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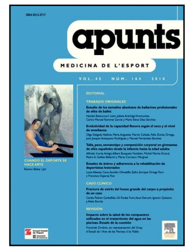

ORIGINAL ARTICLE

Flexibility testing in young competing gymnasts using a trigonometric method: one-year follow-up

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KEYWORDS
Range of motion;
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Field test

Abstract
Introduction and aims. The aim of the present study was to characterize the evolution of flexibility during a complete gymnastics season in a group of 15 young male gymnasts.
Methods. The gymnastics season was divided into three periods, namely general, specific and competitive, and the tests were grouped as follows: a) lower limbs (side and front splits, side and front leg lifts), b) upper limbs (shoulder turn with stick in anteversion and retroversion), and c) multi-joint testing (back bridge and adapted sit & reach test). A series of linear distances and anthropometric measurements were introduced into the trigonometric formulae to provide an indirect estimate of the joint angles.
Results. While the passive range of motion of the lower limbs improved between the last two periods of the season, the active type remained unchanged throughout the season. The extension of the shoulder improved quickly and progressively throughout the season, whereas the flexion of the shoulder only improved in the first two periods. The adapted sit & reach test worsened the range of motion during the competitive period. The back bridge showed no significant changes throughout the season.
Conclusions. Flexibility evolves throughout the gymnastics season, although with different rates of adaptation depending on the anatomical region analyzed (lower limbs, upper limbs, or multi-joint testing) and the type of flexibility developed (passive or active).
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PALABRAS CLAVE
Rango de movimiento;
Estudio longitudinal;
Entrenamiento;
Antropometría;
Prueba de campo

Control de la flexibilidad en jóvenes gimnastas de competición mediante el método trigonométrico: un ano de seguimiento

Resumen
Introducción y objetivos. El objeto del presente estudio fue caracterizar la evolución de la flexibilidad a lo largo de una temporada deportiva en un grupo de 15 jóvenes gimnastas masculinos.
Métodos. Se dividió la temporada en tres periodos: general, específico y competitivo. Se agruparon las pruebas según: a) extremidades inferiores (espagat lateral y frontal, elevación lateral y frontal de la pierna); b) extremidades superiores (giro de hombros con bastón en anteversión y retroversión); c) pruebas multiarticulares (puente dorsal y flexión de tronco sentado). Se tomaron una serie de distancias lineales y de medidas antropométricas que fueron introducidas en la formulación trigonométrica para el cálculo indirecto de cada uno de los ángulos articulares.
Resultados. Mientras que el rango de movimiento pasivo de las extremidades inferiores mejoró entre los dos últimos periodos de la temporada, la manifestación activa no hizo lo propio en ningún momento de la temporada. La extensión del hombro mejoró rápida y progresivamente a lo largo de la temporada. La flexión, en cambio, únicamente lo hizo entre los dos primeros periodos. La flexión de tronco sentado empeoró su rango de movimiento durante el periodo competitivo. El puente dorsal no mostró modificaciones significativas a lo largo de la temporada.
Conclusiones. La flexibilidad evoluciona a lo largo de la temporada en base a diferentes ritmos de adaptación, en función de la región anatómica analizada (extremidades superiores, inferiores o pruebas multiarticulares) y de la manifestación de la flexibilidad desarrollada (pasiva o activa).
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Introduction

From a sporting performance perspective, flexibility is defined as the intrinsic property of bodily tissues which determines the maximum range of joint mobility without resulting in injury[1]. The maximum range of movement (ROM) is usually reached passively as a result of the action of external forces, such as gravity, the help of another person or the action of an apparatus, on the individual. It can, however, also be reached actively as a result of the muscle action of an individual him/herself[2].

The importance of both active and passive flexibility when planning training depends on the characteristics of each particular sporting discipline. For male artistic gymnastics (MAG), for example, the degree of technical and artistic perfection achieved by each gymnast depends on a large extent on the ROM he can develop whilst executing each technical discipline[3]. Indeed, the International Federation of Gymnastics' *Code of Points*[4], which governs all gymnastic competitions, highlights the characteristics of each discipline and assigns penalties on the basis of the level of execution developed. In light of the above, gymnasts' joints are submitted to demands which imply dynamic actions at high execution speeds and with similarly high ranges of joint mobility, as well as static positions which require high maximum force values with sub-maximal joint ranges[5].

