Article Classification:
Original article

EFFECTS OF STRETCHING ON ADOLESCENT TRACK AND FIELD ATHLETES

Tereza Marinova, Diana Popova-Dobreva
National Sports Academy "Vassil Levski", Sofia, Bulgaria

ABSTRACT

Introduction. Flexibility, or joint range of motion, is often highlighted as a crucial aspect of physical fitness. It is commonly believed that improving flexibility can enhance performance and help lower the risk of injury.

Methodology. This study involved a sample of 30 Track and Field athletes who were tested once before the stretching programs were applied (April 2024) and once after (October 2024).

Results. The data from descriptive analyses for both tests before and after the application of stretching programs showed slight improvements in the SLJ, VJ, BOMBT, and SSPMBT metrics. The results from the comparative analysis of the VJ, SLJ 30-meter Flying Start, and BOMBTS indicators showed a statistically significant improvement from Test 1 to Test 2.

The data from the descriptive analysis: M. Triceps Surae: Test 1 mean of 13.27 and Test 2 mean of 16.57 for the right limb; Test 1 mean of 13,2 and Test 2 mean of 17,4 for the left limb; Hamstring: Test 1 mean of 79.47 and Test 2 mean of 86.3, for right limb. Test 1 mean 79.37 and Test 2 mean 85.87 for the left limb; M. Rectus Femoris: Test 1 mean 151.33 and Test 2 mean 153.83 for the right limb. Test 1 mean of 150,9 and Test 2 of 154 for the left limb; M. Erector Spinae: Test 1 mean of 26.77 and Test 2 mean of 28.9.

The improvement in the M. Triceps Surae R/L flexibility (The t-value of -2.35/-2.81 at a significance level of α = .05 suggests a statistically significant difference between the two test results, indicating the effectiveness of the applied intervention or training program.

Conclusions. The comparative analysis of the Vertical Jump, Standing Long Jump, 30-meter Flying Start, and Backward Overhead Medicine Ball Throw indicators showed a statistically significant improvement from Test 1 to Test 2, indicating a positive effect on the development of speed and strength qualities during the application of the stretching programs. Additionally, Welch's t-test results highlighted the effectiveness of the intervention program, demonstrating a statistically significant improvement in the flexibility of the M. Triceps Surae R/L between Test 1 and Test 2.

ORCID
Tereza Marinova
https://orcid.org/0009-0003-0006-1241
Diana Popova-Dobreva
https://orcid.org/0000-0002-3044-8506

Cite this article as:
Marinova, T., Popova-Dobreva, D. (2024). Effects of stretching on adolescent track and sfield athletes. *Journal of Applied Sports Sciences*, Vol. 2, pp. 33 - 44.
DOI: *10.37393/JASS.2024.02.4*

Keywords: *Stretching protocols, Track and Field Athletes*

INTRODUCTION

Flexibility is an essential component of success in many sports, particularly athletics, where it is especially important for runners and jumpers. It is defined as the ability to move a joint or series of joints smoothly and without restriction through a painless range of motion. This quality is directly related to the extensibility of the musculotendinous units surrounding the joint, which is influenced by the muscles' ability to relax, deform, and adapt to stretching forces.

Winchester et al. (2008) began their study with findings indicating that static stretching may harm the stretch-shortening cycle. In contrast, they found that using a dynamic warm-up routine could enhance performance. The authors aimed to find out if the adverse effects of static stretching would offset the performance benefits gained from a dynamic warm-up.

In that study, 11 male and 11 female athletes completed a dynamic warm-up, followed by either a static stretching session or a rest period. The static stretching routine consisted of four partner-assisted stretches targeting the calf and thigh muscles, lasting a total of 10 minutes. The first stretch focused on the hamstrings. The athletes began by lying on their backs with one leg extended straight on the ground. The other leg was bent at approximately a 90-degree angle at the knee and a 45-degree angle at the hip, with the sole flat on the ground. From this position, the extended leg was lifted into a vertical or slightly beyond-vertical position through hip flexion. Throughout the stretch, the buttocks remained entirely in contact with the ground, and the knee of the raised leg stayed wholly extended.

The second, a triceps surae stretch, was performed with the athlete's leg positioned vertically. For the third stretch, the athlete lay on their back with one leg bent and one extended; the extended leg was then flexed at the knee and hip, bringing the heel toward the buttocks and the knee toward the chest. The fourth activity stretched the quadriceps. In this stretch, the athlete began lying face down (prone position). The partner then passively bent the athlete's knee and lifted it off the ground while ensuring the hip remained in contact with the floor. Each stretch was held for 30 seconds at the point of discomfort. The four stretches were performed in sequence, with a 10–20 second rest between each. After completing one entire cycle of stretches, the leg rested for an additional 20–30 seconds before repeating the cycle. Each stretch was performed three times in total.

