EFFECT OF DYNAMIC RANGE OF MOTION AND STATIC STRETCHING TECHNIQUES ON FLEXIBILITY, STRENGTH AND JUMP PERFORMANCE IN FEMALE GYMNASTS

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Original article

Abstract
The aim of this study was to determine the long term effect of dynamic range of motion (DROM) stretching technique and static stretching (SS) on hip range of motion (ROM), hip isometric strength and vertical jump performance in female gymnasts. In a randomized controlled trial eighteen gymnasts (age 13 ± 2 years) were assigned to a DROM group (n= 9) or SS group (n=9). Participants were assessed at baseline and again at completion of the intervention on: hip extensión (HE), hip flexion (HF), 1RM isometric HF strength, squat jump (SJ) and split leap (SL). Results: DROM group improved statistically from pre- to post-test in right leg HE ROM (13.67 ± 4.7 vs. 21.22 ± 5.2), right leg HF ROM (129.9 ± 9.9 vs. 139.0 ± 10.4), hip isometric strength for the right leg (2.0 ± 1.1 vs. 4.7 ± 1.6) and the left leg (1.7 ± 0.7 vs. 4.1 ± 1.6). Jump performance was not affected by type of stretching. Significance was set at 0.05 (2-tailed) for all analyses. DROM was more effective in improving gymnastic performance variables than SS. Such information may assist in determining the applications of various stretching techniques in flexibility-trained female athletes.

Key words: *Dynamic range of motion, gymnasts, young, performance, female.*

INTRODUCTION

Stretching is commonly used by athletes as a part of their conventional warm-up routine, specially in sports requiring the ability to move comfortably through a large range of motion (ROM)(Sands, Caine, & Borms, 2003). Among all stretching techniques, static stretching (SS) has been the most common technique used in warm-up routines, however it has been criticised for impairing muscular performance (i.e. muscle power, sprint time and jump height) (Behm & Chaouachi, 2011). Therefore, more oriented dynamic techniques are recommended before activity for tissue health and performance improvement (Behm & Chaouachi, 2011; Schleip & Müller, 2013).

The acute and chronic effect of SS on ROM is well stablished (Donti et al., 2018; Guissard & Duchateau, 2004; Knudson, 2006; Siatras, Papadopoulos, Mameletzi, Gerodimos, & Kellis, 2003; Yuktasir & Kaya, 2009). The acute effects of SS on ROM are primarily atributed to an increased stretch tolerance (Magnusson, 1998), as well as to changes in the passive stiffness of the musculotendinous unit. On the contrary, long-term extensibility of muscles due to stretching has been attributed to changes in fascicle length and pennation angle (Franchi, Atherton, Maganaris, & Narici, 2016; Freitas, Andrade, Larcoupaille, Mil-homens, & Nordez, 2015; Simpson, Kim, Bourcet, Jones, & Jakobi, 2017). Although the effects of SS on ROM in various joints are widely scientifically supported, its effects on injury prevention (Pope, Herbert, Kirwan, & Graham, 2000; Small, Mc Naughton, & Matthews, 2008; Thacker, Gilchrist, Stroup, & Kimsey Jr, 2004; Weldon & Hill, 2003) and improvement of physical performance have been questioned.

The dynamic range of motion (DROM) technique is an active self-stretching method during which, a contraction by the antagonist muscle causes the joint crossed by the agonist muscle to move through the full ROM at a controlled, slow tempo (Murphy, 1994). DROM is a technique that takes advantage of reciprocal innervation. It begins from a neutral position, followed by a slow movement (4-5 seconds) of the limb to end range, a brief hold at end range (4-5 seconds), and, finally, slowly (4-5 seconds) moving the limb back to the original neutral position using an eccentric contraction. Most studies on DROM are focused on its short and long term effect on hamstring flexibility (Abdel-aziem, Draz, Mosaad, & Abdelraouf, 2013; Askar, Pais, Mohan, Saad, & Shaikhji, 2015; Davis, Ashby, McCale, McQuain, & Wine, 2005; Nishikawa et al., 2015), however there is a lack of research regarding its influence on sports performance.

