재활치료과학 제 13 권 제 4 호
Therapeutic Science for Rehabilitation
Vol. 13. No. 4. 2024.
https://doi.org/10.22683/tsnr.2024.13.4.091

Selective Strengthening of the Subscapularis Muscle: A Comparative Study

Kim, Gyoung-Mo*, Ph.D., P.T., Ha, Sung-Min**, Ph.D., P.T.
*Dept. of Physical Therapy, Daejeon Health Science University, Professor
**Dept. of Physical Therapy, Sangji University, Professor

Abstract

Objective : The objective of this study was to determine the optimal method for selective activation of the subscapularis muscle among the following three strengthening techniques in healthy individuals.

Methods : Fifteen healthy individuals participated in the experiment, and muscle strength and electromyography (EMG) data were collected using handheld dynamometry and surface EMG tools. To compare the subscapularis strength and pectoralis major muscle activity using the three methods, a one-way analysis of variance with repeated measures was used, with the level set at .05.

Results : Significant differences in subscapularis muscle strength were observed between the three methods (F = 51.318, p < .05). There was significant difference between the belly press and bear hug and between the belly press and side-lying wiper internal rotation (p_{adj} = .00). In the pectoralis major EMG data, significant differences were noted among the three methods (F = 61.679, p < .05). The largest increase in muscle activity was observed with the belly press, and the lowest activity was noted with SWI (p_{adj} = .00).

Conclusion : The best method for selectively evaluating or improving subscapularis muscle strength was SWI. Based on the results of this study, we recommend that clinicians perform SWI to accurately evaluate and improve impaired subscapularis muscle strength.

Keywords : Electromyography, Selective Activation, Strengthening, Subscapularis

교신저자 : 하성민(kema98@naver.com)
|| 접수일: 2024.08.13 || 심사일: 2024.08.22
|| 게재승인일: 2024.10.17

Ⅰ. Introduction

The subscapularis muscle is one of the rotator cuff muscles and plays a crucial role in the stability and mobility of the glenohumeral joint (Labriola et al., 2005). The subscapularis is located on the anterior surface of the shoulder and is attached to the lesser tubercle of the humerus, functioning as an axial internal rotator of the glenohumeral joint (Zielinska et al., 2021). This motion is essential for various daily activities, including reaching for objects, throwing, and performing tasks that require rotation of the arm toward the body. As the largest of the rotator cuff muscles, the subscapularis generates the necessary force for efficient and controlled internal rotation (Altintas et al., 2019).

In addition to its primary internal rotator function, the subscapularis also stabilizes the glenohumeral joint. Together with the other rotator cuff muscles, it helps maintain the proper position of the humeral head in the glenoid fossa during various functional movements, such as throwing (Day et al., 2012). This stabilization is crucial for preventing dislocations and ensuring smooth articulation within the joint. By providing dynamic stability to the glenohumeral joint, the subscapularis enhances the efficiency of movements performed by other shoulder muscles (Akhtar et al., 2021).

Injuries to the subscapularis, such as tears or strains, can significantly impact the biomechanics of the shoulder, leading to pain, weakness, and limitations in range of motion. Rehabilitation strategies often focus on strengthening the subscapularis and restoring its proper function to optimize shoulder biomechanics (Altintas et al., 2019). The first step in a therapeutic strategy is to accurately evaluate the condition of the damaged muscle. In the case of muscle damage, tests for muscle length, joint range of motion, and muscle strength are performed. In particular, muscle damage is primarily assessed through muscle strength measurement (Sant'Anna et al., 2022). Muscle strength is typically measured quantitatively using manual muscle strength testing methods, handheld dynamometers, tensiometers, etc. (Bohannon, 2019).

Due to the unique location of the subscapularis muscle, there are few related studies. However, previous research has conducted a comparative study of various clinically used subscapularis muscle measurements. Compared to other measurement methods, the belly press method is considered the most selective for measuring the subscapularis muscle (Ginn et al., 2017). Nonetheless, this method has limitations because subjects did not control the force with which they pressed their abdomen. In studies on selective contraction of the infraspinatus muscle, the side-lying shoulder abduction position (90 degrees) has been shown to selectively contract the infraspinatus muscle most effectively compared to existing methods (Ha et al., 2013). Research on manual muscle testing or electromyography of the infraspinatus muscle has also indicated that measurement in the side-lying wiper position is the most efficient (Jeon et al., 2018). As suggested by previous research, the side-lying wiper position is effective in maintaining the central axis of rotation of the glenohumeral joint. Therefore, it is necessary to determine whether this position is also effective for the subscapularis.