After the warm-up, the participants completed three 40-meter sprints to assess how static stretching affected sprint performance when preceded by a dynamic warm-up.

This study demonstrated that passive muscle stretching could impair performance in tasks requiring repetitive high-power output, even when followed by a dynamic warm-up routine.

Behm and Chaouachi (2011) investigated the acute effects of static and dynamic stretching on athletic performance. They conducted a thorough literature review using databases such as ASAP, ProQuest 5000, MEDLINE, SPORT Discus, AUSPORT, ScienceDirect, Web of Science, and Google Scholar.

Their findings concluded that static stretching should generally be avoided before activities that require strength, speed, explosiveness, or reactive movements. However, they emphasized the importance of incorporating static stretching into overall fitness routines for its health benefits, such as improved range of motion (ROM) and muscle-tendon compliance. To achieve lasting improvements in flexibility for both health and performance, static stretching should be scheduled separately, either as part of a dedicated training session or during post-exercise cool-downs, rather than as part of a warm-up or competitive activity.

Aim and objectives of the study

- To monitor the development of speed-strength training in adolescent jumpers through the application of stretching programs.
- To evaluate the effectiveness of stretching programs in improving joint mobility and flexibility in key elements of the musculoskeletal system for jumpers.

The hypothesis of the research

Previous research has shown mixed effects, including negative impacts of static stretching on athletic performance. In this study, we propose a working hypothesis that structured programs incorporating dynamic stretching during warm-ups and static stretching during cool-downs will positively influence the mobility and flexibility of key components of the musculoskeletal system essential for jumping. This approach is expected to be accompanied by speed and strength training improvements.

Recent research provides a growing body of evidence suggesting that static stretching before activity does not always result in performance impairments. Numerous studies have reported neutral or even positive effects under specific conditions, highlighting that the outcomes of static stretching may depend on factors such as stretch duration, activity type, and individual athlete characteristics (Behm & Chaouachi, 2011). We believe that a thorough examination of both the immediate and long-term effects of various stretching methods on joint mobility and sports performance is crucial. This study focused on incorporating dynamic stretching during warm-ups and static stretching during cool-downs. Future research will further refine these methods and investigate their effects in greater detail.

METHODOLOGY

Organization of the study

The study was conducted from April to October 2024. Thirty adolescent athletes, aged 11 to 16, underwent sports-pedagogical and physical therapy tests. During this period, stretching programs designed by the researchers were incorporated into the jumpers' overall training regimen. These programs featured dynamic stretching for warm-ups and static stretching for cool-downs. The study methodology was explained to the children's parents, and all provided informed consent for their participation in the study. Parents were fully informed that their child's participation in the study was voluntary, and they had the right to withdraw at any time. In compliance with current data protection laws, all personal information will remain anonymous and be used exclusively for scientific purposes.

The research participants were drawn from an individual sports club and consisted of athletes engaged in competitive activities. They ranged in age from 11 to 16 years, with a limited sample size of 30 athletes. These results were not analyzed separately; the broad age range is acknowledged as a study limitation.

Research methods

For the purposes of the study, the participants were tested twice: once before the stretching programs were applied (April 2024) and once after (October 2024).

To monitor the effectiveness of applied stretching programs, we used the following functional evaluation tests:

Functional performance testing for power

Trunk Power Test: Backward Overhead Medicine Ball Throw (BOMBT); Lower Extremity Power Tests: Vertical Jump (VJ); Standing Long Jump (SLJ); Upper Extremity Power Test: Seated Shot-Put Medicine Ball Throw (SSPMBT);

Functional performance testing for speed

Sprint Test (30 Meter Flying Start)

To objectively evaluate the results of applied stretching programs, we used measurements of the following ranges of motion: Dorsiflexion of the ankle joint: to assess the function of the M. Triceps Surae; Hip flexion with the knee extended: to assess hamstring function; Flexion of the knee joint: to assess the function of the M. Rectus Femoris; Flexibility of the hamstrings and M. Erector Spinae. We measured these indicators using the EasyAngle Digital Goniometer and the Baseline Sit n' Reach Tester. EasyAngle is a digital goniometer designed for quick and precise measurements, while the Baseline Sit n' Reach Tester box assesses the flexibility of a person's hamstrings and lower back muscles.