In artistic gymnastics, the high performance demands entail a great technical requirement in which optimal combinations of muscle strength, balance and flexibility are essential. In this line, SS is the most common stretching technique used in gymnastics, however it has been showed detrimental before leaping performance (Di Cagno et al., 2010) and during run of vault (Batista Santos, Lemos, Lebre, & Ávila Carvalho, 2015) . In the last years research has focused on the short term effect of SS compared with other stretching modalities (i.e. dynamic stretching, propioceptive neuromuscular facilitation, whole body vibration) to increase flexibility and jumping performance in gymnastics (G. Dallas et al., 2014; George Dallas & Kirialanis, 2013; Donti, Tsolakis, & Bogdanis, 2014; Kinser et al., 2008; Morrin & Redding, 2013) . However, with the exception of Donti et al. (Donti et al., 2018), who studied the effect of two different SS techniques (continuos vs intermittent) on the ROM enhancement and vertical jump, no studies have examined the long term effect of other dynamic stretching technique compared to SS in gymnastics. Furthermore, there is a growing need for studies in females and this study addresses this gap in the literature. Since DROM stretching is a more natural way to elongate the muscle because of CNS engaging motor control and strength at end of ROM, it might be a more functional and specific method than SS for sports requiering large ROM movements.

The aim of the present investigation was to determine whether, hip ROM and isometric strength, vertical jump and technical leap is influenced by long term SS or DROM stretching training when applied as a part of a warm-up routine in female gymnasts. Such information may assist in determining the applications and limitations of various stretching techniques and programs in flexibility-trained athletes.

METHODS

This is a longitudinal and experimental study aim to assess the effects of DROM versus SS techniques on specific performance variables in young female gymnasts. It was hypothesized that DROM stretching would present more beneficial effects on hip ROM and isometric strength compared to SS, and would be less detrimental for jump performance than SS.

For this purpose, eighteen female participants from a club of gymnastics were randomly assigned to a SS group (n= 9) or a DROM group (n= 9). During 7 weeks and 4 times a week, DROM group performed DROM exercises, while SS group perfomed SS exercises. Participants were assessed at baseline and again at 7 weeks on: hip flexion (HF) ROM, hip extensión (HE) ROM, 1RM isometric HF strength, squat jump (SJ) and split leap (SL). All participants were right leg dominant.

The selection of the 20 gymnasts was performed through a non-probabilistic, accidental type sampling. Inclusion criteria comprised: being a gymnast with a minimun of 4 years experience, willing to train a minimum of 10 hours a week, competing at the regional or national level and not presenting any diagnosed illness and / or injury.

Subjects and their parents were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. Approval for the study was obtained from the Ethics Committee at the University of Valencia (H1542280432742/13-12-2018), in accordance with the 1975 Declaration of Helsinki.

Due to injury, there were two dropouts, therefore 18 gymnasts were finally included in the study. The characteristics of the participants were as follows: age (13 ± 2 y), body height (150 ± 10 cm), and body weight (39.8 ± 8.7 kg), hours of training per week (13 ± 2 h) and years of practice (7 ± 2 y). No significant baseline differences were found between groups in terms of age, weight, height, hours/week practice or years of experience.

Prior to each stretching training intervention and tests measurements a standardized warm-up was performed, including 5 min of jogging at 60% of maximal heart rate measured with heart rate monitors

During the 7 weeks of intervention, both groups performed the same gymnastics training, except for the 30-min flexibility training. SS group continued performing the usual SS technique which was characterized by being pasive and continuos. Exercises (Table 1) were perfomed alternatively and always in the same leg order (right and left).

Table 1
Exercises performed in the static stretching protocol.

