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THE EFFECT OF DIFFERENT TYPES OF WARM-UP PROTOCOLS ON THE RANGE OF MOTION AND ON MOTOR ABILITIES OF RHYTHMIC GYMNASTICS ATHLETES AND BALLET DANCERS

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Abstract The aim of this study was to examine the short-term effects of different types of warming up on the range of motion and on motor abilities of rhythmic gymnasts and ballet athletes. Twenty-five athletes participated in this study (11 ballet dancers and 14 rhythmic gymnasts), aged 14,72 ±1,43. All participants followed an intervention consisting of two warm-up protocols, one with static stretching exercises and the other with dynamic warm up protocol. The two protocols were implemented on two different days for one week. Range of motion (ROM) and hop test measurements were carried out before and after each warm-up session. For the statistical analysis, non-parametric (Wilcoxon) tests and Friedman test were used, and the level of significance was set at $p < 0.05$. The results showed that both warm-ups had positive effects on ROM and on motor abilities. After applying both protocols, significant differences were observed in all joints. In conclusion, both types of warm-up routines resulted in almost the same level of improvement in ROM and motor abilities; however, it was observed that after the dynamic warm up there was a slightly increased improvement in motor abilities, but it was not statistically significant.

Key words: rhythmic gymnastics, ballet, range of motion, motor abilities

Introduction

Warming up is a widely accepted form of exercise that precedes almost any sporting activity. The effect of warm up on performance has been examined since the 1930s as to whether and how much it contributes to improving athletic performance. It is a critical factor used by athletes during training and competition to prevent injury and properly prepare the individual for the activity ahead (Bishop, 2003; Bishop & Maxwell, 2009).

Two basic types of warm-ups have prevailed, static and dynamic; this distinction usually refers to the type of stretching exercises which are used (Behm & Chaouachi, 2011). Stretching is commonly used by athletes as a part of their conventional warm- up routine, especially in sports requiring the ability to move fluidly through an extensive range of motion (ROM) (Ferri-Caruana et al., 2020). Several researchers dealt with the static forms of stretching, specifically: the technique (Davis et al., 2005), the duration (Ford et al., 2005), the number of repetitions (Cipriani et al.,2003), program duration (Chan et al., 2001), frequency (Medina et al., 2007) and location of stretching (Decoster et al., 2004). The duration of static stretching (SS) remains debatable. Some researchers argue that the stretching protocol should be done within 15 minutes before the basic training for optimal results, while others lay emphasis on stretching after the training session (Kay & Blazevich, 2012).

The application of SS during the warm-up is likely to affect the performance. Evidence supports that SS may be detrimental if applied immediately prior to performance (Behm & Chaouachi, 2011). In their studies, Cramer et al. (2004) and Cramer et al. (2005), reported that when SS was performed on the dominant leg there was a decline in the torque and motor unit activation as well as reductions in the peak power output in both stretched and non-stretched legs. The inhibitory mechanism of the central nervous system must be at least partially responsible for these observed changes. According to Cramer et al. (2005), decrements in performance after SS are the result of a combination of mechanical and neural factors. Neurologically, SS appears to be related to muscle activation (McHugh & Cosgrave, 2010). In another research by Peck et al., (2014) it has been found that the combination of SS with dynamic exercises, activation exercises or specialized exercises for each sport, reduces or even reverses their negative effect on performance.

Research also reports that there are a few sports with intense SS across the range of motion (Murphy et al., 2010) which demonstrate that flexibility improves statically and contributes to increased performance. For instance, rhythmic gymnastics, where the athletes take different positions of full stretch, martial arts, synchronized swimming, figure skating and ice hockey. SS is regarded as the most suitable for increasing the length of the gluteal tendon and therefore, are the ones that can bring about the highest values to the range of hip flexion (ROM) (Herman & Smith, 2008).

A dynamic warm-up appears to increase both long-term (>5 min) and intermediate performance (>10 s, but <5 min) if athletes are allowed to begin the ensuing procedure in a relatively rested state, due to increased oxygen consumption (Bishop, 2003; Fletcher, 2010). Mechanically, the effects of dynamic stretching (DS) lead to a reduction in the muscle-tendon unit stiffness (Witvrouw et al., 2004). DS and coordination exercises can be incorporated into the warm-up routine. Studies report that DS lead to an increase in static flexibility which is similar to SS (Behm & Chaouachi, 2011). On the contrary, other studies have shown that DS are not as effective in increasing static flexibility as SS. Therefore, more oriented dynamic routines are suggested before training for performance enhancement and tissue health (Behm & Chaouachi, 2011; Herman & Smith, 2008).

