



INVESTIGATING THE IMMEDIATE EFFECT OF DYNAMIC AND STATIC STRETCHING ON BALANCE, PROPRIOCEPTION, AND LANDING ERROR IN FEMALE GYMNASTS

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ABSTRACT

The objective of the current research was to examine the immediate effects of dynamic and static stretching on balance, proprioception, and landing error in female gymnasts. This research is categorized as applied-developmental based on its purpose, semi-experimental according to its data collection method, and quantitative in terms of data type. The statistical population included female gymnasts aged 18 to 25 in Tehran, from which 36 participants were purposefully selected and randomly divided into three groups ($n = 12$ for the control group, $n = 12$ for the dynamic stretching group, and $n = 12$ for the static stretching group). All statistical analyses were performed using SPSS version 22. A significance level of $\alpha = 0.05$ was applied to all statistical tests. The findings showed that dynamic stretching had a significantly positive effect on measures of dynamic balance, static balance, and overall balance. In contrast, static stretching has a significant impact only on the static balance of female gymnasts, resulting in a decrease in static balance. This study investigated the immediate effects of dynamic and static stretching on the balance, proprioception, and landing errors of female gymnasts. It employed a semi-experimental, quantitative, and applied-developmental design. Thirty-six female gymnasts aged 18 to 25 from Tehran were intentionally selected and randomly divided into three groups: dynamic stretching, static stretching, and control ($n = 12$ in each group). Balance, proprioception, and landing errors were measured before and after the interventions. Data were analyzed using SPSS 22, with a significance threshold of $\alpha = 0.05$. Findings indicated that dynamic stretching led to significant improvements in dynamic balance (anterior, posteromedial, and posterolateral directions), combined balance, and static balance, along with substantial reductions in landing errors and enhancements in proprioception. Conversely, static stretching improved proprioception and static balance but did not significantly influence dynamic balance or landing errors. Therefore, dynamic stretching offered greater immediate advantages in balance, proprioception, and landing error metrics than static stretching.

Keywords: Dynamic stretching, Static stretching, Balance, Proprioception, Landing error, Female gymnasts

INTRODUCTION:

Over the years, gymnastics has evolved into one of the most popular sports worldwide. The risk of injury in this dynamic discipline becomes especially concerning given that many children, particularly girls, begin participating in gymnastics at a very young age. In numerous cases, athletes are compelled to retire from competitive sports due to various injuries before reaching their peak performance and achieving success (1, 2). Each year in the United States alone, more than five million injuries are reported among children under the age of 15, nearly half of which are related to sports. Additionally, between 4% and 7% of these sports-related injuries are linked explicitly to gymnastics (3). According to a study by Sink et al., the majority of sports injuries occur between the ages of 12 and 17 (Sink et al., 4). Another study reported that lower limb injuries constitute 51% of all injuries sustained by gymnasts (5). In this regard, the American College of Sports Medicine and the National Strength and Conditioning Association recommend performing general warm-ups before engaging in any physical activity or sports competition to improve performance. These warm-ups usually consist of submaximal aerobic exercises combined with light stretching and sport-specific movements. While a variety of techniques and activities are used for warming up, stretching is one of the most commonly applied practices before the main activity. The positive effects of stretching are thought to result from two primary factors: firstly, an increase in the length and flexibility of the muscle-tendon unit, and secondly, modifications in the neural mechanisms of proprioceptive receptors that enhance the body's ability to sense and respond to external stimuli. Various types of stretching can be incorporated into pre-exercise routines, with static and dynamic stretching being the most widely practiced.

In a 2005 study, Yamaguchi et al. investigated the effects of 30-second static and dynamic stretching exercises on lower body explosive power, aiming to test the hypothesis that static stretching does not impair muscle performance. In contrast, dynamic stretching improves it (6). Supporting this perspective, research has shown that while static stretching is straightforward, safe, and commonly used in warm-ups, it may lead to decreased performance in certain activities, particularly those that involve balance and strength (7, 8). Conversely, dynamic stretching not only maintains the injury prevention benefits associated with static stretching but also enhances neuromuscular activity, promotes explosive power generation, and improves subsequent performance (9–11).

