

Acute effects of static and dynamic stretching on vertical jump and sprint performance in adolescent basketball players

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Published online: May 31, 2025

Accepted for publication: May 15, 2025

DOI:10.7752/jpes.2025.05114

Abstract

Problem statement: Despite the well-established benefits of stretching during warm-ups for reducing injury risk and optimizing athletic performance, the ideal velocity for dynamic stretching remains a topic of debate. **Approach:** Most warm-up protocols followed by athletes incorporate dynamic stretching or a combination of static and dynamic stretching, with limited or no focus on the velocity of stretching exercises. **Purpose:** The aim of study was to examine the acute effects of static and dynamic stretching, as well as the impact of different stretching velocities on vertical jump and sprint performance in adolescent basketball players. **Methods:** Fifteen male basketball players (mean age: 13.4±0.5 years, mean training experience: 4.4±2.5 years) participated in a 10-min warm-up followed by three stretching protocols (3 x 10 s per muscle) in a randomized order. The protocols included static stretching (SS), slow dynamic stretching (DS) at 50 bpm and fast dynamic stretching (DF) at 100 bpm. Each protocol was performed in three different days, a week apart. Countermovement jumps with arm swing (CMJA) were performed 1-min after the intervention with 2-min rest between trials. Sprint test (0-10m, 0-20m) was performed twice 5-min after the CMJA test with 2-min rest between trials. One week prior to jump and sprint tests, all athletes were tested to ensure that they were in a similar physical condition. **Results:** Participants exhibited significantly greater CMJA after DS (+14.3%, p=.022) and DF (+14.1%, p=.023) compared to SS. Similarly, sprint performance 0-10m improved after DS (+6.25%, p=.047) and DF (+7.1%, p=.018) compared to SS. Sprint performance 0-20m also showed significant improvement following DS (+7.8%, p=.024) and DF (+9.8%, p=.004) compared to SS. No significant differences were observed between DS and DF in either vertical jump or sprint performance. However, DF led to a slightly greater performance improvement compared to DS in both sprints 0-10m (+1%) and 0-20m (+2.2%). **Conclusions:** The findings highlight the effectiveness of dynamic stretching exercises before activities that demand high levels of force production.

Keywords: stretching velocities, countermovement jump with arm swing, sprint, basketball.

Introduction

Basketball is a highly popular sport where anaerobic capacity plays a more important role in performance than aerobic capacity. According to many authors, strength, speed, and flexibility are the key attributes of basketball players. The literature identifies several stretching techniques that enhance flexibility, including static, dynamic, ballistic, and proprioceptive neuromuscular facilitation (PNF) stretching. While all these techniques are known to improve flexibility, their immediate effects on performance, as well as the impact of stretching intensity, remain under investigation.

Static stretching (SS) is commonly included in warm-ups to improve flexibility. However, over the past twenty years, several studies have demonstrated that SS can negatively affect strength (Alipasali et al., 2024; Cornwell et al., 2001; Young & Behm, 2003) and speed (Fletcher & Jones, 2004; Fletcher & Anness, 2007). Therefore, many researchers advise against using SS during warm-ups (Cornwell et al., 2001; Kyranoudis et al., 2018). Additionally, SS appears to impair muscle performance in activities such as sprinting (Galazoulas, 2017; Nelson et al., 2005; Winchester et al., 2008) and vertical jumping (Cornwell et al., 2001; Galazoulas, 2017; Young & Behm, 2003). On the other hand, dynamic stretching is designed to improve dynamic flexibility in targeted muscle groups by contracting opposing muscles (Yamaguchi & Ishii, 2005) and by mimicking the specific movements of each sport (Hedrick, 2002). Additionally, dynamic stretching during warm-up raises heart rate and core temperature (Yamaguchi & Ishii, 2005). Research also indicates that dynamic stretching improves running speed (Fletcher & Jones, 2004; Galazoulas, 2017) and vertical jump performance (Cornwell et al., 2001; Galazoulas, 2017; Wallmann et al., 2005).