Rhythmic gymnastics is an artistic sport like gymnastics, figure skating, synchronized swimming and acrobatics (Fernandez-Villarino et al., 2013). It aims at harmony, the perfect execution of the movement in combination with the musical accompaniment. Rhythmic gymnastics includes body elements and instrument handling, the performance of which is determined by the International Code of Points (Zasada et al., 2016; Donti et al., 2014).

A successful ballet career requires the dancer to be both flexible and strong. The basic ballet movements are the plie and the turnout. These movements are the basis from which a lot of other movements, such as jumps and bouncing (Grossman, & Wilmerding, 2000). Dancers are known to have a good physical condition and shapely bodies, as well as a wide range of motion in their joints, which is a great advantage in many types of dances (Turner & Wainwright, 2003; McCormak, 2004). Flexibility is an important aspect of good physical condition in dancers and a high level of flexibility is necessary to meet the choreographic demands made on them today.

Rhythmic gymnasts and ballet dancers are all about flexibility and must also have a wide range of motion especially in the hip joints (Donti et al., 2014; Wyon et al., 2013). The aim of this study was to examine the short-term effects of different types of warm-ups on the range of motion and on motor abilities of rhythmic gymnastics and ballet athletes. Such information may assist in determining the applications and limitations of various stretching techniques and programs in flexibility-trained athletes.

Materials and Methods

Study design

To achieve the objectives of this study, a prospective, observational study was carried out in which a convenience sample of 25 female ballet dancers and rhythmic gymnasts were analyzed. The following inclusion criteria of the target population were used: (1) being a ballet dancer with more than 7 years of experience; (2) being a rhythmic gymnastics athlete with more than 7 years of competitive participation. The duration of each testing lasted a week, more specifically, 3 days of the week with 2 days of resting between each phase. The purpose of the first day was to familiarize the subjects with the process and the requirements of the intervention; during the second phase, the athletes performed the protocol with the static stretching exercises; during the third phase they performed the protocol with the dynamic stretching exercises. The warm-up protocol included exercises on the barre, in the center and dynamic elements with rotation of approximately 40 minutes' duration. Prior and after each warm-up protocol, ROM and motor abilities were measured. The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the School of Physical Education and Sport Science Aristotle University of Thessaloniki (GRI-2017-18764).

Participants

A total of thirty female participants volunteered to participate in the study: fifteen classical dancers from a private dancing school with more than 7 years of ballet experience and fifteen rhythmic gymnasts with more than 7 years of participation. The young girls did not have any musculoskeletal problems or any serious injury for one month prior to their participation. Five female athletes who did not complete the study procedure were excluded. The final sample for evaluation was 11 rhythmic gymnasts and 14 ballet dancers, aged 13 to 17. The female athletes participated in the research after obtaining written consent from their parents and oral consent from the examiners. All participants received introductory comments about the rationale of the research, the utilization of the data, the themes, and the objects to be pursued. Verbal instructions regarding the research process were also given.

Prior to the data collection, the participants' parents provided a signed consent form allowing their child's participation in the study.

Anthropometric measurements

The weight and height of the female athletes was measured using a Microlife WS80 electronic scale and a SECA216 height meter, respectively. The participants' BMI was calculated (kg/m^2). Body fat percentage [FM (%)] was estimated using four skinfolds (triceps, supra-iliac, abdomen, and thigh), according to the equation, described by McArdle (Katch, & Mcardle, 1973).

Flexibility Assessment

In the study, ROM during hip flexion, knee flexion, and dorsiflexion of the ankle joint was examined by an experienced examiner. All measurements were made with the help of the Myrin goniometer, according to the method introduced by Ekstrand et al. (1982). We collected the data from the best performance. All measurements, apart from the ankle dorsiflexion, were performed on the floor on a soft mattress.

The subject was placed in supine position and the leg was lifted (hip flexion and keeping the knee extended and ankle in neutral position) the other leg as well as the pelvis were stabilized by the examiner. The subjects were asked to actively lift the limb to reach the maximum ROM of the leg to be tested. An experienced examiner held and pressed the limb of the subject from neutral to extreme position, as defined by the American Academy of Orthopedic Surgeons which recorded the value of joint range of motion in degrees. The Myrin was placed on the greater trochanter (Noyes et al., 1991). This passive movement of the joint in its extreme position was performed to the point at which the examiner felt the maximum resistance of the lengthening muscle groups, as determined by Ferber et al. (2002) without the subject feeling discomfort or muscle pain.

