Shoulder muscle activity during the modified dynamic relocation test and side-lying shoulder external rotation: a cross-sectional study on asymptomatic individuals

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Objectives: (1) to compare activity levels between monitored muscles during the dynamic relocation test (DRT); (2) to assess changes in muscle activation variability over 10 trials; (3) to assess within-muscle difference activity levels between the DRT and the unloaded side-lying shoulder external rotation exercise.

Methods: This is a cross-sectional, laboratory-based, repeated measures study. Thirty asymptomatic individuals performed the DRT and unloaded side-lying external rotation. The order of exercises was randomized. Superficial electromyography was used for recording the supraspinatus, infraspinatus, middle deltoid, posterior deltoid, pectoralis major, and latissimus dorsi muscles. The main outcome measures were mean muscle activity, expressed as % of maximal isometric voluntary contraction.

Results: We found significant between-muscles differences in activity ($F_t = 14.11$, $p < 0.001$) during the DRT. Post hoc analysis suggested between-trial variability did not change over the 10 trials, ($F = 18.2$, $p < 0.001$). Within-muscle comparisons between the DRT and side-lying shoulder external rotation suggested significant differences between these exercises ($F = 32.37$, $p < 0.001$).

Conclusions: considering the monitored muscles, supraspinatus, infraspinatus, pectoralis major, and latissimus dorsi are the main muscles contracting during the DRT. Of all monitored muscles, supraspinatus muscle was the only one presenting higher activity levels during the DRT when compared to the unloaded side-lying shoulder external rotation.

Keywords: Shoulder, Rotator cuff muscles, Manual therapy, Motor control

Introduction

Manual therapists commonly target specific muscle and joint impairments when treating shoulder disorders.¹⁻⁴ The dynamic relocation test (DRT) was designed to test the ability of the rotator cuff muscles to stabilize the humeral head in the glenoid against a de-stabilizing load or traction.⁵ The procedure can also be used as an exercise to enhance the control of such muscles.⁵ For this test, the patient is positioned with the shoulder in approximately 60–70° in the scapular plane. The clinician applies a gentle longitudinal traction at the humerus, while asking the patient to ‘draw the arm into the socket’, counterbalancing the traction by retracting the humerus (Fig. 1). During the test, the clinician monitors which muscles are contracting, by palpating the contraction of subscapularis and superficial muscles (e.g. pectoralis major or the latissimus dorsi). The patient is deemed to have good control of the

rotator cuff if no co-contraction of the pectoralis major or latissimus dorsi is observed during the test.

At early stages of rehabilitation, low intensity exercises (e.g. DRT and unloaded side-lying shoulder external rotation) are often prescribed for patients with shoulder disorders with the aim of improving alignment and coordination.^{1,6} A complement to manual therapy interventions includes restoring normal shoulder muscle recruitment and restoring control of the rotator cuff muscles.^{4,7} It has been suggested that exercises should facilitate recruitment of rotator cuff muscles (e.g. infraspinatus) without facilitating the recruitment of the middle deltoid muscle, in order to minimize superior humeral head translation.^{6,8} The DRT focuses on enhancing motor control of the rotator cuff muscles.⁵ Currently, it is unknown what the level of muscle activation is and which shoulder muscles are mainly recruited during the DRT. Side-lying shoulder external rotation focuses on encouraging recruitment of the external rotators of the shoulder, especially the

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Figure 1 The adapted version of the DRT used in this study. Source: Author

infraspinatus and teres minor muscles.^{9,10} In patients with symptomatic subacromial impingement, low intensity shoulder external rotation exercises were found to optimize the relative contribution of the infraspinatus muscle and minimize the relative contribution of the middle deltoid muscle, if compared to medium- or high-load shoulder external rotation exercises.⁸ Both the DRT and side-lying external shoulder rotation may be prescribed to encourage rotator cuff muscle recruitment, however, it is unclear what the differences in muscle activity levels are between these two exercises.

Due to motor redundancy, the central nervous system has an infinite number of possible motor strategies for performing a specific task.¹¹ As a result, the central nervous system does not control muscles individually, instead, it recruits groups of muscles, whereby recruitment is task-specific.^{12,13} When executing a new task, it is usual for motor recruitment to vary considerably while the central nervous system explores different muscle synergies. This is an attempt to identify optimal strategies of executing that specific task.¹⁴ Indeed, there is now evidence that movement variability that is relevant to a task goal actually facilitates motor learning by allowing the nervous system to search many potentially successful movement strategies.¹⁵ When executing the DRT for the first time, it is possible that the motor recruitment will vary considerably.