The research data were processed using statistical tools in Microsoft Excel. Student's *t*-test, Welch's *t*-test, and descriptive and correlation analyses were employed.

Author's programs for stretching

The programs were integrated into the athletes' training process during warm-ups and cool-downs.

Program with dynamic stretching during warm-ups

- From a standing position – 4 minutes;
- From a standing position with forward movement – 4 minutes;
- From a sitting position – 4 minutes;
- Special running exercises – 6 minutes.

Static stretching during cool-downs

- From a standing position – 6 minutes;
- From a sitting position – 6 minutes;
- From a prone position – 2 minutes;
- From the supine position – 4 minutes.

RESULTS

Tables 1 to 8 present the results of the sports-pedagogical tests. Tables 9-16 present the results of the physical therapy tests. The results were analyzed based on the statistical processing of the data using descriptive analysis, correlation analysis, and comparative analysis.

Table 1. *Results from the descriptive analysis of the data test 1*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
SLJ	30	1.44	2.79	1.35	2.07133333	0.37	17.76	0.101	-1.034
VJ	30	26	58	32	35.9	8.66	24.12	0.777	-0.195
30 m	30	3.29	5.03	1.74	4.10233333	0.53	13.00	0.32	-1.115
BOMBT	30	1.45	3.6	2.15	2.425	0.63	25.93	0.245	-0.737
SSPMBT	30	1.1	3.4	2.3	2.11166667	0.64	30.25	0.331	-0.581

Table 1 presents the variation analysis of the data from testing with athletic equipment conducted before the application of stretching methods (April 2024). The SLJ indicator values ranged from a minimum of 1.44 m to a maximum of 2.79 m, with an average value of 2.07 m. The VJ indicator's minimum value was 26 cm, the maximum was 58 cm, and the mean was 35.9 cm. For the 30m indicator, the minimum time was 3.29 s, the maximum was 5.03 s, and the mean was 4.10 s. The BOMBT metric's values ranged from 1.45 m to 3.6 m, with a mean of 2.42 m. For the SSPMBT metric, the minimum value was 1.1 m, the maximum was 3.4 m, and the mean was 2.11 m.

Table 2. *Results from the descriptive analysis of the data test 2*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
SLJ	30	1.49	2.86	1.37	2.12266667	0.38	18.08	0.095	-1.038
VJ	30	25	58	33	36.6666667	8.37	22.83	0.662	-0.25
30 m	30	3.15	5.03	1.88	4.05266667	0.54	13.33	0.273	-1.053
BOMBT	30	1.45	3.75	2.3	2.475	0.65	26.27	0.137	-0.848
SSPMBT	30	1.15	3.6	2.45	2.16333333	0.67	31.06	0.304	-0.59

In the second measurement, the SLJ indicator ranged from 1.49 m to 2.86 m, with an average of 2.12 m. The VJ indicator had a minimum of 25 cm, a maximum of 58 cm, and an average of 36.6 cm. For the 30m indicator, times ranged from 3.15 s to 5.03 s, with an average of 4.05 s. The BOMBT metric ranged from 1.45 m to 3.75 m, with an average of 2.47 m. The SSPMBT metric showed values from 1.15 m to 3.6 m, averaging 2.16 m. There is a clear trend of improvement across all investigated speed-power parameters (Table 2).

Table 3. *Results from the correlation analysis of the data SLJ, VJ,30m, BOMBT, SSPMBT*

Variable	SLJ	VJ	30 m	BOMBT
SLJ	1			
VJ	.885**	1		
30 m	-.94**	-.855**	1	
BOMBT	.883**	.732**	-.792**	1
SSPMBT	.876**	.782**	-.777**	.914**

The correlation analysis (Table 3) performed on the data from the second measurement demonstrated a strong relationship among all the studied speed-strength indicators: Vertical Jump (VJ), Standing Long Jump (SLJ), 30-meter Flying Start, Backward Overhead Medicine Ball Throw (BOMBT), and Seated Shot-Put Medicine Ball Throw (SSPMBT).

Table 4. *Results from the comparative analysis of the data SLJ*

Indicator	N	Test 1		Test 2		Difference		
		$\bar{X}_1$	S1	$\bar{X}_2$	S2	d	*t*	*α*
SLJ	30	2.07	0.37	2.12	0.38	-0.05	6.17	.00

The SLJ indicator showed an average value of 2.07 (S1 = 0.37) in the first measurement and 2.12 (S2 = 0.38) in the second. Statistical significance was observed between these results (Table 4).

