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A biomechanical examination of the differences between active flexibility and mobility in artistic gymnastics. Differences between active flexibility and mobility

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Abstract

Purpose: the study's aim is to make a biomechanical examination of the inclusion of active flexibility in artistic gymnastic movements requiring mobility (actively moving through a range of motion), flexibility and other motor abilities such as force, power, etc. **Methods:** the study included 20 girl gymnasts aged 7-9 years old, with a body height of 140.7±10.2, weight of 34.1±6.4, and body mass index of 17.6±3.0. Data collection in the study was made by using a performance test developed by the World Gymnastics Federation, including the Forward-Backward Split, Side Spit, Arm-Trunk Angle Backward, Leg Raise forward, Leg Raise Sideward, Angle Degree of the Leg Split Position in Cartwheel, and Arm-Upper Body Angle Backward in Bridge Technique. In the data analysis of the variables in the study, the Kinovea 0.8.15 and SPSS 24 software programs were used. **Results:** the results of the study showed statistically significant differences between active flexibility and mobility ($p<0.05$). While the range of motion was found to be high during the application of techniques requiring active flexibility, it was observed that the range of motion was lower in techniques requiring mobility. **Conclusion:** having good flexibility does not necessarily mean that an athlete will have good mobility. Being aware of the differences between active flexibility and mobility is crucial to clarify functional flexibility, which positively affects solving confusion in training programs that aim to improve the flexibility and mobility performance of gymnasts.

Keywords: Range of motion, Active flexibility, Mobility, Functional Flexibility, Artistic Gymnastics.

Introduction

Unlike many sports branches, routines in artistic gymnastics include many motor skills (Prassas et al., 2006). Evaluation of the degree of difficulty of artistic gymnastics elements changes the dominancy of motor skills needed in the routine. Evaluation and changes in motor skills dominancy increase the complexity of the routines in each gymnastics apparatus

(Irwin et al., 2005). According to the literature given by the World Gymnastics Federation, the dominance of the motor skills in artistic gymnastics can be lined as coordination, strength, speed, mobility, flexibility, and balance (Fink et al., 2015; Fink & Hofmann, 2015; Berisha & Mosier, 2020). However, even mobility and flexibility are led by other motor skills, they positively and negatively affect motor skills such as coordination, strength, speed, etc.

Energy consumption and execution difficulties during the execution of the techniques and routines in artistic gymnastics are affected by the level of flexibility ability. Flexibility is a crucial factor in a certain range of motion and mobility (Yiğitbaş, 2020). On the other hand, the literature examination has shown that mobility is the greatest possible range of motion that the joint can do by itself without external force; in other words, it is defined as the application of movement with muscle activity (Koçak, 2019). Active flexibility is the ability of muscles to stretch (Holt et al., 1995). However, there is confusion between these two concepts. Based on this, the effect of active flexibility on techniques requiring mobility seems to be not been clarified in the current literature.

Thus, our study that aims is to clarify the differences between active flexibility and mobility may contribute to the literature and coach training programs using performance development in artistic gymnastics. In addition, when more than 800 gymnastics techniques are examined, results have shown that dominance or importance of mobility is lined as a fourth and flexibility as a fifth motor ability, led by coordination, strength, and speed (Berisha & Mosier, 2020). However, motor skills cannot be analyzed as independent ability. The maximal performance in movements requiring mobility is accompanied by a high range of motion and maximal force. Therefore, the question is whether the range of motion expressed in the same ratio during movements require force, flexibility, motor control, etc. (i.e. leg raise sideward, leg raise forward), and whether movements require just active flexibility (i.e. forward-backward split, side split). This question needs to be answered and it is the motivation of this study.

Based on the literature review made in light of the study's purposes, the literature seems to be limited and cannot provide answers for the questions in our study. According to one of the rare studies related to the topic, increases in active flexibility are not completely functional in the movements requiring mobility (Moreside & McGill, 2013). In fact, the lack of clarity between flexibility and mobility definitions, at the same time means lack of clarity in a used training program to increase the performance. Based on this, the training program complexity and performance decrease may be caused by the complexity between flexibility and mobility. Based on these facts this study aims to determine differences between active flexibility and mobility in artistic gymnastics. Besides, the aim of this study is to the determination of the inclusion ratio of the active flexibility into the movements that require mobility such as a leg raise forward and sideward.

Method

Experimental approach to the problem

To determine the correlations and effects of the active flexibility to mobility in functional movement patterns, a causal relational research model was used. The study included 17 girl gymnasts aged 7-9 years old, with a body height of 140.7±10.2, weight of 34.1±6.4, and body mass index of 17.6±3.0. As some gymnasts did not participate in all performance tests, the study sample may be variable in each test. For that reason, we have given the sample size in each group in the tables of the results.