To measure the quadriceps stretch it is recommended that the subject lie in prone position with the lower extremity in a neutral position. The examiner stands beside the subject, at the side of the leg that will be tested. One hand should be on the lower back, the other holding the leg at the heel. Passively flex the knee in a slow fashion. The heel should touch the gluteus maximus. In order to measure the range of the flexion, the same procedure is followed as before.

Ankle dorsiflexion ROM was measured using a weight-bearing lunge facing a wall. The weight-bearing lunge was performed in a standing position with the heel in contact with the ground, the knee in line with the second toe, and the big toe 10 cm away from the wall. Participants were asked to lunge forward, directing their knees toward the wall (in line with the second toe) until their knees touched the wall. Once the knee was not able to touch the wall, the foot was moved gradually toward the wall until the knee touched the wall with the heel in contact with the ground. While the subject maintained her maximal dorsiflexion position, a standard goniometer was aligned with the floor and through the shaft of the fibula by visually bisecting the lateral malleolus and the fibular head (Konor et al. 2012).

Hop tests

Specific hop tests were implemented to check the stability of the knee joints, which are mainly used in the rehabilitation of people after injury. Additionally, these tests also assess strength and balance (Noyes et al. 1991). Dance requires bounces and jumps, so balance tests are of particular interest when evaluating dancers.

We evaluated four one-legged function tests: single hop and triple hop for distance, cross-over hop and 6 meters in a given time. The four tests are illustrated in Figure 1.

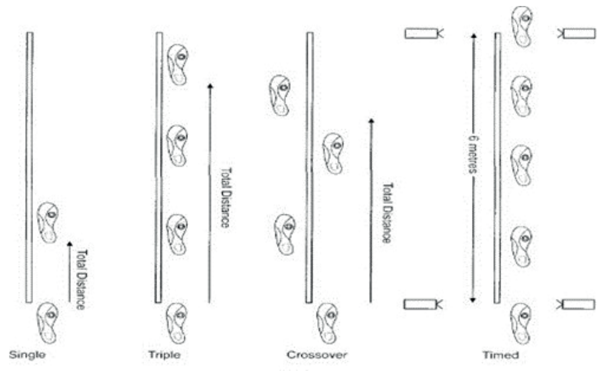

Figure 1. Hop tests

A 6-m long, 15-cm wide line was marked on the floor, along the middle of which was a standard tape measure, perpendicular to the starting line. Subjects performed 2 trials of each hop test, and the best performance was used for the evaluation. Both limbs were tested, and no restrictions were given to subjects regarding the use of arm movement.

For the single hop, athletes were required to hop forward as far as possible along the line of the tape measure and land on the same limb. The triple hop involved participants performing 3 consecutive maximal hops along the line of the tape measure. In the crossover hop test, the time needed to cover a 6 m distance hopping a 15-cm-wide line alternatively from one side to the other, was used for evaluation. In 6-m timed hop, participants hopped on one leg forward to cover a 6-meter distance as quickly as possible and the time they needed was measured. Distance was measured from the starting line to the rear of the foot upon final landing.

Warm-up protocol

According to the warm-up protocol, the two groups had to perform ballet barre and center exercises adapted to static and dynamic stretching (Table 1). The type of training method of this study was based on the Vaganova system, which was a classical ballet technique named after its creator, the Russian ballet dancer (Vaganova, 2012).

Table 1. Warm-up protocol: the exercises performed by the groups are presented in detail below

Centre	Barless execution mode with the same exercises STATIC WARMUP	Barless execution mode with the same exercises DYNAMIC WARM UP
Plié	Standstill for 15 sec in the 4 positions of feet 3 reps in each position	3 reps in the 4 positions of feet
Battement tendu	Standstill for 15 sec in each position for the exercise performance	3 reps in each position
Battement jete	Standstill for 15 sec in each position for the exercise performance	3 reps in each position
Rond de jambe par térre	Slow execution of the exercise staying 15'' in each position	Fast execution 3 reps in each position
Battement Fondu	Slow execution of the exercise staying 15'' in each position	Fast execution 3 reps in each position
Rond de jambe en l' air	Slow execution of the exercise staying 15'' in each position	Fast execution 3 reps in each position
Battement frappé	Standstill for 15 sec in each position for the exercise performance	3 reps in each position for the exercise performance
Adagio	Slow execution of the exercise staying 15'' in each position	Fast execution 3 reps in each position
Grand Battements	Slow execution of the exercise staying 15'' in each position	Fast execution 3 reps in each position
Jumps & Leaps		
Echappe chaute	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Assemble I	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Assemble II	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Petit Jetes	3 reps after landing still in the plie position for 10 sec	3 reps in each position
Grand jete	1 rep after landing still at plie for 10 sec	3 reps in one try extending different leg each time

Data analysis

Statistical analysis was performed using the statistic packet SPSS version 26.0. The quantitative variables were evaluated as mean ± standard deviation (SD). At baseline all dependent variables, regarding the hop tests and range of motion, were found to be not normally distributed using the Kolmogorov-Smirnov tests of normality. For this reason and because of the small number of participants, we applied non- parametric methods. Wilcoxon test was used to evaluate variables' differences, between baseline and after intervention. When the independent variable had three groups Friedman test was used for the analysis. Statistical significance was reported at $p < 0.05$.

