ARAŞTIRMA MAKALESİ/RESEARCH ARTICLE
Karya J Health Sci. 2022; 3(2): 56-61
doi: 10.52831/kjhs.1063292
e-ISSN:2717-9540

KARYA JOURNAL OF HEALTH SCIENCE

journal homepage: www.dergipark.org.tr/kjhs

THE EFFECT OF SINGLE-STAGE PERTURBATION EXERCISE ON THE SHOULDER JOINT POSITION SENSE AND TRAPEZIUS MUSCLE ACTIVATION IN PATIENTS WITH ARTHROSCOPIC ROTATOR CUFF REPAIR

ARTROSKOPİK ROTATOR KILIF TAMİRİ YAPILAN HASTALARDA TEK SEANS PERTURBASYON EGZERSİZİNİN OMUZ AKTİF EKLEM POZİSYON HİSSİ VE TRAPEZİUS KAS AKTİVASYONU ÜZERİNE ETKİSİ

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ABSTRACT

Objective: Perturbation exercises conducted on mobile surfaces in the latter period of the rehabilitation increase the neuromuscular control. The purpose of the study was to investigate the effects of single session perturbation exercises' on active joint position sense and on the electromyography activation of the trapezius muscle in patients who underwent arthroscopic rotator cuff repair in the previous 6 months.

Method: 12 individuals who underwent arthroscopic rotator cuff repair were included in the study as the study group (age: 54.83±3.5), and 13 individuals with in an asymptomatic shoulder joint were included as the control group (age: 49.07±4.5). All subjects were evaluated before and after single-session perturbation exercise. Active joint position sense at 90° shoulder flexion and abduction was assessed using a laser pointer-assisted angle reproduction test. The activation of the trapezius muscles during this test was recorded by the superficial electromyography tool. The pre-exercise and post-exercise values were analyzed using an in-group Wilcoxon signed-rank test. The Mann–Whitney U test was used for group comparisons.

Results: There was no difference between groups in the active angle reproduction test before and after the perturbation exercise (flexion p:0.124; abduction p:0.421). When electromyography activations after the exercise were compared, the activation of the operated upper trapezius (p:0.01) and the non-operated lower trapezius decreased (p:0.024). There was no correlation between the electromyography activation of the trapezius muscle and active joint position sense (flexion p:0.657; abduction p:0.662).

Conclusion: It was observed that single-session perturbation exercises in the sixth month following rotator cuff repair did not have an immediate effect on active joint position sense.

Key Words: Electromyography, Perturbation, Proprioception, Rotator Cuff Injuries

ÖZ

Amaç: Rehabilitasyonun ileri aşamalarında yapılan perturbasyon egzersizleri nöromuskuler kontrolü artırır. Bu çalışmanın amacı 6 ay önce artroskopik rotator kılıf tamiri yapılan hastalarda tek seans uygulanan perturbasyon egzersizinin aktif eklem pozisyon hissi ve trapezius kasının elektromiyografik aktivasyonu üzerine erken etkisini incelemektir.

Yöntem: Artroskopik rotator kılıf tamiri yapılan 12 kişi çalışma grubu olarak (yaş: 54.83±3.5), asemptomatik omuz eklemi olan 13 kişi kontrol grubu olarak (yaş: 49.07±4.5) çalışmaya dahil edildi. Tüm katılımcılar, tek seanslık pertürbasyon egzersizinden önce ve sonra değerlendirildi. 90° omuz fleksiyonunda ve abdüksiyonda aktif eklem pozisyonu hissi, lazer imleç yardımlı açı tekrarlama testi kullanılarak değerlendirildi. Bu test sırasında trapezius kaslarının aktivasyonu yüzeyel elektromiyografi cihazıyla kaydedildi. Egzersiz öncesi ve sonrası değerler grup içi Wilcoxon signed rank testi, grup karşılaştırmaları Mann-Whitney U testi kullanılarak analiz edildi.

Bulgular: Pertürbasyon egzersizi öncesi ve sonrası aktif açı tekrarlama testinde gruplar arasında fark yok idi (fleksiyon p:0.124; abduksiyon p:0.421). Egzersiz sonrası elektromiyografi aktivasyonları karşılaştırıldığında, cerrahi yapılan taraf üst trapez ve diğer taraf alt trapez aktivasyonu azaldı (p:0.01). Trapezius kasının elektromiyografi aktivasyonu ile aktif eklem pozisyon hissi arasında korelasyon yoktu (fleksiyon p:0.657; abduksiyon p:0.662).