According to current literature, few studies have examined the effects of dynamic stretching velocity on performance. In Fletcher's (2010) study, fast dynamic stretching (DF – 100 bpm) produced a greater improvement in countermovement jump (CMJ), squat jump (SJ), and drop jump (DJ) compared to slow dynamic

stretching (DS – 50 bpm). Mizuno's (2020) study found that moderate (86 bpm) and fast (170 bpm) dynamic stretching produced similar effects on ankle range of motion (ROM) and isometric strength, but DF led to muscle fatigue. It is unclear whether the velocity of dynamic stretching exercises affects jump and sprint performance. Therefore, the purpose of this study was to investigate the acute effects of SS, DS, and DF on vertical jump and sprint performance in adolescent basketball players.

Materials and Methods

Participants

Fifteen healthy basketball players with no musculoskeletal problems or injuries participated in the study. Their average training experience was 4.4 ± 2.5 years, with training sessions occurring three to five times per week during the season. All participants agreed to avoid heavy physical activity during the three-week study period. The research was performed on an Olympic-sized indoor basketball court (28×15 m). Before testing, the athletes were familiarized with the stretching and testing protocols. Participants' body weight, height, age, and training experience were recorded (Table 1). Both the athletes and their parents were informed about the study's purpose and significance and provided written consent. The study was performed in accordance with the regulations of the Research Ethics Committee at Aristotle University of Thessaloniki, Greece.

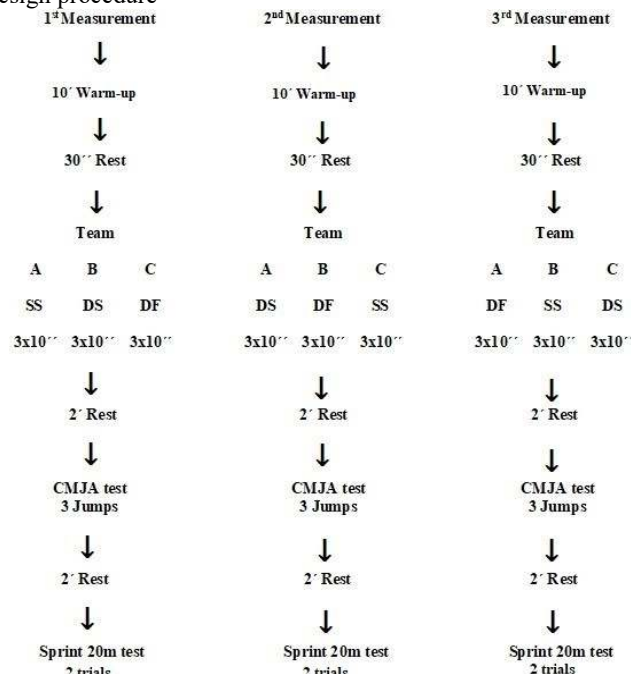
Table 1. Anthropometric characteristics (mean $\pm$ standard deviation)

ANTHROPOMETRIC CHARACTERISTICS	MEAN $\pm$ STANDARD DEVIATION
Age (years)	13.4 ± 0.5
Training age (years)	4.4 ± 2.5
Body weight (kg)	64.0 ± 13.5
Body height (cm)	169.7 ± 7.7

Experimental design

All athletes performed the three stretching protocols on three separate days, each spaced one week apart. The tests were performed by the same researcher, at the same time of day, and using identical testing equipment. Participants were instructed to avoid any physical activity for 24 h before testing to minimize the effects of muscle fatigue on the results. At the beginning, the athletes were randomly divided into three groups and completed a 10-min warm-up. This warm-up began with 5 min of jogging on the basketball court, followed by 5 min of sport-specific warm-up exercises with the ball, as is typical before a basketball game. After completing the warm-up, participants performed the assigned stretching protocols, followed by vertical jump and sprint tests. Specifically, during the first session, group A performed the SS protocol, group B performed DS, and group C performed DF. One week later, in the second session, group A performed DS, group B performed DF, and group C performed SS. In the third and final session, group A performed DF, group B performed SS, and group C performed DS. Immediately after each stretching protocol (within 1 min), the athletes completed three countermovement jumps with arm swing (CMJA), followed by two 20-m sprint attempts, with a 2-min rest between trials. For both jump and sprint tests, only the best performance from the trials was used in the final analysis (Table 2).

Table 2. Experimental design procedure



Procedure

One week before the measurements, participants received detailed instructions regarding the study procedures. Athletes' height and body mass were measured to the nearest 0.1 cm and 0.1 kg, respectively, using an electronic scale with an integrated stadiometer (Seca 220e, Hamburg, Germany). To maintain a consistent pace during the stretching exercises, a metronome was used (Wittner, Taktell Picolo, Germany). Vertical jump performance was assessed using a dynamic plate, while running speed was measured with photocells (Newtest Powertimer 300, Powertimer PC Upgrade Kit, FIN 90220 Oulu, Finland).