Exercise	Hip Motion	Reps x time (sec)	Total Time (min)
Split (bench) Posterior knee bent	Hip Flexion and Extension	1 x 90 (R) 1 x 90 (L)	6
Split (bench) Posterior knee extended		1 x 90 (R) 1 x 90 (L)	6
Penché		1 x 90 (R) 1 x 90 (L)	6
Abduction lying supine on bench with elastics	Abduction	2 x 90	3

**R: Right; L: Left; sec: seconds.*

Stretching exercises included: i.) 3 exercises addressing hip flexion (HF) and hip extension (HE): split supporting the front leg on a bech and back knee extended (Fig.1) and flexed, and penché with elastics and, ii) 1 exercise addressing hip abduction (HA): lying supine on a bench, legs in extension perform abduction with elastics (Fig.2).

Figure 1. Static Stretching exercise: Split supporting the front leg on a bench and back knee extended.

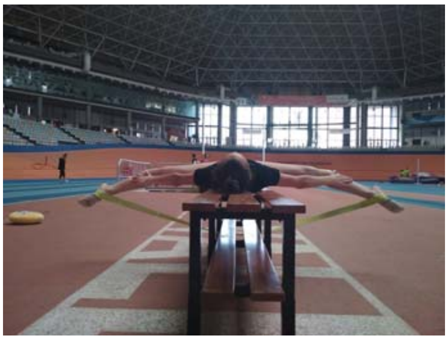

Figure 2. Static Stretching: Abduction exercise with elastics.

The total SS time was 21 min. Subjects were familiar with this stretching movement as they performed it regularly in their flexibility programs.

The DROM exercises included in the study to address the same joints than SS were: i) 6 exercises adressing HF and HE: lying supine on the floor HF (Fig.3) and HE with hip neutral, external and internal rotation, 2 exercises adressing HA: lying supine HA with hip in neutral (Fig.4) and external rotation. For HF, HE and HA double of exercises were selected since the SG stretched both legs at the same time in all exercises, while DROM exercises implied to work one leg at a time.

Figure 3. Dynamic range of motion exercise: Hip flexion lying supine on the floor.

Figure 4. Dynamic range of motion exercise: Hip Abduction with hip in neutral.

Each stretch was performed at a very slow pace: 5 seconds for the concentric and eccentric phase, and 5 seconds for the isometric phase (end ROM position) (Askar et al., 2015; Bandy & Irion, 1994; Murphy, 1994). The isometric phase was carried out at a level of subjectively achieve 90% of the point of discomfort, where 0 represents “no stretch discomfort” and 100% the “maximum imaginable stretch discomfort”. Each DROM exercise took 15 s. Since we wanted to work a similar stretching exercises and time than SS, each exercise was performed 5 times at each hip motion. The total amount of DROM stretching time was 20 minutes. Table 2 show the exercises chosen for the DROM protocol.

Table 2.
Exercises performed in the dynamic range of motion protocol.

Hip Motion	Leg	Reps x time (sec)	Total Time
Flexion + IR	R	5x 15	7 min 30 sec
	L	5x 15	
Flexion + ER	R	5x 15	
	L	5x 15	
Flexion + Neutral	R	5x 15	
	L	5x 15	
Extension + IR	R	5x 15	7 min 30 sec
	L	5x 15	
Extension + ER	R	5x 15	
	L	5x 15	
Extension + Neutral	R	5x 15	
	L	5x 15	
Abduction + Neutral	R	5x15	5 min
	L	5x15	
Abduction + ER	R	5x15	
	L	5x15	

**R: Right; L: Left; sec: seconds; ER: External rotation; IR: Internal rotation*

Since large ROM movements occur at flexibility-trained athletes and different planes of movement were applied in the exercises, a helper was needed to guide the movement without any active intervention on it.

Both stretching protocols were controlled by two technical coaches and one strength and conditioning coach. All DROM participants received one familiarization session (40 min) one day previous to the intervention protocol.

The gymnasts were asked to wear tight sports clothes, especially for the lower part of the body, in order to facilitate the location of the anatomical regions in the analysis of the videos with the Kinovea software. Both measurment tests took place at the time of day.