The development of a medium- (three months to a year) and long-term (1-4 years) sporting plan is undertaken on the basis of the competitions and rhythm of adaptation of the different abilities developed[6]. Due to the low number of competitions and the long time interval between them, MAG trainers usually resort to a classical sporting plan model whereby the season is divided into a general preparatory period, a specific preparatory period and a competitive period[7]. The general preparatory period normally involves the development of passive flexibility by performing non-specific exercises. As the season progresses (specific preparatory period), active flexibility becomes the focus, with specific work blocks including the exercises which the gymnast must perform during his competitive routine being performed. Finally, no specific flexibility work other than that used by the gymnast in his competitive routines is performed during the competitive period.

Thus, despite the importance of flexibility for the sporting performance of gymnasts, the rhythm of adaptation of this physical capacity does not usually affect the different training plan proposals in MAG. Indeed, guideline flexibility values for gymnasts are relatively scarce in both transversal[8-10] and longitudinal studies[11]. Furthermore, other methodological factors inherent to the assessment of flexibility tend to interfere in any generalisation of their adaptation rhythms. Various studies[8,10] have used linear units of measurement (centimetres or millimetres), whereas the appropriate measurement for an arc of movement should be circular (degrees or radians). Linear measurements are usually affected by the individual's own anthropometric parameters[11-14], therefore the use of objective and valid medical tests in a sporting context is not usually sufficient, especially when assessing active flexibility[15-17].

In light of this, various authors have proposed the use of trigonometric formulae to calculate the ROM angle[12-14,18]. The resulting equations use a series of linear distances achieved during the movement and anthropometric measurements for the segments moved. Calculation of the flexibility using such trigonometric methods allows the results to be standardised in terms of circular measurements which are not influenced by anthropometric parameters, thus meaning that they can be used to assess both active and passive flexibility.

Determination of the rhythm of adaptation requires longitudinal monitoring. Thus, whereas other physical capacities, such as muscle force, have been monitored during a single MAG season[19], to the best of our knowledge the same process has not been performed for flexibility. The limited number of related studies[20], and the use of inappropriate methodologies[8-10], suggested the need to perform such a study adapted to the sporting needs of this discipline. The main objective of this study was therefore to characterise the evolution of flexibility in a group of young male gymnasts during a single season using a trigonometric method. Based on the experience of MAG trainers, the hypothesis proposed was that this capacity should improve progressively between each of the periods into which the season can be divided.

Methods

The flexibility of 15 male gymnasts with a mean age of 11.4±1.1 years was assessed at the onset of the study. These gymnasts were selected from the Spanish Royal Gymnastics Federation's National Training Programme (Plan Nacional de Tecnificación Deportiva). All subjects were healthy and injury-free. Prior to participating in this study, each gymnast's legal guardian gave written informed consent for them to participate. This study was approved by the Clinical Research Ethics Committee of the Catalan Sports Administration, and the ethical principles set out in the Declaration of Helsinki[21] regarding biomedical research on human subjects were respected throughout.

A longitudinal follow-up was performed over a single season, which was divided into three three-month preparation periods, namely general (G), specific (S) and competitive (C). A control session was established during each period, with each of these sessions being separated by about three months from the previous one. A standardised general warm-up (20 min) was performed at the start of each control session so that immediately before the start of each test they could be practiced individually (5 min). The tests used were chosen from the numerous batteries of physical tests applied by MAG trainers[5,20,22,23], and were grouped as follows on the basis of the anatomical region analysed: a) lower limbs (side and front splits, side and front leg lifts), b) upper limbs (shoulder turn with stick in anteversion and retroversion); c) multi-joint testing (back bridge and adapted sit & reach test). The protocols followed were as follows:

- *Side split test* (Figura 1A): standing on both feet, separate the lower limbs as much as possible in abduction whilst maintaining the trunk perpendicular to the floor. This test was adapted for those gymnasts who reached 180° (lower limbs in full contact with the floor) by asking them to raise their legs whilst maintaining their pubis in contact with the floor[24,25].
- *Front split test* (Figure 1B): standing on both feet, separate the lower limbs as much as possible, one in anteversion and the other in retroversion, whilst maintaining the trunk perpendicular to the floor. This test was adapted for those gymnasts who reached 180° (lower limbs in full contact with the floor) by asking them to raise their legs whilst maintaining their pubis in contact with the floor[24,25].
- *Straight side leg raise test* (Figure 1C): standing on both feet and whilst holding on laterally to a back support, raise one leg to the maximum in abduction whilst maintaining the body front-on at all times. Hip flexion was not permitted.
- *Straight front leg raise test* (Figure 1D): standing on both feet and whilst holding on laterally to a back support, raise one leg to the maximum in anteversion whilst maintaining the body front-on at all times. Hip flexion was not permitted.
- *Shoulder turn with stick performing an anteversion test* (Figure 1E): holding a stick with both hands in front of the body and with the arms rotated inwards, move the stick to the rear of the body, passing it above the head with the minimum distance between the hands. The trunk should remain perpendicular to the floor and contact between the palm of the hand and the stick should be maintained whilst simultaneously turning the shoulders.
- *Shoulder turn with stick performing a retroversion test* (Figure 1E): holding a stick with both hands behind the body and with the arms in their anatomical position, move the stick to in front of the body, passing it above the head with the minimum distance between the hands. The trunk should remain perpendicular to the floor and contact between the palm of the hand and the stick should be maintained whilst simultaneously turning the shoulders.
- *Back bridge test* (Figure 1F): in dorsal decubitus, flex the elbows and place both hands on the floor at approximately the same height as the head and with a distance between them similar to the width of the shoulders. At the same time, flex the knees and place the tips of the toes against the wall. From this position, lift the body using hands and feet with the smallest distance possible between them.
- *Sit and reach test* (Figure 1G): sitting on the floor with the hip in contact with a wall and the upper limbs extended with the hands on top of each other, flex the trunk as much as possible above the lower limbs to achieve as large a distance as possible between the fingertips and the wall.

The reliability of all the tests used in the present study has been demonstrated previously in both sporting[13] and non-sporting[26] populations, with the degree of reliability (r) in the former ranging between 0.91 and 0.98, depending on the test. Performance of all the tests was supervised by two