Static stretches were performed slowly for 10 s and repeated three times (3×10 s) in the maximum possible joint ROM without causing pain or discomfort (Behm et al., 2001). Dynamic stretches targeted the same muscle groups as the static stretches but involved muscle activation and rhythmic movements (Manoel et al., 2008). These dynamic stretches were performed either at a slow velocity of 50 bpm or a fast velocity of 100 bpm, using the full kinematic ROM. Each stretching exercise was repeated three times, with a 10-second rest between repetitions and a 30-second rest between different exercises.

The stretching exercises targeted the muscle groups involved in the vertical jump, as identified by Jagers et al. (2008), and were performed using the arm swing (AS) technique described by Lees et al. (2004). Specifically, the stretched muscle groups included the hamstrings, quadriceps, adductors, gluteals, soleus, hip flexors, and shoulder girdle muscles. All stretches were performed bilaterally.

During the CMJA test, athletes stood in front of the dynamometer and began their jump immediately after the examiner's audible command. They completed three CMJA repetitions with a 2-min rest between trials. Jump height (cm) was recorded by the device (Newtest Powertimer 300). Each athlete was encouraged to exert maximal effort, and the highest jump was selected for further analysis.

The 20-meter distance was chosen for the sprint test because it is widely used by researchers to represent the average sprint distance covered by athletes in field sports (Spencer et al., 2004). Athletes performed two attempts, with a 2-min rest between them. They started from a standing position 40 cm behind the starting line, where the first photocell was positioned according to the manufacturer's guidelines (Newtest Powertimer 300). Photocells were placed at 10 m and 20 m from the starting line to record running times for the 0–10 m and 0–20 m segments. The best times from the attempts were used for analysis.

Statistical analysis

Statistical analyses were performed using SPSS version 28.0 for Windows (SPSS Inc., Chicago, Illinois, USA). Before the main analysis, assumptions of normality and homogeneity of variances were tested to confirm the appropriateness of the model. Normality was assessed using the Shapiro–Wilk test, while homogeneity of variances was evaluated using Levene's test. The Levene's test results were not statistically significant for any parameter, indicating homogeneity of the sample distribution. Mean values and standard deviations were calculated.

A one-way analysis of variance (ANOVA) was performed to compare the means across the three groups. When a significant main effect was found, post hoc comparisons were performed using the Bonferroni correction. Results are presented as means $\pm$ standard deviations (SD), with statistical significance set at $p < .05$.

Results

The athletes' performance in CMJA and sprint (10 m and 20 m) was higher after DS and DF compared to SS (Table 3).

Table 3. Jump height (cm) and sprint time (s) of the athletes after the three stretching protocols (mean $\pm$ standard deviation)

	Mean $\pm$ Standard deviation		
	DS	DF	SS
CMJA (cm)	36.27 $\pm$ 4.41	36.23 $\pm$ 4.19	31.74 $\pm$ 4.58
Sprint 10 m (s)	2.10 $\pm$ 0.16	2.08 $\pm$ 0.14	2.24 $\pm$ 0.14
Sprint 20 m (s)	3.67 $\pm$ 0.34	3.59 $\pm$ 0.30	3.98 $\pm$ 0.27

The one-way ANOVA with Bonferroni adjustment revealed a significant effect of the stretching protocol on both CMJA and sprint test performance (0–10 m and 0–20 m).

Statistically significant differences were observed between the groups in all tests after the application of the three stretching protocols (Figures 1 and 2). Specifically, significant effects were observed in the CMJA [$F(2,42) = 5.26$, $p < .01$], the 10 m sprint [$F(2,42) = 4.94$, $p < .05$], and the 20 m sprint [$F(2,42) = 6.68$, $p < .01$].