The gymnasts 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. The study was approved by the Ethics Board of the Istanbul Gelisim University, Turkey.

Data collection tests

Forward-Backward Split (FBS^0)

The test's main aim is to measure the active flexibility of the lower limbs and hips *(iliopsoas: psoas major, iliacus, quadriceps femoris group: rectus femoris, vastus lateralis, vastus medialis, sartorius, hamstrings: biceps femoris, semitendinosus, semimembranosus etc.)*. The angle reference point was the hips (greater trochanter) and the angle line was put across the legs to the ankle (lateral malleolus). In exceptional situations (if the athlete's knee was not straight), the angle tool's reference point was the thigh plane to the knee. The test was applied on two sides: right leg forward position, and left leg forward position. The results were recorded us a different variable for the left and right leg and the results were given in degrees (Fink et al., 2015; Fink & Hofmann, 2015).

Note: to calculate the differences of the active flexibility and mobility needed the same measurement unit. For that reason, the angle reference point was the coccyx bone, and the angle line was put across the legs to the ankle and another line was put across the imaginary line of the sagittal plane. This degree was used to compare the results of this test to another test.

Side Spit (SS^0)

The test's main aim is to measure the active flexibility of the lower limbs adductors *(pectineus, gracilis, adductor brevis, adductor longus, adductor magnus, etc.)*. The angle reference point was the coccyx bone, and the angle line was put across the legs to the ankle (lateral malleolus). The results were given in degrees (Fink et al., 2015; Fink & Hofmann, 2015).

Note: to calculate the differences of the active flexibility and mobility needed the same measurement unit. For that reason, the angle reference point was the coccyx bone, and the angle line was put across the legs to the ankle and another line was put across the imaginary line of the sagittal plane. This degree was used to compare the results of this test to another test.

Arm-Trunk Angle Backward (AT_0B)

The test's main aim is to measure the active flexibility and mobility of the shoulders and upper limbs (*triceps brachii, posterior deltoid, teres minor, teres major, latissimus dorsi pectorals abdominal and sternocostal part, etc.)*. The angle reference point was the upper limit of middle axillary line (biacromial elevation level) and the angle line was put across the hand joint (styloid process of ulna) and hips (greater trochanter). The results were recorded us an angle given between the trunk and raised arms (Fink et al., 2015; Fink & Hofmann, 2015).

Leg Raise forward (LRF^0)

The test's main aim is to measure the lower limbs flexor muscles *(iliopsoas, pectineus, rectus femoris, sartorius, adductor longus, tensor fasciae latae, etc.)* mobility *(the ability of the athlete to apply movements from a wide-angle and in different directions as far as the joints allow)* (Süzen, 2013). The reference of the measurement, where the angle was based on, was the hips (greater trochanter). The angle line was put across the raised leg to the ankles (lateral malleolus) and the angle's other line was put across the upper body exactly on the vertical line on the coronal plane (frontal plane). The results of the test were determined by the angle degree between raised leg and upper body (Fink et al., 2015; Fink & Hofmann, 2015).

Note: to calculate the differences of the active flexibility and mobility needed the same measurement unit. For that reason, the angle reference point was the coccyx bone, and the angle line was put across the legs to the ankle and another line was put across the imaginary line of the sagittal plane. This degree was used to compare the results of this test to another test.

Leg Raise Sideward (LRS^0)

The test's main aim is to measure the lower limbs abductor muscles *(gluteus medius, gluteus minimus, tensor fascia lata, gluteus maximus, etc.)* mobility *(the ability of the athlete to apply movements from a wide-angle and in different directions as far as the joints allow)* (Süzen, 2013). The reference of the measurement was the angle based on was the coccyx (tailbone). The angle line was put across the raised leg to the ankles (lateral malleolus) and the angle's other line was put across the upper body exactly on the vertical line on the sagittal plane. The results of the test were determined by the angle degrees between raised leg and upper body (Fink et al., 2015; Fink & Hofmann, 2015).

Note: to calculate the differences of the active flexibility and mobility needed the same measurement unit. For that reason, the angle reference point was the coccyx bone, and the angle line was put across the legs to the ankle and another line was put across the imaginary line of the sagittal plane. This degree was used to compare the results of this test to another test.

Angle Degree of the Leg Split Position in Cartwheel (A^0LSPCT)

The test's aim is to measure the ratio of active flexibility during performance (*inaction*) that requires mobility. Recorded videos of the cartwheel technique were used in the test. The video was stopped in the frame the gymnast is in at a handstand position and the legs are split in the sagittal plane. The criteria of the evaluation for the angle degree of the leg split position in the cartwheel technique based on the angle degree based on the coccyx of two imaginary lines, which were across the leg (heel). The application of the test was no break on the knee (Fink et al., 2015; Fink & Hofmann, 2015).

