Rev Andal Med Deporte. 2020; **13**(**3**): *127-133*

Junta de Andalucía
Consejería de Educación y Deporte

Revista Andaluza de
Medicina del Deporte

https://ws072.juntadeandalucia.es/ojs

Original

Comparison of shoulder and trunk muscle activation between different pullover exercises

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ARTICLE INFORMATION: Received 4 February 2020, accepted 10 March 2020, online 11 March 2020

ABSTRACT

Objective: To quantify and compare the electromyographic activity of trunk and upper limb muscles in three different pullover exercises.
Methods: 15 healthy men, with at least two years of experience in resistance training, executed in random order six repetitions with 60% of 1 Maximum Repetition for three different pullover exercises: lying on a step with a barbell, grip 100% biacromial (E1); lying on a step with a barbell, grip 150% (E2); lying on a Swiss ball with a barbell, grip 100% (E3). Surface electromyography was recorded from the Deltoideus (Clavicular and Spinalis Pars), Pectoralis Major (Clavicular and Sternocostalis Pars), Serratus Anterior, Triceps Brachii (Long Head), Latissimus Dorsi, Infraspinatus, Rectus Abdominis, Obliquus Internus Abdominis and Transversus Abdominis. The normalized electromyogram of maximal voluntary isometric contraction of each muscle was calculated for each exercise.
Results: The most engaged muscles were Infraspinatus (51-53% Electromyogram maximal voluntary isometric contraction) and Posterior Deltoid (49-51% Electromyogram maximal voluntary isometric contraction). Surface electromyography activity was similar between the E1, E2 and E3 exercises.
Conclusions: This study quantified muscular solicitation during pullover exercises performed with 60% Maximum Repetition. The muscles with higher level of activation were the Posterior Deltoid and the Infraspinatus, suggesting that pullover may be a valid option for strengthening the dynamic stabilizing muscles of shoulder joint in trained individuals. No significant differences in muscle electromyography intensity were observed when grip distance and trunk stabilization were altered, showing that these conditions do not influence muscle activation levels. However, the 1 Maximum Repetition was lower when the pullover was performed on a Swiss ball, suggesting that it is possible to obtain higher level of muscle recruitment with lower weights in unstable exercises.
Keywords: Pullover; Resistance training; Electromyography; Muscle strength.

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https://doi.org/10.33155/j.ramd.2020.03.004

Comparación de la activación de los músculos del hombro y del tronco entre diferentes ejercicios de pullover

RESUMEN

Objetivo: cuantificar y comparar la actividad electromiográfica de diez músculos en tres diferentes ejercicios de *pullover*.
Método: 15 hombres sanos, con al menos dos años de experiencia en entrenamiento de resistencia, realizaron seis repeticiones al 60% de 1 Repetición Máxima en orden aleatorio para tres ejercicios de *pullover* diferentes: acostados en una tabla con mancuernas y agarre 100% biacromial (E1), acostados en una tabla con mancuernas, agarre 150% biacromial (E2) y acostado en una pelota suiza con mancuernas, agarre 100% biacromial (E3). Se registró la señal electromiográfica de superfície de Deltoides (anterior y posterior), Pectoral Mayor (clavicular y esternocostal), Serrato Anterior, Tríceps Braquial (porción externa), Dorsal Grande, Infraespinoso, Recto Abdominal, Oblicuo Interno y Transverso del Abdominal. Se calculó la Repetición Máxima para normalizar la señal electromiográfica de cada músculo y para cada ejercicio.
Resultados: los músculos más involucrados fueron el Infraespinoso (51-53% señal electromiográfica de superfície 1 Repetición Máxima) y el Deltoides Posterior (49-51% señal electromiográfica de superfície 1 Repetición Máxima). La actividad electromiográfica de superficie fue similar entre los ejercicios E1, E2 y E3.
Conclusiones: este estudio cuantificó las demandas musculares durante los ejercicios *pullover* realizados con un 60% de la Repetición Máxima. Los músculos con mayor nivel de activación fueron el Deltoides Posterior e Infraespinoso, lo que sugiere que el *pullover* puede ser una opción válida para fortalecer los músculos estabilizadores dinámicos de la articulación del hombro en individuos entrenados. No se observaron diferencias significativas en el nivel de la activación muscular cuando se modificó la distancia del agarre y la estabilización del tronco, lo que demuestra que estas condiciones no influyen en los niveles de activación muscular. Sin embargo, 1 Repetición Máxima fue menor cuando el *pullover* se realizó en una pelota suiza, lo que sugiere que es posible obtener un mayor nivel de reclutamiento muscular con pesos menores en ejercicios inestables.
Palabras clave: Pullover; Entrenamiento fuerza; Electromiografía; Fuerza muscular.