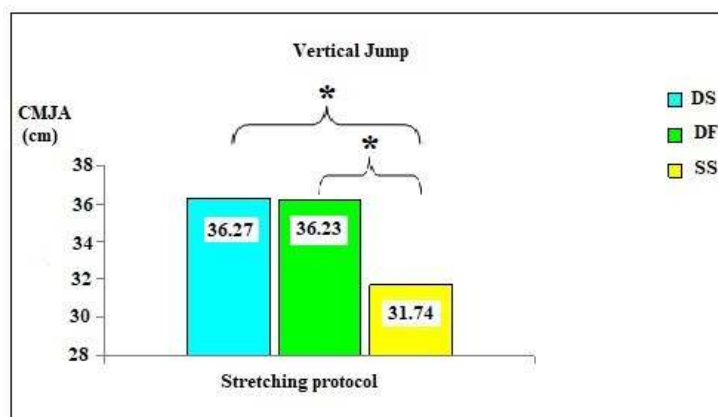


Figure 1. Athletes' performance in the vertical jump (CMJA) test after the application of the three stretching protocols (* $p < .05$)

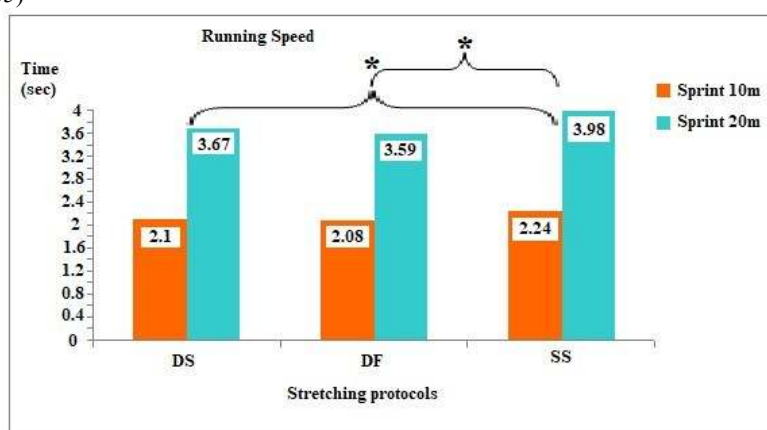


Figure 2. Athletes' performance in the 10 m and 20 m sprint tests after the three stretching protocols (* $p < .05$)

The post hoc analysis with Bonferroni adjustment identified statistically significant differences among the three stretching protocols. Specifically, athletes showed significantly reduced performance in the 10 m and 20 m sprint tests after warm-ups that included SS compared to dynamic stretching ($p < .05$). Similar results were observed in the CMJA test (Table 4). However, no significant differences were detected between DS and DF protocols in either vertical jump or sprint performance ($p = 1.000$).

Table 4. Differences between the three stretching protocols in sprint and CMJA performance (* $p < .05$)

Dependent variables	Stretching protocols		Differences	Significance
Sprint 10m	DS	DF	.01933	1.000 NS
		SS	-.13467	.047*
	DF	DS	-.01933	1.000 NS
		SS	-.15400	.018*
	SS	DS	.13467	.047*
		DF	.15400	.018*
Sprint 20m	DS	DF	.07533	1.000 NS
		SS	-.31333	.024*
	DF	DS	-.07533	1.000 NS
		SS	-.38867	.004*
	SS	DS	.31333	.024*
		DF	.38867	.004*
CMJA	DS	DF	.04000	1.000 NS
		SS	4.53333	.022*
	DF	DS	-.04000	1.000 NS
		SS	4.49333	.023*
	SS	DS	-4.53333	.022*

Dependent variables	Stretching protocols		Differences	Significance
Sprint 10m	DS	DF	.01933	1.000 NS
		SS	-.13467	.047*
	DF	DS	-.01933	1.000 NS
		SS	-.15400	.018*
	SS	DS	.13467	.047*
		DF	.15400	.018*
Sprint 20m	DS	DF	.07533	1.000 NS
		SS	-.31333	.024*
	DF	DS	-.07533	1.000 NS
		SS	-.38867	.004*
	SS	DS	.31333	.024*
		DF	.38867	.004*
		DF	-4.49333	.023*

Discussion

The main findings showed that dynamic stretching significantly improved vertical jump and sprint performance compared to SS. However, no significant performance differences were found between slow and fast dynamic stretching. Specifically, CMJA increased by 14.3% after DS and 14.1% after DF compared to SS. Similar improvements were observed in sprint performance: athletes improved their 10 m sprint times by 6.25% after DS and 7.1% after DF compared to SS. For the 20 m sprint, DS led to a 7.8% improvement, while DF resulted in a 9.8% improvement compared to SS. Additionally, DF produced slightly greater gains than DS in both the 10 m (~1%) and 20 m (~2.2%) sprints; however, these differences were not statistically significant.