Sonuç: Rotator kılıf tamiri sonrası altıncı ayda tek seans pertürbasyon egzersizlerinin aktif eklem pozisyon hissi üzerine erken etkisinin olmadığı görüldü.

Anahtar Kelimeler: Elektromyografi, Perturbasyon, Propriosepsiyon, Rotator Kılıf Yaralanmaları

Makale Bilgisi/Article Info

Yükleme tarihi/Submitted: 26.01.2022, **Revizyon isteği/Revision requested:** 14.03.2022, **Son düzenleme tarihi/Last revision received:** 04.04.2022, **Kabul/Accepted:** 07.04.2022

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INTRODUCTION

Surgical treatment is inevitable for partial and full-thickness tears that are nonresponsive to conservative treatment [1]. The success of the rotator cuff (RC) repair depends on the rehabilitation program as well as the anatomical and surgical factors. Passive and active joint movements, stretching, strengthening, and proprioceptive exercises are used in rehabilitation programs [2]. It was shown that postsurgical proprioceptive sense training is significant to improve the functionality of the shoulder joint [3].

Joint proprioception relays data from the joint capsule, ligaments, and muscles to the central nervous system for muscular activity [4]. Supraspinatus muscle has an important role in the perception of proprioception because it involves muscle spindles, the Golgi tendon organ, and free nerve endings [5]. It has also been identified that the Golgi tendon organ and muscle spindles have a primary role especially in the perception of the lower parameters of the proprioceptive sense, including active JPS and contraction reproduction [6]. Previously it has been shown that the proprioceptive sense decreases when the joints are injured and after surgical treatment; however, it can be restored with proper exercise programs [7,8]. Maenhout et al. demonstrated that active joint position sense (JPS) is affected in patients with RC pathology [7]. It has been considered that the deterioration in muscle continuity with RC tears causes a decrease in the activation of the receptors in related muscles. The data received from the receptors during the active movement may be related to the amount of the activation of the muscles around the joint. Also, Yang et al. identified that mid-range JPS is related with the upper and lower parts of the trapezius and serratus anterior muscle activity [9]. Improving the decreased proprioceptive sense is one of the important goals of the rehabilitation process. Various models have been defined for the assessment and training of the proprioceptive sense [10-12]. It has been thought that perturbation exercises conducted on mobile surfaces in the latter period of the rehabilitation increase the neuromuscular control [5]. During perturbation training, the surface is moved multidirectional with various forces and amplitudes. The purpose of this exercise is to improve the stabilization response by enhancing the sensitivity of the muscle sensors. The number of motor units included in the contraction and the proprioceptive input are believed to be increased with perturbation exercises [6]. Pollock et al. showed the effects of motor unit recruitment in achieving increased levels of activation with external perturbation. It is shown that, after average 6-8 weeks of perturbation training, it has effects on joint position sense [13]. But this effect may be due to the cumulative result of the single-section perturbation exercise which increases the muscle activation. There exist no studies in the literature investigating the effect of perturbation training applied on patients undergoing rotator cuff repair on shoulder JPS and its relationship with the activation level of concurrent scapular muscles. The primary aim of the present study was to investigate the effects of single-session perturbation exercises on active JPS and activity of trapezius muscle and their relation in patients with RC repair. Our second aim is to compare the joint position sense of asymptomatic side of the patient with rotator cuff repair with their healthy pairs. The hypothesis of the present study was that more motor units could be activated with increased sensory input through perturbation exercises, which could thereby improve active JPS.

METHOD

This study was designed as a controlled clinical trial. Active JPS and EMG measurements were performed before and right after perturbation exercises in both groups.

Research ethics committee approval was obtained from the University Faculty of Medicine Clinical Studies Ethical Committee (Ethical Committee Decision Number: 138, Issue: 25901600).

The assessment method utilized was explained to all individuals and their approval was obtained.

A 12 individuals between 45 and 65 years of age who underwent arthroscopic RC repair with variable dominance and 13 asymptomatic individuals in the same age range and matched gender were included in the study.

The inclusion criteria for the study group were: those with grade II to grade III RC tear and underwent arthroscopic RC repair in the previous 6 months, no neurological problems, diabetes mellitus, and disc pathology symptoms around the cervical region, those with a joint limitation below 30°, and those suffering pain less than 3 cm severity during activity based on the visual analogue scale. Those asymptomatic individuals with no shoulder problems in an age range of 45-65 years were included as controls.