Table 5. *Results from the comparative analysis of the data VJ*

Indicator	N	Test 1		Test 2		Difference		
		$\bar{X}_1$	S_1	$\bar{X}_2$	S_2	d	*t*	*α*
VJ	30	35.90	8.66	36.67	8.37	-0.77	2.64	.01

The VJ indicator's average value was 35.90 (S1 = 8.66) in the first measurement and 36.67 (S2 = 8.37) in the second measurement, with statistical significance observed between the results (Table 5).

Table 6. *Results from the comparative analysis of the data 30 m*

Indicator	N	Test 1		Test 2		Difference		
		$\bar{X}_1$	S1	$\bar{X}_2$	S2	d	t	α
30 m	30	4.10	0.53	4.05	0.54	0.05	4.38	.00

The 30 m Flying Start indicator averaged 4.10 (S1 = 0.53) in the first measurement and 4.05 (S2 = 0.54) in the second measurement, with statistical significance noted between the results (Table 6).

Table 7. *Results from the comparative analysis of the data BOMBT*

Indicator	N	Test 1		Test 2		Difference		
		$\bar{X}_1$	S_1	$\bar{X}_2$	S2	d	*t*	*α*
BOMBT	30	2.43	0.63	2.48	0.65	-0.05	2.06	.05

The BOMBT indicator for a sample of 30 participants showed the following results: In Test 1: *Mean* ($\bar{X}_1$) = 2.43, Standard Deviation (S1) = 0.63. In Test 2: *Mean* ($\bar{X}_2$) = 2.48, Standard Deviation (S2) = 0.65. The difference (d) = -0.05. The *t*-value = 2.06, with a significance level (*α*) = .05 (Table 7).

Table 8. *Results from the comparative analysis of the data SSPMBT using Welch's t-test*

Indicator	N	Test 1		Test 2		Difference		
		$\bar{X}_1$	S1	$\bar{X}_2$	S2	d	*t*	*α*
SSPMBT	30	2.11	0.64	2.16	0.67	-0.05	-0.3	.05

In a sample of 30 track and field athletes, the average value of the SSPMBT indicator in the first measurement was 2.11, with S1 = 0.64. The second measurement's mean was 2.16, with S2 = 0.67. No statistical significance was observed between the results (Table 8).

Table 9. *Results from the descriptive analysis of the data test 1 right limb and spine*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
M. Triceps Surae	30	5	23	18	13.2666667	5.55	41.80	0.163	-0.971
Hamstring	30	58	93	35	79.4666667	8.05	10.13	-0.665	0.356
M. Rectus Femoris	30	138	158	20	151.333333	5.09	3.37	-0.513	-0.036
M. Erector Spinae	30	12.5	38.5	26	26.7666667	7.83	29.27	-0.444	-0.609

For the indicator for the M. Triceps Surae (Dorsiflexion of the ankle joint) Min 5 Max: 23 Range (R): 18; *Mean* (Average): 13.27; *SD* (Standard Deviation): 5.55. V (Variance): 41.80. The data for the M. Triceps Surae showed a moderately wide range of values (18), with an average value of 13.27. The standard deviation (5.55) was relatively high, indicating some variability around the mean.

Data for the Hamstring (Hip flexion with the knee extended) are Min: 58; Max: 93; Range: 35; Mean: 79.47 SD: 8.05; Variance: 10.13. The Hamstring data had a range of 35, showing variability. The mean was 79.47, with a moderate standard deviation (8.05), indicating that most values were around the mean but with some spread.

M. Rectus Femoris (Flexion of the knee joint) Min: 138; Max: 158; Range: 20; *Mean*: 151.33; *SD*: 5.09; V: 3.37. The M. Rectus Femoris data showed a range of 20, with values clustered closely around the mean (151.33), indicated by the relatively low standard deviation (5.09).

M. Erector Spinae (Flexibility of the hamstrings and erector spinae) Min: 12.5; Max: 38.5; Range: 26; *Mean*: 26.77; *SD*: 7.83; Variance: 29.27. The M. Erector Spinae data had a range of 26, with an average of 26.77 and a standard deviation of 7.83, suggesting moderate variability.

Overall, the data from these muscle groups showed variability, with most of the distributions not following a perfectly normal shape (Table 9).

