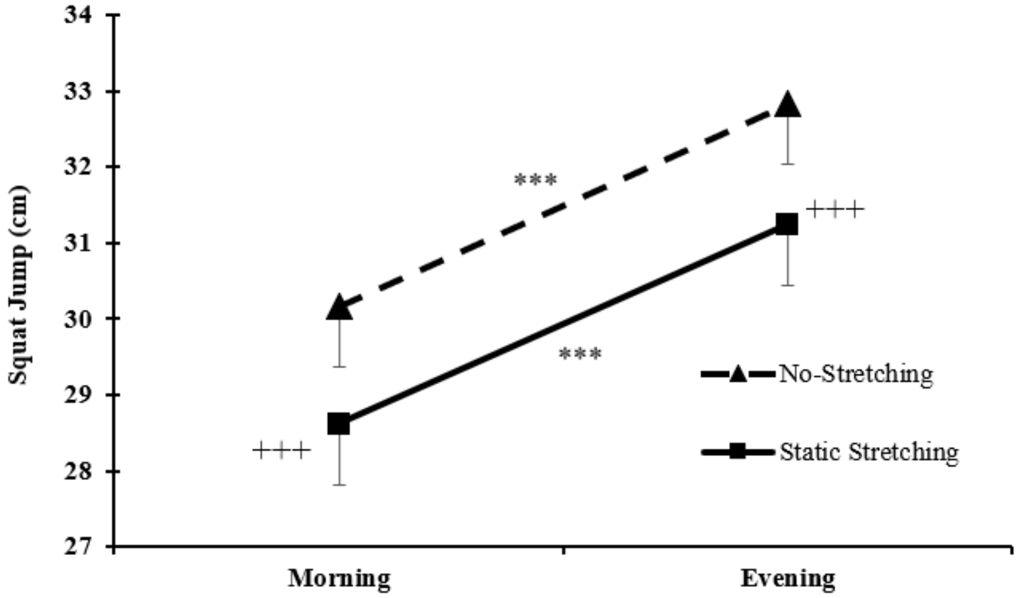
Squat Jump

Analyzed data showed high reliability (ICC higher than 0.95 and SEM <2.3 cm) for squat jump. There was a significant difference between no stretching and static stretching, ($F = 27.5$, $p < .01$, ES = 0.54) and times of the day ($F = 94.6$, $p < .01$, ES = 0.64). Similarly, there was a significant difference between no stretching and static stretching × times of the day ($F = 11.0$, $p < .05$, ES = 0.90). No stretching protocol's squat jump performance was higher at 17:00 (8.8%) than at 07:00 h ($p <0.01$). Static stretching protocol's the squat jump performance was higher at 17:00 (9.1%) compared to 07:00 h ($p <0.01$).

Countermovement Jump — Analyzed data showed high reliability (ICC higher than 0.96 and SEM <2.5 cm) for countermovement jump. There was a significant difference between no stretching and static stretching ($F = 15.3$, $p < .001$, ES = 0.52) and times of the day ($F = 108.6$, $p < .001$, ES = 0.67). Similarly, there was a significant difference between no stretching and static stretching × times of the day ($F = 13.5$, $p < .05$, ES = 0.20). No stretching protocol's countermovement jump performance was higher at 17:00

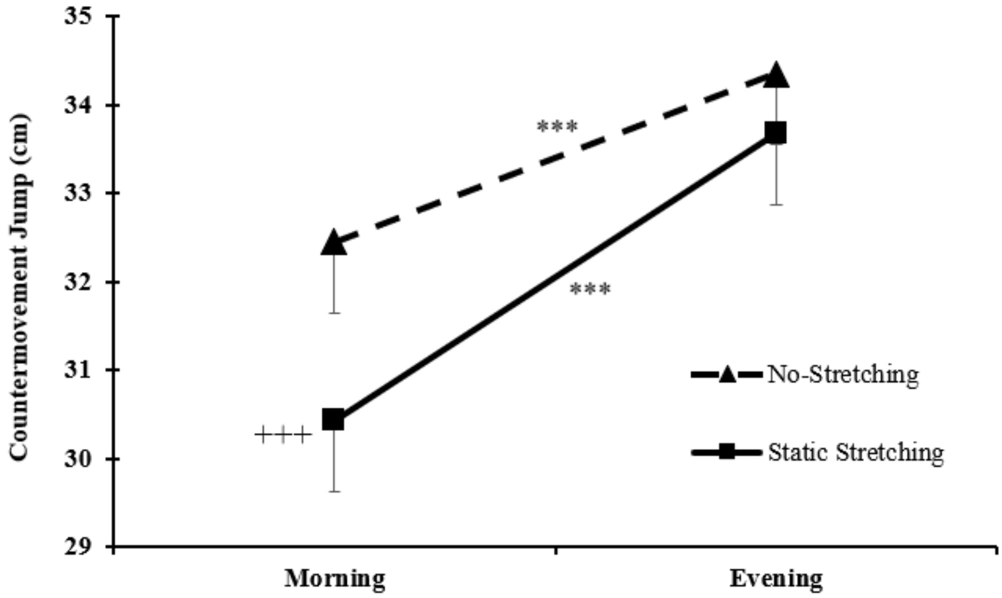
(5.8%) than at 07:00 h ($p < .01$). Static stretching protocol's countermovement jump performance was higher at 17:00 (10.6%) compared to 07:00 h ($p < .01$). Additionally, the difference between static stretching and no stretching percentage diminished to 2.1% (evening) from 6.6% (morning).