Results

Anthropometric and physiological characteristics of ballet dancers and rhythmic gymnasts group are presented in Table 2.

Table 2. Physical characteristics of ballet dancers

	Ballet dancers (n = 11)	Rhythmic gymnasts (n = 14)
Age (years)	15.4 ±1.2	13.86 ±1.03
Weight (kg)	52.1 ±5.7	36.0 ±7.2
Height (cm)	1.60 ±0.05	1.43 ±0.86
Body Fat	9.91 ±0.55	7.71 ±2.14
Body mass index (kg/m^2)	20.13 ±1.8	17.41 ±1.86
Data are mean & standard deviation (SD)		

Regarding the ballet group, significant improvements were observed after the intervention of SS warm up in the single hop test (Figure 2) and triple hop test (Figure 3), $Z = -2.934$ & $p < 0.05$ and $Z = -1.987$ & $p < 0.05$ respectively. Similar results were also observed before and after the intervention of DS warm up in the single (Figure 2) and triple hop test (Figure 3), $Z = -2.938$ & $p < 0.05$ and $Z = -2.401$ & $p < 0.05$ respectively.

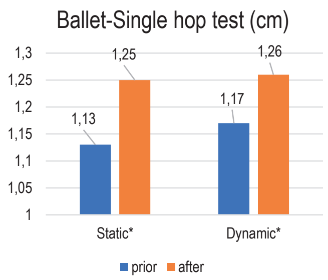

Figure 2. Single hop test prior and after the interventions of SS and DS warm up protocols
*p < 0,05.

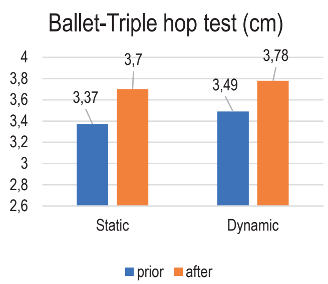

Figure 3. Triple hop test prior and after the interventions of SS and DS warm up protocol

Significant differences were not observed prior and after the intervention of SS warm up in the crossover hop test (Figure 4) and 6m hop test (Figure 5), Z = –0.535 & p > 0.05 and Z = –1.826 & p > 0.05 respectively. Similarly, there were no significant differences before and after the intervention of DS warm up in the crossover (Figure 4) and 6m hop test (Figure 5), Z = –0.711 & p > 0.05 and Z = –0.653 & p > 0.05 respectively.

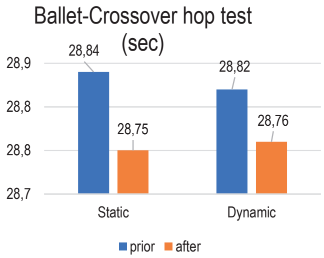

Figure 4. Crossover hop test, prior and after the interventions of SS and DS warm-up protocols

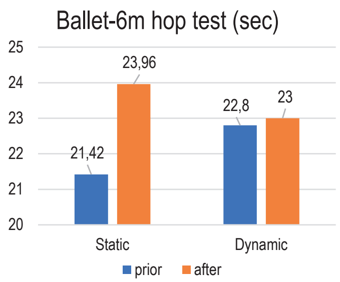

Figure 5. 6m hop test, prior and after the interventions of SS and DS warm-up protocols

Regarding the rhythmic gymnastics group, significant differences were not observed prior and after the intervention of SS warm up in the single hop test Z = –1.455 & p > 0.05 (Figure 6). However, significant improvement was observed in the triple hop test, Z = –3.110 & p < 0.01 (Figure 7). Before and after the intervention of DS warm up significant improvement was observed in the single hop test, Z = –3,299 & p < 0.001 (Figure 6), and no differences in triple hop test, Z = –1,689 & p > 0.05 (Figure 7).