Comparação da ativação dos músculos do ombro e do tronco entre diferentes exercícios de pullover

RESUMO

Objetivo: Quantificar e comparar a atividade eletromiográfica de 10 músculos em três exercícios *pullover*.
Método: 15 homens saudáveis, com pelo menos dois anos de experiência em treinamento resistido, executaram em ordem aleatória seis repetições com 60% de 1 Repetição Máxima para três exercícios *pullover* diferentes: deitado em um step com barra e pegada 100% biacromial (E1), deitado no steep com barra e pegada 150% biacromial (E2) e deitado em uma bola suíça e pegada 100% biacromial (E3). A atividade eletromiográfica de superfície foi registrada dos músculos Deltoide (Clavicular e Spinalis Porção), Peitoral Maior (Porção Clavicular e Esternocostal), Serrátil Anterior, Tríceps Braquial (Cabeça Longa), Grande Dorsal, Infraespinhal, Reto Abdominal, Oblíquo Interno Abdominal e Transverso Abdominal. A atividade eletromiográfica da Contracção Voluntária Máxima de cada músculo foi calculada para normalizar os sinais electromiográficos.
Resultados: Os músculos mais envolvidos foram o Infraespinhoso (51-53% atividade eletromiográfica da Contracção Voluntária Máxima) e o Deltóide Posterior deltóide (49-51% atividade eletromiográfica da Contracção Voluntária Máxima). A atividade eletromiográfica foi semelhante entre os exercícios E1, E2 e E3.
Conclusões: Este estudo quantificou a solicitação muscular durante exercícios pullover realizados com 60% de Repetição Máxima. Os músculos com maior nível de ativação foram o Deltóide Posterior e o Infraspinhoso, sugerindo que o pullover pode ser uma opção válida para o fortalecimento dos músculos estabilizadores dinâmicos da articulação do ombro em indivíduos treinados. Não foram observadas diferenças significativas na intensidade da atividade eletromiográfica muscular quando a distância da pega e a estabilização do tronco foram alteradas, mostrando que essas condições não influenciaram os níveis de ativação muscular. No entanto, a carga deslocada na Repetição Máxima foi menor quando o pullover foi realizado em uma bola suíça (fitball), sugerindo que é possível obter maior nível de recrutamento muscular com pesos menores em exercícios instáveis.
Palavras chave: Pullover; Treinamento resistência; Electromiografia; Força muscular.

Introduction

Resistance training is a popular activity for both athletes and people who want to improve their esthetics, performance or a physical constraint. The pullover is a very common exercise for increasing lean body mass, strength, and power in athletes and recreational weightlifters, and its main movement is shoulder extension.[1] Many sport skills involve performing movements such as pulling the arms toward the body during extension at the shoulder (e.g., glenohumeral extension in basketball rebound or in crawl and butterfly swimming styles, glenohumeral joint adduction during rock climbing, and glenohumeral movements in gymnasts performing exercises on the rings, horizontal parallels and bar). It is therefore important to replicate these movements in a controlled environment and using additional loads.