Figure 2. Mean ± SD for squat jump heights at 07:00 h and 17:00 h after the no-stretching and static stretching protocols.



*** indicates a significant difference at 07:00 h and 17:00 h, $p<0.001$. +++ indicates a significant difference in comparison with no-stretching, $p<0.001$.

Figure 3. Mean ± SD for countermovement jump heights at 07:00 h and 17:00 h after the no-stretching and static stretching protocols.



*** indicates a significant difference at 07:00 h and 17:00 h, $p<0.001$. +++ indicates a significant difference in comparison with no-stretching, $p<0.001$.

4. Discussion

The current study aimed to investigate the effect of static stretching and no stretching protocols on SJ and CMJ in the morning and evening. According to the findings of the current study static stretching adversely influenced jump heights during both morning and evening sessions compared to no stretching protocol. However, it has a less negative effect in the evening on jump performance compared to the morning.

There are few studies may be comparable with ours in the literature. Identical to our findings, in a study (Chtourou, H., Aloui, A., Hammouda, O., Chaouachi, A., Chamari, K., & Souissi, 2013), it was reported that static stretching induced lower jump heights in both morning and evening sessions when compared to dynamic stretching and control protocols in soccer players. Maaouia et al. (Ben Maaouia, Nassib, Negra, Chammari, & Souissi, 2020) found that dynamic stretching induced better results than static stretching and no-stretching group both morning (07:00-08:30 h) and evening (17:00-18:30 h) sessions on agility performance in young soccer players. Another study that did not specifically indicate measurement time of the day found the static stretching group reached lower CMJ heights than dynamic stretching group in collegiate athletes (Holt & Lambourne, 2008). Physiologically, performance reducing effects of static stretching could be induced by nervous system activation, decrement of muscle-tendon stiffness, or a combination of some muscle and neural related factors (Behm, Button, & Butt, 2001; Fowles, Sale, & Macdougall, 2000; Hedrick, 2000). On the other hand, a study showed that static stretching may not be harmful to dynamic activities such as jumping if the fast-stretch shortening cycle is activated via activities such as drop jump (Behm & Chaouachi, 2011) which is not included in our study. However, it influences the length-tension relationship of muscle and may be harmful to activities requiring the use of slow-stretch shortening cycle (Behm & Chaouachi, 2011). In our study, we did not observe any activity related decline. Instead, all decline was related to hours of the day.

The participants reached higher jump heights in the evening than the morning. Pavlovic et al., (Pavlović et al., 2018) in support of our findings showed that jump heights followed by static stretching in warm-up were higher at the evening (18:00-19:30 h) compared to morning (08:00-09:30 h) in handball players. In another study used static stretching in warm-up showed that swimmers performed better in CMJ, 25m swimming time, maximal strength, and free weighted bench press in the evening (18:00 h) than morning (10:00 h) (Pallarés et al., 2014). During evening nerve conduction velocity, enzymatic activity, and elasticity of muscles enhance, and muscle viscosity decreases due to increase in body temperature (Behm & Chaouachi, 2011; Bernard, Giacomoni, Gavarry, Seymat, & Falgairette, 1998). This may be a potential explanation for differences in performance between evening and morning. Another factor also may be the temperature of the environment. However, we did not report it. Due to this fact, it could be considered as one of the limitations of our study. Some studies showed that acute maximal short-term performance may enhance in hot and humid environments in the morning (S. Racinais, 2010; S. Racinais, Hue, Hertogh, Damiani, & Blonc, 2004). However, morning may not be a proper time for the reaching desired central nervous system activation and muscle tonus, and this may explain decrements in flexibility and other abilities (Alter, 2004; Souissi, N., Gauthier, A., Sesboüé, B., Larue, J., & Davenne, 2004). Additionally, studies showed that during evening muscle activation is higher than that of morning (Callard, Davenne, Gauthier, Lagarde, & Van Hoecke, 2000; Gauthier, Davenne, Martin, Cometti, & Van Hoecke, 1996). Exposure to heat and differences in body temperature during the day may cause the passive warm-up effect (S. Racinais et al., 2004; Sebastien Racinais, Blonc, & Hue, 2005). This may explain why performance enhances through the evening. However, constant following of the body temperature throughout day may be too difficult to follow in the experimental process. Since this could be another limitation of our study.

4. Practical Applications.

The current study showed that acute static stretching negatively influences performance both in the morning and evening. Static stretching is not recommended in warm-up. However, sometimes athlete's training programs may require improving both their range of motion and jump performance at the same time. In these cases, if static stretching is preferred, it should be implemented before evening training session. If there is no aim to improve range of motion in training program it is recommended to implement dynamic stretching based on the literature knowledge (Amiri-Khorasani et al., 2011; Behm & Chaouachi, 2011; Hough et al., 2009; Jaggers, Swank, Frost, & Lee, 2008; Opplert & Babault, 2018) or our findings of no stretching methods in warm-up.

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Conflicts of Interest: The authors declare no conflict of interest.

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