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Article

# Effects of dynamic stretching of different duration on lower limb flexibility in male sport dancers: A randomized controlled trial

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**Abstract:** In the field of sports training and teaching, stretching is regarded as a highly valuable technique, particularly in its capacity to facilitate gradual acclimatization of the body to the exercise state during the warm-up session and as a means of enhancing flexibility qualities. As the research on athletic training continues to deepen, the discussion on the respective advantages of static stretching and dynamic stretching is becoming increasingly prominent. In this study, dynamic stretching was selected as the primary intervention to investigate the effects of varying durations of dynamic stretching on the flexibility of the legs of male students majoring in sport dance, with a particular focus on the underlying biomechanical mechanisms. Method: The subjects were 40 male first- and second-year students majoring in physical education dance at Yichun College, randomly assigned to one of four groups of 10 students each. The methodology comprised a dynamic stretching warm-up and quality training prior to the commencement of regular sports dance teaching, after which the basic teaching session was initiated. The study employed SPSS 22.0 software to conduct a *T*-test to analyze the effects of different stretching durations on flexibility. SPSS 22.0 software was utilized to perform a *T*-test. Biomechanical parameters such as muscle fiber recruitment patterns, joint range of motion, and force generation during stretching were also measured and analyzed. Results: (1) Dynamic stretching in warm-ups and training can boost lower limb flexibility. Biomechanically, this is attributed to the activation of specific muscle groups and the modulation of connective tissue properties. A significant difference observed between dominant and non-dominant limbs, which may be related to differences in neuromuscular control and muscle fiber composition. (2) A 20-minute stretch in warm-ups and a 30-minute stretch in training were best for flexibility, showing a more pronounced effect on the dominant side. This could be due to the dominant limb's greater ability to generate force and adapt to biomechanical stress, as well as its more efficient neuromuscular coordination. (3) The right side, which corresponds to the dominant limb in most subjects, improved more than the left with dynamic stretching. This could be attributed to the greater neural activation and muscle recruitment efficiency, which are key biomechanical factors in the stretching response. (4) Although dynamic stretching is slower than static stretching in enhancing flexibility, consistent sessions exceeding 20 minutes can still yield positive results for both limbs though the dominant limb may benefit more initially., likely due to its pre-existing biomechanical advantages and more refined neuromuscular pathways. Conclusion: Dynamic stretching effectively improves lower limb flexibility, though more slowly than static stretching. Regular sessions over 20 min, especially 20-minute warm-ups and 30-minute training, can notably enhance flexibility, with a significant impact on the dominant limb, suggesting that while non-dominant limbs also benefit, the dominant limb may require less time to achieve similar flexibility improvements due to its inherent biomechanical and neuromuscular characteristics.

**Keywords:** dynamic stretching; lower limb; flexibility qualities; warm-up; training; biomechanics

## 1. Introduction

In the educational and training domain, the 'impact' of interventions is recognized for both its immediate and long-term effects, with sports dance training typically divided into warm-up, basic training, and relaxation phases [1,2]. Addressing a significant gap in the biomechanical literature, this study focuses on the impact of dynamic stretching on the lower limb flexibility of male sport dance students during these critical phases [3,4]. While previous research has concentrated on technical and artistic aspects of sports dance [5], the role of dynamic stretching—a method that enhances athletic performance by simulating specific movements and engaging multiple joints and muscle groups—remains underexplored [6,7]. Our hypothesis is that dynamic stretching, when integrated into the warm-up and training phases [8], will positively affect lower limb flexibility, thereby improving the quality of sports dance training and athletic performance [9,10]. This empirical investigation aims to provide theoretical support for the scientific application of dynamic stretching and practical guidance for the field [11], offering a significant contribution to enhancing training quality and reducing the risk of injury.

## 2. Method

### 2.1. Intervention

This 12-week study aimed to assess the impact of dynamic stretching interventions on the flexibility of dance students, ensuring a consistent baseline with no significant differences in any indicators between the two groups before proceeding with the experimental process. Participants were categorized into four groups: no stretching, a 5-minute jog followed by 10 min of stretching, a 5-minute jog followed by 20 min of stretching, and a 5-minute jog followed by 30 min of stretching. The stretching sessions were meticulously organized, beginning with Group 3 initiating a 10-minute stretch, then Group 2 joining for the second stretch, and finally, all groups synchronizing for the first stretch after Group 3 completed their 20 min and Group 2 their 10 min. The detailed schedule of the stretching and testing times is depicted in **Figure 1**. With no breaks between the start of tests for any group, the experimental intervention was implemented as illustrated in **Figure 2**, following the established baseline and ensuring equivalence in all flexibility measures prior to the intervention.