To our knowledge, only three studies have addressed arm extension movement in pullover exercises using surface electromyography (EMG) evaluation.[1-3] Besides assessing a low number of muscles (only two), these studies present other limitations. For instance, Marchetti et al.[1] performed EMG analysis of the Pectoralis Major and the Latissimus on a very small sample (eight subjects). Furthermore, in their EMG evaluation of the Trapezius and the Serratus Anterior muscles in two pullover exercises, Bull et al.[2] did not quantify the EMG signals, but only assessed EMG intensity qualitatively (from low intensity to very intense). For the Trapezius, the EMG activity ranged from weak to strong in the pullover exercise with the elbows extended, and the muscle was inactive in the exercise with the elbows bent. On the other hand, when compared to the Trapezius, the EMG intensity was higher in the Serratus Anterior, particularly in the pullover with the elbows bent, ranging from weak to very strong. The same authors carried out a similar study[3] aiming to determine EMG in two muscles with action at the glenohumeral joint (the Pectoralis Major - pars clavicularis and the Deltoideus - pars clavicularis) using the same two pullover exercise options.[2] However, again the authors did not measure EMG amplitude, but instead used a qualitative assessment. For the Pectoralis Major (pars clavicularis), EMG activity varied from low intensity (pullover exercise with the elbows extended) to average intensity (pullover exercise with the elbows bent), and for the Deltoideus (pars clavicularis), the intensity ranged from moderate to intense (pullover exercise with the elbows extended) and between intense and very intense (pullover with the elbows bent). Although these studies had several methodological limitations, to date no other studies have attempted to characterize the main groups of muscles involved in the pullover exercise, including the agonists and antagonist muscles of the glenohumeral joint, and the muscles acting on the scapula and trunk stabilization. Thus, this study aims to: 1) quantify the activity of the main muscles acting as prime movers and stabilizers in the pullover exercise through surface EMG; and 2) compare the activation level of these muscles in three pullover exercises differing in grip distance and trunk stabilization.

Method

To compare the EMG response in different pullover techniques, subjects performed in random order six repetitions with 60% of 1 maximum repetition (RM) for each pullover exercise (Figure 1): lying on a step with a barbell and grip 100% biacromial (E1), lying on a step with a barbell and grip 150% (E2), lying on a Swiss ball with a barbell and grip 100% (E3).

The study was approved by the Research Ethics Committee of the Faculty of Human Kinetics from the University of Lisbon and was guided in agreement with the 2008 Declaration of Helsinki.

Subjects

Fifteen healthy men (mean age = 29.1±9.3 years; mean height = 174±7 cm; mean mass = 77.3±6.4 kg) volunteered for this study. All the subjects were experienced in weight training, including a minimum of two years of experience in strength training. Before participating, every subject provided a signed consent form by local Ethics Committee. None of the subjects had a previous history of injuries or complaints on the shoulder, elbow or wrist joints.

Procedures

The subjects were pretested approximately one week before the investigation day. The 1RM testing followed the National Strength and Conditioning Association (NSCA) protocol, which requires that participants progressively increase resistance across attempts until 1RM is achieved. 1RM was determined for every subject in random order for each of the variations of pullover. The subjects were asked to warm-up by performing five to 10 repetitions using 40 to 60% of the estimated 1RM. After one minute of rest, there was a second warm-up of three to five repetitions using 60 to 80% of the 1RM. For these 1 RM warm-ups and trials, the subjects were told to pace the movement two seconds in the ascend phase (until the arms where perpendicular to the torso) and two seconds in the descend phase (until the arms were parallel to the floor). The 1RM pretesting was validated after three attempts. Between each attempt, the subjects were allowed to rest for five minutes. The same protocol was used for every subject on the investigation day. All normalization tests were performed on the same day.

On the testing day, the subjects began with a warm-up period of approximately five minutes. The warm-up included eight practice repetitions of each pullover variation, in random order, with a load of 20% of 1 RM. After one minute of rest, the subjects performed five more repetitions of each exercise with a load of 40% of 1RM. The subjects were then allowed to rest two minutes. After warming up, the skin was prepared and the electrodes placed to measure the EMG of maximal voluntary isometric contraction (MVIC). After a resting period of five minutes, the subjects performed the pullover exercises in a randomized sequence. Each subject performed six repetitions for each exercise. The results of the first and last repetitions were discarded and the remainders were used for determining EMG amplitude.