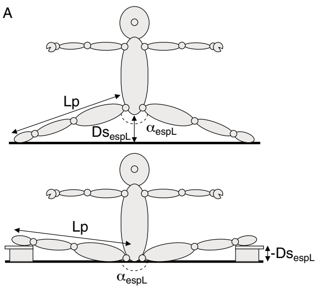
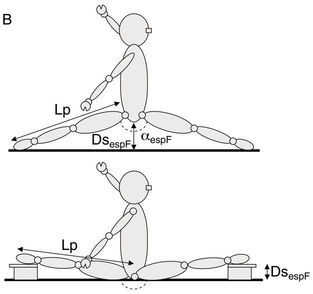
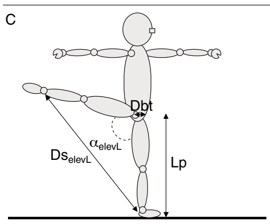
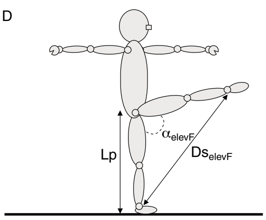
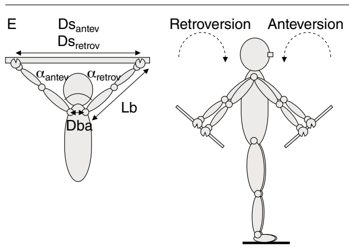
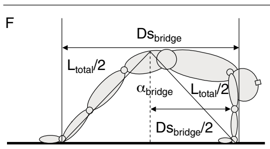
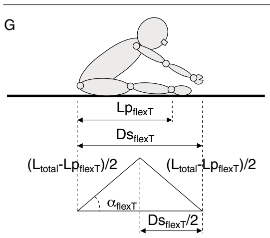
Diagram	Trigonometry equation	Trigonometry equation parameters
A 	Side split ($a_{espL} \le 180º$) $\alpha_{espL} = 2$ arcos (Ds_{espL}/Lp) Microsoft Excel® = (2* (ACOS ((Ds_{espL}/Lp)))* 180/3,1416 Lateral split ($\alpha_{espL} > 180º$) $\alpha_{espL} = 2$ arcos [(–1* Ds_{espL})/Lp] Microsoft Excel® = (2* (ACOS (–1* Ds_{espL})/Lp)))* 180/3,1416	α_{espL} (º) = Angle of lateral split Ds_{espL} (cm) = Separation distance Lp (cm) = Length of leg
B 	Front split ($a_{espF} \le 180º$) $\alpha_{espF} = 2$ arcos (Ds_{espF}/Lp) Microsoft Excel® = (2* (ACOS (Ds_{espF}/Lp)))* 180/3,1416 Front split ($\alpha_{espF} > 180º$) $\alpha_{espF} = 2$ arcos [(–1* Ds_{espF})/Lp] Microsoft Excel® = (2* (ACOS ((–1* Ds_{espF})/Lp)))* 180/3,1416	α_{espF} (º) = Angle of front split Ds_{espF} (cm) = Separation distance Lp (cm) = Length of leg
C 	Straight side leg raise test $\alpha_{elevL} = 2$ arcsen (Ds_{elevL}-Dbt/2 Lp) Microsoft Excel® = (2* ASIN ((Ds_{elevL}-Dbt)/(2* Lp)))* 180/3,1416	α_{elevL} (º) = Lateral elevation angle Ds_{elevL} (cm) = Separation distance Dbt = Bitrochanteric diameter Lp (cm) = Length of leg
D 	Straight front leg raise test $\alpha_{elevF} = 2$ arcsen (Ds_{elevF}/2 Lp) Microsoft Excel® = (2* ASIN (Ds_{elevF}/(2* Lp)))* 180/3,1416	α_{elevF} (º) = Lateral elevation angle Ds_{elevF} (cm) = Separation distance Lp (cm) = Length of leg
E 	Shoulder turns with a stick (antev. and retrov.) $\alpha_{antev} = 2$ arcsen [Ds_{antev}-Dba/(2 Lb)] $\alpha_{retrov} = 2$ arcsen [Ds_{retrov}-Dba/(2 Lb)] Microsoft Excel® = 2* (ASIN ((Ds_{antev}-Dba)/(2* Lb)))* 180/3,1416 = 2* (ASIN ((Ds_{retrov}-Dba)/(2* Lb)))* 180/3,1416	α_{antev} (º) = Shoulder angles in anteversion α_{retrov} (º) = Shoulder angles in retroversion Ds_{antev} (cm) = Separation distance Ds_{retrov} (cm) = Separation distance Dba (cm) = biacromial diameter Lb (cm) = Arm length
F 	Bridge dorsal $\alpha_{puente} = 2$ arcsen (Ds_{puente}-L_{total}) Microsoft Excel® = 2* (ASIN (Ds_{puente}-L_{total})* 180/3,1416	α_{puente} (º) = Bridge angle Ds_{puente} (cm) = Separation distance L_{total} = Total length
G 	Seated trunk flexion $\alpha_{flexT} = 90$ arcsen [(Ds_{flexT}/(L_{total}-Lp_{flexT})] Microsoft Excel® = 90 (ASIN ((Ds_{flexT})/(L_{total}-Lp_{flexT}))* 180/3,1416	α_{flexT} (º) = Trunk angle in flexion Ds_{flexT} (cm) = Separation distance Lp_{flexT} (cm) = Length of leg in the test L_{total} = Total length

Figure 1 Battery of tests used to assess flexibility and equations to calculate the variables (adapted from Moras, 2002)[13].

researchers, who ensured that both the upper and lower extremities were fully extended at all times and the final position reached was maintained for a minimum of three seconds. Each test was performed several times until three matched the established test-performance protocol; the best performance of the three was noted. For the single-sided tests (side split test, side leg lift and front leg lift), measurements were performed on each side.

The trigonometric method used to assess the flexibility requires the linear distances achieved during the test to be measured along with the anthropometric measurements for the segments moved. The linear distances measured in the side and front split tests were the distance between the pubic symphysis and the floor (DS_{splS} and DS_{splF}, respectively) (Figure 1A and B). When the adapted side and front split tests were used, the linear distances measured were those between the heel of the lifted leg and the floor. In the side or front leg-lift tests, the linear distance was obtained from the separation between the posterior side of the calcaneus of the right and left feet (DS_{liftS} for the side lift amd DS_{liftF} for the front lift) (Figure 1C and D). During assessment of the shoulder turn with stick in anteversion and retroversion, the linear distance between the outer sides of both hands (DS_{ante} and DS_{retro}, respectively) was measured (Figure 1E). Likewise, during assessment of the back bridge test, the linear distance between the outer side of the calcaneus and the heel of the hand (DS_{bridge}) was measured (Figure 1F). During performance of the sit and reach test, the linear distance measured was that between the wall and the fingertips (DS_{SR}) (Figure 1G).