All patients' RC repair was performed with two anchors by the same orthopedist. All patients who had RC repair were treated with the same rehabilitation protocol at the same clinic.

Experimental Procedures

The demographic data of the individuals were recorded before the test. All evaluations performed to by same physiotherapist.

Active JPS Evaluation

Shoulder position sense was measured with the use of a laser pointer-assisted angle reproduction test [14]. The individual was asked to stand 1 m away from the front of a 1-m2 graph paper on the wall. The laser pointer was situated 5 cm above the elbow joint in order not to affect the measurements by wrist and elbow movements [14]. The individual was asked to move his or her arm at 90° on the sagittal plane, which is the same position taken during the perturbation exercise, and hold his or her shoulder in this position eyes-open for 10 s. In the next step, the eyes were closed to exclude visual control, and the participant was asked to repeat the same joint position for three times. The participant was asked to identify the same position, and then the end point was marked. The target point at which the individual moved his or her arm was marked on the graph paper. The same process was repeated on the frontal plane. The deviations in the angles given were measured on the horizontal (X) and vertical (Y) coordination axes on the paper, the linear deviation from the target was calculated using the Pythagorean Theorem (√x2+y2), and the arithmetic mean of the three deviation values was recorded. The deviation from the target point was recorded as absolute error in cm. Electromyography (EMG) muscle activations were recorded throughout the angle reproduction test. Both angle reproduction test and EMG muscle activation recorded at the same time in 5 minutes after perturbation exercises.

Electromyography Evaluation

EMG measurement was conducted by using a Delsys Trigno™ (Delsys Inc., Boston, USA) superficial EMG tool. For the upper trapezius, superficial electrodes were placed between the spinous process of the seventh cervical vertebra and the acromion [15]. For the middle trapezius, they were placed between the third thoracic spinous process and horizontally in the middle of the spina scapula. For the lower trapezius, they were placed between the spina scapula and the seventh thoracic spinous process. During the maximum voluntary isometric contraction (MVIC) measurement of the upper trapezius, resistance was applied over the elbow joint while the patient was in a sitting position and the arm was in a 90° abduction position. Resistance was applied over the elbow level for the middle trapezius while the patient was in a prone position, the arm was in a 90° horizontal abduction, and the glenohumeral joint was in external rotation. Resistance was applied over the elbow level for the lower trapezius while the patient was in a prone position and the arm was in a diagonal position, parallel to the fibers of the lower trapezius. MVIC was measured by manual resistance for 5 s, and then they were allowed to rest for 5 min. Muscle activations during the exercise were calculated as the percentage (%) of MVIC.

Intervention

The same physiotherapist performed the perturbation exercises throughout the study. Perturbation exercises were performed by placing an exercise ball between the wall and the participant's hand while he or she was standing with the arm at 90° elevation and the elbow at full extension. By the perturbation exercises done in this position, it is aimed to increase the activation of the shoulder and scapular muscles. While the exercise ball was pushed manually from inferior, superior, lateral, and medial directions randomly, the patient was asked to hold the ball still throughout the exercise (Figure 1). Perturbation exercises were performed as three sets of 15-seconds for both positions with 10 pushes in all directions. One minute of resting was offered between every set. Trapezius muscle activation as well as active JPS were reevaluated after the perturbation exercise. Evaluations were performed on both shoulders of the participants.

Statistical Analysis

Statistical Package for Social Sciences (SPSS) version 22 (Armonk, New York, USA) was used for the statistical analysis of the data. Statistical data were expressed as mean ± standard deviation (X ± SS), percentage (%), or minimum (min) and maximum (max) values. The Kolmogorov–Smirnov test was used to test the normal distribution of the data. The pre-exercise and post-exercise values were analyzed using an in-group Wilcoxon signed-rank test. The Mann–Whitney U test was used for group comparisons. A value of $p < 0.05$ was set as statistical significance. The correlation between the differences of active JPS and EMG muscle activation pre- to post-exercise in all shoulders (n=50) was examined by the Spearman Correlation Test.

Ethical Approval

The Non-Interventional Clinical Research Ethics Committee of Gazi University approved our study (Ethical Committee Decision Number: 138, Issue: 25901600).