The findings of this study align with those of most studies examining the effects of static and dynamic stretching on vertical jump and sprint performance. Galazoulas (2017) reported a significant decrease in CMJ height ($p < .001$) among basketball players after an SS protocol (2×10 s), whereas dynamic stretching led to a significant increase ($p < .01$). In the same study, 10 m sprint times significantly improved ($p < .01$) after dynamic stretching but showed no significant change ($p > .01$) after SS.

Except for the acute effects of stretching on performance, short-term effects appear to be similar. In a recent study, Alipasali et al. (2024) demonstrated that six weeks of dynamic stretching, performed three times per week, significantly improved the dynamic characteristics of the lower limbs in male volleyball players. In contrast, SS over the same period and frequency showed no improvement in dynamic characteristics (concentric force). Similarly, Kyranoudis et al. (2018) found that amateur soccer players experienced a significant decline in 20 m sprint performance after SS ($p < .05$), while a specific warm-up led to significant improvement ($p < .005$). Similarly, Morrin and Redding (2013) reported that in female dancers, both a lower limb dynamic stretching protocol and a combined static–dynamic stretching protocol led to improvements in balance and CMJ height (+9.7%). Turki et al. (2012), investigating the effects of dynamic stretching on 10 m and 20 m sprint performance in male athletes, found that 1–2 sets of 20 m dynamic stretches (14 repetitions) improved 20 m sprint performance by 2.7%. However, in the same study, no significant effect of the dynamic stretching protocol was observed on 10 m sprint performance, which contrasts with the findings of this study and those of Galazoulas (2017). The results of this study contrast with those of Fletcher (2010), who found that DF (100 bpm) led to greater improvements in CMJ, SJ, and DJ performance compared to DS (50 bpm). In this study, DF did not produce significant differences in vertical jump or running speed compared to DS. Fletcher (2010) reported a significant increase in CMJ height (+4.4%) after fast dynamic stretching relative to slow dynamic stretching ($p < .05$), as well as significant gains in SJ (+3.3%) and DJ (+6.6%) (both $p < .05$). The discrepancy between the two studies may be attributed to differences in jump technique. Fletcher's study measured CMJ without an AS, whereas this study included an AS in the CMJ. Additionally, Fletcher's participants were adults, while the current study involved adolescent basketball players.

Furthermore, Richter et al. (2012) noted that jumping performance was closely related to athletes' training experience. Elite athletes with extensive training backgrounds and frequent jumping in their routines demonstrated superior jumping performance compared to less experienced individuals. Although the participants in this study were adolescents, they possessed substantial training experience (4.4 ± 2.5 years) and engaged in three to five training sessions per week. The choice to use CMJA over CMJ was deliberate and multifaceted. While CMJ is generally regarded as a better measure of leg power, CMJA may provide a more sport-specific assessment of jumping performance (Richter et al., 2012). Additionally, Heishman et al. (2020) suggested that CMJA offers more reliable insights into long-term changes across training phases in sport-specific performance, whereas CMJ is more suited for evaluating lower extremity function and acute fluctuations in neuromuscular fatigue and readiness.

In the study by Hara et al. (2008), CMJA resulted in a higher jump height compared to CMJ without AS. Muscle activation in the hips and ankles appeared to be greater after CMJA than CMJ without AS. Additionally, during the push-off phase, hip joint torque increased, and the ankle joint's angular velocity also increased owing to the involvement of AS (Hara et al., 2008). Another possible reason for the increased torque and jump height in CMJA was the increased activation of the plantar flexors, which helped maintain proper posture for the vertical jump (Hara et al., 2008). Regarding the role of the upper limbs in CMJA, Mosier et al. (2019) examined their contribution by comparing CMJA with CMJ performed without AS. The study reported a 32.2% increase in ground reaction force (GRF) during CMJA, compared to an 11.3% increase in CMJ without AS. The contribution of the upper limbs in CMJA was found to be proportional to their relative mass (Mosier et al., 2019). Furthermore, jump height in CMJA was 13.6% greater than in CMJ without AS.

