TIME COURSE OF CHANGES IN STRADDLE JUMP AND VERTICAL JUMP PERFORMANCE AFTER ACUTE STATIC STRETCHING IN ARTISTIC GYMNASTS

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Abstract
The aim of the present study was to examine the time course of changes of the effects of static stretching on straddle jump, vertical jump height and flexibility after performing dynamic movements in artistic gymnasts. The study was participated by 14 female artistic gymnasts aged between 9 and 14. Vertical jump heights were measured using the New Test 2000 testing device. Flexibility measurement was performed with sit and reach flexibility test. Artistic gymnastics-specific jump movement was evaluated looking at the angle between lower extremities using the Dartfish motion analysis program. Baseline measurements taken before the standard warm-up and the measurements taken after static stretching were assessed. Four sets of gymnastics moves each lasting two minutes were performed. The tests were repeated after each set. Static stretching was found to affect vertical jump performance significantly. Significant differences were found between $Jump_2$ *and* $Jump_1$ *(p=0.01),* $Jump_2$ *and* $Jump_3$ *(p=0.03),* $Jump_2$ *and* $Jump_4$ *(p=0.01),* $Jump_2$ *and* $Jumop_5$ *(p=0.004), and* $Jump_2$ *and* $Jump_6$ *(p=0.009). In flexibility-related changes, significant differences were found between* $Reach_2$ *and* $Reach_3$ *(p=0.03), and* $Reach_2$ *and* $Reach_6$ *(p=0.006). Static stretching was found to have no significant effect on the lower extremity straddle jump degree. In conclusion, although the static stretching protocol reduced vertical jump performance significantly, it did not affect the artistic gymnastics-specific jump move. The negative effects of static stretching on jump height approached the baseline value approximately 4 minutes later.*

Keywords: *artistic gymnastics, static stretching, vertical jump, flexibility*

INTRODUCTION

Stretching protocols are widely used by many athletes in the warm-up period before exercise and competitions (Shrier, 2004; Booth, 2008). Flexibility is an important component for the development of many athletes. Therefore, stretching exercises are frequently used for improving flexibility (Stone, 2006). Stretching methods include static stretching (reaching the best possible stretching point and maintaining the position for a certain period of time), ballistic stretching (defined as the method reached by a rhythmic oscillation loading to the muscle's near-maximum stress point), Proprioceptive Neuromuscular Facilitation (PNF, a type of flexibility exercise which combines muscle contraction and relaxation with passive and partner-assisted stretching), and dynamic stretching techniques (Amiri- Khorasani et al., 2010; Behm et al., 2001). Static stretching practices prior to exercise are believed to bring up better performance, reduce the risk of injury (Shellock, & Prentice, 1985; Cross, & Worell, 1999; Hartig, 1999) and increase the joint range of motion (Laban, 1962; Amiri- Khotasani, 2013). However, although static stretching is widely used, it is the most controversial technique with ever-changing views on its positive and negative aspects on muscle strength and power (Chaabene, Behm, Negra, & Granacher, 2019). Such controversial results can be explained by the different stretching times or intensities applied (>10 minutes) (Konrad, Reiner, Thaller, & Tilp, 2019). (Konrad, Reiner, Thaller, & Tilp, 2019). According to various findings, the intensity and duration of static stretching changes performance considerably, and prolonged static stretching causes losses in strength (Freitas et al., 2015; Magnusson, 1998). Static stretching has been found to have negative effects on maximal power performance (Jeni, & Sands, 2003). The change in the strength-speed relationship and decreased muscle tension indicate that static stretching impairs strength generation (Behm, & Button, 2001; Power et al., 2004). As a result of the inverse myotatic reflex on the tendon stretched with the muscle tension, it is related to inhibiting the muscle to which the tendon is connected. The inverse myotatic reflex is initiated by the Golgi tendon organ. The degree to which the Golgi tendon organ influences the motor unit depends on the frequency of the stimulus. (Fox et al., 1988). Thus, it causes difficulty in sports that require maximal power and strength during exercise, like jumping and running (Jeni et al., 2003; Young, 2001; Fletcher, 2004). On the other hand, it is reported that static stretching performed for less than 30 seconds is effective in minimizing the negative outcomes of stretching, and beneficial for the joint range of motion (ROM) in well-trained athletes, while high intensity and long-duration static stretching may play a critical role by causing impairments in strength outputs (Behm et al., 2011). After a static stretching protocol of 90 seconds, athletes' hip ROM improved, and it had no statistically significant effect on jump heights 2 minutes after stretching. This indicated that long-duration flexibility training and the increased musculotendinous pliability could prevent the transient decrease in strength and power (Papia et al., 2018).