The subjects started every exercise lying in a supine position, with their arms raised perpendicular to their trunk, knees bent at 90° and feet on the ground. They were instructed to maintain a slight elbow flexion during the entire movement. Starting from this position (initial position of eccentric phase), the subjects had to flex the upper arms backward at the shoulders, until they were parallel to the ground (final position of eccentric phase, and initial

Figure 1. Illustration of the three pullover exercises: lying on a step with a barbell and grip 100% biacromial (E1), lying on a step with a barbell and grip 150% (E2), lying on a Swiss ball with a barbell and grip 100% (E3).

position of concentric phase). Then the subjects had to flex their arms forward at the shoulders, until they were again perpendicular to the trunk (final position of concentric phase, and initial position of eccentric phase). The movement cadence was controlled by a metronome, at a rate of two seconds for each phase (eccentric and concentric). For the exercises performed on a step, the subjects maintained the head, trunk and pelvis in contact with the step throughout the movement.

Surface electrodes were positioned over 10 muscles. EMG was recorded in each muscle using a pair of disposable Ag/AgCl disk surfaces (Ambu Blue Sensor N-00-S/25) and active bipolar electrodes (PLUX, Lisbon, Portugal). Raw EMG signals were recorded using a wireless EMG telemetry system (bioPLUX® research 2010, PLUX, Lisbon, Portugal) with input impedance higher than 100 MWΩ and a common mode rejection ratio (CMRR) of 110 dB. The gain was set at 1.000±2, with band pass filtering between 10 and 500 Hz. All the electrodes were placed on the dominant side of each subject. In order to decrease the impedance of the interface between skin and electrode the skin surface at each location was shaved, rubbed with light abrasive paper, and cleaned with alcohol to remove dead surface tissue and oils. The electrodes were aligned with muscle fiber orientation with a center-to-center distance of 20 mm, at the most prominent part of the muscle bellies and taking into account the following references: Anterior Deltoid (AD), one finger width distal and anterior to the acromion; Posterior Deltoid (PD), two finger breaths behind the angle of the acromion; Pectoralis Major: Pars Clavicular (PC), one centimeter below the midline of the clavicle, and Pars Sternocostalis (PE), midpoint of the distance between the sternal notch and the axillary fold; Serratus Anterior (SA), just anterior to the border of the Latissimus Dorsi muscle at the level of the inferior tip of the scapula; Triceps Brachii long head (TB), midpoint of the distance between the posterior crista of the acromion and the olecranon at two finger widths medial to the line; Latissimus Dorsi (LD), three finger widths below the posterior axillary fold; Infraspinatus (IF), into the infraspinous fossa 2-4 cm below the medial third of the spine of the scapula; Rectus Abdominis (RA), 3 cm from the sagittal plane and 5 cm below the umbilicus; Obliquus Internus Abdominis/Transversus Abdominis (IO/T), halfway between the anterior superior iliac spine of the pelvis and the midline, just upper the inguinal ligament. The reference electrode was placed on the clavicle.