Although numerous perspectives and scientific findings highlight the advantages of stretching exercises, the contradictory and inconsistent reports regarding their impact on various physical performance indicators may be due to several factors. These include the type of stretching performed (static or dynamic), the duration of the stretch, its intensity (relative to pain threshold), the kind of activity that follows the stretching, participant characteristics and selection criteria, reliability of the measures, differences in methodology, and ultimately, the analysis and interpretation of results. Among the factors contributing to limb injuries, researchers have identified disruptions in the postural control system as a significant cause (12). Balance is defined as the ability to maintain a posture to perform voluntary movements and to resist both internal and external disturbances. It is regarded as a key indicator of independence in daily living and is vital for enhancing both quality of life and athletic performance (13). This function involves a dynamic process that depends on the sensory perception of body movements, the integration of sensory and motor information by the central nervous system, and the execution of appropriate musculoskeletal responses to maintain equilibrium between stabilizing and destabilizing forces (14, 15). Furthermore, balance is essential and fundamental to physical performance and many sports activities. Efficient

postural control plays a crucial role in ensuring successful athletic performance. Any impairment in the balance control system may lead to decreased postural stability, resulting in increased fluctuations in balance. In this regard, several studies have associated changes in an athlete's center of gravity (i.e., balance) with an elevated risk of lower limb injuries (16). Watson (1999) employed a practical method to assess postural sway by measuring the duration a participant could stand on one foot without losing balance or falling. Participants with greater postural sway experienced more frequent ankle instability compared to those with less sway (16).

Proprioception is a fundamental element in maintaining dynamic joint stability and is regarded as a vital somatic sense (17). Impairment of proprioception can lead to various joint dysfunctions. Following an injury, the sensory input related to proprioception is disrupted (18), which can negatively influence posture, balance, and neuromuscular coordination throughout the body. Through proprioception, the nervous system can respond swiftly to incoming stimuli via muscle contractions. Moreover, it helps regulate and correct the stresses applied to joints and ligaments. Proprioception refers to the ability to detect the spatial positioning of joints and bodily movements without relying on visual input, with specialized receptors transmitting this information to the central nervous system (19). Sink et al. (2008) also associated the high incidence of lower limb injuries, particularly ankle injuries, among children aged 6 to 11 with inadequate training in proper landing techniques among gymnasts (Sink et al., 2008). Unlike football players or athletes in other sports, gymnasts are not trained to absorb landing impacts. Instead, they are instructed to execute movements and landings in a straight and extended posture (without joint flexion to absorb force) to achieve higher competition scores (20).

As a result, many studies have emphasized the importance of implementing preventive strategies through structured protocols and training programs, particularly to lower the risk of injury among female athletes. Additionally, jump-landing is a common motor task regularly performed by athletes in both training and competition settings (21). Despite appearing simple, this task can place the knee in a high-risk position. Faulty landing techniques are a well-known mechanism contributing to lower limb injuries in sports (22). A poor landing is characterized by inadequate control of the lower limbs, which can cause the knee to rotate or collapse, potentially straining soft tissue structures and leading to knee injuries. In turn, these injuries can result in prolonged periods of athletic inactivity (23).

As previously discussed, gymnastics has become one of the most popular and widely practiced sports, with a growing number of young girls starting the sport at an early age and frequently encountering lower limb injuries in their pursuit of high performance and success. Therefore, implementing effective injury prevention programs is crucial. Furthermore, a review of existing research reveals that most studies examining the effects of static and dynamic stretching on various dimensions of athletic performance have found that static stretching generally reduces performance. In contrast, dynamic stretching tends to enhance it in most cases. Accordingly, the research question of the present study is as follows: Do static and dynamic stretching exercises, when included in a warm-up routine, influence improvements in balance, proprioception, and the reduction of landing errors in gymnasts and thereby contribute to injury prevention? If so, which type of stretching: static or dynamic has a more significant effect on the dependent variables: balance, proprioception, and landing error?

RESEARCH METHOD:

This study was categorized as applied-developmental in terms of its objective, semi-experimental in terms of data collection method, and quantitative in terms of data type. The statistical population included female gymnasts aged 18 to 25 in Tehran. A total of 36 participants were purposefully selected and randomly assigned to three groups: control (n = 12), dynamic stretching (n = 12), and static stretching (n = 12). The sample size was determined

using G*Power software, based on an effect size of 0.5, a significance level of 0.05, and a statistical power of 0.80—values derived from previous research. Inclusion criteria were: being female, aged between 18 and 25 years, having at least one year of experience in gymnastics, practicing at least three sessions per week at a gym, no history of fractures or surgery in the lower limbs, no history of ligament or meniscus injuries in the knee, and providing informed consent to participate. Exclusion criteria included: withdrawal of consent during the study, irregular participation in training sessions, sustaining a lower limb injury during the study period, and a prior history of knee ligament or meniscus injuries.

