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THE EFFECTS OF HANDGRIP AND RANGE OF MOTION VARIATIONS ON MUSCLE ACTIVITY IN DIFFERENT DELTOID EXERCISES

UČINKI RAZLIČNIH PRIJEMOV UTEŽI IN OBSEGA GIBANJA NA MIŠIČNO AKTIVNOST DELTOIDNIH MIŠIC PRI RAZLIČNIH VAJAH

ABSTRACT

This study aimed to compare the effects of handgrip and range of motion (ROM) variations on muscle activity in different deltoid exercises. 14 resistance-trained men volunteered for 1RM and EMG testing with a load corresponding to 80% of 1RM. The subjects performed three different handgrips during Dumbbell Front Raise (DFR), two different ROM variations for Dumbbell Lateral Raise (DLR), and two different handgrips during Dumbbell Rear Delt Raise (DRDR). Electromyogram (EMG) activity was measured in the anterior, medial, and posterior heads of deltoids. For the DFR exercise, the highest mean EMG activity was greater for the anterior deltoid, and the highest activity was observed in pronate grip (PG) con (51.57%). For the anterior deltoid EMG activity was significantly greater in PG con (51.57%) compared with hammer grip (HG) con (43.36%) ($p<0.05$). HG ecc activity (40.36%) was significantly greater than PG ecc (36.4%) in posterior deltoid ($p<0.05$). For the DLR exercise, the highest activity was observed in medial deltoid, and for limited ROM (LTR) (20.74%). LTR con activity (19.37%) was significantly greater than full ROM con (FLR) (16.88%) in the anterior head ($p<0.05$). For the DRDR exercise, the mean activity was greater in medial deltoid, and HG con showed the highest activity (24.47%). The mean electromyography activity for the posterior deltoid was significantly greater in standard grip (STD) ecc compared with HG ecc (17.3%) ($p<0.05$). In conclusion, for the heads of the deltoid muscle, the use of the different handgrip and ROM variations may increase neuromuscular activity.

Keywords: Resistance training, EMG, shoulder muscles, exercise variations

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IZVLEČEK

Namen te študije je bil primerjati učinke različnih prijemov uteži in obsega gibanja (ROM) na mišično aktivnost deltoidnih mišic pri različnih vajah. V raziskavi je 14 treniranih moških opravilo testiranje 1RM in EMG z obremenitvijo, ki je ustrezala 80 % 1RM. Preiskovanci so izvajali dvig uteži iz priročenja do predročenja (DLR; fleksija ramena) s tremi različnimi prijemi, stranski dvig uteži (DLR; abdukcija ramena) z dvema različicama obsega gibanja in stranski dvig uteži v predklonu (DRDR; abdukcija ramena v predklonu) s dvema različnima prijemoma uteži. Aktivnost sprednje, medialne in zadnje glave deltoidov je bila izmerjena s pomočjo elektromiograma (EMG). Pri vaji DFR je bila največja povprečna aktivnost mišic izmerjena v sprednjem delu deltoida z nadprijemom v koncentrični fazi (51.57%) in kaže na to, da obstajajo statistično značilne razlike ($p<0.05$) v primerjavi z nevtralnim prijemom v koncentrični fazi (43.36%). Statistično pomembne razlike ($p<0.05$) pa obstajajo tudi pri aktivnosti mišic v zadnji glavi deltoida pri nevtralnem prijemu v ekscentrični fazi (40.36%) in nadprijemom v ekscentrični fazi (36.4 %). Pri vaji DLR je bila največja aktivnost opažena v medialnem deltoidu pri omejenem gibanju (LTR) (20.74 %). Aktivnost pri vaji LTR v koncentrični fazi (19.37 %) je bila pri sprednji glavi deltoida bistveno večja kot pri vaji popolnega obsega gibanja (FLR) (16.88 %) ($p<0.05$). Pri vaji DRDR je bila povprečna aktivnost večja v medialnem deltoidu z nevtralnim prijemom v koncentrični fazi (24.47 %). Povprečna EMG aktivnost zadnjega dela deltoida je bila statistično pomembno večja ($p<0.05$) pri nadprijemu v ekscentrični fazi (23.07%) v primerjavi z nevtralnim prijemom v ekscentrični fazi. Zaključimo lahko, da se živčno-mišična aktivnost glav deltoidne mišice poveča z uporabo različnih prijemov uteži in obsega gibanja.