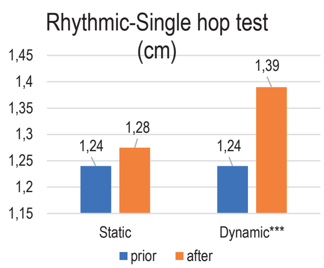

Figure 6. Single hop test, prior and after the interventions of SS and DS warm-up protocols
***p < 0,001

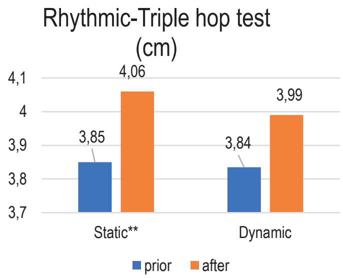

Figure 7. Triple hop test, prior and after the interventions of SS and DS warm-up protocols
**$p < 0,01$

Significant differences were not observed prior and after the intervention of SS warm-up in the crossover hop test (Figure 8) and the 6m hop test (Figure 9), with Z = –0.094 & p > 0.05 and Z = –1.036 & p > 0.05 respectively. Similarly, there were no significant differences before and after the intervention of DS warm-up in the crossover (Figure 8) and the 6m hop test (Figure 9), with Z = –1.783 & p > 0.05 and Z = –0.126 & p > 0.05 respectively.

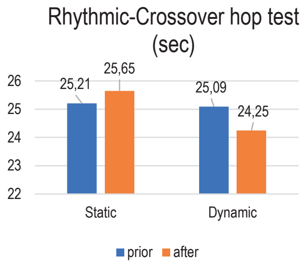

Figure 8. Crossover hop test, prior and after the interventions of SS and DS warm-ups

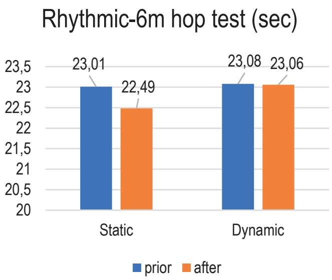

Figure 9. 6m hop test, prior and after the interventions of SS and DS warm-ups

The ROM (biceps, quadriceps, ankle joint) was assessed before and after SS and DS warm-ups. Friedman test was used to estimate the potential differences between them. Regarding the ballet group, the results drawn from the measurements showed significant improvements after both interventions in the biceps, X2 = 15.805 & p < 0.001. From these measurements significant improvements were also found after both interventions in quadriceps, X2 = 6,348 & p < 0.05, and in ankle joint, X2 = 11.474 & p < 0.001 (Figure 10).

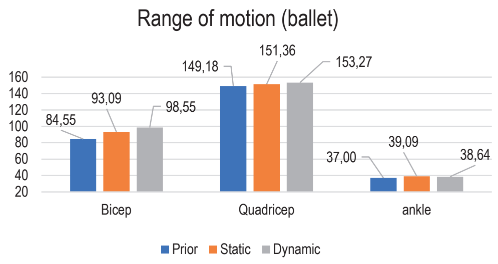

Figure 10. Range of motion assessment before and after SS and DS warm- ups, for ballet group

Similarly, the results from the rhythmic group showed significant improvements after both interventions in biceps, X2 = 24.500 & $p < 0.001$, with range of motion in biceps being significant grater after the DS warm-up than after the SS warm-up, Z = –2.929 & $p < 0.01$. Significant improvements after both interventions were also found in quadriceps, X2 = 12.000 & $p < 0.01$, and in ankle joint, X2 = 9.250 & $p < 0.05$ (Figure 11).

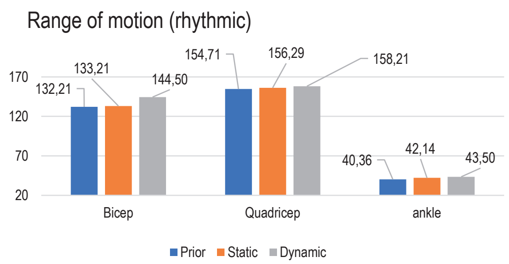

Figure 11. Range of motion assessment before and after SS and DS warm-ups, for rhythmic group

Discussion

The purpose of this study was to examine the effect of two different forms of warm-up protocols on joint mobility and motor abilities of female rhythmic gymnastics and ballet athletes. The results of the present study, show that joint mobility of ballet and rhythmic gymnastics athletes as well as their motor abilities improved with both warm-up protocols. Specifically, in the ballet group, an increase in joint mobility was observed in all joints that were measured after the application of both protocols. The rhythmic gymnastics group showed an increase in joint mobility in the extension of the hip and ankle joint after the application of both protocols. However, an increase in knee flexion was observed only after the dynamic warm-up in both groups.