Although many studies have examined the negative effects of static stretching on performance, no study has been found that would look into how long this effect lasts during training or competition. In addition, physical exercise affects the balance of the homeostasis. Muscles that contract during exercise produce force and heat. Physical exercise is actually a form of mechanical energy. This produced energy will deplete the energy stocks in the body. Depending on the form of exercise, sooner or later, fatigue and exhaustion will occur (Ament & Verkerke, 2009). Therefore, it is important to determine whether the effects are due to fatigue or to static stretching. The aim of the present study was to examine the time course of changes of the effects of static stretching on artistic gymnastics-specific jump moves, vertical jump height and flexibility in artistic gymnasts.

The hypotheses of our study: Static stretching increases flexibility. It negatively affects vertical jump height and straddle jump performance.

The present study is important as we think the negative effects of static stretching may disappear after a while.

METHODS

14 female (age: 10.78 ± 1.80, weight (kg): 32.25 ± 8.62, height (cm): 136.75± 11.07) artistic gymnasts participated in the study. They were aged 9-14, had at least 4 years of sport experience and had no injury or disease in the last 6 months prior to the study. The athletes took the tests in the

Gymnastics Sports Hall where they do their regular training. Informed consent forms regarding the purpose, safety and ethics of the research were also distributed to their parents, and all participants completed a statement of informed consent. The Medical Research Ethics Committee of Faculty of Medicine approved this study (protocol no: 2740-GOA).

First, the participants' height and weight were measured. This was followed by a 10-minute standardized (without static stretching) general warm-up protocol. After the warm-up, the participants took a vertical jump test and their flexibility measurements were taken. A two-minute standardized gymnastics series (Figure 4) that lasted 8 minutes in total was performed between the tests. The tests were taken immediately after the applied series. 2 minutes of active rest was given before the series were applied. A one-minute rest was given between the tests. The change in these effects was examined with the help of the tests applied while performing the series. The series was performed four times in total. Jump tests and flexibility measurements were performed between the series, and after the last one, the time course of changes of the results was evaluated. These two separate implementations showed whether the possible changes resulted from static stretching or fatigue. In order to prevent the samples to be affected by such factors as circadian rhythm, temperature, moisture etc., the tests were performed at the same times of the day. The total tests and series took approximately 65 minutes.

The tests used vertical jump heights (NewTest 2000; the Newtest Powertimer testing system was shown to be a useful instrument for measuring jump height and running speed); body fat percentages (skinfold) motion analysis software (Dart Fish); height (cm)-weight (kg) measurements; high definition camera (Go-pro) markers, and the sit and reach test. It was recorded at 240fps in 1:1 mode. Wide angle was not used. Following a ten-minute general warm-up, the vertical jump test and flexibility measurements were taken. All measurements were taken at 9.00 a.m.

Vertical jump performance was measured using a portable force platform (Newtest, Finland). Each subject performed two maximal counter-movement jumps with approximately two minutes' recovery in between. The best vertical jump results were recorded in centimeters (Bosco et al., 1995).

Sit and reach flexibility test: athletes stretched forward from the trunk (waist and hip) without bending the knees, with their hands in front of the body (Liemohn, Sharpe, & Wasserman, 1994) (figure 2). In order to get the most accurate result, there was a pause of two seconds without stretching forward or backward; the test was repeated twice, and the highest value was obtained. Also, approximately two minutes rest was given in between the tests.