Ključne besede: vaje za moč, EMG, mišice ramenskega sklepa, prijem, obseg gibanja

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INTRODUCTION

Resistance exercises are used by recreational or competitive athletes to increase muscle strength and hypertrophy (Vigotsky et al., 2018). Planning and development of a resistance training program are based on the creation of combinations of basic training variables such as the number of repetitions and sets performed, the external loads lifted, and the selection and order of exercises (Fleck & Kraemer, 2014). The exercise selection and the variations of these exercises has great importance in reaching the goals of the planned training program (Lusk et al., 2010).

Recently, there has been increasing interest in the effect of technical variations in exercises for the development of upper body muscle groups on muscle activity pattern (Cogley et al., 2005). Shoulder muscles, one of the upper body muscle groups, is a penne muscle that surrounds the shoulder joint with three muscle parts assigned to move the humerus relative to the scapula and is considered the primary motor muscle in many upper body strength training exercises (Botton et al., 2013; Franke et al., 2015; Smith, 1996). In most sports and daily life activities, the muscles surrounding the shoulders are involved in a series of multi-plane movements and various exercises are performed to strengthen these muscles (Escamilla et al., 2009). The glenohumeral joint is a complex joint and allows six main movements of the shoulder to take place (flexion, extension, adduction, abduction, internal rotation, and external rotation). The deltoid muscle of the shoulder consists of three heads as anterior, medial, and posterior (Escamilla et al., 2009; Hik & Ackland, 2019; Sweeney, 2014). The anterior head of the shoulder attaches to the collarbone and raises the arm forward. The medial head attaches to the acromion process of the scapula and lifts the arm outward and laterally. Its posterior head attaches to the scapula and moves the arm backward (Sweeney, 2014).

Since the shoulder is such a complex joint, it becomes difficult to choose the best exercise for shoulder muscle development. For this reason, it has been strongly recommended to use different mechanical stress methods and different exercise types for the development of all muscle groups of the shoulder (Campos et al., 2020). One way to determine the level of muscle activation associated with these different methods and exercises is to use electromyography (EMG) (Jakobsen et al., 2012). When the previous studies that investigated the activity level in the shoulder muscles using EMG are examined, Campos et al. (2020) found that the shoulder press exercise activates the anterior and lateral shoulder muscle groups more than the bench press and dumbbell fly exercises, but the lateral raise exercise shows higher muscle activity in the lateral and posterior shoulder muscle groups than the shoulder press. Botton et al. (2013) reported that for the medial part of the shoulder, cable or dumbbell lateral lifting exercise provides higher muscle activity than shoulder press exercise. Coratella et al. (2020) observed that in variations of the lateral raise exercise, when the humerus is rotated outward, the anterior shoulder activity increases, when it is rotated inwards, the posterior shoulder activity increases, and when the humerus tends to rotate inward, the upper trapezius shows more activity. Saeterbakken and Fimland (2013) compared 4 shoulder press exercises in their study. This study showed that combining 2 unbalanced strategies in shoulder presses (standing + dumbbells) increased shoulder muscle activation. Franke et al. (2015) examined the activity level of the seated row, incline lat pulldown, and reverse peck deck fly exercises in the shoulder muscles and found that seated row was effective in working the medial part of the shoulder and reverse peck deck fly was effective in working the medial and back parts of the shoulder. Dickie et al. (2017) compared the muscle activity level of different variations in the pull-up exercise and found that the pronation grip variation activates the medial trapezius muscle more than the neutral grip. Also, they did not observe any difference between supination grip and neutral grip. At the same time, it is seen that training experience can positively affect the stimulation of the targeted muscles in such studies. Compared to other athletes, bodybuilders have a unique sensitivity to focus on metabolic stimuli and muscle stimulation (Hackett et al., 2013; Maeo et al., 2013).

The effects of different grip and ROM variations on muscle activation in the deltoid muscle have not been fully observed in the current literature. We believe that it is valuable to determine effects of hand grip and ROM variations on muscle activation of deltoid muscle heads for improving muscle strength and hypertrophy in many sports branches and reducing the risk of injury. This study aimed to compare the dumbbell front raise (DFR), dumbbell lateral raise (DLR), and dumbbell rear delt raise exercises (DRDR) muscle activity with different handgrip and ROM variations in males with a resistance training background. The current research can help trainers, physiotherapists, and athletes to choose and apply the most appropriate exercise for performance improvement and hypertrophic adaptation.