All measurements were conducted on a single day at a gymnastics hall located in District 6 of Tehran. Thirty-six eligible female gymnasts who met the inclusion criteria were selected as participants. Before collecting the signed consent forms, each subject was provided with comprehensive information regarding the study's purpose, procedures, and participation requirements. After obtaining the signed consent forms, individual data, medical history, and athletic background were gathered through a questionnaire and interviews. Participants then completed a five-minute warm-up consisting solely of running, with no stretching exercises included. They were subsequently divided into two groups: static stretching and dynamic stretching and underwent the Y-Balance Test to evaluate dynamic balance, the BESS Balance Test for static balance, as well as assessments of knee proprioception and jump-landing technique. These pre-tests were conducted on the same day.

All stretches and tests were performed on the designated leg, as studies by Barak (1994) and Gerusch (1996) indicated no significant difference between dominant and non-dominant limbs (24, 25). The Step Test was used to identify the dominant leg. Additionally, based on expert opinion, the optimal angle for measuring knee joint position sense is within the mid-range of motion, specifically between 40 and 80 degrees of flexion. In this study, a target angle of 45 degrees of knee flexion was used to assess position sense, which is a standard measurement angle in the seated position (26). After applying stretching exercises targeting the hamstrings, quadriceps, and gastrocnemius muscles, all tests were repeated one minute later as post-tests, and the scores were recorded accordingly. It is essential to note that, before the commencement of the research procedures, detailed explanations of all tests and their correct execution were provided to the participants. However, to eliminate the potential influence of learning effects from the pre-tests, no feedback on performance or pre-test results was given to the subjects.

For the assessment of knee joint position sense, each participant was seated on a chair with a height adjusted so that their feet did not touch the ground. A sensor attached with an elastic strap was secured to a specific location identified using anatomical landmarks. The knee joint position sense was measured using a G-Pro digital goniometer. All participants wore sports shorts with no additional clothing covering the lower limbs to allow precise measurements. While standing in a relaxed position, four markers were placed on the skin over prominent bony landmarks along the longitudinal axes of the thigh and leg. The placement of these markers followed protocols outlined in the studies conducted by Lafortune et al., Capozzo et al., Lamoureux, and Stillman & Tully.

To assess dynamic balance, the Y-Balance Test was employed. Given the significant correlation between this test and leg length, the actual leg length was measured before the test using a tape measure, from the anterior superior iliac spine to the medial malleolus. At the same time, the subject was in a supine position. The test was performed in three directions: anterior, posteromedial, and posterolateral. The participant stood on one leg at the center of the Y-measurement device, placed their hands on their hips, and, while maintaining balance on the supporting leg, attempted to reach in each direction with the opposite leg. Static balance was assessed using the Balance Error Scoring System (BESS), evaluated in six conditions: standing on both feet, standing on one foot, and tandem stance, performed on both a floor and a foam surface. Each stance was held for 20 seconds.

In this study, the static stretching protocol was based on the method used by Larsen et al., with

a modification to the rest period between sets, reducing it from 30 seconds to 15 seconds. The dynamic stretching protocol used in this research was adapted from Herda et al. (2008). Immediately after performing the stretching exercises, participants were prepared for the re-evaluation of proprioception, static balance, and jump-landing, following the same procedures as in the pre-test. The same protocols were applied during the post-test. Between-group comparisons of the dependent variables, while controlling for the pre-test effect in a 2×3 pre-test–post-test design, were conducted using one-way analysis of covariance (ANCOVA). To compare the group means pairwise, the Bonferroni post hoc test was applied.

The significance level for all statistical tests was set at $\alpha = 0.05$. All statistical analyses were carried out using SPSS version 22.

FINDINGS:

The descriptive findings (mean and standard error) for the variables of height, weight, and body mass index (BMI) of the participants, grouped by category, are presented in Table 1.

Table 1: Descriptive statistics of the research variables

Variable	Stage		Group	Mean ± Standard Error	Significance Level
Height (m)	Pre-test		Dynamic Stretching	55/08±1/602	0.159
			Static Stretching	53/25±2/973	
			Control	59/08±0/692	
Weight (Kg)	Pre-test		Dynamic Stretching	100.82±2.76	0.539
			Static Stretching	102.34±2.91	
			Control	100.25±1.64	
Body Mass Index (BMI) (kg/m ²)	Pre-test		Dynamic Stretching	20.38±0.457	0.280
			Static Stretching	20.34±0.657	
			Control	21.91±0.950	

The results showed no statistically significant differences in height, weight, and body mass index between the research groups in the pre-test ($P > 0.05$).