As seen in Figure 3, the participants were asked to do the branch-specific straddle jump, As to the specific jumping test, their pictures taken with a high definition camera were evaluated on the Dartfish motion analysis software and the athletes' flexibility was estimated by looking at the angular change. The frame rate is 29 frames per second. Markers were placed on the athletes in order to make it easier to watch the pictures. Two of the markers were placed on the patella and the other two in the middle of the iliac bones, which made it possible to watch the straddle jump degree during exercise. Immediately after the baseline measurements, static stretching exercise was performed in four stations, each one lasting 30 seconds. This was followed by a two-minute standardized gymnastics series. The series were performed four times in total. Jump height and flexibility were measured after each series and the results were examined for time course of changes. In the study, four static stretching exercises were performed. These exercises are usually performed as gymnastics moves (Figure 4). Each stretching exercise lasted 30 seconds. The series included 12 most commonly performed gymnastics moves. The tests were performed in the same order after each series

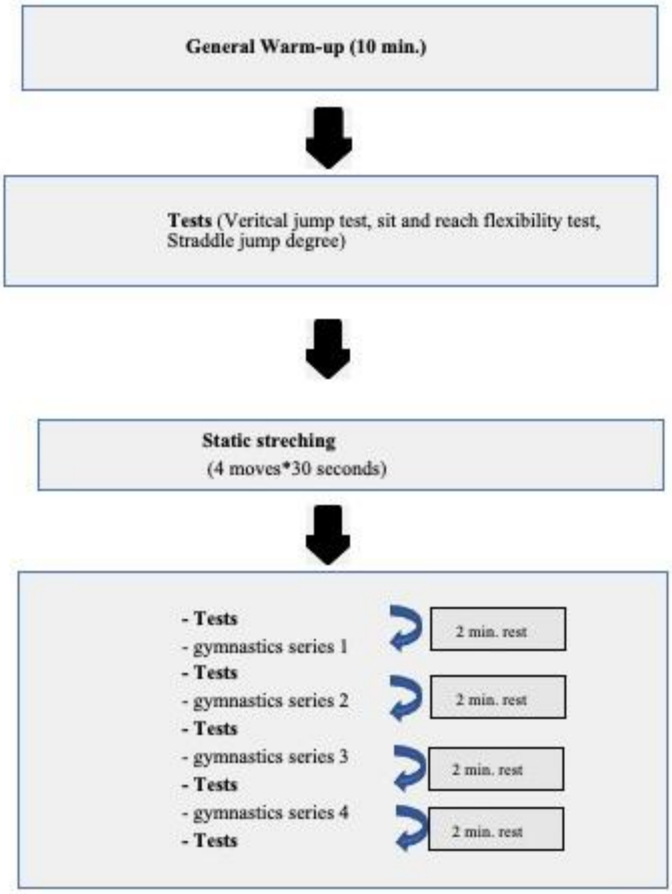

Figure 1. Schematic illustration of the experimental protocol instruments

Figure 2. Sit and reach test
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Figure 3. Angular evaluation in straddle movement with the Dartfish motion analysis software

For data analysis, descriptive statistics were calculated for the athletes' physical characteristics, jumping values (cm) and flexibility (cm) values. The Shapiro-Wilk test was performed to see whether the participants' descriptive statistics were normally distributed or not. The Shapiro-Wilk test results showed that the data distributed normally, and repeated measures ANOVA analysis was conducted with a Bonferroni correction. The tables show standard deviation, the lowest and the highest values, Δ difference (difference between mean values), statistical values and effect sizes.

The data analysis was conducted using SPSS 21.0 software. The effect size (ES) was calculated according to means and standard deviation. Cohen's d ESs were categorized as no effect (0-0.2), small effect (0.2-0.5), moderate effect (0.5-0.8) and large effect (0.8) Cohen, J. E. (1988). The level of significance was accepted as $p<0.05$.