The results of this study cannot be directly compared with previous research. Nevertheless, there are some studies that raise the same issues as this project but with different populations or with a different warm-up protocol (DiCagno et al., 2010; Samson et al., 2012). A statistically significant difference was found in all joints with both protocols. Moreover, both warm-up protocols seem effective in terms of joint mobility with a statistically significant difference for both groups.

DiCagno et al. (2010) in their research with thirty-eight female rhythmic gymnasts, support that when SS is included in the warm-up, it has a negative effect on technical jumps by 7% and a reduction in vertical jumps. However, having used the hop tests in the warm-up, their results showed an increase after SS and an increase in contact time. Examination of our data from the hop test agree with this study since they showed an increase in contact time and distance after measuring single leg support jumps.

After the general warm-up and SS for up to 30 sec, a specific warm-up combination of SS and DS was applied and an increase in joint mobility was observed (Samson et.al, 2012). It has been found that the combination of SS with DS, activation exercises or specialized exercises for each sport, reduces, or even reverses their negative effect on performance (Peck et al., 2014). Similarly, Perrier et al. (2011) suggest that SS and DS are equally effective in improving hamstring flexibility performance. Thus, DS may be particularly beneficial in sports requiring a combination of flexibility and explosive force because it appears to provide the greatest performance benefits without sacrificing acute flexibility in the process. Lima et al. (2016) also examined the combination of SS and DS on strength and muscular fatigue between ballet dancers and resistance trained women after testing them with sit-and-reach and quadriceps ROM tests. Both groups improved similarly with pre fatigue tests compared to posttests following both stretching types. The findings of our research agree with these studies, since the results of functional tests and joint mobility combined with the warm-up protocol had positive effects on both groups.

Several of our finding's present similarities with the study of McNair and Stanley (1996) who studied the effect of SS. The results showed a beneficial effect on people engaged in sports activities. Additionally, it was observed that, after SS, the joint mobility of the ankle joint increased. In our research, an increase in the ankle joint was also observed, although the difference was not statistically significant; in the ballet group it was slightly greater after both types of warm up whereas in the rhythmic gymnastics group it was slightly greater only after the dynamic warm-up.

A significant amount of research shows that in various parameters of maximum performance, the short-term effect of SS in the warm-up is negative (Behm & Kibele, 2007; Caruana et al., 2020). For that reason, it is recommended that SS be avoided before physical exercise that requires speed, power, and muscle strength. Caruana et al. (2020) defined the long-term effect of the dynamic ROM stretching technique and SS on vertical jump performance in female acrobatic gymnasts. They found that when the long-term dynamic ROM stretching exercises are applied during warm-ups, they result in a slight increase in vertical jump performance compared to SS.

Also, Lima et al. (2016), suggested that stretching decreases hamstrings strength, similarly in ballet dancers and resistance-trained women, with no differences between modes of stretching. Regarding the outcomes of the present research, the rhythmic gymnastics team presented negative results after the dynamic warm-up, specifically in the hop test, the cross over test and the 6-meter test, in terms of time performance. A dynamic warm-up does not affect sprint performance but may reduce explosive power. Additionally, the female athletes obtained a negative result, possibly due to fatigue. Bacurau et al. (2009), used 20 min of ballistic stretch activities and reported a 2.2% decrease in leg press 1-RM and a 5%–7% decrease in knee flexion and extension 1-RMs, respectively (likely fatigue related).

Faigenbaum et al. (2005) after three different SS warm-up protocols, observed a decrease in the vertical jump by 6.5% and 1.9% in the long jump, as well as a decrease in flexibility by 2.6% after all three SS warm-ups. Research suggests that improvement in lower extremity peak strength and power can occur after years of flexibility training (Behara, & Jacobson, 2015; Hartmann et al., 2015).

Conclusions

Our findings demonstrate that the warm-up protocols had a positive effect on ballet dancers and rhythmic gymnasts. However, it was observed that the SS warm-up had a better application in ballet dancers whereas, the DS warm up had a greater impact on rhythmic gymnasts. Possibly with a larger sample the results would be more strengthened. The utilization of hop tests may be of particular interest for further research in the assessment of dancers.

References

Bacurau, R. F. P., Monteiro, G. A., Ugrinowitsch, C., Tricoli, V., Cabral, L. F., & Aoki, M. S. (2009). Acute effect of a ballistic and a static stretching exercise bout on flexibility and maximal strength. *The Journal of Strength & Conditioning Research*, *23*(1), 304–308.

Behara, B., & Jacobson, B. H. (2017). Acute effects of deep tissue foam rolling and dynamic stretching on muscular strength, power, and flexibility in division I linemen. *Journal of Strength & Conditioning Research*, *31*(4), 888–892.