Before the exercise, MVIC were recorded to measure maximal EMG activation in each muscle and normalize the amplitude of the EMG signals. For Deltoideus (pars clavicularis) and Pectoralis Major (clavicularis pars), the shoulder isometric flexion was performed on a technogym pullover machine, 144° on the machine, 45° of the arm relative to the trunk. For Latissimus Dorsi, Deltoideus (pars spinalis) and Triceps Brachii (Long Head), the shoulder isometric extension was performed on a technogym pullover machine, 126° on the machine, 90° of the arm relative to the trunk. For Pectoralis Major (pars esternocostalis) and Serratus Anterior, the supine position was performed on a Smith machine, grip 150% biacromial with elbows flexed at 90°. For Infraspinatus, the isometric external rotation of the shoulder was performed with the shoulder at 0° abduction, neutral rotation, and elbow flexed to 90°, with resistance applied just above the wrist to create shoulder external rotation. For Rectus Abdominis, the flexion of the trunk was performed with the subject lying down, applying isometric resistance on both shoulders. For Obliquus Internus and Transverses Abdominis, the isometric flexion combined with rotation of the trunk was performed applying resistance on the opposite shoulder. The subjects were instructed to do a forced expiration during contraction. As it impossible to ensure that the surface EMG activity of these muscles (Obliquus Internus and Transverses Abdominis) is totally separated, we assume that EMG recordings represent the combined activity of the two muscles. The subjects were verbally instructed and encouraged to slowly increase force, maintaining a maximal level for 4/5 seconds, and then to slowly reduce it. Each measurement of muscle strength was performed twice, with a minimum of 30-second rest between the two measurements.

During the pullover exercises an accelerometer (PLUX, Lisbon, Portugal) was placed in the center of the barbell or in the handle of the cable for analyzing the displacement and determining the start and end of each repetition.

The signals were digitized with a sampling rate of 1000 Hz using a 16-bit A/D converter (DataPac, Laguna Beach, CA) and stored using a microcomputer.

Prior to signal processing, the quality of the recorded raw EMG signals was verified by an experienced researcher by visual inspection. The raw EMG data was then digitally filtered (10-490 Hz), full-wave rectified, smoothed through a low-pass filter (12 Hz, fourth-order Butterworth digital filter), and the amplitude was normalized using the peak 1-second EMG signal during MVICs as reference. Next, the EMG amplitude of each repetition was calculated by determining the root-mean-square (RMS) of the EMG signal defined through the movement sensor signal from the start to the end of each repetition. EMG data processing was performed using MATLAB® software V.R2010a (The Mathworks Inc., Natick Massachusetts, USA).

Statistical Analysis

The RMS value for each repetition (for every subject, exercise and muscle) was calculated by averaging the EMG signal of all repetitions except the first and last.

To test the normality of the data, the Shapiro-Wilk test was used; all values registered a normal distribution ($p<0.05$). The sphericity assumption was verified using the Mauchly's Test. For each muscle, the EMG differences between exercises were tested with repeated ANOVA measures. Finally, as significant differences were found between the three exercises, a Pairwise Comparisons test for multiple comparisons of means was applied using Bonferroni adjustment. For all statistical tests, the 0.05 probability was accepted as the criterion for statistical significance. Statistical analysis was performed using SPSS® v14 statistical software.

Results

The average value of maximum force (1RM) achieved by the group of participants in each exercise was 42.3 ± 3.6 kg in E1, 40.3 ± 4.7 kg in E2, and 37.9 ± 2.7 in E3. The average values of 60% RM used in the tests were 25.4 ± 2.1 (E1), 24.2 ± 2.8 (E2), 22.7 ± 1.6 (E3). Table 1 shows the results of ANOVA and Pairwise comparisons between conditions (Exercises 1, 2 and 3) of 1RM and EMG RMS for each muscle during the pullover exercises. 1RM is significantly different between the three exercises ($F(2.28) = 22.875$, $p<0.001$, partial eta square=0.620, power=1.0). E3 shows the largest differences in 1RM, to both E1 ($p<0.001$) and E2 ($p=0.013$), of 4.5 kg and 2.5 kg, respectively. However, E1 and E2 also differ significantly from each other ($p=.026$) by 2.0 kg.

The measurements of central tendency and dispersion of the normalized EMG values for each exercise are shown in Figure 2.

With the exception of one muscle (RA), none of the muscles analyzed showed significant differences in activation in the three pullovers exercises performed with a barbell. RA registered a significant superior activation ($p=0.012$) in E2 (42%) when compared to E3 (35%). For the other muscles, the EMG RMS values varied between 33 and 36% (AD), 36 and 39% (SA), 43 and 47% (PE, LD, TB, IO/T) and 51 and 53% (IF).