Table 10. *Results from the descriptive analysis of the data test 2 right limb and spine*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
M. Triceps Surae	30	5	26	21	16.5666667	5.32	32.12	-0.011	-0.705
Hamstring	30	69	95	26	86.3	6.77	7.85	-1.129*	1.095
M. Rectus Femoris	30	144	158	14	153.833333	4.20	2.73	-0.932*	-0.123
M. Erector Spinae	30	13	40.5	27.5	28.9	7.48	25.90	-0.579	-0.387

After analyzing the data from Test 2, which focused on the right limb and spine, we obtained the following results:

M. Triceps Surae Min: 5; Max: 26; Range: 21; *Mean*: 16.57; *SD*: 5.32; V: 32. Hamstring Min: 69; Max: 95; Range: 26; *Mean*: 86.30; *SD*: 6.77; V: 7.85. The Hamstring data showed a range of 26, with values around a mean of 86.30.

M. Rectus Femoris Min: 144; Max: 158; Range: 14; *Mean*: 153.83; *SD*: 4.20; V: 2.73. The M. Rectus Femoris data showed a small range of 14, with values clustering around the mean of 153.83.

M. Erector Spinae Min: 13; Max: 40.5; Range: 27.5; *Mean*: 28.90; *SD*: 7.48; V: 25.90. The M. Erector Spinae data showed a range of 27.5, with values averaging 28.90.

Table 11. *Results from the descriptive analysis of the data test 1 left limb*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
M. Triceps Surae	30	4	26	22	13.2	5.93	44.95	0.094	-0.754
Hamstring	30	60	93	33	79.3666667	8.21	10.34	-0.554	-0.534
M. Rectus Femoris	30	139	162	23	150.966667	5.22	3.46	-0.387	0.397

Analysis of Descriptive Statistics (Table 11). M. Triceps Surae: Min: 4; Max: 26; R: 22; *Mean*: 13.20; *SD*: 5.93; V: 44.95. The data for M. Triceps Surae showed a moderate range of 22, with an average value of 13.20 and a standard deviation of 5.93, indicating some variability.

Hamstring: Min: 60; Max: 93; Range: 33; *Mean*: 79.37; *SD*: 8.21; V: 10.34. The Hamstring data showed a relatively wide range of 33 and a mean value of 79.37. The standard deviation (8.21) indicated moderate variability around the mean.

M. Rectus Femoris: Min: 139; Max: 162; Range: 23; *Mean*: 150.97; *SD*: 5.22; V: 3.46. The M. Rectus Femoris data had a moderate range of 23 and a mean value of 150.97, with a relatively low standard deviation (5.22), indicating that the data were closely clustered around the mean.

Table 12. *Results from the descriptive analysis of the data test 2 left limb*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
M. Triceps Surae	30	5	27	22	17.4	5.64	32.43	-0.018	-0.704
Hamstring	30	71	96	25	85.8666667	7.18	8.36	-0.602	-0.471
M. Rectus Femoris	30	145	163	18	154.233333	4.32	2.80	-0.627	0.211

Results from the descriptive analysis of the data test 2 left limb (Table 12). M. Triceps Surae: Min: 5; Max: 27; Range: 22; *Mean*: 17.4; *SD*: 5.64; V: 32.43. The data for M. Triceps Surae exhibited a moderate range of 22 and a mean of 17.4, with a standard deviation of 5.64 indicating moderate variability.

Hamstring: Min: 71; Max: 96; Range: 25; *Mean*: 85.87; *SD*: 7.18; V: 8.36. The Hamstring data showed a range of 25 and an average of 85.87. The standard deviation of 7.18 indicated moderate variability.

Table 13. *Results from the descriptive analysis of the data from the test for M. Triceps Surae D*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
M. Triceps Surae Test 1	30	5	26	21	13.27	5.55	41.80	0.163	-0.971
M. Triceps Surae Test 2	30	5	26	21	16.57	5.32	32.12	-0.011	-0.705

Results from the descriptive analysis of the data from the test for M. Triceps Surae D (Table 13). Test 1: Min: 5; Max: 26; Range: 21; *Mean*: 13.27; *SD*: 5.55; V: 41.80; Test 2: Min: 5; Max: 26; Range: 21; *Mean*: 16.57; *SD*: 5.32; V: 32.12.

Both tests shared the same range (21), indicating no change in the minimum and maximum flexibility levels between them. The mean value increased from 13.27 in Test 1 to 16.57 in Test 2, suggesting an improvement in the overall flexibility of the M. Triceps Surae group. The standard deviation and variance decreased from Test 1 (*SD* = 5.55, V = 41.80) to Test 2 (*SD* = 5.32, V = 32.12), indicating reduced variability and more consistent performance in Test 2.