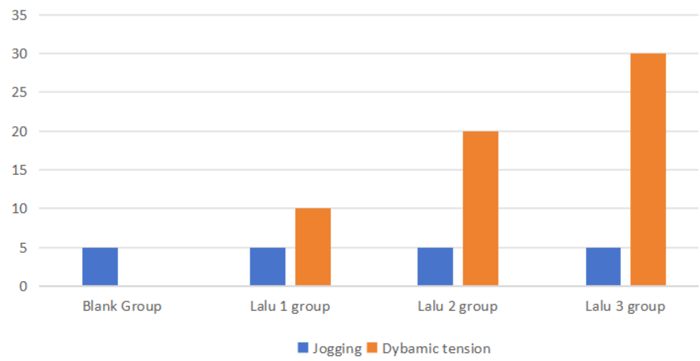


**Figure 1.** Nodal schedule of stretching time and testing time.

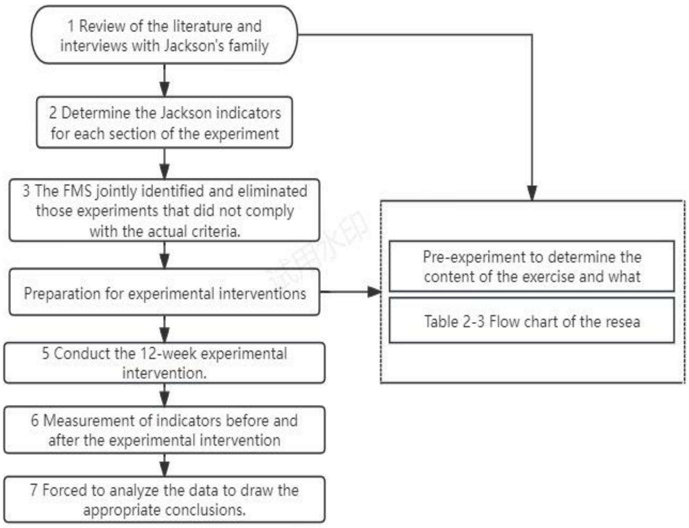


**Figure 2.** Flow chart of the research experiment.

## 2.2. Subjects

The study subjects were 40 male students specializing in sport dance from a university in Yichun, China. Inclusion criteria were as follows: no significant differences in age, height, or weight; familiarity with dynamic stretching techniques; good recent physical condition; no diseases or sports injuries (as determined by FMS screening); and eligibility for the experiment, as confirmed by baseline testing. To provide a more detailed demographic profile, the average age of the group was 21.5 years, with a standard deviation of 1.2 years. The average height and weight of the participants were 175 cm and 68 kg, respectively. Given the potential influence of experience on flexibility values, it is noteworthy that the students had an average of 5.3 years of experience in sports dancing, with a range from 3 to 8 years. The requisite baseline criteria and the content of the necessary personal information, including these additional data points, are presented in **Table 1**.

**Table 1.** List of contents of pre-test subject condition screening.

| type of message | index | concrete content |
|---|---|---|
| Personal information | age | |
| FMS Screen | Squatting | |
| | Stepping | |
| | Lunging | |
| | Reaching | |
| | LegRasing | |
| before measurement | bending | |

The results of the FMS screening of male students specializing in sports dance in the Dance Performance Major of the School of Physical Education of Yichun College in grades 18 and 19 are presented in **Table 1**. Only those who scored 1 or above met the safety criteria for the movement intervention. The study will group the 40 subjects according to the pre-test indicators to ensure that the four groups have balanced indicators at the beginning of the experiment.

## 2.3. Intervention group

A week prior to the commencement of the experiment, all subjects were required to learn the stretching movements and become acquainted with the testing procedure to reduce the influence of the learning effect on the experimental results. Given that the participation of two subjects in yoga clubs might impact the experiment's results, the sample size was adjusted. The control group and the first stretching group were reduced to nine participants each, while the second and third stretching groups maintained ten participants. To ensure the quality of instruction and uniformity across the experiment, it was crucial for the lecturers to possess a comparable level of expertise and to elucidate essential theoretical concepts. Except for the control group, all other groups were required to demonstrate proficiency in all movements associated with dynamic stretching. The movement design, informed by a physical fitness expert, aimed to ensure control, mobility, and limitation of movement while avoiding uncontrolled bouncy stretching. The physical trainer controlled the speed and interval time of the movements, and the physical dance teacher supervised and cooperated to ensure the accuracy and safety of the movements.

During the experimental implementation, male students who had been participating in physical dance training for a considerable length of time were screened for Functional Movement Screen (FMS) to guarantee the safety of the training program, and heart rate monitoring equipment was utilized to track the intensity of the training. The experimental design included a gradual increase in training intensity over a three-month period in a wave-like progression to ensure participants adapted and improved their training. Details regarding heart rate control are presented in **Table 2** to guide adjustments to the training program and ensure its safety and effectiveness.

**Table 2.** Stage heart rate control table.

| Stage | HR (mext/'minute) |
|---|---|
| September-October | 105.48 ± 14.84 |
| October-November | 138.78 ± 18.72 |
| November-December | 145.25 ± 20.88 |

To provide further clarity, the exercises and stretching structures applied for the three experimental groups were as follows: Group 1 focused on lower body dynamic stretches, Group 2 on upper body dynamic stretches, and Group 3 on a combination of both. The dosage of these variants was structured to incrementally increase in intensity, with each session starting with a 10-minute warm-up, followed by 20 min of dynamic stretching, and concluding with a 10-minute cool-down. The increase in intensity was designed to facilitate the application of dynamic stretching without resorting to ballistic stretching, which was avoided due to its potential for injury and lack of control.