Before testing, we proceeded to measure weight (a model NMP scale, of 6mm tempered glass with accuracy of ± 100 g and capacity up to 180 kg) and height of the gymnasts.

For the measurement of jumping height, distance from greater trocanter to big toe in full plantar flexion (lying supine) and distance from greater trochanter to floor, from the standing in squat position, a flexible and roll-up measuring tape (350cm long and 3cm wide of the JUNGEN brand) was used.

The tests were applied in the following order: i.) Hip extension lying prone with knee bent 90º. The three anatomical points to measure the angle were: greater trochanter, initial and final position of head of fibula bone; ii.) Hip flexion lying supine with leg extended and neutral spine. The three anatomical points to measure the angle were: greater trochanter, initial and final position of head of fibula bone; iii.) Split leap with back leg in extension. A double step was made previous the split leap. Flying time was measured; iv.) Squat jump. The gymnast had to place the legs shoulder width apart, the arms in jug and the knees flexed to 90º. All subjects made three attempts (30 s rest between jumps), all of them were analyzed to keep the best mark; v.) 1 RM Isometric hip flexion strength. The gymnast in the supine position with HF at 90º and dorsiflexion of the ankle. It was carried out by means of a Mutronic CTSR 100 load cell (Mutronic S.A, Madrid, Spain) which was connected to a monitor. The cell was placed on the subject by means of a hook attached to the malleoli of the ankle. The gymnast performed a 3 seconds maximum HF strength, while the researcher held the load cell.

For ROM measurement, one digital camera was placed 3 meters away, perpendicular to hip point and 10 cms height. The Kinovea Video Analysis Software (v.0.8.15) was used to measure joints angles during the test movements. We used 2D video analysis to measure ROM, as opposed to goniometer, for two reasons: firstly, it has become very common as a simple, inexpensive, and reliable alternative for researchers, rehabilitation professionals, and coaches to investigate athletes' ROM (Damsted, Nielsen, & Larsen, 2015; Elrahim, Embaby, Ali, & Kamel, 2016) and secondly, data obtained from this method would be more reproductible since coaches were used to capture videos and analyzed them at Kinovea`s to provide inmediate feedback to gymnasts in order to improve performance. Reflective motion analysis markers were placed on: greater trochanter, lateral malleolus of the fibular bone and styloid process of the ulna bone.

The same person was responsible for placing the marks to all participants and made sure they did not move or detached from the skin during the performance of body movements.

The app My jump 2 (v.3.6) (Balsalobre-Fernández, Glaister, & Lockey, 2015) was used for SJ and SL measurement. It has been validated with almost perfect reliability compared to platform forces, being considered the gold standard for measuring jump height (Balsalobre-Fernández et al., 2015; Gallardo-Fuentes et al., 2016). It was installed on an Xiaomi Redmi 4X with the version of the operating system Android 6.0 Marshmallow (Xiaomi, Inc., Pekín, China).

The load cell with a tensile and compression force sensor, 1000 N capacity and a measurement error of 1%, was used to obtain the 1RM isometric HF strength.

The load cell was connected to a monitor (Mutronic Sp 51 HiLine) to observe the values of the force applied. An ankle wrap with a hook was used to join the load cell to the subject`s ankle (Fig. 5).

Figure 5. Maximal isometric hip flexion strength measured with a load cell.

A goniometer Baseline® HiRes™ 360º ISOM (STFR) with the accesory 12-1016 (Fabrication Enterprises, Inc. Baseline Absolute Axis Attachment) was used to measure 90º hip flexion from the horizontal plane in the supine lying position.

The storage of the information and analysis was performed on a Lenovo ideapad 520S with the version of the operating system Windows 10 Home (Lenovo Group Ltd. Hong Kong, China).

All data are presented as mean ± SD unless otherwise stated. Assumptions of normal distribution, sphericity of data and covariate analysis were checked accordingly. Greenhouse-Geisser correction to the degrees of freedom was applied when violations to sphericity were present. Given the variability in the Pre-test intervention, one way ANCOVAs were used to assess if there were differences at post-test between the two groups (DROM vs. SS) for HE ROM, HF ROM, 1RM HF isometric strength, SJ flight height and SL flight time. Where ANCOVAs` assumptions were violated Mixed 2 x 2 (Group by Time) ANOVAs were used.