Arm-Upper Body Angle Backward in Bridge Technique (AUB°BB)

The bridge technique was made according to the FIG rules and used to measure the mobility *(the ability of the gymnast to apply movements from a wide-angle and in different directions as far as the joints allow)* of the gymnasts (Süzen, 2013). The criteria of the evaluation for the bridge technique was based on the angle degree between two imaginary lines which were across the leg *(the line was across malleolus and greater trochanter)* and arm *(the line was across the styloid process of the ulna and acromial elevation level)*. The application of the test was no break on the knee, and elbow ankle (Fink et al., 2015; Fink & Hofmann, 2015).

Data analysis

In the data analysis of the variables in the study the Kinovea 0.8.15 program was used, which is a video player for sports analysis and provides a set of tools to capture, slow down, study, compare, annotate and measure technical performance (Kinovea, 2021). To mark the location, measure distance and determine the angle degree of the videos used tools of the program such as a line, circle, cross marker, angle, etc. The videos are made by the Galaxy S10, which has three cameras on the back: a main 12-megapixel with an aperture that shifts between f/1.5 and f/2.4 depending on light, with an ultra-wide 16-megapixel unit and a telephoto 12-megapixel for zooming.

In the data analysis, the SPSS 24 program was used. General descriptive analysis was made by using descriptive analysis, correlations between variables were made by the Pearson correlation and relationships between variables and success scores revealed by the Pearson correlation analysis. The percentage of the functional active flexibility was calculated by using the formula "%= (angle^0 of the mobility in functional movement / angle0 of the active flexibility) *100".

Results

Table 1. Differences between techniques requiring active flexibility ''Side Split (SS°)'' and techniques requiring mobility ''Leg Raise Sideward (LRS°)''.

Variables	N	X̄±SD		p
		SS°	LRS°	
LL_RS°	20	168.3±14.53	106.8±11.46	.033*
RL_RS°			105.5±11.07	.050*

X̄±SD: mean and std. Deviation, LL_RS°: Left Leg Raise Sideward (°), RL_RS°: Right Leg Raise Sideward (°), N: sample, SS°: Side Split (°), LRS°: Leg Raise Sideward (°), p: sig. ($p < 0.05$*).

Table 1 shows the significant differences between SS° and LRS° in the left and right leg ($p < 0.05$). These differences have shown that the leg split degrees were higher in the SS° technique compared to the LRS° technique.

Table 2. Differences between techniques requiring active flexibility ''Side Split (SS°)'' and techniques requiring mobility ''Leg Split in Handstand Position in Cartwheel Technique (A°LSPCT)''.

Variables	N	X̄±SD	p
SS°	20	173.6±13.17	.000*
A°LSPCT		136.0±12.23	

SS°: Side Split (°), A°LSPCT: Angle Degree of the Leg Split Position in Cartwheel Technique (°), N: sample, X̄±SD: mean and std. Deviation, p: sig. ($p < 0.05$*).

In the findings of Table 2, it can be seen a significant difference between SS° and A°LSPCT, where it can be seen that leg split in SS° technique were higher in comparison to the A°LSPCT technique.

Table 3. Differences between techniques requiring active flexibility "Arm-Trunk Angle Backward (AT_°B)" and techniques requiring mobility "Arm-Upper Body Angle Backward in Bridge Technique (AUB°BB)".

Variables	N	X̄±SD	p
AT_°B	20	139.9±11.83	.000*
AUB°BB		174.6±13.21	

AT_°B: Arm-Trunk Angle Backward (°), AUB°BB: Arm-Upper Body Angle Backward in Bridge Technique (°), N: sample, X̄±SD: mean and std. Deviation, p: sig. ($p < 0.05$*).

Table 3 results determined that the AT_°B technique angle degree was lower than the AUB°BB technique (a small angle degree means higher flexibility ROM) ($p < 0.05$*).

Table 4. Differences between techniques requiring active flexibility "Forward-Backward Split Technique (FBS°)" and techniques requiring mobility "Leg Raise Forward (LRF°)".

N	FBS°		LRF°		p
	Variables	X̄±SD	Variables	X̄±SD	
20	LLA_FBS°	146.7±12.11	LL_RF°	99.5±9.97	.956
	RLA_FBS°	153.3±12.38	RL_RF°	99.4±9.97	.427

N: sample, FBS°: Forward-Backward Split (°), LLA_FBS°: Left Leg Ahead Forward-Backward Split Degree (°), RLA_FBS°: Right Leg Ahead Forward Backward Split Degree (°), LRF°: Leg Raise Forward (°), LL_RF°: Left Leg Raise Forward Degree (°), RL_RF°: Right Leg Raise Forward Degree (°), X̄±SD: mean and std. Deviation, p: sig. ($p< 0.05$*).