RESULTS

A 12 individuals (6 female/6 male) who underwent arthroscopic RC repair with variable dominance and 13 asymptomatic individuals (6 female/7 male) analyzed. There was no statistical difference between the BMI of the study group (28.41±3.38 kg/m2) and control group (26.97±3.11 kg/m2) (p>0.05). However, the mean age of the study group (54.83±3.5 years) was older than the control group (49.07±4.5 years) (p=0.003). Shoulder joint active JPS deviation values are shown in Table 1. There was no statistical difference between groups in terms of pre-exercise active JPS (p:0.146). Single-session perturbation exercises were not found to be effective in terms of post-exercise active JPS in both groups (Table 1).

Trapezius muscle EMG activation values are shown in Table 3. When the pre- and post-exercise EMG activations of the study group were compared, it was observed that while the activation of the dominant (operated) upper trapezius decreased (p:0.01), the activation of the nondominant side lower trapezius also decreased (p:0.024). There was no difference in the values of both shoulder joints in the in-group pre- and post-exercise comparison of the control group (Table 2). There was no correlation between differences in pre- and post-exercise active JPS and also between differences in pre- and post-exercise EMG activation of the trapezius muscle (Table 3).

DISCUSSION

This study assessed the immediate effects of single-session perturbation exercises on active JPS and the relationship between single-session perturbation exercises and the EMG activation of the trapezius muscle in patients who underwent RC repair. It was concluded that single-session perturbation exercises have no immediate effect on active JPS. Moreover, EMG activation decreased in the operated side upper trapezius and in the non- operated side lower trapezius. The present hypothesis regarding the correlation between active JPS and EMG muscle activation was not validated.

Figure 1. Perturbation exercises on the wall

Tissue injuries, such as muscle tear, affect the tendons on the shoulder joint, fascia, joint capsule, and proprioceptors on the ligaments. It was demonstrated that the tear in the muscle tissue decreases the sensitivity of the receptors, especially those located in the affected area, and correspondingly affects active JPS [16]. Furthermore, kinesthesia is affected in patients with RC tendinopathy as a result of the suppression of the proprioceptive input [17]. Gumina et al. found that, the size of the tear affects active JPS in patients who underwent RC repair, with a greater loss of sense in massive ruptures [8].

In this study, no difference was found between active JPS of the patients who had completed 6 months of rehabilitation program after RC repair and the control group of their healthy pairs. Gumina et al. did not report exactly the timing of their active JPS measure after surgery [8]. In the present study, patients may have regained active JPS in 6-12 months after repair.

The main purpose of RC repair is to enable muscle continuity and regulate the mechanisms. The present study, based on the idea that the number of active receptors can be increased when muscle continuity is achieved, which can be effective in the restoration of the proprioceptive sense, has suggested that the restoration of this sense has already been attained within 6–12 months after surgery.

A previous study showed that, proprioception is improved after a Bankart repair in comparison with the presurgical state, and the results are close to that of the uninjured shoulders [18]. The restoration of JPS 6 months following RC repair can be related to the increase in the proprioceptive input coming from muscle spindles, providing muscle continuity. However, histologic studies are required to show this relation.

Immediate effects of single-session exercises were evaluated in the present study; however, it is known in the literature that neuromuscular training is applied for at least 6 months [13]. This effect may be due to the cumulative result of the single-section perturbation exercise which increases the muscle activation.

Table 1. Shoulder joints' active joint position sense deviations

Variables			Study group (n:12)			Control group (n:13)		
			M(SD)	z	p	M(SD)	z	p
Flexion on dominant side	X	pre-training	111(63)	-0.157	0.875	91(91)	-1.922	0.055
		post-training	112(83)			117(83)		
	Y	pre-training	86(78)	0.000	1.000	61(51)	-1.049	0.294
		post-training	91(53)			67(49)		
	$\sqrt{X^2+Y^2}$	pre-training	153(86)	-1.098	0.272	124(89)	-1.538	0.124
		post-training	151(87)			150(80)		
Abduction on dominant side	X	pre-training	82(70)	-0.784	0.433	109(90)	-0.524	0.600
		post-training	73(42)			87(63)		
	Y	pre-training	56(46)	-0.863	0.388	56(41)	-0.454	0.650
		post-training	62(35)			52(19)		
	$\sqrt{X^2+Y^2}$	pre-training	113(68)	-0.078	0.937	135(66)	-0.804	0.421
		post-training	97(41)			109(55)		
Flexion on non-dominant side	X	pre-training	79(45)	-0.784	0.433	68(40)	-0.105	0.917
		post-training	93(82)			67(35)		
	Y	pre-training	86(52)	-0.941	0.347	59(35)	-1.223	0.221
		post-training	78(59)			56(58)		
	$\sqrt{X^2+Y^2}$	pre-training	129(68)	-0.235	0.814	102(31)	-1.224	0.221
		post-training	138(112)			88(40)		
Abduction on non-dominant side	X	pre-training	131(74)	-0.786	0.432	117(102)	-0.175	0.861
		post-training	120(79)			105(55)		
	Y	pre-training	68(43)	-0.628	0.530	87(68)	-1.572	0.116
		post-training	77(63)			57(54)		
	$\sqrt{X^2+Y^2}$	pre-training	147(45)	-0.549	0.583	161(117)	-0.594	0.552
		post-training	160(91)			131(68)		