Significance was set at 0.05 (2-tailed) for all analyses. The effect sizes for one way ANCOVAs and repeated measure ANOVA`s were calculated as partial eta squared (n^2p), using the small = 0.02, medium = 0.13 and large = 0.26 interpretation for effect size.

All data analysis was conducted using the statistical packages for social science (SPSS Version 20).

RESULTS

In the ROM HE performed with the right leg (Fig. 6), there was a significant group x time interaction ($F_{(1,16)}$= 7.29 p = 0.016, n_p^2 = 0.31). Follow-up tests revealed that SS group did not change significantly from pre- to post-test (16.77 ± 3.8 vs. 18.67± 3.6 degrees), however, mean values for the DROM group increased significantly at post-test (13.67 ± 4.7 vs. 21.22 ± 5.2). Analysis of Ancova showed no significant statistical differences in post-intervention ROM HE with the rigth leg between the groups when adjusted for pre-intervention ROM HE with the right leg (p= 0.062).

Likewise, in the ROM HE performed with the left leg, no significant interaction was detected ($F_{(1,16)}$= 0.77 p=0.4 n_p^2=0.05). However, there was a significant main effect of time ($F_{(1,16)}$= 13.85, p=0.002 n_p^2=0.46) showing an increase in both groups from pre- to post-test. Analysis of Ancova showed no significant statistical differences in post-intervention ROM HE with the left leg between the groups when adjusted for pre-intervention ROM HE with the left leg (p= 0.43).

Regarding ROM HF no significant interaction was detected ($F_{(1,16)}$= 0.89 p= 0.36 n_p^2= 0.05) for the right leg neither for the left leg ($F_{(1,16)}$= 1.91 p= 0.19 n_p^2= 0.11). However, there was a significant main effect of time for the right leg ($F_{(1,16)}$ = 7.38, p=0.15 n_p^2=0.32) and also for the left leg ($F_{(1,16)}$ = 16.82, p=0.01 n_p^2=0.51). Both legs showed an increase in both groups from pre- to post-test.

Regarding ROM HF for the right leg (Fig. 7) there was a significant group x time interaction ($F_{(1,16)}$=6.46, p=0.022 n_p^2 = 0.29). Follow up test revealed that SS group decreased 2.6 % from pre to post-test, while mean values for the DROM group increased 6.5% from pre- to post-test. Analysis of Ancova showed significant statistical differences in post-intervention ROM HF with the right leg between the groups when adjusted for pre-intervention ROM HE with the left leg (p menor 0.005).

Regarding ROM HF for the left leg (Fig.7) no significant interaction was detected ($F_{(1,16)}$= 1.55, p= 0.23 n_p^2 = 0.09). However, there was a significant main effect of time ($F_{(1,16)}$= 15.36, p=0.01 n_p^2=0.49) showing an increase in both groups from pre- to post-test, and group ($F_{(1,16)}$= 10.35, p=0.05 n_p^2=0.40). Analysis of Ancova showed no significant statistical differences in post-intervention ROM HF with the left leg between the groups when adjusted for pre-intervention ROM HF with the left leg (p= 0.37).

There was a significant group x time interaction on 1RM Isometric HF for the right leg F (1,16)= 9.54 p = 0.007, n_p^2 = 0.37) and the left leg F (1,16)= 12.73 p = 0.003, n_p^2 = 0.44) (Fig. 7). Follow-up tests revealed that SS group did not change significantly from pre- to post-test (1.2 ± 0.5 vs. 2.7± 0.7), however, mean values for the DROM increased significantly at post-test (2.0 ± 1.1 vs. 4.7 ± 1.6) when performed with the right leg. When performed with the left leg, SS did not change significantly from pre- to post-test (1.1 ± 0.4 vs. 2.0 ± 0.9), however, mean values for the DROM increased significantly at post-test (1.7 ± 0.7 vs. 4.1 ± 1.6) (Fig.8).