## 2.4. Measurement

To measure flexibility in sport dance, we focused on key lower limb indicators:

seated forward bend and fork angles (both horizontal and vertical for each leg).

The testing tools and methods are as follows:

(1) Seated Forward Bend Tester

In order to align with the elevated flexibility standards observed in male students enrolled in physical education and dance programs, the seated forward bending tester from the Chinese National Physical Fitness Standard was selected. This instrument is crafted from ABS engineering plastic to withstand the rigors of testing, and a vernier scale is incorporated to enhance the precision of measurements. The apparatus is depicted in **Figure 3**.

**Figure 3.** Seated forward bend tester.

The following test method will be employed: The students will be directed by the instructor to perform the Seated Forward Bend Test, utilizing a carpeted floor and a heel on the standing board. The legs should be straight, the body bent forward, and both hands should push the baffle to its limit. The instructor supervised the test to prevent uncontrolled bouncing and vibration and requested that the participant perform three controlled pushes of the block, with the maximum value recorded as the result.

(2) 180-degree human joint angle ruler

The joint angle ruler is employed for the measurement of the mobility of human joints. In this experiment, a triangle is formed by the downward fork action, and the angle of the two legs is measured by placing the center of the angle ruler at the bottom of the fibula of the lower leg, with one end parallel to the ground and the other end aligned with the fibula. Subsequently, the hip mobility was calculated by subtracting the aforementioned two angles from 180 degrees. The identical methodology was employed to ascertain the vertical fork angle of the left and right legs. The measuring instrument is illustrated in **Figure 4**.


**Figure 4.** 180 degree human joint angle ruler.

The test method requires that all students, under the direction of the instructor, perform the measurement in a stable and controlled manner. It is essential to ensure that the students are fully stabilized at the lowest point of the fibula, which serves as the reference point for the measurement. Concurrently, the angle of the feet must be recorded, and the hip joint angle is then calculated.

### 2.5. Mathematical and statistical methods

The study employed a three-point data collection approach, with measurements taken at three distinct time points: pre-experimental measurement C1, C2 following the initial dynamic stretching, and C3 at the conclusion of the 12-week experimental period. To assess the data, paired samples t-tests and ANOVA were conducted to compare the The differences between C1, C2, and C3 were analyzed using SPSS 23.0. The comparisons between C1 and C2 were conducted to evaluate the impact of the warm-up, while the comparisons between C1 and C3 were employed to assess the efficacy of the training. The data are presented as mean ± standard deviation (M ± SD), with $P < 0.05$ indicating statistically significant differences and $P < 0.01$ indicating highly significant differences.

## 3. Results

### 3.1. A comparison of the two groups' basic condition tests before the experiment

The objectives of the pre-test were threefold: firstly, to ensure the safety of participants and reduce the risk of injury through the screening of functional movement screenings (FMS); secondly, to group participants according to flexibility and endurance indicators in order to ensure that the four groups commenced the test at the same level; and thirdly, to adjust the groupings according to the test data in order to ensure that the indicator averages were balanced. The results of the FMS screening are detailed in **Table 3**.

**Table 3.** Statistics of FMS screening in the two groups before the experiment ($N$ = 40).

| index | C | DS1 | DS2 | DS3 | *F* | *P* |
|---|---|---|---|---|---|---|
| FMS Screen | 10.30 ± 1.49 | 10.10 ± 2.28 | 11.00 ± 1.70 | 10.45 ± 1.71 | 0.452 | 0.717 |
| Squatting | 1.40 ± 0.51 | 1.60 ± 0.51 | 1.80 ± 0.42 | 1.50 ± 0.53 | 1.180 | 0.331 |
| Stepping | 1.50 ± 0.42 | 1.60 ± 0.51 | 1.40 ± 0.52 | 1.70 ± 0.48 | 1.235 | 0.331 |
| Lunging | 1.60 ± 0.52 | 1.50 ± 0.53 | 1.80 ± 0.42 | 1.90 ± 0.32 | 1.622 | 0.201 |
| Reaching | 1.40 ± 0.52 | 1.50 ± 0.53 | 1.60 ± 0.70 | 1.70 ± 0.48 | 0.526 | 0.667 |
| Leg Raising | 1.40 ± 0.52 | 1.20 ± 0.42 | 1.60 ± 0.52 | 1.50 ± 0.53 | 1.180 | 0.331 |
| Push-up | 1.40 ± 0.52 | 1.20 ± 0.42 | 1.50 ± 0.52 | 1.40 ± 0.52 | 0.640 | 0.594 |
| Rotary Stability | 1.10 ± 0.57 | 1.60 ± 0.52 | 1.40 ± 0.52 | 1.30 ± 0.67 | 1.322 | 0.282 |

Note: * index $P < 0.05$, ** index $P < 0.01$.

Before delving into the specifics of the dynamic stretching intervention, it was crucial to establish a baseline equivalence between the groups. The pre-test data, presented in **Table 3**, indicated no significant differences in functional movement screenings (FMS) and other physical safety indicators across all groups. This baseline equivalence ensures the validity of subsequent comparisons and highlights the homogeneity of the groups at the outset of the experiment.