The comparison between the two tests indicated a notable improvement in the mean flexibility of the M. Triceps Surae and a reduction in variability. Test 2 showed more consistent results across the sample.

Table 14. *Results from the test for M. triceps sure R a comparative analysis using Welch's t-test*

Indicator	N	Test 1		Test 2		Difference		
		$\bar{X}_1$	S1	$\bar{X}_2$	S2	d	*t*	*α*
M. Triceps Surae R	30	13.27	5.55	16.57	5.32	-3.30	-2.35	.05

Welch's *t*-test Results for M. Triceps Surae R: *Mean* ($\bar{X}_1$, Test 1): 13.27; *Standard Deviation* (S1, Test 1): 5.55; *Mean* ($\bar{X}_2$, Test 2): 16.57; *Standard Deviation* (S2, Test 2): 5.32; Difference (d): -3.30; *t*-value: -2.35. Significance Level (α): .05.

The mean value for Test 2 (16.57) was notably higher than that for Test 1 (13.27), indicating an improvement in performance for the M. Triceps Surae indicator.

The *t*-value of -2.35 at a significance level of $\alpha = .05$ suggests a statistically significant difference between the two test results. The negative *t*-value reflects the direction of change (an increase from Test 1 to Test 2).

The results from Welch's *t*-test confirmed a statistically significant improvement in the M. Triceps Surae R between Test 1 and Test 2, demonstrating the training program's positive impact.

Table 15. *Results from the descriptive analysis of the data from the test for M. triceps sure L*

	N	Min	Max	R	*Mean*	*SD*	V	As	Ex
M. Triceps Surae Test 1	30	4	27	23	13.20	5.93	44.95	0.094	-0.754
M. Triceps Surae Test 2	30	5	27	22	17.40	5.64	32.43	-0.018	-0.704

Descriptive Analysis: M. Triceps Surae L Test 1 vs. Test 2 (Table 15). Test 1: Min: 4; Max: 27; Range: 23; *Mean*: 13.20; *SD*: 5.93; V: 44.95. Test 2: 30; Min: 5; Max: 27; Range: 22; *Mean*: 17.40; *SD*: 5.64; V: 32.43.

Test 1 had a slightly broader range (23) compared to Test 2 (22), indicating a slight narrowing in the variability of results in Test 2.

The mean score increased from 13.20 in Test 1 to 17.40 in Test 2, demonstrating an improvement in flexibility for the M. Triceps Surae L group.

The standard deviation (*SD* = 5.64) and variance (V = 32.43) decreased in Test 2 compared to Test 1 (*SD* = 5.93, V = 44.95), indicating greater consistency in the results for Test 2.

The comparison between the two tests highlighted a significant improvement in the mean flexibility for the M. Triceps Surae L group and reduced variability and more uniform performance in Test 2.

Table 16. *Results from the test for M. triceps sure L a comparative analysis using Welch's t-test*

Indicator	N	Test 1		Test 2		Difference		
		$\bar{X}_1$	S1	$\bar{X}_2$	S2	d	*t*	*α*
M. Triceps Surae L	30	13.20	5.93	17.40	5.64	-4.20	-2.81	.05

Welch's *t*-test Results for M. Triceps Surae L: *Mean* ($\bar{X}_1$, Test 1): 13.20; *Standard Deviation* (S1, Test 1): 5.93; *Mean* ($\bar{X}_2$, Test 2): 17.40; *Standard Deviation* (S2, Test 2): 5.64; Difference (d): -4.20; *t*-value: -2.81; Significance Level (*α*): .05.

The mean value for Test 2 (17.40) was significantly higher than for Test 1 (13.20), indicating improved flexibility in the M. Triceps Surae L.

The *t*-value of -2.81 exceeded the threshold for significance at $\alpha = .05$, confirming a statistically significant difference between the results of Test 1 and Test 2. The negative *t*-value reflected the improvement from Test 1 to Test 2.

The improvement in the M. Triceps Surae L performance highlighted the positive impact of the applied stretching program or intervention.

Based on our research and the results obtained, we, as researchers and specialists, are focusing on a more detailed examination and refinement of methodologies targeting key muscle groups. Future studies will emphasize the effects on the triceps surae, hamstrings, and quadriceps. In future studies, we plan to refine our methods further and present detailed results focusing on the triceps surae, hamstrings, and quadriceps.