No significant group x time interaction was found for SJ ($F_{(1,16)}$=0.54, p=0.47 n_p^2 = 0.03). However, there was a significant main effect of time F (1,16)=11.97, p=0.003 n_p^2= 0.43, showing an increase in both groups from pre- to post-test.

No significant group x time interaction was found for SL ($F_{(1,16)}$=1.03, p=0.32 n_p^2 = 0.06). However, there was a significant main effect of group (F (1,16)=8.38, p=0.11 n_p^2= 0.34) on SL performance. The main values (SD) for the DS and SS were: at pre test 0.41 (0.07) seconds vs. 0.36 (0.04) seconds, at the pos test 0.42 (0.06) seconds vs. 0.34 (0.05) seconds. Jump performance was not affected by type of stretching.

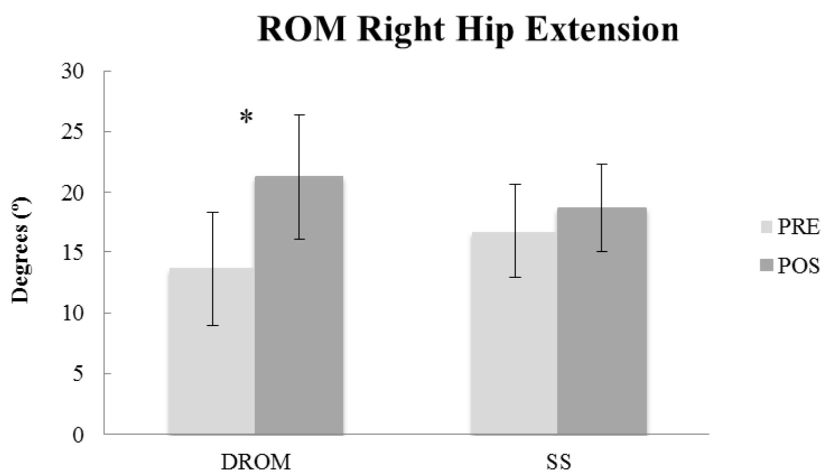

Figure 6 . ROM Right Hip extension of the DROM and SS at pre and post-test.
* Significant difference between groups (p < 0.05).

A) B)

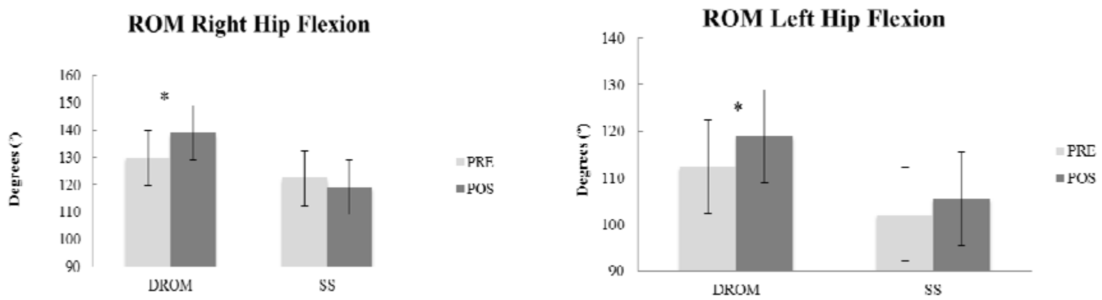

Figure 7. ROM right (A) and left (B) hip extensión at pre- and post-test in DROM and SS groups.