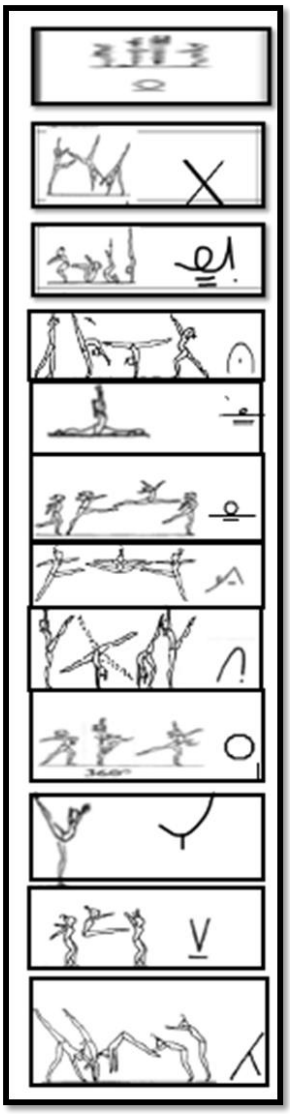

Figure 4. Gymnastics series consisting of 12 movements (FİG,2022)

RESULTS AND DISCUSSION

Participants' descriptive statistics are presented in Table 1.

As shown in Table 2, according to the ANOVA results, the values obtained were F (5.65) = 5.588, p= 0.00, np2 =0.301 in the jump test. Changes were examined between the vertical jump measurements after static stretching and repeated measurements. The test results showed a significant difference between $Jump_2$ (after static stretching) measurements and all repeated measurements. A significant difference (p=0,01) was seen between $Jump_1$ and $Jump_2$. A 2.42cm decrease was found in the vertical jump height between the baseline measurements and measurements after static stretching. Significant differences were found between $Jump_2$ and $Jump_3$ (p=0.03), $Jump_2$ and $Jump_4$ (p=0.01), $Jump_2$ and $Jump_5$ (p=0.004), and between $Jump_2$ and $Jump_6$ (p=0.009).

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Table 1
Participants characteristics N= 14 (Mean ± SD).

	Min.	Max.	X ± SD
Age	9.0	14.0	10.78 ± 1.80
Weight (kg)	23.0	48.4	32.25 ± 8.62
Height (cm)	122.6	159.0	136.7 5± 11.07
BMI (Kg/m^2)	14.6	21.3	16.95 ± 1.88
Sports experience (years)	4.0	10.0	6.14 ± 2.07
Body fat (%)	7.0	17.1	11.2 ± 3.16

X ± SD; Mean and Standard deviation.

Table 2
Changes between observations in vertical jump height (cm) after the static stretching protocol (N=14).

	X ± SD	Min.	Max.	Δ Difference	Bonferroni P	Effect Size
$Jump_1$	34.9 ± 2.6	31.0	41.0	-2.4	0.01	0.07
$Jump_2$	32 5 ± 3.6	24.0	38.0			
$Jump_2$	32 5 ± 3.6	24.0	38.0	+1.9	0.03	
$Jump_3$	34 4 ± 3.5	31.0	41.0			0.05
$Jump_2$	32.5 ± 3.6	24.0	38.0	+2.5	0.01	
$Jump_4$	35.0 ± 2.3	31.0	39.0			0.08
$Jump_2$	32.5 ± 3.6	24.0	38.0	+3.7	0.004	
$Jump_5$	36.2 ± 2.7	33.0	42.0			0.11
$Jump_2$	32.5 ± 3.6	24.0	38.0	+3.5	0.009	
$Jump_6$	36.0 ± 2.8	30.0	40.0			0.10

Jump; Jumping Performance, SS; Static stretching protocol, X ± SD; Mean and Standard deviation. *p<0.05.

As seen in Table 3, according to the ANOVA results, the values obtained were F (2.147, 27.908) = 2.443, p = 0.102, np2 = 0.158 in the reach test. No statistically significant difference was found between the baseline measurements ($reach_1$) and measurements after static stretching ($reach_2$) in the sit and reach flexibility test results. Significant differences were found in Reach3, Reach5 and Reach 6 between the measurements taken after static stretching and the repeated measurements ($reach_{2)}$

According to the ANOVA results, the values obtained were F (3.159, 41.07) = 2.45, p= 0.74, np2 =0.159 in the SJD test. In the straddle jump degree (SJD) measurements, no significant difference was found between the baseline measurements (SJD_1) and measurements after static stretching (SJD_2) and repeated measurements (SJD_3, SJD_4, SJD_5, SJD_6) (Table 4).