The purpose of this study is to examine the optimal method for selective activation of the subscapularis muscle among three strengthening techniques: belly press, bear hug, and side-lying wiper internal rotation, in healthy subjects. The hypothesis of this study is that side-lying wiper internal rotation (SWI) will more selectively activate the subscapularis compared to the other methods.

II. Methods

1. Subjects

A total of 15 manufacturing healthy male workers participated in this study (Age = 32 ± 3.5 yrs, Height = 172 ± 10.1 cm, Weight = 70.3 ± 8.9 kg, BMI = 23.7 ± 5.5 kg/m^2). Necessary sample size was calculated a priori for a power of 0.80, and effect size of 0.80, and alpha level of 0.05 by G*Power software (version 3.1.2). This calculation indicated that a sample size of 14 subjects was required for the study. Volunteers were selected as subjects who could perform shoulder internal rotation motion and manual muscle strength tests were conducted in this study. All subjects were recruited voluntarily after receiving a thorough explanation of the purpose and experimental procedure prior to participation and written informed consent was obtained from all participants. Those with a history of orthopedic or neurosurgical issues of the arm or neck within the previous year were excluded. This study was approved by the Sangji University Institutional Review Board (No. 1040782-240122-HR-11-119).

2. Instrumentation

1) 2-Channel Wireless EMG

To measure the muscle activity of the pectoralis major, a 2EM (2EM 4D-MT, Relive, Gimhae, Korea), a surface electromyography measurement device, was used (Figure 1-A). The sampling rate was set at 1000Hz. The electrode attachment locations for the pectoralis major muscles were determined according to Cram's method (Criswell, 2010).

2) Hand-Held Dynamometer (HHD)

HHD is an alternative to manual muscle testing for objectively documenting muscle performance. The reliability of HHD has been the subject of many studies, with those considering interrater and intrarater reliability for muscle strength measurement (Schrama et al., 2014). Several investigations have supported the concurrent validity of HHD with isokinetic dynamometry for muscle strength measurement (Chamorro et al., 2017). Maximum voluntary shoulder internal rotation was measured using a hand-held

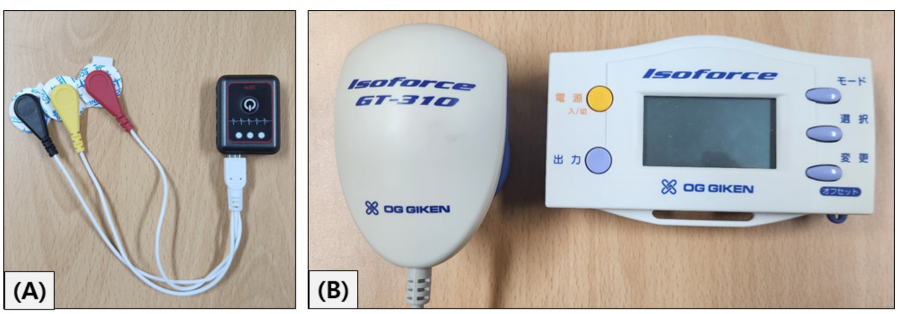

Figure 1. (A) 2-Channel Wireless EMG, (B) Hand-Held Dynamometer

dynamometer (Isoforce GT-300, OG Giken Co. Ltd., Okayama, Japan) during isometric contraction for 3 seconds against manual resistance (Figure 1-B). The hand-held dynamometer was placed distal to the forearm to exclude wrist and finger flexor involvement (Brown et al., 2013).