Kruse et al. (2013) investigated the effects of static (30 s) and dynamic stretching (30 s or 10 m) on CMJ performance in elite female volleyball players. They found that CMJ height was 6.7% greater after 1 and 5 s of dynamic stretching compared to SS. In a study by Vaverka et al. (2016), CMJA performance in elite male volleyball players was 37.7% higher than CMJ without AS. The accelerating impulse was significantly greater with AS, while the braking impulse was significantly greater without AS ($p < .01$). The performance improvement observed in that study exceeded the average increases reported in other studies. This difference was attributed by the authors to the volleyball players' extensive jump training experience and the more controlled technique used in the CMJA.

Several studies have shown that AS increases jump height by 10%–20%, depending on the specific sport (Gerodimos et al., 2008; Lees et al., 2004; Richter et al., 2012). In the study by Lees et al. (2004), participants jumped 28% higher in CMJA compared to CMJ without AS, attributed to the elevation of the arm segments. Additionally, AS resulted in a 72% increase in take-off velocity owing to greater muscle activation in the shoulders, elbow joints, and hips. A greater trunk ROM (5°) was also observed, along with higher muscle activity in the gastrocnemius (12%) and vastus lateralis (5%), but lower activity in the rectus femoris (-5%) and biceps femoris (-19%) compared to the CMJ without arm swing (Lees et al., 2004).

Gerodimos et al. (2008) investigated the contribution of the stretch-shortening cycle (SSC) and AS to vertical jump performance in children (12 ± 0.23 years), young adolescents (14.5 ± 0.41 years), older adolescents (16.9 ± 0.27 years), and adult basketball players (21.9 ± 0.32 years). AS increased CMJ height by 7–10 cm across all age groups. The authors reported no significant differences between age groups in the contribution of SSC and AS to vertical jump performance. They concluded that the effectiveness of SSC and AS is not influenced by the level of maturity in basketball players (Gerodimos et al., 2008). A significant decrease in CMJA performance after SS was reported in the study by Annino et al. (2017), contrasting with the effects of moderate- to high-intensity dynamic stretching in elite Italian basketball players.

Yamaguchi and Ishii (2014) noted that when dynamic stretching was performed "as fast as possible," explosive performance improved by 7.6%, compared to only a 1.1% increase when the protocol was performed without a specified speed. They also recommended that the optimal dynamic stretching protocol consists of 1–2 sets of 10–15 repetitions or a 20-m distance, as applied in this study. In the study by Paradisis et al. (2014), adolescent boys and girls—similar in age to the participants of this study—showed a reduction in performance after 40 seconds of SS: a 2.5% decrease in the 20-m sprint and a 6.3% decrease in CMJ performance. In contrast, 40 s of dynamic stretching had no effect on the 20-meter sprint, but resulted in a 2.2% increase in CMJ performance (Paradisis et al., 2014).

In this study, dynamic stretching protocols resulted in an increase in the final jump height of basketball players compared to SS. Furthermore, both DS and DF had a more positive impact on vertical jump performance and running speed than SS. In contrast to these findings, Jagers et al. (2008) examined the effects of ballistic and dynamic stretching on CMJ performance in college students and found that neither stretching technique led to an improvement in jump height.

Contrary to the findings of Yamaguchi and Ishii (2014), Mizuno (2020) suggested that DF might decrease performance owing to muscle fatigue. Mizuno investigated the effects of four sets of 10 repetitions of dynamic stretching performed at maximal (100%) and moderate (50%) velocities during active plantar flexion–dorsiflexion in males. Joint ROM increased after both dynamic stretching protocols, with no significant differences between the two velocities. Additionally, isometric maximal voluntary contractions of the ankle plantar flexors and dorsiflexors, as well as passive torque at submaximal angles, remained unchanged regardless of stretching velocity.

The only significant difference observed from pre- to post-stretching was an increase in fatigue after dynamic stretching at maximal velocity ($p < .05$). As a result, Mizuno (2020) recommended performing dynamic stretching at moderate velocities to avoid muscle fatigue. In his study, the maximum velocity (100%) corresponded to 170 bpm, while the moderate velocity was 86 bpm. Similarly, in Fletcher's (2010) study and this research, DF was set at 100 bpm and DS at 50 bpm. Based on these findings, we conclude that moderate intensities of dynamic stretching, between 50 and 100 bpm, appear to improve performance compared to maximal stretching velocities.

Conclusions

The results of this study indicate that incorporating dynamic stretching into warm-up routines positively affects vertical jump and sprint performance in adolescent basketball players, while SS has a less favorable effect. Furthermore, both slow (50 bpm) and fast (100 bpm) dynamic stretching velocities appear effective in improving athletic performance when performed during warm-ups in basketball practices and games.

