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Activity of Different Shoulder Muscles during Dynamic Bear Crawl Exercise

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Abstract

Comparative repeated-measure study done on 21 healthy male subjects to compare electromyographic (EMG) activity of the serratus anterior (SA), upper trapezius (UT), middle trapezius (MT), and lower trapezius (LT) muscles during push-up plus (PUP) and dynamic bear crawl (DBC) exercises. The subjects performed PUP and DBC exercises 3 times on a stable surface. Surface EMG activity of the SA, UT, MT, and LT was collected from the dominant arm and presented as a percentage of the maximal voluntary contraction. One-way repeated-measures ANOVA with a Friedman's test was performed to compare differences in EMG activity of SA, UT, MT, and LT during PUP and DBC exercises. The SA and UT activities were significantly greater during the DBC exercise. LT and MT muscle activities were significantly greater during the PUP exercise. The peak and average SA and UT activity were greatest during the DBC exercise on a static stable surface. This result indicates that DBC exercise on the static stable surface is more effective to activate the SA and UT.

Keywords: Dynamic bear crawl, Electromyography, Push-up plus, Serratus anterior, Trapezius

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Introduction

The glenohumeral joint is a multiaxial ball and socket synovial joint which, in combination with the acromioclavicular, sternoclavicular, and scapulothoracic articulations, facilitates the movement of the upper limb.[1]

The serratus anterior (SA) is an important scapular stabilizer that helps in maintaining normal scapulohumeral rhythm during arm raises by holding the scapula to the thorax and prevents winging. It plays an important role in scapula stabilization and strengthening of the SA significantly contributes to shoulder stability. Decreased SA motor recruitment induces altered scapular motion during shoulder elevation in the frontal and scapular planes, which might cause shoulder impingement and pain to the player with overhead activities.[2,3]

The trapezius muscle is also of substantial importance in the painful shoulder condition, contributing to abnormal rotation of the scapula.[4] When examining individuals with shoulder impingement, most populations have greater activation of the upper trapezius (UT) combined with decreased activation of the lower trapezius (LT) and SA.[5] Patients with a UT/SA imbalance, rather than exercises that globally activate several scapula thoracic muscles, selective activation of the SA while minimizing activation of the UT (low ratio of UT/SA activation) may be advantageous, allowing selective SA strengthening to the reduce the imbalance.[2]

The push-up plus (PUP) exercise has been widely used as an exercise method to strengthen the SA. It is an effective exercise method that decreases the action of the trapezius muscle and increases the activity of SA on an unstable base of support.[6] Ludewig *et al*.[7] reported that the PUP exercise is not appropriate for patients with shoulder pain in the early rehabilitation period because bodyweight load of >35% on the upper extremity of one side is required to perform the PUP exercise. However, there are no comparative studies done on PUP exercise with other exercises on a stable surface.

The bear position consists of a progression of a static hold, stationary contralateral arm and leg lift, and a traveling crawling movement, with the goal of maintaining a neutral spine in each step. Pyka *et al*.[8] already reported the bear crawl as an effective isometric trunk exercise. In a quadruped position, the exercise integrates distal muscle stabilizers and with the knees raised slightly off the ground it serves the same purpose as a plank, to maintain the pelvis position against gravity testing endurance. The exercise loads and challenges trunk coordination, neuromuscular coordination, and balance with the stationary contralateral limb lift and a traveling crawling movement. The bear crawl may also help in improving the dynamic scapular stability by the activation of SA and trapezius muscles while performing the exercise.

Therefore, the present study purported the most effective exercise method for shoulder stabilization by analyzing the muscle activities of the SA and trapezius during the PUP and dynamic bear crawl (DBC) exercises.

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Subjects and Methods

Subject Characteristics

The Institutional Ethical Committee of Guru Nanak Dev University approved the study. Twenty-one healthy male subjects (demographic characteristics are mentioned in Table 1) were recruited after detailing them about the procedures to be followed in the study and obtaining the written consent.

Table 1: Demographic characteristics of the subjects

Characteristics	*Mean (SD)*
Age (years)	20.80 (2.15)
Weight (kg)	73.57 (5.66)
Height (cm)	176 (4.62)
BMI (kg/m^2)	23.78 (2.15)

SD: Standard deviation, Kg: Kilogram, Cm: Centimeter, BMI: Body mass index

Data Collection and Hardware Characteristics

The electromyographic (EMG) signals were recorded from SA, UT, middle trapezius (MT), and LT muscles of the dominant side using a bipolar surface EMG configuration with an interelectrode distance of 2 cm. Before applying the electrode pairs, placement sites were abraded to lower the impedance level. All electrode pairs were connected to a wireless probe and placed on the bellies of all four muscles. The probe served as the reference electrode and pre-amplified the EMG signal (gain 400 µV) before transmitting the data in real time into a 16-channel 16-bit PC-interface receiver (Noraxon Telemyo DTS Telemetry; Noraxon, Arizona, USA). All data were collected at a sample rate of 1500 Hz within a bandwidth of 10–500 Hz. Raw EMG signals were collected at 2000 Hz by a Myotrace 400 EMG unit (Noraxon USA Inc., Scottsdale, AZ, USA). Data were sent in real time to a computer through Bluetooth and the recorded data were analyzed by Myomuscle V 3.8 clinical Applications software (Noraxon USA, Inc., Scottsdale, AZ, USA).