METHODS

Participants

14 healthy men (mean ± SD age: 23.6 ± 0.90 years, body weight = 77.8 ± 6.43 kg, height = 176 ± 0.07) participated in the study. Gpower 3.9.1 software was used to determine the number of subjects to be included in the study. The total number necessary for the expectation of a high effect size (f = 0.25) to be found statistically significant was determined as 14 (α = 0.05; 1-β = 0.80). Participants were well trained athletes with at least 5 years of resistance training history. All athletes were accustomed to the shoulder exercises included in the study and used these exercises consistently in their training programs. In addition, the athletes stated that they do split resistance training 4-5 times a week. All athletes were informed about the measurement procedures and possible risks, and a written consent form was signed before the measurement. Participants were selected from athletes who had not experienced any upper extremity muscle or joint injury and cardiovascular disease in the last 1 year, and who did not use any prohibited substance. Before the study, ethical approval was obtained from the ethics committee of Sakarya University of Applied Sciences (100/7428) and it was applied in accordance with the Declaration of Helsinki (1975) for studies with human subjects.

Experimental design

Repeated measures design was used to examine the effects of grip variations in shoulder exercises on 1RM strength and neuromuscular activity. On the first day, trial training was carried out in order to adapt to the different variations. On the second day, 1RM strength measurements were taken in three different DFR variations of the athletes and after 30 minutes of passive recovery, the athletes performed three different DFR variations in random order, at 80% intensity, and 5 repetitions. Finally, on the third day, 1RM strength measurements were taken in two different DLR and DRDR variations of the athletes and after 30 minutes of passive recovery, the athletes performed two different variations of DLR and DRDR in random order, at 80% intensity and 5 repetitions. A minimum of 72 hours of rest was given between all sessions and the athletes were instructed not to do any other resistance training until the end of the measurements. Participants were instructed to continue their normal diet and routine training preparations throughout the study period. Athletes came to the measurement area at a time as close as possible to their routine training hours.

Maximal Strength Assessment

Before 1RM strength tests the athletes performed a standard 10-minute warm-up protocol on the bicycle ergometer. Immediately after, they performed dynamic mobility exercises for the shoulder muscles. While performing 1RM strength measurements, 1 retest protocol recommended by the American College of Sports Medicine (ACSM) was applied. First, 2 warm-up sets of light to moderate were applied. After the first set was performed 5-10 repetitions, 1 minute rest was given. The second set was performed 2-5 repetitions and 2 minutes of rest were given. With the third set, 1 repetition attempt was started and 2-4 minutes of rest was given. In the following sets, 5-10% load increase was continued with each successful lift and a rest period of 2-4 minutes was given. When an unsuccessful lift occurred, the load was reduced by 2.5-5% and the lift was performed again (ACSM 2013).

Exercise Protocol

In general, for strength and hypertrophy gain, resistance training is performed at 80% intensity of 1RM. This percentage of intensity corresponds to a load of 8 to 12 RM. In order to avoid the confusing effects of fatigue and postural sway on neuromuscular activation the exercises were performed as five repetitions. Each exercise was applied for 2 seconds for the concentric phase, 2 seconds for the eccentric phase and 0.5 seconds for the isometric phase. A metronome was used to facilitate the implementation of the targeted protocol and a camera was used to provide feedback for each exercise technique. All exercises were performed standing up, and a square rope was used approximately 1 cm from the skin and 3 cm above the iliac crest to prevent postural sway while performing the exercises. The position was adjusted with the feet shoulder-width apart and the knees extended. Movement forms were kept under control by 3 researchers and feedback was given. In the study, firstly, random measurements were taken in the hammer grip (HG), supinate grip (SG) and pronate grip (PG) grip variations of the DFR exercise (Fig. 1). The DFR HG (Fig. 1a) was performed as follows: From a neutral starting position, the athlete, holding the weight upright, raises one arm to 90 degrees of shoulder flexion and returns to the neutral position on the same route. The DFR SG (Fig. 1b) and DFR PG (Fig. 1c) grips also start from a neutral starting position and lift the weight until the athlete reaches 90 degrees of shoulder flexion. At the same time, the SG rotates the arm outward, while in the PG, it rotates the arm inward. In all variations, the position is maintained with the elbows slightly bent throughout the range of motion. In the DLR exercise, measurements were taken in full ROM (FLR) and limited ROM (LTR) variations (Fig. 2). In the DLR FLR variation (Fig. 2a), the athletes performed the exercise with their hips against the wall, in a position of 30 degrees trunk flexion, and lifting the weights from the anterior aspect of the pelvic bone to 90º shoulder abduction.