A) B)

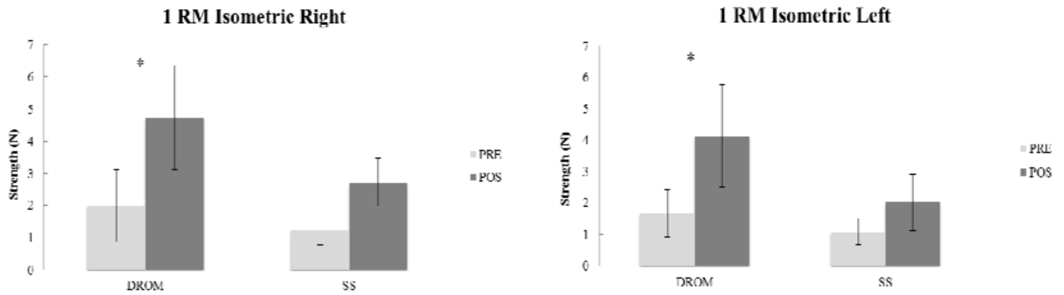

Figure 8. 1RM Isometric right (A) and left (B) strength at pre- and post-test in the DROM and the SS groups. *Significant difference between groups ($p < 0.05$).

DISCUSSION

The main finding of this study was that DROM conferred a larger long-term improvement than SS in three key areas of gymnastics performance: hip ROM, hip isometric strength, and jump performance compared to SS. Thus it might be suggested that in young flexibility-trained female athletes, the influence of engaging the CNS and perform isometric strength at end ROM joint angles during DROM exercises may be a key issue in providing more positive performance effects than SS.

DROM was better at increasing hip ROM than SS. Askar et al. (2015) and Scott Davis et al. (2005) also compared the long effect of DROM on hamstring flexibility compared to other stretching techniques. Askar at al. (Askar et al., 2015) who used DROM with the same time stretching protocol than in our study [5 sec concentric (hip flexion movement)-5 sec isometric (holding hip flexion at end range of motion) -5 sec eccentric (hip extensión movement)] concluded that although eccentric training, SS and DROM were all suitable to improve hamstring flexibility, the gains achieved by DROM exercise was significantly higher than eccentric training and SS. On the other hand, Scott Davis et al. (Davis et al., 2005) found that SS was better at increasing hamstring flexibility compared to DROM and PNF. However in their study they tested the hip ROM in a passive manner and the time stretching protocol for DROM was only 1 exercise x 30 sec (3 sesions a week). They considered it was not sufficient stretching time to significantly increase hamstring length in healthy individuals.

Another interesting finding of our study is that hip ROM improved significantly in the dominat leg but not in the non-dominant. Santos et al. (Batista Santos et al., 2015) also found a high level of active and passive flexibility for the dominant (preferred) lower limb compared to the non-dominat (non-preferred) leg in rhythmic gymnasts. Flexibility asymmetries may appear as a result of the training type. The dominant leg of gymnasts, is the one executing a higher number of repetitions consisting on moving the leg in a fast controlled movement through the full ROM. The non-dominant leg is usually the supporting leg. Therefore, it can be speculated that the dominant leg might have received an added stimulus (DROM + regular training skills exercises) to increased the long term hip ROM in particular for active stretching exercise that it is subjected to, compared to the non-dominat leg that does a more passive static work. Moreover, dominant leg has in general more muscle mass compared to the counterpart and therefore the DROM training may have elicit a greater effect in the leg more constrainted by greater muscle mass (17). These assymetries could be addressed since it has been postulated that the non-dominant leg can achieve a similar performance to the dominant leg when properly stimulated (Cobalchini & Silva, 2008).

As opposed to hip ROM, both legs improved HF isometric strength, in this regard, Frutuoso et al. (Frutuoso, Diefenthaeler, Vaz, & de la Rocha Freitas, 2016) found that the dominant limb in rhythmic gymnasts showed larger thigh girth and anatomical cross-sectional area, higher hip flexor and plantar flexor torque compared to the non-dominant limb. This discrepancy in the results may be due to the fact that they tested hip flexor torque at 60 s^{-1} while in our study HF 1RM isometric strength

Since holding a body figure for some seconds in rhythmic gimnasts is mandatory, it seems that isometric strength at end ROM it is a key issue in gymnastics performance that DROM stretching addresses efficiently. However, in the present study we did not have any measure of strength endurance, which is the specific form of strength displayed in activities which require a relatively long duration of muscle tension with minimal decrease in efficiencythe ability(Verkhoshansky & Siff, 2009). This variable is also a key component in rhythmic gymnastic.