In the clinical setting, it is common to observe patients presenting an immediate response to the DRT, with increased range of motion and decreased pain. In these cases, it is reasonable to assume that practicing the DRT leads to change in motor recruitment patterns. If that is true, patients may be able to enhance motor control of shoulder muscles after practicing a few DRT trials, and muscle recruitment variability should reduce over time.

To date, we found no study assessing muscle activity during the DRT. Prior to assessing how patients perform the DRT, we deemed it appropriate to explore whether or not asymptomatic individuals were capable of performing the DRT without recruiting superficial muscles, such as pectoralis major and latissimus dorsi. The aims of this study were to: (1) compare activity levels between muscles

during the DRT; (2) assess changes in muscle activation variability over 10 trials; (3) assess within-muscle differences in activity levels between the DRT and the unloaded side-lying shoulder external rotation exercise.

Methods

Study design

A cross-sectional study design with a sample of convenience was used. Surface electromyography (SEMG) was used to measure activity of the following shoulder muscles: supraspinatus, infraspinatus, posterior deltoid, middle deltoid, pectoralis major, and latissimus dorsi. We could not find previous studies exploring muscle activity levels during the DRT for estimating the sample size. For that reason, and considering this is a Phase I study, we collected a sample of 30 participants, as per sample size recommendations for different research phases.¹⁶ Participants performed two exercises: the DRT and unloaded side-lying external rotation. The order of the exercises was randomized using a computer-generated number list.¹⁷

Participants

Thirty asymptomatic individuals from a University community were recruited for the study, approved by the University of Otago Human Ethics Committee (13/253), and the trial was registered at the ANZCTR (ACTRN12616000253404). Participants underwent a physical screening examination for the shoulder and cervical spine to ensure normal and pain free range of motion.¹⁸ Participants were included if they presented no current neck and shoulder injuries, and were excluded if they presented any positive response to the screening tests. Written informed consent was gained prior to data collection.

Surface EMG

Skin preparation included hair removal with a razor over the muscle area where the surface electrodes were placed. The area was abraded with a coarse towel and then cleaned with alcohol wipes to ensure good conductivity. To reduce SEMG baseline noise, this procedure was repeated until skin impedance was verified as $<5 \text{ k}\Omega$ using a standard voltmeter.

Similar to recent published studies in the field, shoulder muscle activity was recorded using disposable, self-adhesive surface Ag/AgCl electrodes (Product SP-00-S/50, Ambu, DK-2750 Ballerup, Denmark), an arrangement shown to accurately characterize the activation of individual rotator cuff muscles.¹⁹⁻²¹ Surface electrodes were placed 2 cm apart in parallel alignment with muscle fibers according to the SEMG for the Non-Invasive Assessment of Muscles guidelines.²² One ground electrode was placed over the spinous process of the seventh cervical vertebrae.²² Myoelectric signals were recorded using a 16 channel wireless Noraxon TeleMyo 2400T G2 (Noraxon USA Inc., Arizona, USA) at a 3000 Hz sampling frequency with a gain of 500. To minimize crosstalk, we judiciously

placed electrodes parallel to muscle fibers, based on previous research and the literature.²³

Procedures

Participants performed a series of seven maximal voluntary isometric contraction (MVIC), one for each muscle, against stationary resistance provided by the researcher.²⁴ Each MVIC was sustained for 5 s. The MVIC was used during data processing for normalizing SEMG data collected during the trials.

The dynamic relocation test

For the purpose of this study, the DRT was adapted from the original description by Magarey and Jones.⁵ Participants were seated with their dominant arm in the scapular plane (defined as 30° anterior to the frontal plane), approximately 60° shoulder elevation, approximately 30° of external rotation and 30° of elbow flexion (Fig. 2). One experienced musculoskeletal physiotherapist, performed a gentle traction of the humerus, while manually inspecting contraction of shoulder superficial muscles (i.e. pectoralis major and latissimus dorsi). During pilot trials, we confirmed that hand placement did not interfere with SEMG signals. Participants were requested to imagine moving their humerus against the gentle pull performed by the researcher, and to sustain this contraction for 10 s. The between-trial interval was 5 s. For a trial to be considered successful, and therefore, be recorded, participants had to sustain an isometric contraction without palpable superficial muscles activity (pectoralis major and latissimus dorsi). The DRT was repeated until 10 'successful' trials were obtained. In order to increase the external validity of our findings, we opted to subjectively monitor the participant's positioning.