In the DLR LTR (Fig. 2b) variation, the athletes applied by leaning against the wall in the anatomical position and lifting the weights from the lateral side of the pelvic bone until 90º shoulder abduction. Finally, measurements were taken in the STD and HG variations of the DRDR exercise (Fig. 3). In the DRDR STD (Fig. 3a) variation, the athletes performed the exercise with the trunk in 90 degrees flexion position and internal rotation of the arm. In the DRDR HG (Fig. 3b) variation, the athletes only performed the exercise without any rotation of the arm. In both variations, the elbows are kept in a slightly bent position throughout the range of motion.

Figure 1. Handgrip variations for Dumbbell Front Raise. a) Hammer grip (HG) b) Pronate grip (PG) c) Supinate grip (SG).

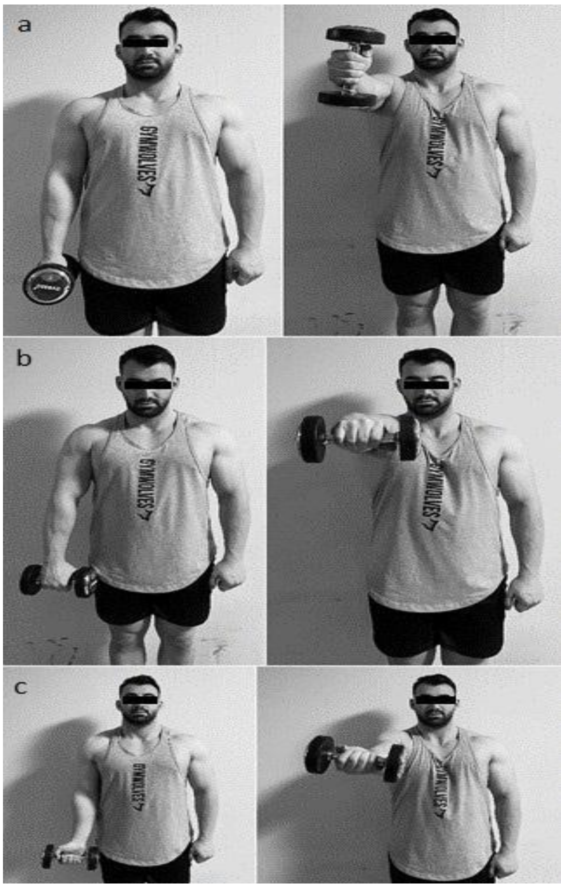


Figure 2. ROM variation for Dumbbell Lateral Rise. a) Limited ROM (LTD) b) Full ROM (FLR).

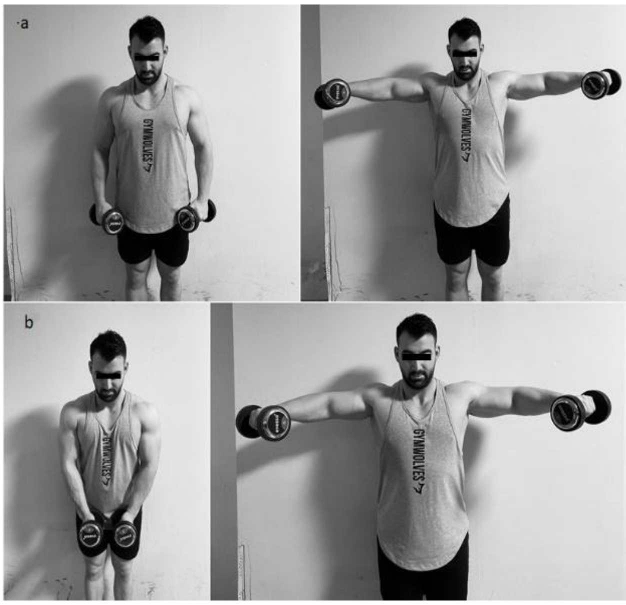


Figure 3. Handgrip variations for Dumbbell Rear Delt Raise. a) Hammer grip (HG) b) Standart grip (STD).