3. Experimental Procedure

The dominant arm, defined as the upper extremity used for eating and writing, was tested for all participants, all of whom were right-arm dominant. Three standardized subscapularis strengthening methods commonly used in clinical practice were tested, with each method measured three times. Prior to the experiment, electromyography (EMG) electrodes were attached to the pectoralis major, and a hand-held dynamometer was placed on the wrist (palm side) of the subjects. First, to perform the belly-press method, subjects sat with their arms bent at 90 degrees, placing the palm on the upper abdomen (just below the xiphoid process). The subjects were instructed to press their palms against their abdomens through maximal shoulder internal rotation and to maintain this position while resisting an external rotation force applied by the examiner by performing maximal shoulder internal rotation. Second, to perform the bear hug method, subjects placed the palm of the tested side on the opposite shoulder, with the fingers extended and the elbow positioned in front of the body. The subjects were instructed to maintain this arm position while the examiner applied an external rotation resistance force perpendicular to the forearm. subjects resisted by performing maximal shoulder internal rotation. Third, to perform the side-lying wiper internal rotation (SWI) method, subjects lay on their side with the tested arm flexed and internally rotated to 90°, and the elbow bent to 90°. The distal humerus of the dominant arm was supported by the opposite hand. From this starting position, subjects moved to achieve maximal shoulder internal rotation. The subjects were instructed to maintain this arm position while the examiner applied an external rotation resistance force to the forearm. subjects resisted by performing maximal shoulder internal rotation (Figure 2). Each test was randomized using Excel, and the maximal contraction position was maintained for 5 seconds during each trial. EMG data was collected for 3 out of the 5 seconds. Each participant performed 3 trials with a 1-minute rest between trials, and the mean value of the 3 trials was used for data analysis. Subjects rested for 3 minutes between different exercises to minimize the chance of muscle fatigue (Figure 2).

Figure 2. (A) Belly-Press Method, (B) Bear Hug, (C) Side-lying Wiper Internal Rotation Method

4. Statistical Analysis

Statistical analyses were performed using the SPSS for Windows (SPSS 25.0; SPSS Inc., Chicago, Illinois, USA). To verify the normality of data distribution, the Kolmogorov-Smirnov test was used. To compare the subscapularis strength and pectoralis major muscle activity among the three tests, one-way analysis of variance with repeated measures was used with the level set at .05. For comparison between each exercise, Bonferroni adjustment (p_{adj}) with the level set at .016 (.05/3).

III. Results

There was a significant difference in shoulder internal rotator muscle strength among the three methods (Table 1) (Table 2) (F = 51.318, p 〈 .05). No significant difference was observed between the bear hug test and the SWI test (Table 2) (p = .997), but there was a significant difference between the belly-press test and the bear hug test, as well as between the belly-press test and the SWI test (Table 2) (p_{adj} 〈 .001). For the pectoralis major EMG data, significant differences were also observed (Table 1) (Table 2) (F = 61.679, p 〈 .05). The greatest increase in muscle activity was seen during the belly-press test, while the least was observed during the SWI test (Table 2) (p_{adj} 〈 .001).

IV. Discussion

This study compared different exercise methods to determine which could selectively strengthen the subscapularis muscles. Due to the subscapularis muscle's location, measurements using only needle

Table 1. The Variables (Shoulder Internal Rotation Strength and Pectoralis Major EMG Data) for Each Method

Variable	Methods			F	p
	Belly-press	Bear hug	SWI		
SIR strength (kg)	10.36	8.81	8.79	51.318	〈 .001
PM EMG (%MVIC)	8.85 ± 4.22	6.03 ± 2.91	5.15 ± 2.85	61.679	〈 .001

PM EMG = Pectoralis Major Electormyography; SIR = Shoulder Internal Rotation; SWI = Side-lying Wiper Internal Rotation.
%MVIC = Percentage of Maximum Voluntary Isometric Contraction.

Table 2. Multiple Comparison between Methods

Variable	Method comparison	p
SIR strength (kg)	Belly press vs. Bear hug	〈 .001
	Belly press vs. SWI	〈 .001
	Bear hug vs. SWI	.997
PM EMG (%MVIC)	Belly press vs. Bear hug	〈 .001
	Belly press vs. SWI	〈 .001
	Bear hug vs. SWI	.997

PM EMG = Pectoralis Major Electormyography; SIR = Shoulder Internal Rotation; SWI = Side-lying Wiper Internal Rotation.
%MVIC = Percentage of Maximum Voluntary Isometric Contraction.

EMG or ultrasonography were previously considered feasible (Zielinska et al., 2021). However, in this study, based on prior research, selective activation of the subscapularis was assessed through the activity of the pectoralis major, a muscle that primarily compensates for subscapularis function (Ginn et al., 2017). In addition to previously proposed subscapularis-selective strengthening methods, a new exercise involving "wiper" shoulder internal rotation in a side-lying position was added and compared. This method has been shown to be effective in selectively strengthening the infraspinatus muscle, and we aimed to determine how this posture and method affect the selective activation of the subscapularis (Ha et al., 2013; Jeon et al., 2018).