## 3.2. Analysis of the results of the pre-test screening of experimental safety indicators

Due to the limited space available for the presentation of the four groups in the tables, each group is described in abbreviated form. The blank group is denoted by C, the DS1 group by DS1, the DS2 group by DS2, and the DS3 group by DS3. This same format is used for all tables.

In order to provide a comprehensive understanding of the Functional Movement Screen (FMS) assessments, we have included a detailed description. The FMS is a critical tool in identifying movement patterns and potential compensatory mechanisms that may lead to poor biomechanics and increased risk of injury. Each of the seven fundamental movement patterns assessed by the FMS is designed to challenge different aspects of an individual's mobility, stability, and neuromuscular control.

The FMS assessments included in this table are as follows:

Deep Squat: Tests bilateral, symmetrical functional mobility and stability of the hips, knees, and ankles, as well as shoulder, scapular region, and thoracic spine mobility and stability.

Hurdle Step: Challenges the body's step and stride mechanics, testing stability and control in a single-leg stance, requiring bilateral mobility and stability of the hips, knees, and ankles.

Inline Lunge: Simulates stresses during rotation, deceleration, and lateral movements, challenging hip, knee, ankle, and foot mobility and stability, while demanding spine stabilization.

Shoulder Mobility: Demonstrates the natural complementary rhythm of the scapular-thoracic region, thoracic spine, and rib cage during reciprocal upper-extremity shoulder movements.

Active Straight-Leg Raise: Identifies active mobility of the flexed hip, core stability within the pattern, and the available hip extension of the alternate hip.

Trunk Stability Push-Up: Observes reflex core stabilization, testing the ability to stabilize the spine in the sagittal plane during closed kinetic chain, upper body symmetrical movement.

Rotary Stability: Requires proper neuromuscular coordination and energy transfer through the torso, observing multi-plane pelvis, core, and shoulder girdle stability during combined upper and lower extremity movement.

**Table 3** demonstrates that the *p*-values of all groups are greater than 0.05, indicating comparable levels of physical safety. Furthermore, there is no statistically significant difference in age and FMS screening indexes between groups RT and C. The Rotary Stability manoeuvre is more challenging, with six students scoring a mere 1, making it challenging to maintain the manoeuvre in a stable manner. However, the FMS screening is designed to exclude risk and ensure safety, and all other movements achieved a score of 1 or more, thus meeting the experimental requirements. There was no significant difference between the groups on the seven indicators.

The qualitative analysis of the pre-test screening results reveals that all groups were well-matched in terms of physical safety and readiness for the intervention. This is exemplified by the non-significant *p*-values observed in **Table 3**, indicating that the groups were indeed balanced in their initial conditions.

## 3.3. Analysis of the results of the pre-experimental test for each index of lower limb flexibility quality

In this study, the lower limb flexibility qualities were evaluated using a seated forward body flexion tester and a joint mobility ruler, the specific use of which has been previously described. The flexibility quality test employed in this study utilized two indices: the basic index of seated forward body flexion and the special index of hip joint flexibility (lower fork). Despite the importance of shoulder joint flexibility for sports and dance, it was not included in the test due to the lack of authoritative information and the presence of distinctive characteristics. The comparative analyses of the flexibility quality indicators of the four groups before the experiment are presented in **Table 4**.

**Table 4.** Comparative analysis results of flexibility quality indicators.

| index | C | DS1 | DS2 | DS3 | *F* | *P* |
|---|---|---|---|---|---|---|
| bending(cm) | 11.2 ± 5.7 | 11.3 ± 6.3 | 11.8 ± 6.6 | 12.5 ± 5.8 | 0.090 | 0.065 |
| Left vertical fork (°) | 153..6 ± 12.2 | 155.0 ± 12.4 | 155.8 ± 11.4 | 154.9 ± 11.1 | 0.060 | 0.981 |
| Right vertical fork (°) | 154.4 ± 6.2 | 157.3 ± 10.9 | 156.0 ± 10.4 | 155.2 ± 8.7 | 0.178 | 0.910 |
| parallel split (°) | 138.1 ± 15.8 | 137.7 ± 13.2 | 139.7 ± 17.0 | 137.7 ± 20.5 | 0.032 | 0.992 |

* denotes $P < 0.05$ compared to overall; ** denotes $P < 0.01$ compared to overall.

**Table 4** demonstrates that there was no statistically significant difference between the four groups with regard to the four flexibility quality indicators. It was observed that the majority of students exhibited superior flexibility of the left vertical fork in comparison to the right vertical fork, with the vertical fork angle demonstrating a greater range of motion than the horizontal fork angle. Prior to the commencement of the experiment, the lower limb flexibility quality levels of the four groups were found to be essentially comparable.

## 3.4. Comparative analysis of the immediate effects of lower limb flexibility qualities following different simultaneous durations of dynamic stretching

### 3.4.1. Comparison of the magnitude of change in post-warm-up forward body flexion for different durations of dynamic stretching

The immediate impact of each group after a complete dynamic stretching session exhibited slight alterations at disparate time points. However, notable distinctions emerged in the characteristics of these alterations across different time periods. The changes in specific flexibility qualities are illustrated in **Figure 5**.