Discussion

The first aim of this study was to quantify the activity of the muscles acting as prime movers and stabilizers in three pullover exercises by measuring surface EMG. Regarding the prime movers of arm extension, important levels of activation were observed in

Table 1. Results of ANOVA and Pairwise Comparisons between conditions (Exercises 1, 2 and 3) of 1 RM and EMG RMS of each muscle during the pullover exercises.

	F(m.n)	*p*	η_p^2	π	*Pairwise Comparisons*	
					Exercises	*p*
1 RM	22.875(2,28)	<0.001*	0.620	1.0	1-3	<0.001*
					2-3	0.013
RMS						
AD	0.951 (2.28)	0.399	0.064	0.198	-	-
PC	0.648 (2.28)	0.531	0.044	0.148	-	-
PE	2.508 (1.375,19.251)	0.122	0.152	0.461	-	-
SA	1.911 (2.28)	0.167	0.120	0.363	-	-
RA	7.651 (2.28)	0.002*	0.353	0.923	2-3	0.012*
IO/T	1.627 (2.28)	0.214	0.104	0.314	-	-
PD	0.929 (2.28)	0.407	0.062	0.194	-	-
IF	0.704 (2.28)	0.503	0.048	0.157	-	-
TB	0.040 (2.28)	0.961	0.003	0.055	-	-
LD	0.598 (2.28)	0.557	0.041	0.140	-	-

1 RM: Maximum repetition; AD: Anterior Deltoid; PC: Pectoralis Major (pars clavicular); PE: Pectoralis Major (pars sternocostalis); SA: Serratus Anterior; RABD: Rectus Abdominis; IO/T: Obliquus Internus Abdominis and Transversus Abdominis; PD: Posterior Deltoid; IF: Infraspinatus; TB: Triceps Brachii; LD: Latissimus Dorsi; RMS: root-mean-square; *significant differences.