In comparing the three tests, pectoralis major muscle activity was found to be lowest during the side-lying wiper internal rotation (SWI) exercise. In terms of subscapularis strength, no significant difference was observed between the bear hug test and the SWI test. However, a significant difference was found between the belly-press test and the bear hug test, as well as between the belly-press test and the SWI test (p_{adj} = .00). The reasoning for these results is as follows. First, unlike the belly-press, SWI was performed with the shoulder abducted to 90 degrees, which likely minimized pectoralis major involvement. The bear hug test also reduced pectoralis major involvement due to the similar 90-degree shoulder abduction. Second, in the SWI method, the subject's arm was supported, reducing the weight on the arm and minimizing pectoralis major involvement, while also providing a mechanical advantage for subscapularis activation and helping maintain joint neutrality during internal rotation, unlike other methods. The bear hug position also had arm support, so the compensatory action of pectoralis major showed a low level of activity, but it showed relatively low SIR strength compared to SWI. Based on these results, the SWI method is considered a subscapularis strengthening exercise that can selectively target the subscapularis. The findings of this study may offer valuable insights into the optimal method for selectively activating the subscapularis muscle, providing clinicians and researchers with evidence-based information to enhance rehabilitation strategies. A better understanding of muscle testing methods could lead to more targeted and effective interventions for individuals with subscapularis injuries, ultimately promoting improved shoulder function and outcomes.

There are several limitations to this study. First, the study was conducted exclusively on young male subjects. Future research should include various age groups, including women, to provide more generalizable findings. Additionally, it will be important to identify effective exercises tailored to different subject characteristics. Second, the subscapularis muscle was not measured directly. Future studies using wire EMG are needed to evaluate the subscapularis muscle's activity during shoulder internal rotation exercises, including SWI. Third, compensatory muscles such as the teres major and latissimus dorsi, which may assist during subscapularis activation, were not measured. Future studies should include a broader range of muscles that could be affected during these exercises.

V. Conclusion

This study confirmed that the SWI method is the most optimal for selectively evaluating and improving subscapularis muscle strength. Based on the findings, SWI is an effective exercise for selectively strengthening the subscapularis muscle and is considered a reliable method for accurately assessing subscapularis muscle strength.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Acknowledgements

This research was supported by Sangji University Research Fund, 2023.

References

Akhtar, A., Richards, J., & Monga, P. (2021). The biomechanics of the rotator cuff in health and disease: A narrative review. *Journal of Clinical Orthopaedics and Trauma*, *18*, 150-156. https://doi.org/10.1016/j.jcot.2021.04.019

Altintas, B., Bradley, H., Logan, C., Delvecchio, B., Anderson, N., & Millett, P. J. (2019). Rehabilitation following subscapularis tendon repair. *International Journal of Sports Physical Therapy*, *14*(2), 318-332. https://10.26603/ijspt20190318

Bohannon, R. W. (2019). Considerations and practical options for measuring muscle strength: A narrative review. *Biomed Research International*, *2019*, Article 8194537. https://doi.org/10.1155/2019/8194537

Brown, M., Hislop, H., & Avers, D. (2013). *Daniels and Worthingham's muscle testing: Techniques of manual examination and performance testing* (9th ed.). Saunders.

Chamorro, C., Armijo-Olivo, S., & De la Fuente, C. I. (2017). Absolute reliability and concurrent validity of hand-held dynamometry and isokinetic dynamometry in the hip, knee, and ankle joint: Systematic review and meta-analysis. *Open Medicine (Warsaw)*, *12*(1), 359-375. https://doi.org/10.1515/med-2017-0052

Criswell, E. (2010). *Cram's introduction to surface electromyography* (2nd ed.). Jones & Bartlett Learning.