Table 2: Results of the Bonferroni post-hoc test for pairwise comparison of the means of anterior dynamic balance among the research groups

	Group <i>I</i>	Group <i>J</i>	I-J — Mean Difference	Significance Level
Dynamic Anterior Balance	Control	Dynamic Stretching	-11.704	0.006
		Static Stretching	-2.371	1.000
	Dynamic Stretching	Static Stretching	9.371	0.034
Dynamic Posterior Internal Balance	Control	Dynamic Stretching	-15.40	0.003
		Static Stretching	-2.25	1.000
	Dynamic Stretching	Static Stretching	13.15	0.012
Dynamic Posterior External Balance	Control	Dynamic Stretching	-17.426	0.006
		Static Stretching	1.810	0.981
	Dynamic Stretching	Static Stretching	19.456	0.002
Balance Error	Control	Dynamic Stretching	4.45	0.000
		Static Stretching	3.20	0.000
	Dynamic Stretching	Static Stretching	-1.25	0.232
Combined Balance	Control	Dynamic Stretching	-14.701	0.000
		Static Stretching	0.726	1.000
	Dynamic Stretching	Static Stretching	13.975	0.000

Based on the results presented in Table 2, dynamic stretching led to an immediate improvement in the anterior dynamic balance of adolescent female gymnasts ($P = 0.006$). In contrast, static stretching did not have a significant immediate effect on anterior dynamic balance ($P = 1.000$). Dynamic stretching also resulted in an immediate improvement in posterior internal dynamic balance ($P = 0.003$), whereas static stretching showed no significant effect on this measure ($P = 1.000$). Furthermore, dynamic stretching resulted in an immediate improvement in posterior external dynamic balance ($P = 0.006$), whereas static stretching did not significantly affect anterior dynamic balance ($P = 0.981$). Dynamic stretching was found to cause an immediate reduction in balance error ($P < 0.001$), while static stretching also led to a decrease in balance error ($P = 0.010$). However, no significant difference was observed between the immediate effects of dynamic and static stretching on balance error ($P = 0.232$).

Finally, dynamic stretching resulted in a significant immediate improvement in combined balance ($P < 0.001$), while static stretching did not show any significant effect on combined balance ($P = 1.000$).

Table 3: Results of the paired t-test for within-group comparison of anterior dynamic balance

Group		Paired Differences					T-statistic	Degrees of Freedom	Significance Level
		Mean	Standard Deviation	Standard Error	95% CI				
					Minimum	Maximum			
Dynamic Stretching	Pre-test – Post-test	-12.40	11.97	3.45	-20.00	-4.79	-3.588	11	0.004
Static Stretching	Pre-test – Post-test	-2.39	10.09	2.91	-8/80	4.01	-0.82	11	0.428
Control	Pre-test – Post-test	0.43	2.75	0.79	-1/31	2.18	0.55	11	0.593

The results of the paired t-test (within-group comparison) showed that the mean of anterior dynamic balance significantly improved from the pre-test to the post-test only in the dynamic stretching group (P = 0.004) (Table 3).

Table 4: Results of the Paired t-test for Within-Group Comparison of Posterior Internal Dynamic Balance

Group		Paired Differences					T-statistic	Degrees of Freedom	Significance Level
		Mean	Standard Deviation	Standard Error	95% CI				
					Minimum	Maximum			
Dynamic Stretching	Pre-test – Post-test	-14.02	16.13	4.65	-24.28	-3.77	-3.01	11	0.012
Static Stretching	Pre-test – Post-test	-0.62	15.96	4.60	-10.76	9.51	-0.13	11	0.894
Control	Pre-test – Post-test	0.22	2.84	0.82	-1.58	2.03	0.27	11	0.786

The results of the paired t-test (within-group comparison) showed that the mean of posterior internal dynamic balance significantly increased only in the dynamic stretching group from pre-test to post-test (P = 0.012) (Table 4).