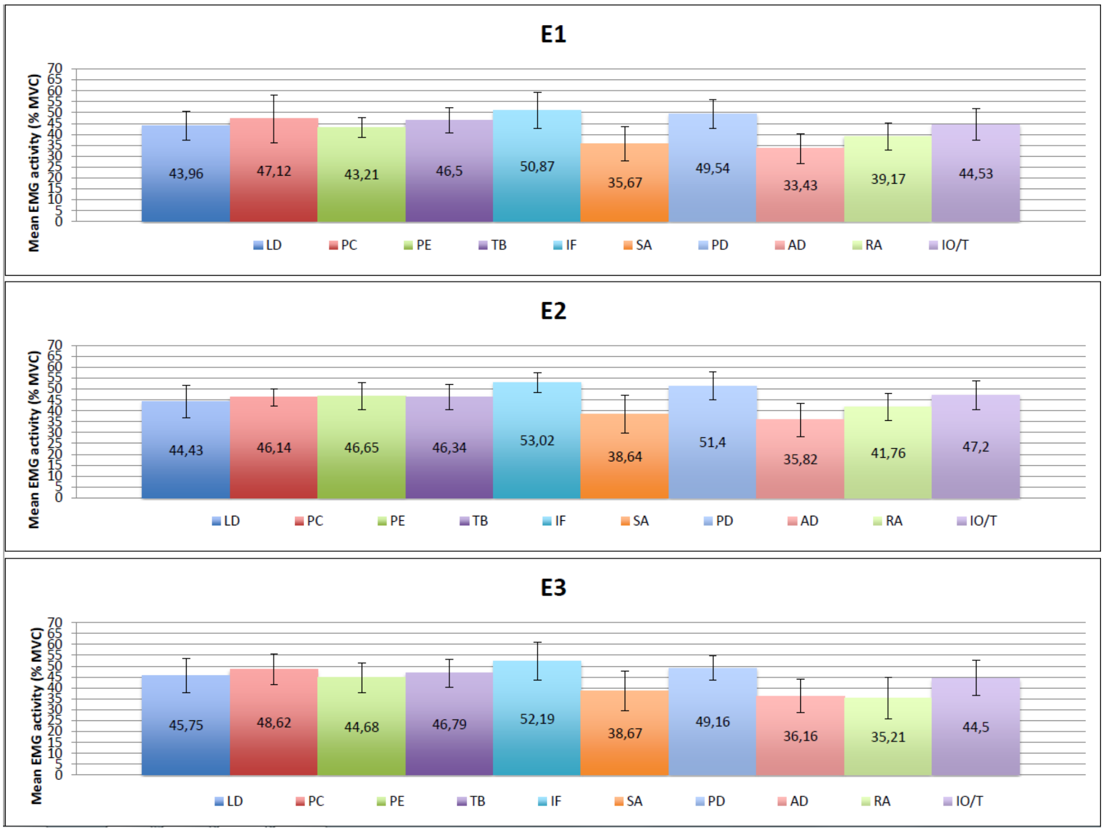

Figure 2. Measurements of central tendency and dispersion of the normalized electromyography values for each exercise

PD (49-51% CVM) and LD (44-46% CVM) in all exercises. Although the TB muscle mainly acts on elbow extension, it showed similar levels of activation (46-47% CVM) as PD and LD, possibly because the electrodes were placed on its long head, which combines biarticular elbow extension and glenohumeral extension. Furthermore, the performers were instructed to always maintain a slight elbow flexion during the movements, which may also have influenced the TB activation measurements. The high activities of PC (46-49% CVM) and PE (43-47% CVM), which are usually considered arm flexor muscles, are probably due to their role as agonist in the first phase of arm extension, as they are required to bring the arms from 180° to 90°.[4]

Our results show that IF (51-53% CVM) was always the most engaged muscle during pullover exercises, which contradicts a study by Kronenberg et al.[5] showing that IF has very low activity during arm extension. However, these differences in IF may be explained by the load used in the studies, as Kronenberg et al.[5] used loads of only 2 kg, in contrast to our study which used loads of about 40kg. Indeed, since IF is one of the rotator cuff muscles, and hence a dynamic stabilizer of the shoulder joint, higher activation is expected during exercises with heavy loads. This muscle plays an important role in the glenohumeral joint compression, by pulling the humeral head down and thus avoiding exceeding superior migration and keeping the humeral head in the glenoid cavity, particularly when the arm is overhead.[6] In addition to its dynamic stabilizing role, the IF also assists the arm extension.[7] Due to this double role as dynamic stabilizer of the glenohumeral joint and antagonist of arm internal rotation, IF muscle weakness may induce instability in the glenohumeral joint, ultimately allowing excessive translation of the humeral head during overhead arm movements. Thus, strengthening this muscle is important particularly for overhead athletes; exercises with arm external rotation and horizontal abduction are therefore typically recommended.[8,9] As IF muscle activity had not been previously evaluated in the pullover exercise, our results provide new insights suggesting that pullover could be an alternative exercise for strengthening the IF muscle.

The activation levels of the SA (36-39% CVM) have been associated to its stabilizer role in the scapulothoracic joint[10-12] and its synergistic action, which enable an appropriate scapulothoracic rhythm critical for maintaining the scapulohumeral muscles' length-tension ratio and the normal biomechanics of the shoulder during humerus elevation movements.[11]

The levels of activity of OI/T (45-47% CVM) were higher than those of RA (35-42% CVM), which is consistent with the important function of these trunk muscles in maintaining the pelvis and the spine in a stable position during movement, since there is a trend toward a pelvic anteversion and increased lumbar lordosis as the arms are moved away from the trunk.[13]