Unloaded side-lying external rotation

Participants performed 10 repetitions of unloaded side-lying external rotation. A towel was placed between the

elbow and the trunk. A metronome (set at 60 beats/min) was used to control the rhythm of the movement. The range of shoulder external rotation was from hand in contact with abdomen to neutral shoulder rotation (forearm horizontally oriented and pointing forward).

Data processing

Surface EMG data were processed using MyoResearch XP, Master Edition. SEMG recordings were reduced to eliminate electrocardiogram artifact spikes, root mean square smoothed using a 50 ms average window. For normalization purposes, the MVIC was defined as the peak of muscle activity during a 500 ms window of the 5 s contraction. The SEMG recordings were then normalized by expressing the peak SEMG value for each muscle and trial as a percentage of the participant's MVIC for the corresponding muscle. Normalized mean values for the processed SEMG signals were calculated using MATLAB 7.12 (Mathworks Inc., USA).

Main outcome measures

The primary outcome measure was the mean level of activity for each monitored muscle within each trial, expressed as a percentage of MVIC. A grand mean for each participant and monitored muscle was calculated across the 10 DRT and side-lying shoulder external rotation trials. A secondary outcome measure was the mean and standard deviation (SD) of activity for each monitored muscle within each DRT trial to assess changes in motor control of the monitored shoulder muscles.

Statistical analysis

All statistical analyses were performed using R software.²⁵ For all statistical analysis alpha was set at 0.05, and it was adjusted for multiple comparisons.

For assessing between-muscle differences during the DRT, we compared the mean activity for each monitored muscle across the 10 trials. Not all muscles presented a normal distribution, nor presented homogeneous variance, therefore, a robust method based on trimmed means was used.²⁶ Data were bootstrapped 2000 times. The robust ANOVA test was used for between-muscle comparisons, and robust *post hoc* tests were performed, as described by Wilcox.²⁶

For assessing changes in variability over 10 trials, the robust MANOVA test was conducted on the ranked data using Munzel and Brunner's²⁷ method (implemented in R through the *mulrank* function).²⁶ For this analysis, muscles were considered as independent variables, while the SD of the mean muscle activity during each of the 10 trials was considered as the dependent variable. Significant MANOVA results were followed-up with robust ANOVA for each muscle, based on trimmed means, with data bootstrapped 2000 times.²⁶

For assessing differences in muscle activity between DRT and side-lying shoulder external rotation, the robust

Figure 2 Experimental set-up and participants' positioning during the DRT. Source: Author

MANOVA test was conducted on the ranked data using Munzel and Brunner's²⁷ method, which was implemented in R through the *mulrank()* function.²⁶ For such analysis, muscles were considered as independent variables, while exercises (i.e. DRT and side-lying shoulder external rotation) were considered as dependent variables. Significant MANOVA results were followed-up with robust paired

t-test for each muscle, based on 20% trimmed means,²⁶ with data bootstrapped 2000 times.

Results

Thirty participants took part in the study (anthropometric data presented in Table 1). A representative example of the electromyography recordings is illustrated in Fig. 3.

Table 1 Participants' anthropometric data

	Range	Mean (SD)
Age (years)	21–35	24.2 (4.1)
Height (cm)	150.5–184.8	170.3 (8.8)
Weight (kg)	51.9–85.9	69.2 (10.2)
Gender (Male/Female)	8/12	
Dominance (Right/Left)	17/3	

Note: SD = standard deviation.

Figure 3 An illustrative example of electromyographic activity recorded during the DRT test.

Notes: Supra = supraspinatus; Infra = infraspinatus; MD = middle deltoid; PD = posterior deltoid; PM = pectoralis major; LD = latissimus dorsi.