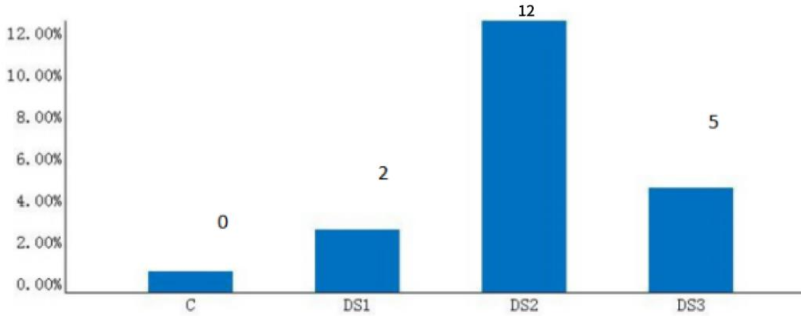


**Figure 5.** An overview of the magnitude of change in seated forward bending for each group after a single dynamic stretching session.

**Figure 5** illustrates that the degree of forward body flexion increased in all four groups. However, the Stretch 2 group exhibited the most pronounced improvement, at least twice that of the other groups. The control group demonstrated a modest enhancement due to their early arrival and exposure to the surrounding environment. The three dynamic stretching groups demonstrated notable improvement, with Stretch 2 exhibiting the most pronounced outcomes, followed by Stretch 1 and then Stretch 3. As a preliminary indicator of flexibility, 20 min of dynamic stretching proved to be the most effective, while 10 min was slightly less effective, suggesting that 20 min represents the optimal duration for stretching.

### 3.4.2. Comparison of the magnitude of change in the vertical fork after warm-up for different durations of dynamic stretching

The vertical fork is an important indicator of hip and leg flexibility, and is commonly included in the assessment of professional dancers. The amplitude of the vertical fork is typically greater than that of the horizontal fork. However, due to the difference in dominance between the right and left feet, physical dance trainers often demonstrate a slight discrepancy in the level of the left and right vertical forks, with the left foot typically exhibiting a slightly greater amplitude of the vertical fork. Furthermore, dynamic stretching in the warm-up has been observed to exert disparate effects on the two types of vertical forks. In this experimental setup, the dynamic stretching movements were designed to be symmetrical between the left and right sides, and the specific effects on the vertical forks are illustrated in **Figure 6**.

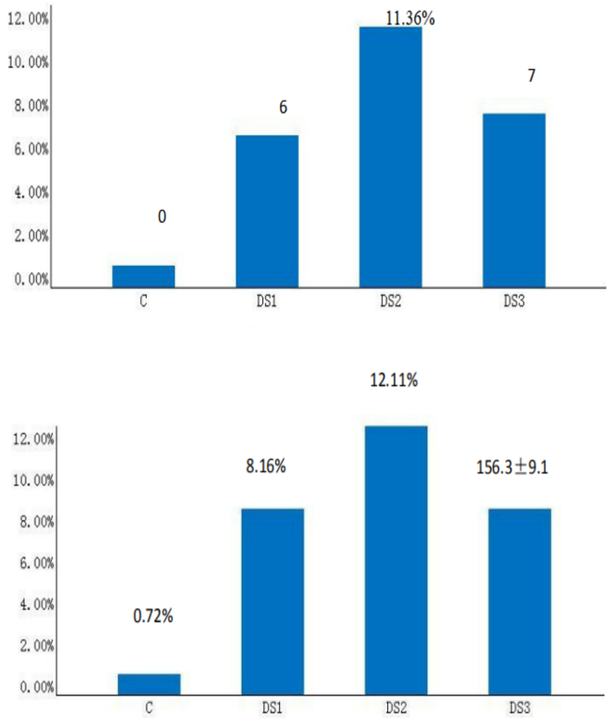


**Figure 6.** List of changes in the left and right vertical forks of each group after one dynamic stretching.

**Figure 6** illustrates that the vertical fork level was elevated following dynamic stretching, with improvement observed in all groups except the blank group. The most notable elevation was observed in stretch 2, while similar elevations were noted in stretches 1 and 3. This suggests that 10-minute and 30-minute stretches were comparable in terms of improvement of the vertical fork. The right vertical fork exhibited a slight but statistically significant improvement compared to the left vertical fork. However, 20 min of stretching proved to be the optimal duration for both the left and right forks.

The horizontal fork represents the most challenging flexibility quality index for physical education dance students, with improvement involving the inner thigh and calf muscles. **Figure 7** illustrates the changes in the transverse forks after dynamic stretching. To assess the impact of different durations of stretching on the transverse forks, it is essential to evaluate the difference in body sensation of the movements on both sides of the body, with the aim of promoting balanced development.