Maximum Voluntary Contractions (MVC) and Electrode Positioning

SA

The electrodes were placed on the muscle belly in the mid-axillary line of the right side over the fifth rib. The shoulder was flexed to 125° and resistance was applied above the elbow and at the inferior angle of the scapula in an attempt to derotate the scapula.[9]

UT

The electrodes were placed on the muscle belly midway between the C7 spinous process and the trapezius' insertion on the right acromioclavicular joint. The MVC was performed with the dominant arm abducted to 90° and the head laterally flexed 10°–15° toward the abducted arm. The subject was instructed to maximally attempt to approximate the abducted arm and head toward each other against the examiner's matching immovable resistance.[9]

MT

The electrodes were placed at center of the medial border of the scapula and the spines of thoracic vertebrae (T-1–T-6). Shoulder horizontally abducted and internally rotated as resistance was applied above the elbow with the subject in the prone position.[10]

LT

The electrodes were placed on the muscle belly 1.5 cm lateral and obliquely (inferior electrode more medial) to the T6 spinous process on the subject's right side. With the right arm fully flexed 180° (in line with the LT), the subject attempted to continue flexing further against the examiner's resistance applied to the upper arm.[9]

Exercise Description

Participants identically performed the exercises. Participants were in an upright position when the EMG collection began. The eccentric (lowering) portion lasted 2 s and the concentric portion lasted 2 s with a slight pause at the bottom of the repetition. An electrical trigger (pressed by the experimenter) was used to mark the beginning of the first descent and the finish of the last repetition. A minimum of 3 min of rest was given in between two exercises to prevent influence of fatigue on myoelectric amplitude changes.

1. Subject performed the PUP activity on the floor. PUP movement was done in a standardized position with the hands shoulder width apart with the subject's middle finger under the acromioclavicular joint on the floor. Three repetitions were performed for each exercise at same tempo. Between every repetition 5 s rest was given. During the PUP exercise, activity of SA, UT, MT, and LT muscles was recorded.
2. Participant performed the DBC on even surface. Subject was in a tabletop position on his hands and his knees with hands directly under his shoulders and his knees directly under his hips. Tuck his back toes under and bring his knees to a hover at a 90° angle. Subject crawl up to 10 meters on the even surface. This activity is performed 3 times by the subject, after every repetition 5 s rest was given. The activity of the studied muscles was recorded from 11th to 20th s.

Normalization of EMG

For normalization of the EMG, the maximal voluntary isometric contraction (MVIC) of each muscle was recorded in the manual muscle testing position (9, 10). In the following analysis, all raw EMG signals obtained during MVICs and during exercises were digitally filtered, consisting of high-pass filtering at 10–500 Hz and a moving root mean square (RMS) filter of 150 ms. For each muscle, peak RMS EMG of the three repetitions performed at each level was determined, and the average value of these three repetitions was then normalized to the maximum RMS EMG. Both MVC and exercise task EMG data were processed identically. The EMG signal having bias was removed (remove mean from the raw signal), then, a moving average technique was used to smoothen the data thus providing a linear envelope of EMG activity. Using the electrical markings left by the foot switch trigger at the start and end of the movement, the mean activity throughout the course of three repetitions of smoothed data was calculate. These mean activities were expressed as a percentage of the peak activity find during the MVC for the corresponding muscle.[9]

Data and Statistical Analysis

Friedman's analysis was also performed to determine if an adequate sample size was used assuming a clinically/physiologically significant difference between exercises. Kolmogorov–Smirnov and Shapiro–Wilk tests are used to determine if the data are normally distributed. Variables are not normally distributed in SA and LT muscle. A repeated-measure ANOVA with Friedman's (two-way analysis of variance) test was used to identify differences across the exercises for each muscle measured. In all tests, the 95%

($P < 0.05$) level of confidence was used for the rejection of the null hypothesis. No adjustments are made for multiple comparisons based on the descriptive nature of the study.