Day, A., Taylor, N. F., & Green, R. A. (2012). The stabilizing role of the rotator cuff at the shoulder: Responses to external perturbations. *Clinical Biomechanics*, *27*(6), 551-556. https://doi.org/10.1016/j.clinbiomech.2012.02.003

Ginn, K. A., Reed, D., Jones, C., & others. (2017). Is subscapularis recruited in a similar manner during shoulder internal rotation exercises and belly press and lift-off tests? *Journal of Science and Medicine in Sport*, *20*(6), 566-571. https://doi.org/10.1016/j.jsams.2016.10.018

Ha, S. M., Kwon, O. Y., Cynn, H. S., Lee, W. H., Kim, S. J., & Park, K. N. (2013). Selective activation of the infraspinatus muscle. *Journal of Athletic Training*, *48*(3), 346-352. https://doi.org/10.4085/1062-6050-48.2.18

Labriola, J. E., Lee, T. Q., Debski, R. E., & McMahon, P. J. (2005). Stability and instability of the glenohumeral joint: The role of shoulder muscles. *Journal of Shoulder and Elbow Surgery*, *14*(1), S32-S38. https://doi.org/10.1016/j.jse.2004.09.014

Jeon, I. C., Ha, S. M., & Jung, S. H. (2018). Isolated activation of the infraspinatus muscle in four manual muscle testing positions. *Journal of Musculoskeletal Science and Technology*, *2*(2), 38-42. https://doi.org/10.29273/jmst.2018.2.2.38

Sant'Anna, J. P., Pedrinelli, A., Hernandez, A. J., & others. (2022). Muscle injury: Pathophysiology, diagnosis, and treatment. *Revista Brasileira de Ortopedia (São Paulo)*, *57*(1), 1-13. https://doi.org/10.1055/s-0041-1731417

Schrama, P. P. M., Stenneberg, M. S., Lucas, C., & Van Trijffel, E. (2014). Intraexaminer reliability of hand-held dynamometry in the upper extremity: A systematic review. *Archives of Physical Medicine and Rehabilitation*, *95*(12), 2444-2469. https://doi.org/10.1016/j.apmr.2014.05.019

Zielinska, N., Tubbs, R. S., Borowski, A., Podgórski, M., & Olewnik, L. (2021). The subscapularis muscle: A proposed classification system. *Biomed Research International*, *2021*, 7450000. https://doi.org/10.1155/2021/7450000

국문초록

어깨밑근의 선택적 강화: 비교 연구

김경모*, 하성민**

*대전보건과학대학 물리치료학과 교수

**상지대학교 물리치료학과 교수

목적 : 본 연구는 건강한 피험자를 대상으로 배꼽 누르기, 곰 껴안기, 옆으로 누운 자세의 와이퍼 운동 중 어떠한 운동 방법이 어깨밑근을 선택적으로 강화할 수 있는지 알아보고자 하였다.

연구방법 : 15명의 건강한 피험자가 연구에 참여하였고, 근력과 근전도 데이터는 휴대용 근력 측정기와 근전도기를 사용하여 수집하였다. 세 가지 운동 방법 간의 어깨 안쪽 돌림근 근력과 큰가슴근의 근활성도를 비교하기 위하여 반복측정 일원배치 분산분석을 사용하였으며, 유의 수준은 .05로 설정하였다.

결과 : 세 가지 운동 방법 간에 어깨 안쪽돌림근 근력에서 유의미한 차이가 나타났다(F = 51.318, p 〈 .05). 곰 껴안기 운동과 옆으로 누운 자세에서 와이퍼 운동 간에는 유의한 차이가 없었지만, 배꼽 누르기와 곰 껴안기, 배꼽 누르기와 옆으로 누운 자세의 와이퍼 운동 간에는 유의한 차이가 있었다(p_{adj} = .00). 큰가슴근의 근전도 데이터에서도 세 가지 방법 간에 유의한 차이가 나타났다(F = 61.679, p 〈 .05). 가장 큰 근육 활동의 증가는 배꼽 누르기 운동에서 관찰되었으며, 가장 낮은 활동은 옆으로 누운 자세의 와이퍼 운동이었다(p_{adj} = .00).

결론 : 어깨밑근의 근력을 선택적으로 평가하거나 개선하기 위해서는 옆으로 누운 자세의 와이퍼 운동이 최적의 운동 방법임을 확인하였다. 이 연구의 결과를 바탕으로, 임상가들은 손상된 어깨밑근의 근력을 정확하게 평가하고 개선하기 위해서는 옆으로 누운 자세의 와이퍼 자세(또는 운동)에서 시행하는 것을 권장한다.

주제어 : 강화, 근전도, 선택적 활성화, 어깨밑근