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., & Kibele, A. (2007). Effects of differing intensities of static stretching on jump performance. *European Journal of Applied Physiology*, *101*, 587–594.

Bishop, D. (2003). Warm up II: performance changes following active warm up and how to structure the warm-up. *Sports Medicine*, *33*, 483–498.

Bishop, D., & Maxwell, N. S. (2009). Effects of active warm up on thermoregulation and intermittent-sprint performance in hot conditions. *Journal of Science and Medicine in Sport*, *12*(1), 196–204.

Chan, S. P., Hong, Y., & Robinson, P. D. (2001). Flexibility and passive resistance of the hamstrings of young adults using two different static stretching protocols. *The Scandinavian Journal of Medicine & Science in Sports*, *11*(2), 81–86.

Cipriani, D., Abel, B., & Pirrwitz, D. (2003). A comparison of two stretching protocols on hip range of motion: implications for total daily stretch duration. *The Journal of Strength & Conditioning Research*, *17*(2), 274–278.

Cramer, J. T., Housh, T. J., Johnson, G. O., Miller, J. M., Coburn, J. W., & Beck, T. W. (2004). Acute effects of static stretching on peak torque in women. *The Journal of Strength & Conditioning Research*, *18*(2), 236–241.

Cramer, J. T., Housh, T. J., Weir, J. P., Johnson, G. O., Coburn, J. W., & Beck, T. W. (2005). The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. *European Journal of Applied Physiology*, *93*, 530–539.

Davis, D. S., Ashby, P. E., McCale, K. L., McQuain, J. A., & Wine, J. M. (2005). The effectiveness of 3stretching techniques on hamstring flexibility using consistent stretching parameters. *Journal of Strength and Conditioning Research*, *19*(1), 27–32.

Decoster, L. C., Scanlon, R. L., Horn, K. D., & Cleland, J. (2004). Standing and supine hamstring stretching are equally effective. *Journal of Athletic Training*, *39*(4), 330.

Di Cagno, A., Baldari, C., Battaglia, C., Gallotta, M. C., Videira, M., Piazza, M., & Guidetti, L. (2010). Preexercise static stretching effect on leaping performance in elite rhythmic gymnasts. *The Journal of Strength & Conditioning Research*, *24*(8), 1995–2000.

Donti, O., Tsolakis, C., & Bogdanis, G. C. (2014). Effects of baseline levels of flexibility and vertical jump ability on performance following different volumes of static stretching and potentiating exercises in elite gymnasts. *Journal of Sports Science & Medicine*, *13*(1), 105.

Ekstrand, J. W. M. O., Wiktorsson, M., Oberg, B., & Gillquist, J. (1982). Lower extremity goniometric measurements: a study to determine their reliability. *Archives of Physical Medicine and Rehabilitation*, *63*(4), 171–175.

Faigenbaum, A. D., Bellucci, M., Bernieri, A., Bakker, B., & Hoorens, K. (2005). Acute effects of different warm-up protocols on fitness performance in children. *The Journal of Strength & Conditioning Research*, *19*(2), 376–381.

Ferber, R., Osternig, L. R., & Gravelle, D. C. (2002). Effect of PNF stretch techniques on knee flexor muscle EMG activity in older adults. *Journal of Electromyography and Kinesiology*, 12(5), 391-397.

Fernandez-Villarino, M. A., Bobo-Arce, M., & Sierra-Palmeiro, E. (2013). Practical skills of rhythmic gymnastics judges. *Journal of Human Kinetics*, *39*(1), 243–249.

Ferri-Caruana, A., Roig-Ballester, N., & Romagnoli, M. (2020). Effect of dynamic range of motion and static stretching techniques on flexibility, strength and jump performance in female gymnasts. *Science of Gymnastics Journal*, *12*(1), 87–100.

Fletcher, I. M. (2010). The effect of different dynamic stretch velocities on jump performance. *European Journal of Applied Physiology*, *109*, 491–498.

Ford, G. S., Mazzone, M. A., & Taylor, K. (2005). The effect of 4 different durations of static hamstring stretching on passive knee-extension range of motion. *Journal of Sport Rehabilitation*, *14*(2), 95–107.

Grossman, G., & Wilmerding, V. (2000). Dance physical therapy for the leg and foot: Plantar fasciitis and Achilles tendinopathy. *Journal of Dance Medicine & Science*, *4*(2), 66–72.

Hartmann, H., Wirth, K., Keiner, M., Mickel, C., Sander, A., & Szilvas, E. (2015). Short-term periodization models: effects on strength and speed-strength performance. *Sports Medicine*, *45*, 1373–1386.