EMG Recording

The skin of the athletes was cleaned using cotton and skin cleansing alcohol. Then, electrodes were placed on the anterior deltoid (AD), medial deltoid (MD) , posterior deltoid (PD) and flexor carpi radialis muscles (FCR) of each participant according to the SENIAM recommendations (Hermens et al., 1999). The IMU data of the FCR muscle and the surface EMG data of the AD, MD, PD muscles were recorded using the Trigno wireless biofeedback system with the EMG plot software at 1000Hz sampling frequency. The recorded data was analyzed with EMGwork analysis software. Filtering was applied according to SENIAM recommendations to remove noise from the data. The filtered signal (mV) root mean square (RMS) was calculated using a moving window (window length 11sample, window overlap 3sample). Concentric and eccentric phases of five repetitions were determined by using the angular position data obtained from the IMU sensor. The first repetition was not included to avoid possible mistakes when starting the exercises (Saeterbakken & Fimland, 2012). The RMS of filtered sEMG data of each muscle was normalized for 1RM maximal activation and MVC% values were calculated. The mean and maximum MCV% values of four repetitions were calculated.

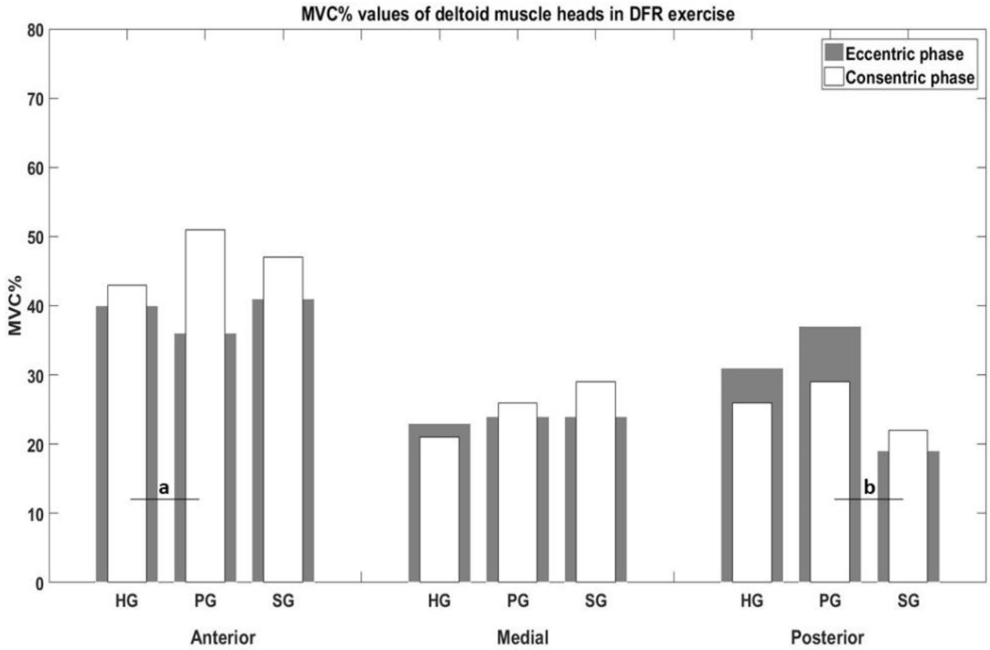
Statistical analysis

Means of the data are presented. The normality of the data was examined using the Shapiro–Wilk test. It was determined that the data did not showed normal distribution. To compare the differences in 1-RM strength and neuromuscular activity of DFR exercise variations, Friedman test, one of the nonparametric tests, was used. The Wilcoxon test was used to compare variations of DLR and DRDR exercises. In this exploratory study, the level of significance of each comparison was set to $p < 0.05$. The entire analysis was conducted using the software SPSS (Version 22.0).

RESULTS

In the DFR exercise, three different grip variations were compared with the Friedman test, and the Wilcoxon test was applied to find the source of the difference. DLR and DRDR exercises were compared with the Wilcoxon test and the mean values are given in the figure. Muscle responses of anterior, medial and posterior head in concentric and eccentric phases in DFR, DLR, DRDR exercises are given in the figure below.