As seen in *Figure 3*, on the day of static stretching, vertical jump height measured after static stretching was found to be significantly lower than the baseline measurements. A decrease of 2.42cm can be seen between the baseline measurements (1) and the measurements taken after static stretching. Jump performance gradually improved in the repeated measurements

Table 4
Changes between SJD *Measurements after Static Stretching and Repeated Measurements (N=14.)*

	X ± SD	Min.	Max.	Δ Difference	P	Effect Size.
SJD° 1 SJD° 2	198.1 ± 13.3 199.1± 11.1	179.4 183.3	216.0 216.6	+0.9	0.550	0.08
SJD °2 SJD 3	199.1± 11.1 201.0± 11.0	183.3 184.3	216.6 217.0	+1.8	0.232	0.17
SJD °2 SJD °4	199.1± 11.1 201.8 ± 14.0	183.3 180.0	216.6 218.9	+2.7	0.214	0.21
SJD° 2 SJD 5	199.1± 11.1 195.5± 14.3	183.3 178.1	216,6 215.1	-3.5	0.258	0.27
SJD° 2 SJD° 6	199.1± 11.1 198.6 ± 13.0	183.3 175.8	216.6 218.4	-0.4	0.871	0.03

SJD°; Straddle jump degree, X ± SD; Mean and Standard deviation. *p<0.05

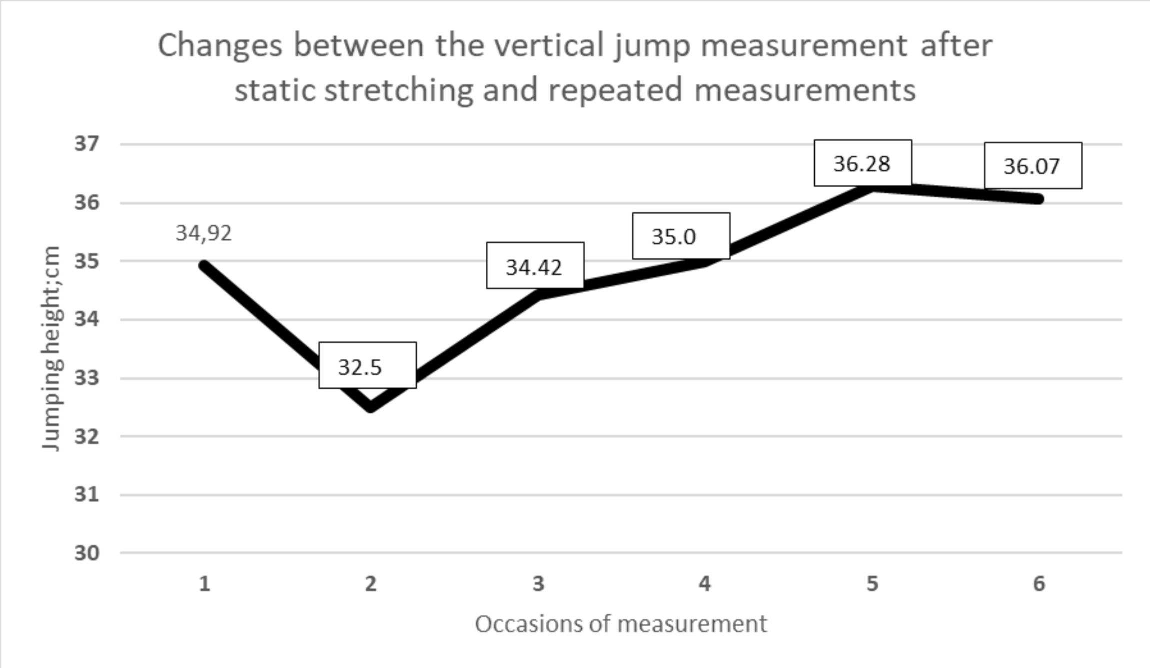

Figure 5. Changes between the vertical jump measurements after static stretching and repeated measurements (cm). 1 (Baseline measurement), 2 (Measurement after static stretching), 3 (Measurement after series 1), 4 (Measurement after series 2), 5 (Measurement after series 3), 6 (Measurement after series 4).