Table 2 Between-muscles differences during the DRT (%MIVC)

	Mean difference (95% CI)	Standard error	p-value
MD – PD	–0.03 (–0.84 to 0.11)	0.11	0.86
MD – Infra	–1.75 (–3.22 to –0.52)	0.47	<0.001*
MD – LD	–1.60 (–2.99 to –0.52)	0.41	<0.001*
MD – PM	–0.61 (–1.57 to 0.02)	0.25	0.03
MD – Supra	–2.58 (–5.89 to –0.93)	0.89	<0.001*
PD – Infra	–1.45 (–2.92 to –0.23)	0.47	<0.001*
PD – LD	–1.29 (–2.73 to –0.19)	0.41	<0.001*
PD – PM	–0.31 (–1.39 to 0.43)	0.25	0.01
PD – Supra	–2.28 (–5.52 to –0.65)	0.89	<0.001*
Infra – LD	0.15 (–1.40 to 1.92)	0.62	0.76
Infra – PM	1.14 (–0.40 to 2.83)	0.52	0.01
Infra – Supra	–0.83 (–4.33 to 1.47)	1.00	0.19
LD – PM	0.99 (–0.41 to 2.47)	0.47	0.03
LD – Supra	–0.98 (–4.51 to 1.15)	0.98	0.13
PM – Supra	–1.97 (–5.28 to 0.05)	0.92	0.01

*Statistically significant differences.

Notes: MD = middle deltoid; PD = posterior deltoid; Infra = infraspinatus; LD = latissimus dorsi; PM = pectoralis major; Supra = supraspinatus. Critical p-value = <0.0032.

Figure 4 Mean muscle activity during 10 trials of the ‘Dynamic Relocation Test’ as percent of individual maximal voluntary contraction. (a) Supraspinatus, (b) Infraspinatus, (c) Middle deltoid, (d) Posterior deltoid, (e) Pectoralis major, (f) Latissimus dorsi. Notes: EMG = electromyography; SD = standard deviation.

Table 3 Muscle variability, expressed as SD (%MIVC), over the 10 trials

Muscle	Trials										p-value
	1	2	3	4	5	6	7	8	9	10	
Supraspinatus	6.4	5.7	5.1	4.0	4.3	4.1	5.1	5.1	4.4	4.2	0.91
Infraspinatus	2.9	2.7	3.0	2.8	3.0	2.9	2.9	2.4	2.6	2.5	0.79
Middle deltoid	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.7	0.5	0.6	1.00
Posterior deltoid	4.0	5.2	5.0	4.3	5.3	5.2	3.9	4.2	3.2	3.4	0.58
Latissimus dorsi	4.1	5.5	3.9	4.7	5.0	4.9	4.9	5.0	5.9	4.7	1.00
Pectoralis major	4.5	3.8	4.8	3.0	2.8	2.9	2.7	2.2	2.3	2.6	0.99

Table 4 Within-muscle differences in muscle activity between the DRT and side-lying shoulder external rotation

Muscle	Mean difference (95% CI)
Supraspinatus	-3.0 (-4.8 to -1.2)*
Infraspinatus	9.1 (5.7 to 12.5)*
Middle deltoid	3.9 (2.5 to 5.3)*
Posterior deltoid	4.6 (3.4 to 5.8)*
Latissimus dorsi	4.6 (2.6 to 6.7)*
Pectoralis major	0.1 (-0.4 to 0.7)

Notes: Negative values suggest higher muscle activity levels during the DRT.

* Indicates statistically significant differences.

During between-trial intervals, most muscles presented low activity levels, with some random peak activities from pectoralis major. The increase in muscle activity (Fig. 3) indicates that participants were able to recruit the rotator cuff muscles (and superficial shoulder muscles)

once they received the verbal command for retracting the humerus.

We found significant between-muscles differences in muscle activity ($F_t = 7.82$, $p = 0.004$, Table 2). Post hoc analyses showed significant differences between: (1)

middle deltoid and supraspinatus, infraspinatus, latissimus dorsi; (2) posterior deltoid and supraspinatus, infraspinatus, latissimus dorsi. We found no significant differences between infraspinatus and pectoralis major or latissimus dorsi, and between supraspinatus muscle and pectoralis major or latissimus dorsi (Table 2). Mean SEMG amplitudes for each muscle, for the 10 trials are presented in Fig. 4.

Between-trial variability, assessed through robust MANOVA, suggested there were significant changes on muscle variability over the 10 trials, ($F = 18.2, p < 0.001$). However, follow-up analyses through robust ANOVA, computed for each muscle, resulted in no statistically significant differences (Table 3).