Practical applications

The CMJA during the take-off phase is a fundamental movement in basketball, involved in actions such as jump shots, rebounds, and blocks. These movements are performed frequently by basketball players during both training sessions and games, with jump height playing an important role in their effectiveness. Dynamic stretching during warm-ups is likely to have a more positive impact on these performances compared to SS. Additionally, sprint performance also appears to improve when warm-ups include dynamic stretching, whereas SS may have a detrimental effect. Therefore, coaches and athletes are encouraged to prioritize dynamic stretching during warm-ups before engaging in strength-based activities.

References

- Alipasali, F., Papadopoulou, S.D, Komsis, S. (2024). The effect of static and dynamic stretching exercises on lower limbs concentric strength of amateur male volleyball players. *Journal of Physical Education and Sport*, 24(4), 1016-1023.
- Annino, G., Ruscello, B., Lebone, P., Palazzo, F., Lombardo, M., Padua, E., Tancredi, V., Iellamo, F. (2017). Acute effects of static and dynamic stretching on jump performance after 15min of reconditioning shooting phase in basketball players. *Journal of Sport Medicine and Physical Fitness*, 57(4), 330-337.
- Behm, D.G., Button, D.C., Butt, J.C. (2001). Factors affecting force loss with prolonged stretching. *Canadian Journal of Applied Physiology*, 26(3), 262-272.
- Bishop, D. (2003). Warm up I: Potential mechanism and the effects of passive warm up on exercise performance. *Sports Medicine*, 33(6), 439-454.
- Bishop, D. (2003). Warm up II: Performance changes following active warm up and how to structure the warm up. *Sports Medicine*, 33(7), 483-498.
- Cornwell, A., Nelson, A.G., Heise, G.D., Sidaway, B. (2001). Acute effects of passive muscle stretching on vertical jump performance. *Journal of Human Movement Studies*, 40(2), 307-324.
- Fletcher, I.M. (2010). The effect of different dynamic stretch velocities on jump performance. *European Journal of Applied Physiology*, 109(3), 491-498.
- Fletcher, I.M., Anness, R. (2007). The acute effects of combined static and dynamic stretch protocols on fifty-meter sprint performance in track-and-field athletes. *Journal of Strength and Conditioning Research*, 21(3), 784-787.
- Fletcher, I.M., Jones, B. (2004). The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *Journal of Strength and Conditioning Research*, 18(4), 885-888.
- Galazoulas, C. (2017). Acute effects of static and dynamic stretching on the sprint and countermovement jump of basketball players. *Journal of Physical Education and Sport*, 17(1), 219-223.
- Gerodimos, V., Zafeiridis, A., Perkios, S., Dipla, K., Manou, V., Kellis, S. (2008). The contribution of stretch-shortening cycle and arm-swing to vertical jumping performance in children, adolescents, and adult basketball players. *Pediatric Exercise Science*, 20(4), 379-389.
- Hara, M., Shibayama, A., Takeshita, D., Hay, D.C., Fukushima, S. (2008). A comparison of the mechanical effect of arm swing and countermovement on the lower extremities in vertical jumping. *Human Movement Science*, 27(4), 636 – 648.
- Hedrick, A. (2002). Flexibility training for range of motion. *National Strength and Conditioning Association Performance Training Journal*, 1(2), 13-20.
- Heishman, A.D., Daub, B.D., Miller, R.M., Freitas, E.D.S., Frantz, B.A., Bemben, M.G. (2020). Countermovement jump reliability performed with and without an arm swing in NCAA division I intercollegiate basketball players. *Journal of Strength and Conditioning Research*, 34(2), 546-558.
- Jaggers, J.R., Swank, A.M., Frost, K.L., Lee, C.D. (2008). The acute effects of dynamic and ballistic stretching on vertical jump height, force, and power. *Journal of Strength and Conditioning Research*, 22(6), 1844-1849.
- Kruse, N.T., Barr, M.W., Gilders, R.M., Kushnick, M.R., Rana, S.R. (2013). Using a practical approach for determining the most effective stretching strategy in female college division I volleyball players. *Journal of Strength and Conditioning Research*, 27(11), 3060-3067.
- Kyranoudis, A., Nikolaidis, V., Ispirlidis, I., Galazoulas, C., Alipasali, F., Famisis, K. (2018). Acute effect of specific warm-up exercises on sprint performance after static and dynamic stretching in amateur soccer players. *Journal of Physical Education and Sport*, 18(2), 825-830.