VJ performance was increased with both stretching methods, 16% with DROM and 13.6% with SS. These results extend previous reports of studies that support the positive acute effects of DS to enhance many aspects of sports on jumping performance such as vertical jump (Hough, Ross, & Howatson, 2009; Jaggers, Swank, Frost, & Lee, 2008; Morrin & Redding, 2013). However, these conclusions are constrained to acute enhancements in performance outcomes that were evident immediately or shortly after the stretching intervention was performed. On the other hand, and contrary to most SS studies showing a decrease in jumping performance after acute SS (Brusco, Pompermayer, Esnaola, Lima, & Pinto, 2018; Galazoulas, 2017), and the no influence on jump performance when a chronic SS intervention is applied (Bazett-Jones, Gibson, & McBride, 2008; Ikeda & Ryushi, 2018; Yuktasir & Kaya, 2009), our results showed that long term SS did improved SJ performance. This may be due to the fact that warm-ups takes only a small time (25% approx.) of total training volumen performed by a gymnast. Training sessions involves many other jumping and specific exercises that may counteract the long-term negative effects of a specific stretching protocol on jumping performance. Furthermore, our participants were also used to do those specific SS exercises therefore their negative influence it might not be the same than when applied to non-trained healthy individuals (34).

The present study showed that when long-term DROM exercises are applied during warm-ups it produces slighly larger improvements in VJ compared to SS, and furthermore, SS doesn´t affect negatively VJ.

When we tested the SL, both stretching protocols improved the results from pre- to post- test, in fact, the SS decreased SL performance (-5.8%). In a study carried out by Di Cagno et al. (12), gymnasts performed the same technical leap than in our study and they found similar results: an approximately 7% decrease in the flight time after performing static stretches. Although, their results are related to acute effect the long-term effects of SS affected leap technical jump in the same way.

This specific technical jump requieres a fast movement in a large hip ROM (one leg goes into HF and the other into HE), and unilateral non-dominant leg jump. Regarding the first issue, DROM stretches were performed in the same ROM hip movement in a slow tempo, contributing maybe to affect negatively the capacity of fast contraction in the inner ROM hip flexor and extensor muscles. The second issue maybe linked to the result of left HE assymetry obtained in the tests.Gymnasts didn´t improved left HE ROM which may affect negatively left unilateral jumping performance.

Thus SS may have the same long-term effect on the neurophysiological and mechanical factors underlying stretch response.

The strength of this intervention is that took place in a real-life training set-up, highlighting the external validity of the study. However, this study presents some limitations such as the sample size and the fact that we did not performed test-retest reliability assessment of the ROM measurements. However, we used the same tests and all of them were performed by the same person that had been doing those same testing procedures during the last 10 years at the Club. Althougth we did not track estrogen levels, which has been showed to influence joint and muscle laxity (Yim, Petrofsky, & Lee, 2018), the number of athletes with the menarche were equally distributed at both groups. It would have been interesting having a control group, nonetheless it is very difficult in the sports performance environment having a group of gymnasts doing no stretching at all. So, due to the fact that static stretching is the gold standard stretching technique in gymnasts, we could consider it as a control group.

Further research should examine the acute effects of DROM exercises on sports performance variables and other type of athletes, and add measurements like musculotendinous stiffness and shear wave elastography to provide more information related to the cause of the results obtained.

CONCLUSION

Although continuous stretching of long duration (>90 s) is commonly used in sports requiring large ROM movements (Suchilin & Arkaev, 2004) (e.g. artistic, rhythmic gymnastics, figure skating, diving and dance) the results of this study indicate that DROM stretching technique may be preferable when the aim is to achieve long-term hip ROM, hip isometric strength and no decrement on jumping performance (jumping performance in flexibility young trained athletes).

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