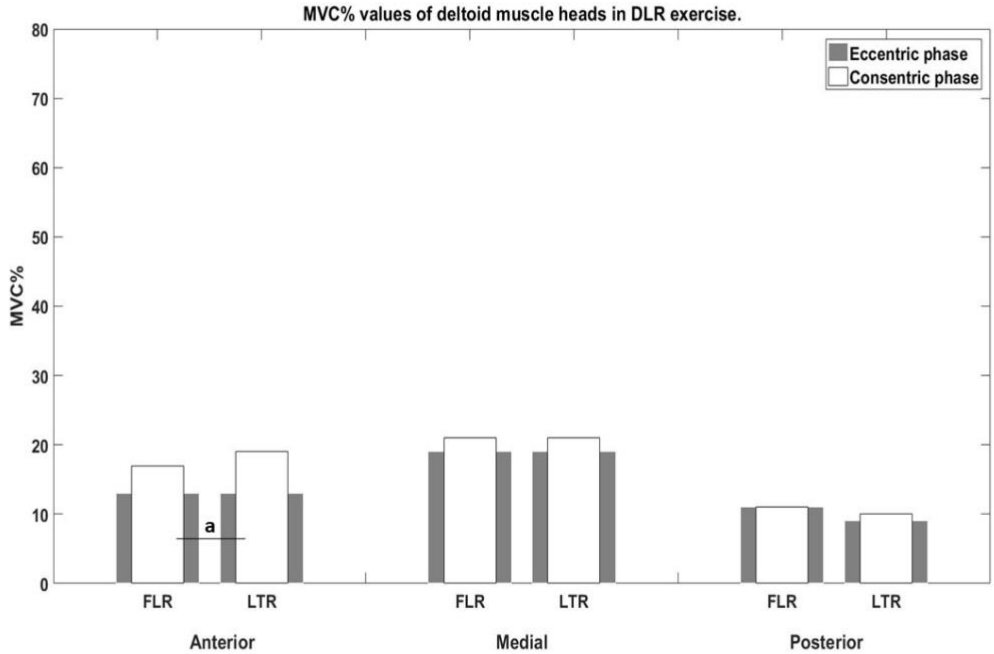
Figure 4. MVC% values of anterior, medial and posterior heads of deltoid in DFR exercise.



a: Significant difference between Anterior Dfr Hg Con, Dfr Pg Con and b: Posterior Dfr Pg Ecc, Dfr Sg Ecc p<0.05.

Muscle responses from each head of the deltoid muscle in the DFR exercise were compared for different grip variations. It was observed that the highest muscle activation occurred in the anterior head in the concentric phase with the PG (51.57%). When the anterior deltoid muscle responses compared related to the variations, it was observed that, difference between HG and PG con variations was statistically significant (HG con 43.36% PG con 51.57% p<0.05). However, no significant difference was observed between the HG, PG ecc (HG ecc 40.36%, PG ecc36.4%) and the SG variations (SG con 47.00%, SG ecc 41.51%, p>0.05). It was observed that the highest muscle activation in the medial deltoid occurred in the concentric phase with SG (29.63%). For medial deltoid, no significant difference was observed between the variations (HG con 21.11%, HG ecc 23.50%, PG Con 26.82%, PG ecc 24.19%, SG con 29.63%, SG ecc 24.37%, p>0.05). It was observed that the highest muscle activation in the posterior deltoid occurred in the eccentric phase for PG (37.50%). The difference between SG and PG ecc variations was statistically significant (SG ecc 19.65%, Pg ecc 37.40%, p<0.05). No significant difference was observed between the PG, SG con (SG con 22.59%, PG con 29.43%) and the HG variations (HG con 26.59% HG ecc 31.14% p>0.05) (Fig. 4).

Figure 5. MVC% values of anterior, medial and posterior heads of deltoid in DLR exercise.