- Lees, A., Vanrenterghem, J., Clercq, D.D. (2004). Understanding how an arm swing enhances performance in the vertical jump. *Journal of Biomechanics*, 37(12), 1929-1940.
- Manoel, M.E., Harris-Love, M.O., Danoff, J.V., Miller, T.A. (2008). Acute effects of static, dynamic, and proprioceptive neuromuscular facilitation stretching on muscle power in women. *Journal of Strength and Conditioning Research* 22(5), 1528-1534.
- Mizuno, T. (2020). Effects of dynamic stretching velocity on joint range of motion, muscle strength, and subjective fatigue. *Journal of Strength and Conditioning Research*, 36(9), 2440-2447.
- Morrin, N., Redding, E. (2013). Acute effects of warm-up stretch protocols on balance, vertical jump height, and range of motion in dancers. *Journal of Dance Medicine and Science*, 17(1), 34-40.
- Mosier, E.M., Fry, A.C., Lane, M.T. (2019). Kinetic contributions of the upper limbs during counter-movement vertical jumps with and without arm swing. *Journal of Strength and Conditioning Research*, 33(8), 2066-2073.
- Nelson, A.G., Driscoll, N.M., Landin, D.K., Young, M.A., Schexnayder, I.C. (2005). Acute effects of passive muscle stretching on sprint performance. *Journal of Sports Science*, 23(5), 449-454.
- Nelson, A.G., Kokkonen, J., Arnall, D.A. (2005). Acute muscle stretching inhibits muscle strength endurance performance. *Journal of Strength and Conditioning Research*, 19(2), 338-343.
- Paradisis, G.P., Pappas, P.T., Theodorou, A.S., Zacharogiannis, E.G., Skordilis, E.K., Smirniotou, A.S. (2014). Effects of static and dynamic stretching on sprint and jump performance in boys and girls. *Journal of Strength Conditioning Research*, 28(1), 154-160.
- Richter, A., Rappale, S., Kurz, G., Schwameder, H. (2012). Countermovement jump in performance diagnostics: Use of the correct jumping technique. *European Journal of Sport Science*, 12(3), 231-237.
- Spencer, M., Lawrence, S., Rechichi, C., Bishop, D., Dawson, B., Goodman, C. (2004). Time motion analysis of elite field hockey, with special reference to repeated sprint ability. *Journal of Sports Science*, 22(9), 843-850.
- Turki, O., Chaouachi, A., Behm, D.G., Chtara, H., Chtara, M., Bishop, D., Chamari, K., Amri, M. (2012). The effect of warm-ups incorporating different volumes of dynamic stretching on 10- and 20-m sprint performance in highly trained male athletes. *Journal of Strength and Conditioning Research*, 26(1), 63-72.
- Vaverka, F., Jandacka, D., Zahradnik, D., Uchtyl, J., Farana, R., Supej, M., Vodicar, J. (2016). Effect of an arm swing on countermovement vertical jump performance in elite volleyball players. *Journal of Human Kinetics*, 53(1), 41-50.
- Wallmann, H.W., Mercer, J.A., McWhorter, J.W. (2005). Surface electromyographic assessment of the effect of static stretching of the gastrocnemius on vertical jump performance. *Journal of Strength and Conditioning Research*, 19(3), 684-688.
- Winchester, J.B., Nelson, A.G., Landin, D., Young, M., Schexnayder, I.C. (2008). Static stretching impairs sprint performances in collegiate track and field athletes. *Journal of Strength and Conditioning Research*, 22(1), 13-19.
- Yamaguchi, T., Ishii, K. (2014). An optimal protocol for dynamic stretching to improve explosive performance. *Journal of Physical Fitness and Sports Medicine*, 3(1), 121-129.
- Yamaguchi, T., Ishii, K. (2005). Science of stretching: Your stretching may be wrong (in Japanese). *Hokkaido Journal of Sports Medicine and Science*, 10, 27-36.
- Young, W.B., Behm, D.G. (2003). Effects of running, static stretching and practice jumps on explosive force production and jumping performance. *Journal of Sports Medicine and Physical Fitness*, 43(1), 21-27.