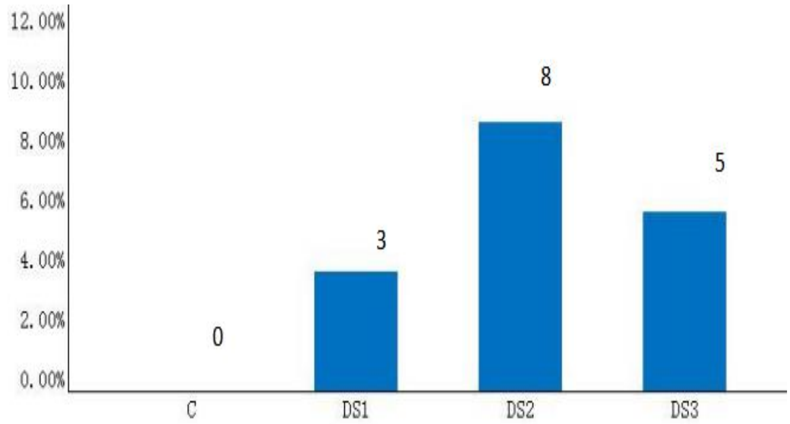


**Figure 7.** Overview of the magnitude of change of each group of transverse forks after one dynamic stretching.

**Figure 7** illustrates that the level of transverse forks exhibited an improvement following dynamic stretching; however, the magnitude of this improvement was less pronounced than that observed for the other indicators. This suggests that transverse forks may be more challenging to enhance. The improvement effect was ranked by duration as 20 min > 30 min > 10 min, with 20 min stretching identified as the optimal warm-up duration for all flexibility indicators, although the improvement effect was not as significant as the other indicators. The training of transverse forks is an important indicator of success in a dance profession, and the optimal dynamic stretching warm-up duration for all flexibility indicators in this study was 20 min.

The immediate effects of dynamic stretching sessions on lower limb flexibility are notably pronounced, with the 20-minute group demonstrating superior performance across all key indicators. For instance, the 20-minute dynamic stretching group showed a significant increase in seated forward bend and fork angles compared to the other groups. This suggests that a moderate duration of dynamic stretching may be optimal for enhancing flexibility in male sport dancers.

### 3.5. Posttest cross-sectional comparative analysis of lower limb flexibility qualities between the four groups

The three-month dynamic stretching and physical dance training programmer was conducted in a blinded design, with balanced starting groupings. This allowed for a direct comparison of the post-test data C3 of the groups, thus enabling an assessment of the effect of the intervention. The optimal duration of dynamic stretching training may be determined by cross-sectional comparison of the relevant indicators.

The basic flexibility quality indicators, such as seated forward bending, were selected based on information such as the Interpretation of the National Physical Fitness Standard for Students, which reflects the flexibility of the hip joint and lower limbs. The analysis of variance (ANOVA) demonstrated that, in comparison to the control group, all experimental groups exhibited an increase in forward body flexion following the three-month dynamic stretching intervention, with the greatest improvement observed in the stretching 2 and stretching 3 groups. This finding suggests that a dynamic stretching regimen exceeding 20 min in duration can significantly enhance forward body flexion.

The results presented in **Table 5** demonstrate that dynamic stretching training has a beneficial impact on enhancing the quality of lower limb flexibility. Furthermore, the duration of the training regimen is a crucial factor influencing the efficacy of this intervention.

**Table 5.** Comparison of posttest results of body forward bending index among groups ($N = 38$).

| group | C | DS1 | DS2 | DS3 |
|---|---|---|---|---|
| Bending (cm) | 11.6 ± 5.8 | 13.7 ± 5.0 | 17.2 ± 7.5* | 20.7 ± 3.6** |
| *F* | 5.089 | | | |
| *P* | 0.005 | | | |

Note: *P*-value less than 0.05 indicates significant difference, and very significant difference is indicated by **.

In dance for sport, both skills and aesthetics are of importance, and the quality of lower limb flexibility is of particular significance in determining athletic performance. This study examined the lower fork as a specialized quality in addition to the basic index of seated forward body flexion. Although lower limb flexibility encompasses the ankle and knee joints, this study concentrated on the hip and thigh muscle groups, utilizing the left vertical fork, right vertical fork, and horizontal fork as indicators. As evidenced by the data displayed in **Table 6**, the dynamic stretching group exhibited elevated levels of left vertical fork in comparison to the blank group. However, only the stretching 3 group yielded statistically significant results. Overall improvement was limited, with the best results observed in the stretching 3 group.

**Table 6.** Comparison of left fork index posttest results by group ($N = 38$).

| group | C | DS1 | DS2 | DS3 |
|---|---|---|---|---|
| Left vertical fork (°) | 154.5 ± 11.5 | 159.4 ± 9.4 | 162.2 ± 9.4 | 162.8 ± 5.3* |
| *F* | | 1.698 | | |
| *P* | | 0.185 | | |

As there are inherent left-right asymmetries within the human body, including a tendency for the heart to be positioned on the left side, as well as a natural dominance of the right arms and legs, coupled with the impact of lifestyle habits and patterns of movement that affect body equilibrium, the dynamic stretching design of this study prioritizes left-right balance. However, the precise execution of the movements involved may vary due to differences in muscle group and joint mechanics. The findings regarding the right vertical fork will serve to validate this hypothesis.