Herman, S. L., & Smith, D. T. (2008). Four-week dynamic stretching warm-up intervention elicits longer-term performance benefits. *The Journal of Strength & Conditioning Research*, *22*(4), 1286–1297.

Katch, F. I., & McArdle, W. D. (1973). Prediction of body density from simple anthropometric measurements in college-age men and women. *Human Biology*, 445–455.

Kay, A. D., & Blazevich, A. J. (2012). Effect of acute static stretch on maximal muscle performance: a systematic review. *Medicine & Science in Sports & Exercise®*, *44*(1), 154–164.

Konor, M. M., Morton, S., Eckerson, J. M., & Grindstaff, T. L. (2012). Reliability of three measures of ankle dorsiflexion range of motion. *International Journal of Sports Physical Therapy*, *7*(3), 279.

Lima, C. D., Brown, L. E., Wong, M. A., Leyva, W. D., Pinto, R. S., Cadore, E. L., & Ruas, C. V. (2016). Acute effects of static vs. ballistic stretching on strength and muscular fatigue between ballet dancers and resistance-trained women. *Journal of Strength & Conditioning Research*, *30*(11), 3220–3227.

McCormack, M. O. I. R. A., Briggs, J., Hakim, A., & Grahame, R. (2004). Joint laxity and the benign joint hypermobility syndrome in student and professional ballet dancers. *The Journal of Rheumatology*, *31*(1), 173–178.

McHugh, M. P., & Cosgrave, C. H. (2010). To stretch or not to stretch: the role of stretching in injury prevention and performance. *Scandinavian Journal of Medicine & Science in Sports*, *20*(2), 169–181.

McNair, P. J., & Stanley, S. N. (1996). Effect of passive stretching and jogging on the series elastic muscle stiffness and range of motion of the ankle joint. *British Journal of Sports Medicine*, *30*(4), 313–317.

Medina, F. S., Andújar, P. S. D. B., García, P. R., Miñarro, P. L., & Jordana, M. C. (2007). Effects of frequency of static stretching on straight-leg raise in elementary school children. *Journal of Sports Medicine and Physical Fitness*, *47*(3), 304–308.

Murphy, J. R., Di Santo, M. C., Alkanani, T., & Behm, D. G. (2010). Aerobic activity before and following short-duration static stretching improves range of motion and performance vs. a traditional warm-up. *Applied Physiology, Nutrition, and Metabolism*, *35*(5), 679–690.

Noyes, F. R., Barber, S. D., & Mangine, R. E. (1991). Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *The American Journal of Sports Medicine*, *19*(5), 513–518.

Peck, E., Chomko, G., Gaz, D. V., & Farrell, A. M. (2014). The effects of stretching on performance. *Current Sports Medicine Reports*, *13*(3), 179–185.

Perrier, E. T., Pavol, M. J., & Hoffman, M. A. (2011). The acute effects of a warm-up including static or dynamic stretching on countermovement jump height, reaction time, and flexibility. *The Journal of Strength & Conditioning Research*, *25*(7), 1925–1931.

Power, K., Behm, D., Cahill, F., Carroll, M., & Young, W. (2004). An acute bout of static stretching: effects on force and jumping performance. *Medicine & Science in Sports & Exercise*, *36*(8), 1389–1396.

Samson, M., Button, D. C., Chaouachi, A., & Behm, D. G. (2012). Effects of dynamic and static stretching within general and activity specific warm-up protocols. *Journal of sports science & medicine*, *11*(2), 279.

Turner, B. S., & Wainwright, S. P. (2003). Corps de ballet: The case of the injured ballet dancer. *Sociology of Health & Illness*, *25*(4), 269–288.

Vaganova, A. (2012). *Basic principles of classical ballet*. Courier Corporation.

Witvrouw, E., Mahieu, N., Danneels, L., & McNair, P. (2004). Stretching and injury prevention: an obscure relationship. *Sports Medicine*, *34*, 443–449.

Wyon, M. A., Smith, A., & Koutedakis, Y. (2013). A comparison of strength and stretch interventions on active and passive ranges of movement in dancers: a randomized controlled trial. *The Journal of Strength & Conditioning Research*, *27*(11), 3053–3059.

Zasada, S., Zasada, M., Kochanowicz, A., Niespodzinski, B., Sawczyn, M., & Mishchenko, V. (2016). The effect of specific strength training on the quality of gymnastic elements execution in young gymnasts. *Baltic Journal of Health and Physical Activity*, *8*(4), 79–91.

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