Within-muscle comparison between the DRT and side-lying shoulder external rotation, assessed through robust MANOVA, suggested there were significant differences between the DRT and side-lying shoulder external rotation, ($F = 32.37, p < 0.001$). Follow-up analyses suggested statistically significant differences between DRT and side-lying shoulder external rotation for supraspinatus, infraspinatus, middle and posterior deltoid, and latissimus dorsi. Mean differences and its respective 95% confidence interval are presented in Table 4.

Discussion

This study assessed activity levels of seven shoulder muscles during the DRT and side-lying shoulder external rotation in a young, asymptomatic group. Our results suggest that when performing the DRT correctly, superficial muscles are also recruited. Muscle activation variability did not change over the 10 DRT trials, suggesting 10 executions did not lead to significant motor learning changes. With regard to within-muscle differences between the DRT and side-lying shoulder external rotation, we found higher activity levels for the supraspinatus during the DRT; and higher activity levels for infraspinatus, middle deltoid, posterior deltoid and latissimus dorsi during side-lying external rotation.

Between-muscles differences during the DRT

The supraspinatus, infraspinatus, pectoralis major, and latissimus dorsi muscles appear to be the main muscles involved during the DRT (Table 2). The activation of superficial muscles may reflect: (1) a need for balancing shoulder moments generated by the rotator cuff muscles, and/or (2) the fine-tuning of motor execution. Our findings also indicate that variability of muscle activation did not reduce over the trials. This finding was contrary to our second hypothesis, and suggests 10 trials may not be enough for changing motor activation patterns in asymptomatic participants.

When first described, it was suggested that the DRT should assess patients' ability to recruit the rotator cuff muscles, and compensatory recruitment of other superficial

muscles should be avoided.⁵ Our findings indicate that when assessing asymptomatic individuals, superficial muscles were also recruited during successful trials. We suggest that co-contraction of the rotator cuff and the monitored superficial muscles, as demonstrated in these asymptomatic individuals, can be explained from neuro-mechanical and motor control perspectives.

It is commonly accepted that the stabilizing role of the rotator cuff muscle requires sustained contractions, while surrounding muscles with large moment arms produce rotational movements of the humerus with regard to the scapula.²⁸ Muscles at the glenohumeral joint are capable of producing movements around three axes of rotation, thus when contracting individually, they will generate moments in different directions. Consequently, while contracting during the DRT, the rotator cuff muscles are likely to pull the head of humerus against the glenoid cavity, but also generate moments at the glenohumeral joint (e.g. external rotation, extension, etc...).

Our findings may suggest rotator cuff muscles and superficial shoulder muscles act together to increase functional stability of the glenohumeral joint. Muscle contraction increases joint reaction forces and, as a consequence, joint stability.²⁹ Due to the number of muscles in any given joint, there are an infinite number of possible motor solutions (i.e. motor redundancy) for achieving the same movement outcome. In other words, to perform a movement, there are an infinite number of possible muscle synergy combinations.³⁰ During the DRT, both pectoralis major and latissimus dorsi muscles are contracting at small intensities. The net effect of such contraction could, theoretically, balance each other's moment production (i.e. shoulder flexion and shoulder extension, respectively) as well as moment produced by the rotator cuff muscles.

Changes in muscle recruitment variability over 10 DRT trials

The lack of between-trial differences, for each muscle, suggests that muscle recruitment variability remained large through the 10 trials. As a result of motor learning, we would expect a smoother activation pattern, expressed by reduced SD magnitudes. Within-trial variability may occur due to noise in neuromotor executions or closed-loop corrections.¹⁴ Our findings suggest that 10 trials may have not been enough to improve neuromotor efficiency.

Clinically, the practice of DRT may lead to observable immediate results, with improvements in shoulder pain or increases in range of motion. Such clinical observations would suggest there is a learning effect when patients are exposed to the DRT as an intervention. The learning effect would be translated into an optimized motor strategy, with enhanced glenohumeral stability. For the present study, we explored motor recruitment in asymptomatic individuals, and it is possible that symptomatic

participants respond differently when exposed to DRT training.

Within-muscle differences in muscle activity between DRT and side-lying shoulder external rotation

Both the DRT and unloaded side-lying shoulder external rotation can be considered as low intensity exercises. Each of these may target different muscles. When performing the DRT, participants presented higher activation levels for supraspinatus and lower activation levels for infraspinatus, middle and posterior deltoid and latissimus dorsi, when compared to side-lying shoulder external rotation. Based on these findings, it is reasonable to suggest that the DRT could be prescribed to encourage recruitment of the supraspinatus muscle.