*M: means, SD:standard deviation X:Horizantal axis deviations mean, Y:Longitudinal axis deviations mean, $\sqrt{X^2+Y^2}$:Deviations mean from the origin, *p<0.05*

Table 2. Trapezius muscle EMG values

Variables			Study group (n:12)			Control group (n:13)		
			M(SD)	z	p	M(SD)	z	p
Flexion on dominant side	Upper trapezius	pre-training	28(19)	-2578	0.010*	78(222)	-0.210	*0.834*
		post-training	27(19)			73(202)		
	Middle trapezius	pre-training	14(9)	-1.157	0.247	44(121)	-0.035	*0.972*
		post-training	15(15)			34(44)		
	Lower trapezius	pre-training	16(15)	-0.764	0.445	29(49)	-0.734	*0.463*
		post-training	17(16)			80(204)		
Abduction on dominant side	Upper trapezius	pre-training	34(21)	-0.534	0.593	80(217)	-1.258	*0.208*
		post-training	35(21)			80(212)		
	Middle trapezius	pre-training	41(29)	-0.784	0.433	37(31)	-0.945	*0.345*
		post-training	31(19)			36(31)		
	Lower trapezius	pre-training	18(14)	-0.078	0.937	29(67)	-1.334	*0.182*
		post-training	17(16)			44(126)		
Flexion on non-dominant side	Upper trapezius	pre-training	36(44)	-0.314	0.754	79(219)	-0.356	*0.722*
		post-training	43(58)			74(204)		
	Middle trapezius	pre-training	10(7)	-0.706	0.480	40(65)	-0.356	*0.722*
		post-training	8(4)			56(118)		
	Lower trapezius	pre-training	29(45)	-2.253	0.024*	54(110)	-1.490	*0.136*
		post-training	22(37)			25(32)		
Abduction on non-dominant side	Upper trapezius	pre-training	49(49)	-0.357	0.721	98(286)	-1.153	*0.249*
		post-training	46(49)			61(144)		
	Middle trapezius	pre-training	16(12)	-0.712	0.477	21(12)	-0.392	*0.695*
		post-training	17(11)			50(116)		
	Lower trapezius	pre-training	27(62)	-0.178	0.859	20(23)	-0.734	*0.463*
		post-training	59(116)			18(23)		

*M:Means,SD:Standard Deviation, *p<0.05*

Table 3. The correlation between JPS and EMG activities

EMG activity	Upper trapezius		Middle trapezius		Lower trapezius	
	r	p	r	p	r	p
JPS-Flexion	0.179	0.214	-0.149	0.303	-0.064	0.657
JPS-Abduction	-0.020	0.890	-0.088	0.542	-0.063	0.662

*JPS:Joint position sense, r:correlation coefficient values, *:p<0.05*

But, it was found that single-session exercise does not make any difference in proprioceptive sense. On the other hand, Yang et al. showed that the activation of the scapular muscles increases the joint position sense [9].

Trapezius has a crucial role at control of scapula. So, in this study it is aimed to assess the EMG muscle activation of different parts of the trapezius muscle and compare its relation with joint position sense. By the perturbation exercises done in this position, it is aimed to increase the activation of the shoulder and scapular muscles. There was no correlation between active JPS and EMG activation of trapezius muscle as a result of the present study. The present hypothesis was that EMG muscle activation may improve active JPS. We considered that an increase in the EMG activity of the muscle during the movement might activate more muscle fibers; thus, more correct impulses might be sent to the upper centers by firing of more muscle spindles. As a result, we assumed that the margin of error in active JPS might be decreased. However, the results of the present study did not validate the study hypothesis. The low number of the participants could be the reason for this result. Further studies should focus also on this issue.