DISCUSSION

The aim of the present study was to examine the time course of changes of the effects of static stretching on artistic gymnastics-specific jump moves, vertical jump height and flexibility in artistic gymnasts. According to our findings, the static stretching protocol decreased vertical jump performance but had no effect on the artistic gymnastics- straddle jump move.

Many types of warm-up exercises are used in artistic gymnastics, so it is important to determine their effects on performance in planning training programs, decreasing injuries and optimizing performance (Robbins, & Scheuermann, 2008). Studies have reported many negative effects of static stretching on performance. Static stretching was found to decrease quadriceps and hamstring muscle strength significantly (Sekir et al., 2015). It is also reported that the intensity and duration of static stretching can change performance considerably and that high-intensity and long-duration static stretching exercise leads to losses in strength (Freitas et al., 2015). The negative effects of static stretching are considered to result from the decreased participation of motor units and the resulting decrease in the muscular tension and inhibition of the muscle (Knudson et al., 2011). Researchers associated the static stretching related decrease in performance with neural factors. For instance, when stretched beyond its resting length, the muscle reduces strength transfer to the skeletal system, which may lead to losses in performance (McHugh & Nesse, 2008).

Additionally, one of the causes of these strength losses is the reaction of the Golgi tendon organ to the stretched muscle (Avela et al., 1999). A significant difference was found between $Jump_1$ and $Jump_2$ in our study (p=0,01). In the New Test results, taken following a general warm-up, the athletes recorded an average vertical jump height of 34.92cm. A mean jumping performance was measured at 32.50 cm after static stretching, which indicated a decrease of approximately 2.50cm in jump height. This finding supports many other studies reporting that static stretching negatively affects jump performance. The mean heights in the New Test of the 2-minute series 1, 2, 3 and 4 performed after static stretching were 34.42cm, 35.00cm, 36.28cm, and 36.07cm, respectively. Although the post-static stretching negative effect weakened after the first series, it could not reach the baseline value as a 0.5 cm difference was still found from the baseline measurement. However, it returned to the baseline value following the second series with an increase of 0.07 cm in jump height. Nevertheless, these differences are not significant statistically. The reason for all these could be the fact that as a result of the inverse myotatic reflex on the tendon stretched with the muscle tension, the tendon inhibits the muscle to which it is connected. Stretching exercises are generally performed to improve flexibility (Stone et al., 2006). Static stretching increases joint motion range (Laban, 1962). Unlike many other studies, no significant result was obtained showing that static stretching improves flexibility in the sit and reach flexibility tests in our study.

The fact that no significant difference was found in the flexibility measurements after static stretching may be because the participants are elite athletes with an advanced level of flexibility. The straddle jump is a move that is frequently used in gymnastics and has several variations. In our study, no significant difference was found in the SJD measurements of the athletes in the artistic gymnastics-specific jump move after static stretching. This could have resulted from the negative effect on their jump performance. Their vertical jump performance decreased on average by 2.42cm after static stretching. Since the athletes could not perform a good vertical jump, their SJD measurement results may not have differed significantly. Another reason could be the dynamic stretch reflex. The dynamic stretch reflex is activated by the strong dynamic impulse sent by the primary endpoints of the muscle fibers because of the rapid stretching of the muscle (Mukherjee & Chakravarty, 2010).

CONCLUSIONS

The static stretching protocol decreased vertical jump performance but had no effect on the artistic gymnastics-straddle jump move. In addition, static stretching was seen to have no acute effect on gymnasts' flexibility as a result of the sit and reach flexibility test. Therefore, if static stretching is performed before a competition, as it decreases jump performance, a two-minute static stretching protocol with each stretch held for 30 seconds may cause the athlete to experience a considerable deterioration in her jumping performance. It is recommended that protocols of different durations with different techniques for static stretching be conducted in future studies to examine the effects on the athletes' performance in further detail.

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