The second aim of this study was to compare the activity of the main muscles acting as prime movers and stabilizers in pullover exercises with different grip distance and trunk stabilization conditions. In exercises E1 and E2, the subject was lying on a step in supine position and the grip distance on the barbell was either 100% (E1) or 150% (E2). The grip has a major impact on which glenohumeral muscles are most engaged and we aim to investigate the effect of the grip on prime movers recruitment. In exercise E3, which was identical to E1 except that the subject was lying on a Swiss ball, we aimed to investigate the influence of trunk stabilization on muscle activity of agonist and stabilizer muscles. We found no significant differences in the activity of muscles acting on the shoulder complex (e.g., in the glenohumeral joint and also in the scapula) when we compared the three exercises. Furthermore, adopting different hand spacing distances in exercises E1 and E1 did not cause any significant changes in muscle activation ($p > 0.05$). Studies addressing the influence of hand distance on muscle activity using exercises such as the bench press,[14] pushup,[15,16] lat pull down[17] and upright row[18] found that hand distance is associated with intensity of shoulder muscular activation, which we did not find in the pullover exercise. However, these studies analyzed exercises where movements were performed both in the glenohumeral joint and the elbow, and the changes in grip distance affected muscular activity between both joints. In the pullover exercise the movement is essentially performed in the glenohumeral joint, and the elbow maintains a stable position during the exercise. Thus, we can conclude that different hand spacing distances in pullover exercises do not influence muscle activation in the glenohumeral joint. A comparison between stable (E1) and unstable (E3) conditions showed that trunk stabilization influences muscle activity during the pullover exercise, but only for the RA muscle. Indeed, RA showed significantly higher activity when the pullover exercise was performed on the bench (39% CVM) instead of a Swiss ball (35% CVM). This result suggests that the position on the Swiss ball potentiates the action of the extensor muscles of the trunk, with a clear decrease in activation of the antagonist muscle (RA). Previous studies examining the activity of RA during a seated overhead press on a Swiss ball showed that this muscle does not appear to play a strong role in stabilizing the trunk during the movement.[19,20] Furthermore, Marshall & Murphy[21] proposed that "there is no scientific evidence to support the increased abdominal muscle work, when a strength training exercise is performed on a Swiss ball", and this observation has been further supported by studies that found no differences in the activity of agonist/synergistic and stabilizer muscles between exercises performed on stable or unstable surfaces.[22-24] Behm et al.[20] suggested that only unilateral exercises were able to produce a greater activation of the stabilizing muscles of the trunk when performed on a Swiss Ball rather than on a stable surface. In a study by Valadés Cerrato et al.[25] is reported to increase the effect of eight weeks of upper-body plyometric training during the competitive season on professional female volleyball players.

As expected, a higher 1RM was associated with the stable exercise (E1) when compared to their unstable version (E3), because a stable support creates a more favorable position for moving the load, due to the better fixation of the origin of the agonist muscles. However, as mentioned above, except for the RA we found no significant differences in muscle EMG activation between the stable and unstable exercises. So, we can obtain the same level of muscle recruitment with lower weight in unstable exercises, when compared to stable exercises.

This study quantified the muscular solicitation of agonist, antagonist and stabilizer muscles during the pullover exercise performed with 60% 1RM. The muscles with the highest level of activation were the infraspinatus and the posterior deltoid, suggesting that pullover may be a valid option for strengthening the dynamic stabilizing muscles of shoulder joint for trained individuals. Additionally, with the exception of the rectus abdominis muscle, no differences were found in muscle EMG intensity when the pullover was performed with different supports or grip distances, suggesting that trunk stabilization and hand distance do not influence muscle activation levels. However, the 1RM was lower when the pullover was performed on a Swiss ball, suggesting that it is possible to obtain higher level of muscle recruitment with lower weights in unstable exercises.

Authotship. All the authors have intellectually contributed to the development of the study, assume responsibility for its content and also agree with the definitive version of the article. **Confilcts of interest.** The authors declare no conflict of interest. **Provenance and peer review.** Not commissioned; externally peer reviewed. **Ethical Responsabilities.** *Protection of individuals and animals:* The authors declare that the conducted procedures met the ethical standards of the responsible committee on human experimentation of the World Medical Association and the Declaration of Helsinki . *Confidentiality:* The authors are responsible for following the protocols established by their respective healthcare centers for accessing data from medical records for performing this type of publication in order to conduct research/dissemination for the community. *Privacy:* The authors declare no patient data appear in this article.

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