DISCUSSION

The subtleties and enhancement of sports performance in athletes (sprint, jumpers, and others) remain a primary focus for many researchers. (Gadev, M., Peev, P., & Hristov, O. (2020); Miladinov, O., & Velin, V. (2018); Bachev, V., Gadev, M., et al. (2018). Tsvetkov, V., Gadev, M., & Peev, P. (2017); Gadev, M., & Gutev, G. (2015); Gutev, G., & Njagin, P. (2012); Miladinov, O. (2006); Miladinov, O., & Bonov, P. (2004).

The application of dynamic and static stretching in athletes attracts the interest of strength researchers (Behm et al. al., (2023); Behm et al. al., (2016); Opplert et al., N. (2018); Raya-Gonzalez et al. (2021); Zakaria et al., A. (2015); Melocchi, I. et al. (2021); McCrary et al., M. (2015). Static stretching (SS), dynamic stretching (DS), and combined stretching (CS; a combination of DS and SS) are commonly used as warm-up exercises. However, the most effective method for improving flexibility and performance remains unclear. In a randomized crossover trial, Matsuo et al. (2023) examine the acute and prolonged effects of SS, DS, and CS on a range of motion (ROM), peak passive torque (PPT), passive stiffness, and isometric and concentric muscle forces. Twenty healthy young men performed 300 seconds of active SS, DS, or CS (150 seconds of SS followed by 150 seconds of DS, or 150 seconds of DS followed by 150 seconds of SS) on the right knee flexors over four separate days in random order. After each session, ROM, PPT, and passive stiffness measurements were taken during passive knee extension. Results revealed similar increases in ROM and PPT and decreases in isometric muscle strength across SS, DS, and CS. However, CS tended to have longer-lasting effects on passive stiffness compared to SS and DS. Additionally, concentric muscle strength remained unchanged after DS but decreased following SS and CS. The study's results confirmed the benefits of applying dynamic stretching to achieve optimal sports performance.

Behm, D. G., & Chaouachi, A. (2011) identified several limitations in comparing results, including a significantly lower number of female participants, the lack of randomization, absence of tester blinding, inconsistencies in inter-tester reliability, and variations in participants' hydration status.

While presenting opportunities for refining and enhancing research methodologies, these limitations are often constrained by practical realities and the specific nature of the study population. By this, we mean that youth training groups are inherently diverse and cannot be perfectly tailored to meet the ideal conditions for scientific study. As specialists with expertise in high-performance sports, we prioritize gathering authentic empirical data that can advance sports science and benefit those passionate about the field.

In the available literature, we did not identify any studies involving adolescent track and field athletes that directly compare the indicators we examined following the implementation of stretching protocols. This study has some limitations in the number of participants and the age differences among them, which affect the results of the sports-pedagogical tests.

CONCLUSION

The results from the comparative analysis of the Vertical Jump (VJ), Standing Long Jump (SLJ), 30-meter Flying Start, and Backward Overhead Medicine Ball Throw (BOMBT), indicators show a statistically significant improvement from Test 1 to Test 2, indicating a positive effect on the development of speed and strength qualities during the application of the stretching programs.

Highlighting the effectiveness of the intervention program, Welch's *t*-test results demonstrate a statistically significant improvement in the flexibility of the M. Triceps Surae R/L between Test 1 and Test 2.

We encourage coaches to allocate dedicated time and attention to dynamic warm-up and static stretching exercises for the triceps surae, hamstrings, and quadriceps.

REFERENCES

Amazon. (2024). *Baseline Sit and Reach flexibility assessment testing*. Retrieved February 27, 2024, from https://www.amazon.com/Baseline-Reach-Flexibility-Assessment-Testing/dp/B00AIH255S?th=1

Bachev, V., Gadev, M., Groshev, O., Yordanov, P., & Zlatev, B. (2018). Computer-aided research and analysis of biomechanical indicators for starting the acceleration of sprint running. *Человек. Спорт. Медицина, 18*(1), 95–102.

Behm, D. G., & Chaouachi, A. (2011). A review of the acute effects of static and dynamic stretching on performance. *European Journal of Applied Physiology, 111*, 2633–2651.