Table 5: Results of the paired t-test for within-group comparison of posterior dynamic balance

Group		Paired Differences					T-statistic	Degrees of Freedom	Significance Level
		Mean	Standard Deviation	Standard Error	95% CI				
					Minimum	Maximum			
Dynamic Stretching	Pre-test – Post-test	-1.307	20.20	5.83	-30.14	-4.46	-2.96	11	0.013
Static Stretching	Pre-test – Post-test	2.00	16.26	4.69	-8.32	12.34	0.42	11	0.677
Control	Pre-test – Post-test	0.19	2.02	0.58	-1.08	1.48	0.33	11	0.741

The results of the paired t-test (within-group comparison) showed that the mean score for posterior dynamic balance in the dynamic stretching group increased significantly from the pre-test to the post-test ($P = 0.013$) (Table 5).

Table 6: Results of the paired t-test for within-group comparison of static balance

Group		Paired Differences					T-statistic	Degrees of Freedom	Significance Level
		Mean	Standard Deviation	Standard Error	95% CI				
					Minimum	Maximum			
Dynamic Stretching	Pre-test – Post-test	350	2.50	0.72	1.90	5.09	4.84	11	0.001
Static Stretching	Pre-test – Post-test	2.25	2.52	0.72	0.64	3.85	3.08	11	0.010
Control	Pre-test – Post-test	-0.803	0.99	0.28	-0.176	0.54	-0.29	11	0.777

The results of the paired t-test (within-group comparison) indicated that the mean balance error significantly decreased from pre-test to post-test in both the dynamic stretching group ($P < 0.001$) and the static stretching group ($P = 0.010$) (Table 6).

Table 7: Results of the paired t-test for within-group comparison of the combined balance

Group		Paired Differences					T- statistic	Degrees of Freedom	Significance Level
		Mean	Standard Deviation	Standard Error	95% CI				
					Minimum	Maximum			
Dynamic Stretching	Pre- test – Post- test	- 1.157	12.40	3.58	-22.46	-6.69	-4.07	11	0.002
Static Stretching	Pre- test – Post- test	-0.33	8.30	2.39	-5.61	4.93	-0.14	11	0.890
Control	Pre- test – Post- test	0.28	1.33	0.38	-0.56	1.13	0.74	11	0.472

The results of the paired t-test (within-group comparison) indicated that the mean combined balance significantly increased from the pre-test to the post-test only in the dynamic stretching group ($P = 0.002$) (Table 7).

Table 8: Results of the paired t-test for within-group comparison of landing error

Group		Paired Differences					T- statistic	Degrees of Freedom	Significance Level
		Mean	Standard Deviation	Standard Error	95% CI				
					Minimum	Maximum			
Dynamic Stretching	Pre- test – Post- test	2.16	2.28	0.66	0.71	3.62	3.27	11	0.007
Static Stretching	Pre- test – Post- test	-0.66	2.96	0.85	-2.55	1.21	-0.77	11	0.452
Control	Pre- test – Post- test	-0.41	0.99	0.28	-1.04	0.21	-1.44	11	0.175

The results of the paired t-test (within-group comparison) indicated that the landing error mean significantly decreased from the pre-test to the post-test only in the dynamic stretching group ($P = 0.010$) ($P = 0.007$) (Table 8).

Table 9: Results of the Paired t-test for Within-Group Comparison of Proprioception

Group		Paired Differences					T-statistic	Degrees of Freedom	Significance Level
		Mean	Standard Deviation	Standard Error	95% CI				
					Minimum	Maximum			
Dynamic Stretching	Pre-test – Post-test	2.750	3.07	0.88	0.79	4.70	3.09	11	0.010
Static Stretching	Pre-test – Post-test	2.08	2.99	0.86	0.17	3.98	2.40	11	0.035
Control	Pre-test – Post-test	0.160	0.93	0.27	-0.76	0.42	-0.61	11	0.551

The results of the paired t-test (within-group comparison) indicated that the mean proprioception significantly decreased from the pre-test to the post-test in both the dynamic stretching group ($P = 0.010$) and the static stretching group ($P = 0.035$) (Table 9).