The anthropometric measurements were taken according to the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK), which have also been adopted by the Spanish Kinanthropometry Group, and were taken by a single, accredited anthropometrist (Level 2, ISAK). The anthropometric measurements required in order to use the trigonometric method with the battery of tests proposed were as follows: (1) the length of the lower limb (Lp), the shortest distance between the anatomical point of the trochanter and the floor; (2) the length of the upper limb (Lb), the shortest distance between the acromion and the fingertips; (3) the bitrochanteric diameter (Dbt), the shortest distance between each trochanter; and (4) the biacromial diameter (Dba), the shortest distance between each acromion. The following anthropometric measurements were also used: (a) the length of reach (L_{total}), the longest distance which a subject can reach between the floor (heels in contact with it) and the hands placed on top of each other with the arms as an extension of the body; (b) the length of the lower limbs in the sit and reach test (Lp_{SR}), the longest distance between the wall and the subject's heels in the initial position in the test (slightly longer than Lp due to the additional distance between the trochanter and the wall as a result of sitting).

The linear distances and anthropometric measurements for each test were introduced into the trigonometric formulae to estimate the corresponding joint angles in degrees (α_{splS}, α_{splF}, α_{liftS}, α_{liftF}, α_{ante}, α_{retro}, α_{bridge} and α_{SR}) Due to the nature of the trigonometric formulation (Figure 1), an increase in α_{splS}, α_{splF}, α_{liftS}, α_{liftF}, α_{bridge} represents an improved ROM. In contrast, an increase in the remaining variables (α_{ante}, α_{retro}, α_{SR}) represents a reduced ROM.

A one-sided repeated-measures ANOVA was performed to detect any flexibility changes during the training season. A Friedman repeated-measures analysis of variance by ranks was performed for those cases in which the sample distribution could not be fitted to normality. The inter-group comparison was performed using the post hoc Tukey test. The level of significance was set to $p<0.05$, with the values being adjusted to control multiple comparisons. All calculations were performed using the statistical software package SPSS v.15 (Chicago, USA).

Results

The passive ROM for the lower extremities increased significantly during the season: α_{splS} ($F_{2.13}$=32.71; $p<0.001$), α_{splF} ($F_{2.13}$=17.17; $p<0.001$). Indeed, both the side (α_{splS}; $p=0.015$) and front splits (α_{splF}; $p=0.003$) increased in value between the periods S and C. No increase in the active component of joint mobility was found for the lower body (Table 1). Shoulder joint mobility improved significantly throughout the season in terms of both α_{ante} (χ^2_2=28.13; $p=0.001$) and α_{retro} (χ^2_2=16.53; $p=0.001$). In the shoulder turn with stick test, α_{ante} improved significantly between each of

Table 1 Results of the flexibility tests performed throughout a MAG season

Anatomical region	Tests (n=8)	Variable (°)	G (X±SD)	S (X±SD)	C (X±SD)
Lower limbs	Side split	(α_{splS})	172.0±8.7	173.3±7.8	179.0±7.0
	Front split	(α_{splF})	166.2±11.8	169.1±7.2	173.3±6.9
	Straight side leg raise test	(α_{liftS})	80.9±6.2	81.2±5.0	82.8±7.2
	Straight front leg raise test	(α_{liftF})	85.0±8.1	85.4±6.8	86.8±7.9
Upper limbs	Shoulder turn with stick: anteversion	(α_{ante})	49.3±20.4	33.9±11.8	26.4±10.6
	Shoulder turn with stick: retroversion	(α_{retro})	58.8±20.4	47.4±13.1	45.0±11.6
Multi-joint	Back bridge	(α_{bridge})	58.8±7.0	56.9±9.7	57.4±10.1
	Sit and reach	(α_{SR})	24.8±5.0	21.7±5.2	26.3±3.7

C: competitive period; G: General period; S: specific period; SD: standard deviation; X: average.

the three different periods ($p<0.05$), whereas α_{retro} only improved between the periods G and S ($p<0.05$) (Table 1). As far as the multi-joint tests are concerned, the ROM for α_{SR} ($F_{2.13}=14.87$; $p=0.001$) changed significantly throughout the season, improving between the periods G and S ($p=0.012$) but worsening between the periods S and C ($p=0.003$). In contrast, α_{bridge} did not change significantly during the season (Table 1).