Clinical implications

Based on findings from asymptomatic individuals, clinicians may expect some superficial shoulder muscles activation during the DRT. The fact that it does not isolate the rotator cuff muscles should not prevent the use of DRT as part of a clinical assessment or rehabilitation program. It is possible that the net result of shoulder muscle contraction helps increasing glenohumeral joint stability, and that small magnitude contractions from superficial muscles may be required for minor movement corrections or shoulder moment balancing.

Patients with shoulder disorders may have different shoulder muscle recruitment response following 10 repetitions of the DRT, and that may be linked to the shoulder neuromuscular impairments.^{4,31,32} Changes in muscle recruitment pattern seem to be linked with the shoulder disorder with which patients present.^{4,31,32} For example, symptomatic patients with rotator cuff tears present with lower activity for the deltoid muscle³²; patients with shoulder impingement syndrome present with lower activity of the infraspinatus and middle deltoid muscles during shoulder elevation in the scapular plane when compared to controls³¹, while patients with massive rotator cuff muscle tear present with higher activity of biceps brachialis, latissimus dorsi, and teres major.⁴ Therefore, it is possible that the response to DRT will vary according to the shoulder disorder or injury.

It is unknown whether symptomatic individuals present with similar relative muscle contributions during the DRT. It is also unknown what the specificity and sensitivity of the DRT are, when it is used as part of clinical objective assessment. Future research should explore: (a) the psychometric properties of this clinical test; (b) what the injured and/or symptomatic patients' relative contributions of shoulder muscles are during the DRT; and (c) whether patients with shoulder disorders present immediate changes in muscle recruitment variability over 10 trials.

Limitations

For the present study, we used surface electrodes to monitor two rotator cuff muscles. While surface electrodes provide a painless and non-invasive method for recording muscle activity, their spatial resolution is somewhat limited.^{33,34} An alternative for surface electrodes is the use of indwelling electrodes, which have far smaller receptive fields but may be limited in their ability to accurately represent whole-muscle activation levels.^{34–36} Despite its spatial limitation, SEMG has been commonly used for recording rotator cuff muscle activity.^{19–21,37} One of the main criticisms for its use is the potential crosstalk from adjacent muscles.^{38,39} However, previous research has shown minimal crosstalk between surface electrodes for shoulder muscles.³⁴ The literature suggests SEMG can overestimate indwelling data, and that may be affected by posture and muscle exertion levels.³⁶ Assuming rotator cuff muscle activity is being overestimated, that would suggest even higher contributions from superficial muscles when the DRT is executed, compared to supraspinatus. This limitation is not a problem for within-muscle comparisons between the DRT and unloaded side-lying external rotation.

We did not monitor the scapulothoracic muscles (e.g. rhomboids, trapezius), anterior deltoid or the subscapularis muscle. Subjective observation from clinical practice suggests that patients may compensate by retracting the scapula,⁵ while attempting to retract the humerus against the glenoid cavity. Future studies could assess the relative contribution of those muscles during the DRT. It is also possible that a longer period of practice is required to achieve observable changes in motor pattern variability. Future research could explore the effect of practice on motor recruitment and its respective variability. The present study explored the relative muscle contributions during the DRT at one specific range of motion. Clinically, the DRT could be performed in different shoulder ranges of motion, to challenge the neuromotor control of glenohumeral muscles at ranges that reproduce the patient's symptoms. It is unknown whether similar muscle activation patterns would be observed in different shoulder range of motion.

Conclusion

This study presents novel and clinically relevant information regarding shoulder muscle activity during the DRT. Based on the data collected from asymptomatic, young participants, our findings suggest the supraspinatus, infraspinatus, pectoralis major, and latissimus dorsi are the main muscles recruited during the DRT. Muscle variability did not reduce over the 10 trials, suggesting that 10 repetitions may not be enough for motor learning to occur in asymptomatic individuals. The supraspinatus muscle was the only one presenting higher activity levels

during the DRT when compared to the unloaded side-lying shoulder external rotation.

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Notes on contributor

Daniel Cury Ribeiro was involved in conceiving and designing the study, obtaining funding and ethics approval, analyzing the data, writing the article in whole, and revising the article. Jonathan Shemmell was involved in analyzing the data, writing the article in part, and revising the article. Carrie Falling was involved in collecting and analyzing the data and revising the article. Gisela Sole was involved in collecting and analyzing the data and revising the article.

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