*P*-value less than 0.05 indicates a significant difference. Significant differences between each group and the blank group in the LSD post-hoc test are denoted by *, and highly significant differences are denoted by **.

**Table 7** demonstrate that dynamic stretching had a beneficial impact on the left vertical fork, with a notable distinction between the stretch 2 and stretch 3 groups in comparison to the blank group ($p < 0.01$). Conversely, there was no statistically significant difference observed in the stretch 1 group ($p > 0.05$). The 30-minute stretching intervention following the 3-month period demonstrated the most pronounced effect on the right vertical fork, with the 20-minute and 30-minute interventions also exhibiting a statistically significant impact. Conversely, the 10-minute stretching intervention did not yield a notable enhancement in the right vertical fork, Suggests that the 10-minute stretch has limited lift on the right vertical fork.

**Table 7.** Comparison of posttest results of right fork indicators among groups ($N$ = 38).

| group | C | DS1 | DS2 | DS3 |
|---|---|---|---|---|
| Right vertical fork (°) | 155.1 ± 6.6 | 158.1 ± 10.9 | 166.9 ± 2.3** | 165.5 ± 4.6** |
| *F* | | | 6.895 | |
| *P* | | | 0.001 | |

*P*-value less than 0.05 indicates a significant difference. Significant differences between each group and the blank group in the LSD post-hoc test are denoted by *, and highly significant differences are denoted by **.

**Table 8** demonstrate that dynamic stretching had a beneficial impact on the transverse forks, with notable distinctions between the Stretch 2 and Stretch 3 groups and the blank group ($P$ < 0.01). Conversely, the Stretch 1 group exhibited no statistically significant divergence from the control ($P$ > 0.05). The transverse fork demonstrated notable improvement with 30 min of stretching identified as the optimal duration, with 10 min of stretching proving less efficacious.

**Table 8.** Comparison of post-test results of cross-talk indicators among groups ($N$ = 38).

| group | C | DS1 | DS2 | DS3 |
|---|---|---|---|---|
| Transverse Fork (°) | 139.2 ± 14.2 | 140.9 ± 13.8 | 153.4 ± 4.9** | 154.5 ± 5.6** |
| *F* | | | 5.801 | |
| *P* | | | 0.002 | |

*P*-value less than 0.05 indicates a significant difference. Significant differences between each group and the blank group in the LSD post-hoc test are denoted by *, and highly significant differences are denoted by **.

A comprehensive analysis of the basic and specialized flexibility quality indicators revealed that the optimal training duration for dynamic stretching was 30 min. This duration had a significant lifting effect on forward bends, right vertical and horizontal forks, and a relatively weak lifting effect on left vertical forks. It is therefore recommended that attention be paid to the left-right balance of movements and muscle firing during dynamic stretching training, with a view to reducing left-right discrepancies and optimizing performance in sports and dance.

From the **Table 9**, Summarizing the post-intervention results, the 20-minute and 30-minute dynamic stretching groups outperformed the control and 10-minute groups in terms of flexibility enhancement. The practical implication of this finding is that incorporating dynamic stretching into warm-up and training routines can significantly improve lower limb flexibility, which is crucial for sport dance performance. The 20-minute dynamic stretching during warm-ups and 30-minute sessions during training were particularly effective, aligning with the recommendations for enhancing dance technique and reducing injury risk.

**Table 9.** Effect of dynamic stretching duration on flexibility qualities (M ± SD).

| Indicator | Group | Pre-exercise intervention | Post-exercise intervention | F/*P* 组间 | F/*P* 时间 | F/*P* 组间 × 时间 |
|---|---|---|---|---|---|---|
| SR | C | 11.2 ± 5.7 | 11.6 ± 5.8 | 1.771/0.170 | 36.641 | 6.419 |
| | DS1 | 11.3 ± 6.3 | 13.7 ± 5.0 | | /0.000 | /0.001 |
| | DS2 | 11.8 ± 6.6 | 17.2 ± 7.5 | | | |
| | DS3 | 12.5 ± 5.8 | 20.7 ± 3.6 | | | |
| CF | C | 138.1 ± 15.8 | 139.2 ± 14.2 | 1.101/0.361 | 22.574/0.000 | 4.439/0.009 |
| | DS1 | 137.7 ± 13.2 | 140.9 ± 13.8 | | | |
| | DS2 | 139.7 ± 17.0 | 153.4 ± 4.9 | | | |
| | DS3 | 137.7 ± 20.5 | 154.5 ± 5.6 | | | |
| VF(L) | C | 153..6 ± 12.2 | 154.5 ± 11.5 | 0.522/0.670 | 23.352/0.000 | 2.229/0.102 |
| | DS1 | 155.0 ± 12.4 | 159.4 ± 9.4 | | | |
| | DS2 | 155.8 ± 11.4 | 162.2 ± 9.4 | | | |
| | DS3 | 154.9 ± 11.1 | 162.8 ± 5.3 | | | |
| VF(R) | C | 154.4 ± 6.2 | 155.1 ± 6.6 | 1.584/0.210 | 32.012/0.000 | 8.052/0.000 |
| | DS1 | 157.3 ± 10.9 | 158.1 ± 10.9 | | | |
| | DS2 | 156.0 ± 10.4 | 166.9 ± 2.3 | | | |
| | DS3 | 155.2 ± 8.7 | 165.5 ± 4.6 | | | |