Discussion

Flexibility is considered by both gymnasts and trainers consider the flexibility as the most important physical capacity, after force and its various manifestations, in order to be able to perform artistic gymnastic routines with the highest technical quality[27]. The training process in a competitive environment should systematically modify its performance objectives to meet the demands of the sporting discipline concerned. The planning of this process should therefore take into account the rhythm of adaptation of the different physical capacities[6]. Despite the importance of flexibility in male artistic gymnastics (MAG), to the best of our knowledge there have been no studies concerning its rhythm of adaptation during a gymnastics season. The objective of the present study was therefore to use a trigonometric method to characterise the evolution of flexibility during a MAG sporting season based on the application of a battery of tests to a selected group of young gymnasts. The flexibility was expected to improve from one period to the next throughout the sporting season. The results showed that this initial hypothesis was only fulfilled for the shoulder turn with stick in anteversion test, with the other variables analysed showing different rhythms of adaptation. The trend observed for the improvement in shoulder flexion could be due to the characteristics inherent to the work undertaken in MAG during these initial training stages, where the gymnasts dedicate a large amount of time to assimilating and/or learning the best technical execution possible. Thus, despite the fact that the International Federation of Gymnastics' *Code of Points* does not state this explicitly, the majority of theoretical models applied by trainers involve executing most gymnastic techniques with full extension of the arms, their placement essentially in parallel, or, in those cases where these techniques begin with, result in or pass through a state of inverted or vertical hand support, a full extension of the shoulders as an extension of the body (180°). It could therefore be the case that the large amount of practice and high degree of technical perfection required by certain gymnastic techniques, such as the vertical, contributed to the significant period-to-period improvement observed for shoulder flexion mobility.

Despite not improving with the expected rhythm of adaptation, the majority of the remaining tests showed significant improvements between some of the periods into which the season was divided. Thus, the shoulder turn with stick in retroversion and the sit and reach tests showed improvements between periods G and S, with the former maintaining the levels achieved during period S throughout period C as well. Period G was characterised by development of flexibility essentially because of passive methods and general exercises. In contrast, the following two periods were characterised by development of this capacity in a more active and specific manner (S) and its manifestation during the execution of competitive exercises (C). Indeed, it is precisely because the learning (S) and performance (C) of the technical abilities outweigh the physical-preparation work during these two periods, and the fact that the majority of these abilities do not require a similar degree of flexibility to that required to perform the shoulder turn with stick in retroversion test, that the training time used by the gymnasts and their trainers to improve shoulder mobility in flexion could be less than that required to continue its improvement. In contrast, and irrespective of the different rhythms of adaptation when in flexion or extension, the increased shoulder mobility observed during the season is not in accordance with the results of other studies involving adult gymnasts[9,20]. Thus, Jancarik y Salmela[20] reported that shoulder joint movement was negatively correlated with gymnastic performance as age and ability increased. This inverse relationship between performance and flexibility with increasing age could be due to the demands inherent to MAG. Indeed, the abilities which the gymnast must develop during advanced training levels require high levels of force. These demands increase progressively with age and the difficulty of the exercise, with the demands on the upper limbs increasingly notably as four of the six apparatus exercises in MAG are performed with them. In light of this, the lack of muscle volume in the gymnasts in the present study could explain their higher shoulder flexibility with respect to adult gymnasts[28].

The multi-joint mobility developed in the sit and reach test also improved between periods G and S, although it subsequently worsened between periods S and C. The high ROM noted for this test at the beginning of the study would appear to lead to an only modest subsequent improvement in flexibility during period S and a worsening during period C due to the almost complete lack of time dedicated to the development of this ability beyond its performance during the gymnasts' competitive routines.