Behm, D. G., Alizadeh, S., Daneshjoo, A., & Konrad, A. (2023). Potential effects of dynamic stretching on injury incidence of athletes: A narrative review of risk factors. *Sports Medicine, 53*(7), 1359–1373. https://doi.org/10.1007/s40279-023-01847-8

Behm, D. G., Blazevich, A. J., Kay, A. D., & McHugh, M. (2016). Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: A systematic review. *Applied Physiology, Nutrition, and Metabolism, 41*(1), 1–11. https://doi.org/10.1139/apnm-2015-0235

Calculator Academy. (2024). *Welch's t-test calculator*. Retrieved November 11, 2024, from https://calculator.academy/welchs-t-test-calculator/

Gadev, M., & Gutev, G. (2015). Analysis of covered distance intensity in official junior and youth football with different match time duration. *Research in Kinesiology, 43*(2).

Gadev, M., Peev, P., & Hristov, O. (2020). Agreement between measurement of jump height in different vertical jump tests executed by young football players. *Journal of Applied Sports Sciences, 2*, 40–52.

Gigova, V. (2002). *Statisticheska obrabotka i analiz na danni*. Sofia: NSA-IPB.

Gutev, G., & Njagin, P. (2012). Research on the Bulgarian U14 track and field status and tendency of development. In *Međunarodna naučna konferencija efekti primene fizičke aktivnosti na antropološki status dece, omladine i odraslih zbornik sažetaka* (p. 183). https://doi.orig/10.1519/JSC.0b013e31815ef202

Matsuo, S., Iwata, M., Miyazaki, M., Fukaya, T., Yamanaka, E., Nagata, K., Tsuchida, W., Asai, Y., & Suzuki, S. (2023). Acute and prolonged effects of 300 sec of static, dynamic, and combined stretching on flexibility and muscle force. *Journal of Sports Science & Medicine, 22*(4), 626–636. https://doi.org/10.52082/jssm.2023.626

McCrary, J. M., Ackermann, B. J., & Halaki, M. (2015). A systematic review of the effects of upper body warm-up on performance and injury. *British Journal of Sports Medicine, 49*(14), 935–942. https://doi.org/10.1136/bjsports-2014-094228

Melocchi, I., Filipas, L., Lovecchio, N., De Nardi, M., La Torre, A., & Codella, R. (2021). Effects of different stretching methods on vertical jump ability and range of motion in young female artistic gymnastics athletes. *The Journal of Sports Medicine and Physical Fitness, 61*(4), 527–533. https://doi.org/10.23736/S0022-4707.20.11386-0

Meloq. (2024). *EasyAngle digital goniometer*. Retrieved February 27, 2024, from https://meloqdevices.com/pages/easyangle-digital-goniometer

Miladinov, O. (2006). New aspects in perfecting the long jump technique. *New Studies in Athletics, 21*(4), 7.

Miladinov, O., & Bonov, P. (2004). Individual approach in improving the technique of triple jump for women. *New Studies in Athletics, 19*(4), 27–36.

Miladinov, O., & Velin, V. (2018). Kinematic-dynamic interrelations between the drop jump on inclined platform and the take-off in the horizontal athletics jumps. *Journal of Applied Sports Sciences, 1*, 3–13.

Opplert, J., & Babault, N. (2018). Acute effects of dynamic stretching on muscle flexibility and performance: An analysis of the current literature. *Sports Medicine, 48*(2), 299–325. https://doi.org/10.1007/s40279-017-0797-9

Raya-Gonzalez, J., Castillo, D., & Clemente, F. M. (2021). Injury prevention of hamstring injuries through exercise interventions. *The Journal of Sports Medicine and Physical Fitness, 61*(9), 1242–1251. https://doi.org/10.23736/S0022-4707.21.11670-6

Tsvetkov, V., Gadev, M., & Peev, P. (2017, December). Determination of motor mobility speed zones for players from age groups U16 and U17. In *International Scientific Congress "Applied Sports Sciences"* (p. 102).

Winchester, J. B., Nelson, A. G., Landin, D., Young, M. A., & Schexnayder, I. C. (2008). Static stretching impairs sprint performance in collegiate track and field athletes. *Journal of Strength and Conditioning Research, 22*(1), 13–19.

Zakaria, A. A., Kiningham, R. B., & Sen, A. (2015). Effects of static and dynamic stretching on injury prevention in high school soccer athletes: A randomized trial. *Journal of Sport Rehabilitation, 24*(3), 229–235. https://doi.org/10.1123/jsr.2013-0114

Corresponding author:

Tereza Marinova, PhD
Department of Track and Field Athletics,
National Sports Academy „Vassil Levski“,
21 Acad. Stefan Mladenov“ Str,
1700, Sofia, Bulgaria
Email: terza.marinova@nsa.bg