## 4. Discussion

### 4.1. Discussion of the effect of different dynamic stretching durations on lower limb flexibility qualities

Our experimental data revealed significant improvements in at least three flexibility indicators after three months of all stretching programs. This finding aligns with previous research by Behm et al. [3], which also observed enhancements in flexibility following dynamic stretching interventions. The statistically significant differences between groups and time point comparisons, as well as the interaction effects, indicate that the intervention modality influences the trajectory of flexibility change [12,13]. While longer durations of dynamic stretching have been suggested to improve flexibility, our results did not support this, suggesting that the optimal duration for dynamic stretching may vary and is specific to the individual and the activity [5,14]. This discrepancy could be due to the specific characteristics of the individuals and the activities they engage in, as highlighted in studies like the one by Takeuchi et al. [6].

### 4.2. Discussion of the effect of dynamic stretching on the warm-up effect of flexibility qualities

The findings of this study indicate that a five-minute jog followed by dynamic stretching is a more effective warm-up than a static stretching routine, which is consistent with the narrative review by Behm [3]. Our results demonstrate that a 20-

minute warm-up is optimal for dynamic stretching, which may be associated with the extent of specialization in the combination of stretching movements and test metrics. Although longer periods of dynamic stretching may improve flexibility, our findings suggest that targeted dynamic stretching of 20 min exerts a beneficial impact on flexibility conditioning [15,16]. This aligns with the endurance conditioning results observed in previous studies, such as the one by Yamaguchi et al. [5].

### 4.3. Discussion of the effect of dynamic stretching on the training effect of flexibility qualities

The selection of stretching techniques and movement combinations should consider the specific characteristics of the individual. Our study investigated the impact of whole-body dynamic stretching on the lower limb flexibility of male physical education dance students [17]. The findings indicated that a 30-minute dynamic stretching regimen demonstrated more pronounced effects, which is in line with the study by Takeuchi et al. [6]. Additionally, dynamic stretching plays a pivotal role in enhancing the performance of fast short-distance running and jumping, as evidenced by studies like the one by Robles-Palazón et al. [11]. The discrepancy in study outcomes may be attributed to various factors, including training level, movement differences, and environmental influences [18,19].

Limitations of the study include a relatively small sample size and the lack of female participants, which may limit the generalizability of the results [20]. Future studies should aim to include larger and more diverse samples to address these limitations and provide a more comprehensive understanding of the effects of dynamic stretching on flexibility [21].

Practical implications of our findings suggest that dynamic stretching can be effectively incorporated into sports dance training to enhance flexibility and performance [22]. Coaches can benefit from these findings by designing warm-up and training sessions that include dynamic stretching, focusing on durations that have been shown to be most effective in our study.

## 5. Conclusion

Dynamic stretching is an effective way to improve lower limb flexibility. The best results are seen when dancers perform dynamic stretches for 20 min during warm-ups and 30 min during training sessions. Although the effects are not as immediate as static stretching, consistent dynamic stretching sessions of over 20 min can lead to significant improvements in flexibility.

To optimize the benefits of dynamic stretching in sports dance, the following practical recommendations are proposed for coaches:

Incorporate 20-minute dynamic stretching routines in warm-up sessions: Start with whole-body movements that gradually increase in intensity, followed by specific lower limb dynamic stretches. This will effectively prepare dancers for intense physical activity by enhancing blood circulation and muscle elasticity.

Implement 30-minute dynamic stretching sessions during training: Include a mix of stretching exercises targeting different muscle groups, focusing on those critical for dance movements (e.g., hip flexors, hamstrings, calves). A longer stretching session during training helps to progressively enhance flexibility and performance in complex dance techniques.

Focus on symmetry by balancing exercises between the left and right limbs: Incorporate exercises that specifically target weaker or less flexible sides to address any existing asymmetries. This will help dancers achieve more balanced and controlled performances, reducing the likelihood of injury due to muscular imbalances.

Avoid excessive ballistic movements during stretching: Emphasize controlled and fluid dynamic stretches rather than rapid, bouncing motions. This approach minimizes injury risk and maximizes flexibility gains. Encourage dancers to perform each movement in a deliberate and steady manner, focusing on range of motion rather than speed.

Monitor progress and adjust the routine accordingly: Track individual flexibility improvements and adapt the dynamic stretching routine to ensure continual progress. For dancers struggling with flexibility, consider incorporating additional targeted stretching or complementary strength training exercises.

These recommendations provide a framework for sports dance coaches to design effective training programs that enhance flexibility, reduce injury risk, and improve overall dance performance. By implementing structured and targeted dynamic stretching routines, coaches can help dancers achieve optimal physical readiness and performance quality.

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**Ethical approval:** The study was conducted in accordance with the Declaration of Helsinki. The studies involving humans were approved by University Ethics Committee of Jeonbuk National University (JBNU2022-01-004-002). Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

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