Results

Table 2 shows a significant difference ($P < 0.000$) between the two activities for SA and LT. Median and IQR value of SA muscle activity is 15.40 and 14.21 during the PUP exercise and 39.00 and 36.00 during the DBC exercise. For the LT muscle, the median and IQR values are 24.85 and 13.82 during the PUP, and 10.44 and 5.81 during the DBC exercises.

Table 3 shows a significant difference ($P < 0.000$) between the two activities for upper and MT muscles. The mean (SD) values for UT muscle are 6.08 (3.03) and 40.82 (20.33) during the PUP and DBC exercises, respectively. Mean (SD) values for MT muscle are 18.80 (5.34) and 12.47 (3.54) during the PUP and DBC exercises, respectively.

Graphs 1-4 show the difference in activity of all the muscles studied in the push-up plus exercise and DBC exercise, expressed as a percentage of MVIC.

Table 2: EMG activity of SA and LT muscles during the PUP and DBC exercises

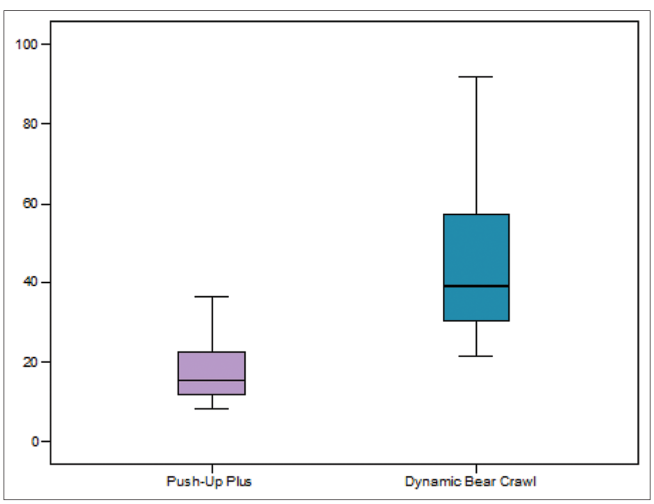
Muscle	*Activity*	*Min.*	*Max.*	*Median*	*IQR*	*P-value*
SA	PUP	8.44	36.28	15.40	14.21	0.000
	DBC	21.39	91.88	39.00	36.00	
LT	PUP	12.93	87.05	24.85	13.82	0.000
	DBC	5.43	36.59	10.44	5.81	

EMG: Electromyographic, SA: Serratus anterior, LT: Lower trapezius, PUP: Push-up plus, DBC: Dynamic bear crawl

Table 3: EMG activity of UT and MT muscles during the PUP and DBC exercises

Muscle	*Activity*	*Mean*	*SD*	*P-value*
UT	PUP	6.08	3.03	0.000
	DBC	40.82	20.33	
MT	PUP	18.80	5.34	0.000
	DBC	12.47	3.54	

EMG: Electromyographic, UT: Upper trapezius, MT: Middle trapezius, PUP: Push-up Plus, DBC: Dynamic bear crawl



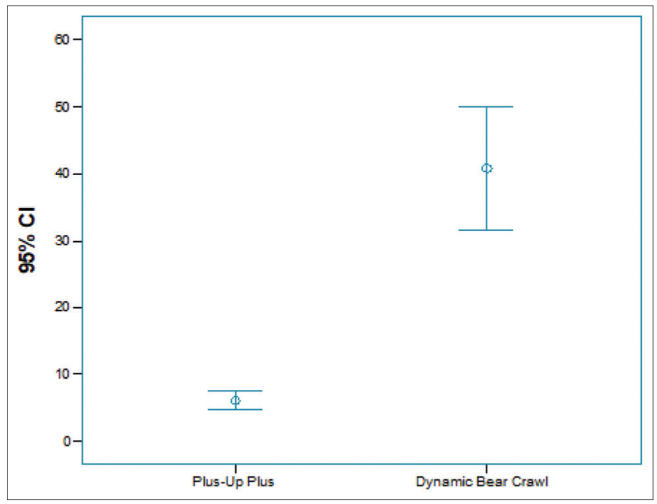
Graph 1: Comparison of serratus anterior muscle in two different activities