DISCUSSION:

The results of the present study revealed that dynamic stretching had a significant positive effect on dynamic anterior, posterior internal, and posterior external balance, combined balance, and static balance ($P < 0.05$). In contrast, static stretching had a significant impact on static balance ($P < 0.05$) but showed no significant effect on dynamic balance ($P > 0.05$). This finding is consistent with studies by Lablibisi et al. (27) and Gharam et al. (28), which also found that static stretching did not significantly influence static balance. However, other studies have shown contradictory results. For instance, Hendrakis et al. (2010) investigated the effects of an acute static stretching protocol on balance and jump performance in middle-aged adults, finding that static stretching improved balance, which aligns with the findings of this study (Hendrakis et al., 2010; 29). Similarly, Behm et al. (2004) reported significant improvements in balance scores following static stretching, particularly targeting the quadriceps, hamstrings, and foot flexors (30). These studies suggest that static stretching can have a positive effect on balance, particularly when the method and duration of application are optimized. Interestingly, the current study found that static stretching had positive effects on static balance under unstable conditions, suggesting that the impact of static stretching may vary based on individual characteristics. The positive outcomes observed may be attributed to the specific application methods and the appropriate duration of the stretches, which likely contributed to improvements in balance during the warm-up phase. This finding highlights the importance of tailoring stretching exercises to an individual's specific needs to optimize warm-up and performance outcomes.

The intergroup comparison of proprioception in the present study revealed that both dynamic and static stretching significantly enhanced the proprioception of female gymnasts ($P < 0.05$). Both types of stretching resulted in substantial improvements in proprioception from pre-test to post-test ($P < 0.05$). Specifically, static stretching led to a significant reduction in errors in knee joint position sense and an improvement in proprioception. This finding is consistent with those of Ghafarnejad et al. (2007), who demonstrated that static stretching at a 45-degree knee

angle improved proprioception, whereas at a 20-degree angle, it had no significant effect. Likewise, Walsh (2017) investigated the effects of static and dynamic stretching on knee proprioception and strength, showing that both types of stretching positively influenced knee joint position sense. However, static stretching also led to a reduction in muscle strength (31). These findings suggest that static stretching may be beneficial for enhancing knee proprioception, likely due to changes in the receptors and spindles responsible for sensing joint position. The results also highlight the potential effectiveness of integrating both static and dynamic stretching into warm-up routines to enhance proprioception, particularly in sports such as gymnastics, where precise control and coordination are essential. Furthermore, the observed improvement in proprioception across both groups supports the hypothesis that stretching can positively impact sensory feedback mechanisms, contributing to joint stability and performance.

The results also showed a significant difference in the immediate effect of dynamic stretching on knee proprioception in female gymnasts. Yamauchi et al. (2005) conducted a study examining the impact of dynamic stretching on the muscles surrounding the knee joint on knee extension strength and found that dynamic stretching enhanced performance. They attributed this improvement to an increase in muscle temperature and the occurrence of post-activation potentiation (PAP), which refers to the increased force generated by a muscle after contracting its antagonist (32). Furthermore, the findings of Prieur et al. (2009), Skier et al. (2009), Little et al. (2006), and Abraki et al. align with Yamauchi et al.'s results, suggesting that the performance enhancement following dynamic stretching is due to the increase in muscle temperature and the PAP phenomenon (33, 34, 35).

The results indicated that only dynamic stretching significantly decreased landing error in female gymnasts, both intergroup and intragroup ($P < 0.05$), while static stretching had no impact on landing error ($P > 0.05$). As discussed in previous studies, as referenced in Chapter 2, Prieur et al. (2009) demonstrated that dynamic stretching of the knee muscles enhanced reaction time and vertical jump performance with a half-squat (34). This finding aligns with the work of Araki et al., who reported that dynamic stretching improved performance in agility, 35-meter sprints, vertical jumps, and reaction times (Araki et al., 35). Additionally, McMillan et al. (2006) found that dynamic stretching warm-up exercises improved agility tests, medicine ball throws, and explosive lower limb power in USMA athletes (McMillan et al., 2006, p. 36).

CONCLUSION:

The findings showed that dynamic stretching significantly improved dynamic balance, static balance, and combined balance. However, static stretching only influenced the static balance of the female gymnasts, resulting in a significant decrease. One limitation of this study is that it focused only on the immediate effects of static and dynamic stretching, overlooking potential long-term adaptations that may result from consistent routines. Environmental factors, such as surface type, fatigue levels, and individual flexibility differences, were not controlled beyond minimal pre-test instructions, which may have impacted the balance and proprioception results. Future researchers should build on these findings by incorporating larger, more diverse athletic populations across various age groups, genders, and sports. Longitudinal studies are needed to examine the long-term effects of dynamic and static stretching on balance, proprioception, and injury prevention. Exploring the impact of different stretching intensities, durations, and combinations, such as mixed static-dynamic protocols, on neuromuscular performance is also recommended.

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