Moreover, the exercise in the present study was applied in three 15-s sets both in flexion and abduction positions, which resulted in tiredness, which was reported by the participants verbally. It is considered that, due to the tiredness of the mechanoreceptors on the shoulder girdle muscles, it may be difficult to observe improvements in active JPS. Lee et al. researched the effect of muscle tiredness on proprioception, which plays an important role in shoulder joint stability, and stated that external rotation was affected by tiredness during the active position reproduction test [19].

Previous studies have shown that perturbation exercises are especially effective in improving dynamic stability by normalizing the muscle balance and appropriate kinematics [20-24]. Moreover, various studies have shown that perturbation training increases joint stability and balance by improving the proprioceptive sense [20,21,24]. However, there exists no studies on shoulder girdle stability.

This study aimed to examine whether there was a difference in muscle activation levels of the trapezius muscle parts, which are believed to play an important role especially in scapular stability after perturbation exercises. It was found that EMG activation decreases in the operated side upper trapezius and in the non-operated side lower trapezius with perturbation exercises. It has been acknowledged that the upper trapezius muscle activity increases in people with shoulder problems [25-27]. Shinozaki et al. found that the activation of the upper trapezius in patients with RC tear is more than that of the asymptomatic individuals [26]. Recently, it has been emphasized that the balance in the upper, middle, and lower trapezius is important for shoulder rehabilitation, and it is necessary to achieve a balance between the forces of the upper, middle, and lower trapezius [27]. The purpose of this study was to determine whether perturbation exercises make a difference in trapezius muscle activation. It was observed that the activation of the upper trapezius decreased in the operated group with perturbation exercises. This decrease is required for normal shoulder girdle motions. Perturbation exercises have been considered to be preferable for these patients in terms of trapezius muscle activation. The literature shows that the shoulder exercises conducted on unstable surfaces change the scapulothoracic muscle activation, and this change is usually seen as an increase in the activation of the upper and lower trapezius [23,28,29].

Interestingly, this study showed that the activation of the lower trapezius also decreased on the non-operated side. This result may be related to the cross-effect of the exercise. However, Cools et al. found delayed activity in the lower trapezius in individuals with subacromial impingement syndrome in comparison with healthy individuals [27]. The decrease in the activity in the lower trapezius is not desired for the asymptomatic shoulders in terms of the balance between the trapezius muscle parts. Decreased contralateral side lower trapezius muscle activity during perturbation exercises composes a risk for contralateral side. This decrease is considered to be related to the cross-effect of the training.

In general, the trapezius muscle EMG activities tend to decrease after perturbation exercises even though it is not significant. This decrease has been thought to be related to tiredness. Moreover, the decrease in the trapezius muscle activation on the non-operated shoulder can be related to the fact that the mechanism of both shoulders is affected after the operation. The right and left parts of the trapezius muscle are not totally independent from each other. Thus, it has been established that when a part is affected, this improves some adaptations on the other side, which is recognized as healthy [30].

The present study has a number of limitations. We could not match the mean age between the study group and groups even though they were both in the same age range. The absence of blindness in our study can be seen as a limitation. However, the surgical scar found in patients with rotator cuff repair did not allow us to do this.

CONCLUSION

The proprioceptive sense was restored 6–12 months after RC repair. It is considered that the use of perturbation exercises in rehabilitation does not yield a negative effect on the operated side because it decreases the activation of the upper trapezius; however, it could be a risk on non-operated side because of a decrease in the activation of the lower trapezius. Addition to single-session perturbation exercises have no effect on active JPS, also no relation between JPS and EMG activity of Trapezius. It is considered that long-term results should be investigated.

Ethical Approval: *2013/25901600-138, Non-Interventional Clinical Research Ethics Committee of Gazi University*

Conflict of Interest: *The authors have no conflicts of interest to declare.*

Funding: *None.*

Acknowledgements: *The authors would like to thank all participants.*

Author Contribution: Concept: *İD,ÖK,NÖ,BE,ÖAA;* ***Desing:*** *İD,ÖK,NÖ,BE,ÖAA;* ***Data collecting:*** *İD,ÖK,NÖ;* ***Statistical analysis:*** *ÖK,NÖ,BE;* ***Literature review:*** *ÖK,NÖ,İD;* ***Writing:*** *ÖK,İD,NÖ;* ***Critical review:*** *İD,BE,ÖAA*

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