Discussion

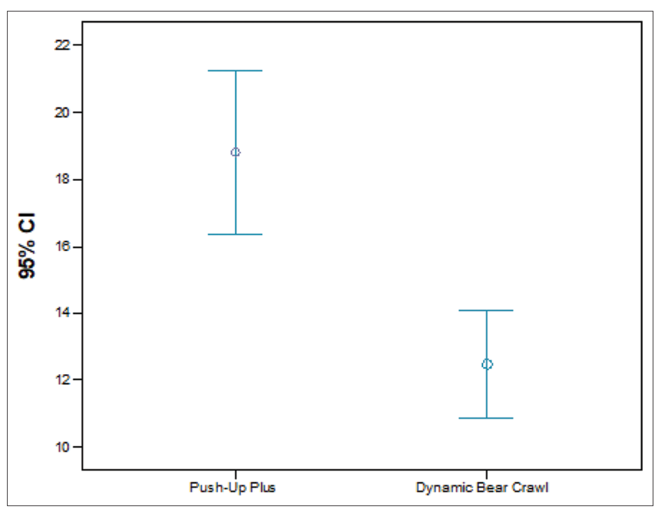
The results of the present study showed that there is a significant difference in the EMG activity of SA, UT, MT, and LT muscles during the PUP and DBC exercises. The EMG activity of SA and UT muscle is significantly more during the DBC, whereas the middle and LT muscles showed increased activity during PUP exercise.

The PUP exercise showed increased EMG activity in the SA (15.40), middle (18.80), and lower (24.85) trapezius muscles than the UT (6.08) muscle. These findings are in accordance with Ludewig and Cook[2] who reported that PUP activity elicits more activity in SA than UT. Thereby, the PUP exercise can be used in the rehabilitation of shoulder to strengthen the SA, middle and LT muscles.

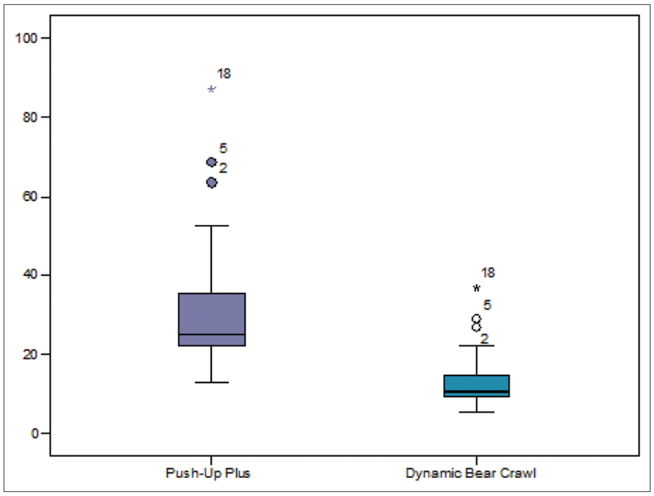
The EMG activity of the SA (39.00) and UT (40.82) is greater than the middle (12.47) and lower (10.44) trapezius muscles during the DBC exercise. This suggests that the DBC which is an effective isometric trunk exercise as reported by Pyka *et al.*[8] can also be used for the strengthening of the SA and UT muscles.



Graph 2: Comparison of upper trapezius muscle in two different activities



Graph 3: Comparison of middle trapezius muscle in two different activities



Graph4: Comparison of lower trapezius muscle in two different activities

When the EMG activities of the SA, upper middle, and LT during the PUP and DBC were compared, there was a significant ($P < 0.05$) difference among the activity patterns of all these muscles. However, the greater activity was found in SA and UT during DBC compared to the PUP exercise which produced more activity in middle and LT muscles when both the exercises were compared. This suggests the effectiveness of DBC exercise in strengthening of the SA and UT muscles. This exercise may also help in improving the dynamic scapular stability because of the dynamic nature and the challenging posture.

The scapular upward rotator muscles are essential for normal movement and function of the shoulder girdle.[11] Therefore, it is important to be able to effectively strengthen the trapezius and SA muscles during the rehabilitation of patients with shoulder pathology. The EMG data presented may assist physical therapists in developing exercise programs that will optimally activate the trapezius and SA muscles. However, when selecting the exercises, the clinicians should be careful to select the PUP exercise in the earlier phases of rehab and the DBC exercise could be used in the later phases of strengthening due to the complexity and the dynamic nature of the exercise.

The limitations of the study are; during the EMG normalization procedures, there was no single muscle test that always produced maximum EMG activity in the SA across all subjects. The electrodes were attached carefully, we could not completely prevent the potential for crosstalk because of the close proximity of the latissimus dorsi, and this is a common problem when surface EMG is used.[12] This study was performed with male subjects. Thus, these results cannot be generalized to female subjects or other populations; we did not measure the activities of other scapular muscles that may contribute to scapular stabilization.

Conclusion

This study was performed to compare the peak and average amplitudes of SA activity during the PUP exercise and DBC on a static stable surface. The peak and average SA and UT activity were greatest during the DBC exercise on a static stable surface. The peak and average middle and LT activity were greatest during the PUP exercise on a static stable surface. These results indicate that the DBC exercise on a static stable surface in three dimensions is more effective to activate the SA and the UT.

Further studies need to consider other ages, female subjects, and scapular stabilizer muscles other than the SA, UT, MT, and LT during the PUP and DBC.

Conflicts of Interest

None declared.

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