In contrast, the side and front split tests, both of which are a measure of the passive flexibility of the lower limbs, improved between periods S and C, whereas similar mobility values were maintained between earlier periods (G and S). It therefore appears that the benefits of the work performed during period G (mainly passive flexibility), together with that performed during period E (mainly active flexibility), appeared during period C (flexibility applied to competitive elements). It is interesting to note that the passive flexibility work performed during period G did not affect the lower limbs in the same manner as the upper limbs (shoulder turn with stick in anteversion and retroversion). This could be due to the fact that the coxofemoral joint is characterised by a higher anatomical robustness than the glenohumeral joint, thereby explaining the slower rhythm of adaptation observed for the former. Furthermore, it is interesting to note that the active manifestation of flexibility in the lower limbs, as represented in this study by the side and front leg lift tests, did not improve during the season. The greater mobility of the lower limbs achieved as a result of the passive tests was therefore not carried forward to the active tests. The reasons for this could include the fact that, in biomechanical terms, maintaining the leg at an angle of 90° involves the point of greatest moment of force, in other words the position in which the length of the resistance arm (governed by the weight and degree of tension of the posterior muscles in the lower limbs) is greater than that of the power arm (level of tension generated by the elevator muscles in the lower limbs). The improved passive flexibility in the lower limbs (front and side split), together with the optimal results in the sit and reach test, appear to indicate that any improvement in active flexibility in the lower limbs would tend to depend more on the prior increase in the force of the elevator muscles than on the lack of extensibility of the posterior muscles in the lower limbs.

No significant differences were observed for the back bridge test during the season. Despite being classified as a multi-joint test where both the back and shoulder affect the result, artistic gymnasts attempt to minimise involvement of the former by fully extending their lower limbs, thereby limiting the curve of the back at a cost of increasing the distance between feet and hands (Ds_{bridge}). Thus, as it is clear from the trigonometric formula that a lower value for Ds_{bridge} leads to a lower angle and therefore a better performance in the test, the different strategies used by each gymnast all tend to result in a greater involvement of the shoulder joint. In contrast to the mobility of the shoulder joint, which improved from one period to the next throughout the season, the back bridge did not. This finding suggests that either the mobility of the back affected the performance of the back bridge negatively throughout the season, or that the relationship between the degree of shoulder extension proposed on the basis of the results of the shoulder turn with stick in anteversion test and the back bridge is not so straightforward. The trigonometric method used herein does not allow the relationship established between the back and the shoulder in the final results of the back bridge test to be described, therefore further studies in this respect are required.

Nevertheless, our use of an indirect method for assessing flexibility has allowed us to obtain some information regarding the different rhythms of adaptation in MAG as regards the anatomical region analysed and the type of flexibility developed. However, longitudinal studies with longer observational periods involving gymnasts of different ages and abilities will need to be carried out in order to analyse the actual rate of the rhythms of adaptation in this sporting discipline Such studies should include anthropometric variables related to the diameter of the segments analysed in order to facilitate the understanding of any possible worsening of joint mobility as a result of the inevitable morphological changes in the muscle component. Finally, in order to better understand the influence of certain gymnastic abilities on the development of flexibility, specific variables and procedures for this purpose should also be included.

Conclusions

From a general perspective, the results of the present study show that the flexibility of gymnasts in the early stages of their progress towards the sporting elite evolves throughout the season. However, this evolution occurs at different rhythms of adaptation depending on the anatomical region analysed (upper limb, lower limb or multi-joint) and the type of flexibility developed (passive or active). The development of flexibility during the season meant that the gains in mobility were maintained, or even increased, during the competitive period for almost all the tests studied. The rapid and continual improvement in shoulder mobility observed could be a result of both the anatomical characteristics of this joint and the high amount of practice and degree of technical perfection demanded by certain gymnastic abilities involving the shoulder. Training planning in MAG should therefore take into account an earlier development of the passive flexibility of the lower limbs. Likewise, work aimed at improving the active type should prioritise those specific force exercises which allow the optimal performance of all those gymnastic abilities which require them. Interpretation of the results of the multi-joint tests is complex as, although the trigonometric method shows the presence or absence of improvements, it does not allow them to be located. In any case, the sit and reach test was the only one which worsened during the latter two training periods, thus suggesting the need to work on it more, especially during the competitive period. Whereas the mobility of the shoulder joint improved from one period to the next throughout the season, the back bridge did not. Irrespective of the possible explanations for this finding detailed above, further studies are required to pinpoint the greater or lesser degree of involvement of all the joints which intervene in this type of multi-joint test.

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Conflict of interest

Authors state that they don't have any conflict of interest.

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