In Table 4, it can be seen that there are no statistically significant differences between FBS° and LRF° techniques in the left or right leg ($p< 0.05$). Factors that may cause differences that are no statistically significant can be found in the discussion section.

Discussion

In the study conducted to determine the differences between active flexibility and mobility, was found a difference in range of motion between techniques requiring active flexibility and mobility in artistic gymnastics. While the range of motion was found to be high during the application of techniques requiring active flexibility, it was observed that the range of motion was lower in techniques requiring mobility. The inclusion of the motor skills such as power, dynamic balance, motor control and strength in the techniques requiring mobility caused lower range of motion.

Results of the study have shown significant differences between SS° and LRS° in the left and right leg ($p< 0.05$). These differences have shown that the leg split degrees were higher in the SS° technique compare to the LRS° technique. This means that not all active flexibility angle degrees were functional in the movements requiring mobility. In the study conducted by Moreside & Mcgill (2012), passive flexibility exercises and motor control exercises were applied to the participants for 6 weeks. As a result of the study, it was determined that the participants switched from the limited hip mobility group to the extreme hip mobility group.

Thus, development of the mobility is related to motor skills development as it is related to flexibility. Flexibility exercises applied to the young adults who participate in sports activities for at least 60 minutes and 3 days a week resulted in significant increases in the hip range of motion values of the participants were determined (Ayala & Baranda, 2010). In addition, the study identified that active flexibility exercises applied to the participants in the absence of the sports activities did not cause a significant increase in hip range of motion (Davis et al., 2005). In light of these data, it can be concluded that mobility is not related only to flexibility but that the increase in motor skills affects mobility. Moreover, Hrysomallis (2009) stated that movement in the hip joint is associated with strength and flexibility.

When analyzing the differences between SS° and A°LSPCT, it was determined that leg split in SS° technique were higher in comparison to the A°LSPCT technique. As it can be seen, not all flexibility of the leg is expressed in the side split was functional in the movements requiring mobility such as an angle degree of leg split in the cartwheel technique. Similarly, a study investigating the same joint in different anatomical positions, made by Haser et al. (2017) has shown that the increase in thigh muscle strength significantly increased the degrees of hip flexion range of motion.

Similar to the techniques mentioned above, the AT_°B technique angle degrees were lower than the AUB°BB technique. Being small-angle degree in the Arm-Trunk Angle Backward and Arm-Upper Body Angle Backward in Bridge Technique means better higher range of motion. Therefore, similar to other techniques included in the study, flexibility expressed in the movements requiring mobility (Arm-Upper Body Angle Backward in Bridge Technique) was lower than the flexibility expressed in an arm-trunk angle backward movements. As a result of the study in which Barnes et al. (2001) examined shoulder range of motion degrees in different anatomical planes, it was found that passive range of motion degrees in the dominant shoulder were higher than the range of motion degrees measured in the techniques requiring mobility. Oliver et al. (2020) determined that range of motion in the shoulder joint differs between passive flexibility and flexibility expressed during certain techniques. In parallel to age increases, detected decreases in the range of motion degree of the shoulders joint is caused by force improvements (Meister et al., 2005).

Unlike the techniques mentioned above, there are no statistically significant differences between Forward-Backward Split and LRF°: Leg Raise Forward techniques in the left or right leg. As another technique has shown differences between active flexibility and mobility in these techniques significant differences were expected. However, one of the biggest reasons why in these variables the functioning ratio of the flexibility in the movements requiring high mobility, is the fact that the test measures flexibility and tests that measure mobility were not identical in the biomechanics and anatomic perspective. In the measurement of the right or left leg flexibility, another leg was extended back also, the extension of the quadriceps muscle group of the leg which is back, reduced the extension of the leg which is ahead. Whereas during the leg raise ahead test, another leg was straight in the standing position, which did not stretch the quadriceps muscle. If we eliminate the effect of this anatomical difference, it can be seen that the ratio of flexibility/mobility will be similar to the above variables. To reach more reliable results, there needs to the inclusion of techniques with a higher difficulty degree that is directly related to mobility and flexibility. This method may increase the reliability of the results in future studies.

In conclusion, our study on the concepts of active flexibility and mobility, which have not been clarified in the literature and have been defined as the same skill, has been revealed that these are two separate skills that are interconnected. While active flexibility is the ability of muscles to stretch, mobility is related to skills such as flexibility, strength, dynamic balance characterized by functional flexibility. Therefore, having good flexibility does not necessarily mean that an athlete will have good mobility. Being aware of the differences between active flexibility and mobility is crucial to clarify functional flexibility that positively affects solving confusions in training programs that aim to improve the flexibility and mobility performance of gymnasts.

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