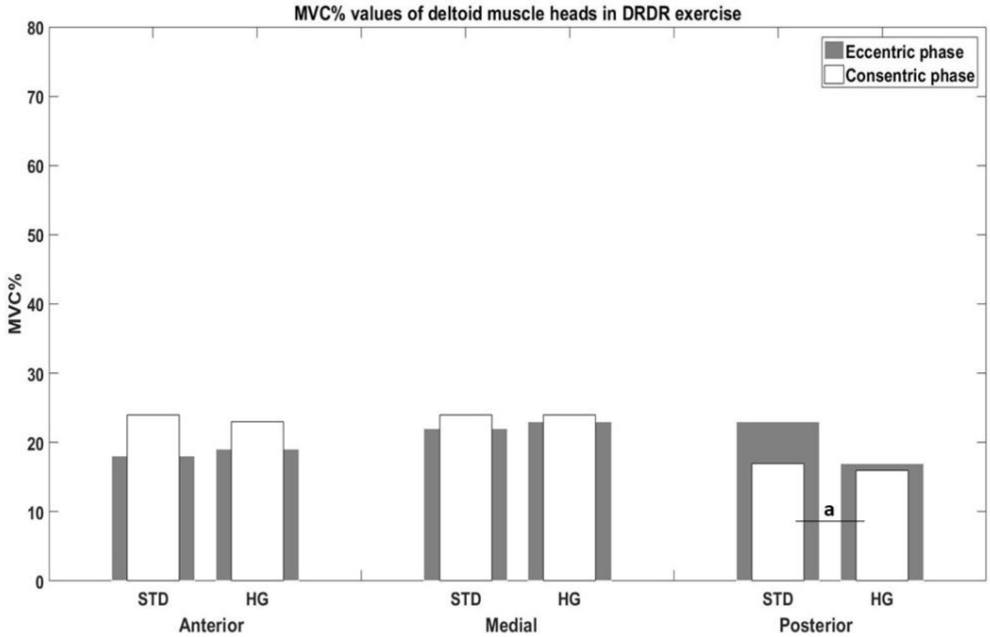


a: Significant difference between Anterior Dlr Flr Con and Dlr Ltr Con p<0.05.

Muscle responses from each deltoid heads in the DLR exercise were compared for different ROM variations. It was observed that the highest muscle activation occurred in the medial head in the concentric phase for the LTR (20.74%). When the anterior deltoid responses compared related to the variations, it was observed that, difference between FLR and LTR con variations was statistically significant (FLR con 16.88%, LTR con 19.37%, $p<0.05$). However, no significant difference was observed between the FLR and LTR ecc variations (FLR ecc 13.76%, LTR ecc 16.88%, $p>0.05$). It was observed that the highest muscle activation in the medial deltoid occurred in the concentric phase with LTR (20.74%).

For medial deltoid, no significant difference was observed between the variations (FLR con 20.60%, FLR ecc 18.99%, LTR con %20.74, LTR ecc 19.62%, $p>0.05$). It was observed that the highest muscle activation in the posterior deltoid occurred in the ecc phase with FLR (11.49%). However, no significant difference was observed between the FLR and LTR (FLR con 10.89% FLR ecc 11.49%, LTR con 10.41%, LTR ecc 9.20%) variations (Fig. 5).

Figure 6. MVC% values of the anterior, medial and posterior heads of the deltoid in DRDR exercise.



a: Significant difference between Posterior Drdr Std Ecc and Drdr Hg Ecc p<0.05.

Muscle responses from each deltoid heads in the DRDR exercise were compared different handgrip variations. It was observed that the highest muscle activation occurred in the medial head in the concentric phase with the HG (24.47%). It was observed that the highest muscle activation in the anterior deltoid occurred in the concentric phase with STD (24.10%). However, no significant difference was observed between the STD and HG (STD con 24.10%, STD ecc 17.95%, HG con 22.95%, HG ecc 19.39%) variations (p>0.05). It was observed that the highest muscle activation in the medial deltoid occurred in the concentric phase with HG (24.47%). For medial deltoid, no significant difference was observed between the variations (STD con 24.14%, STD ecc 21.55%, HG con %24.47, HG ecc 23.06%, p>0.05). When the posterior deltoid responses compared related to the variations, it was observed that, difference between STD and HG variations was statistically significant (STD con 17.27%, STD ecc 23.07, HG con 15.72%, HG ecc 17.30%, p<0.05) (Fig. 6).

DISCUSSION

In this study, the muscle activity levels of the deltoid muscle heads were measured for 3 exercises (DFR, DLR, DRDR) at the different handgrip and ROM variations. For the DFR exercise, the level of anterior head activation was higher than the medial and posterior heads. The activation level of anterior and posterior heads was higher for PG at the concentric and eccentric phases. For DLR exercise, the highest muscle activation was observed at the medial deltoid but only the concentric phase anterior deltoid activity level differentiated for LTR. DRDR exercise activation was higher for the anterior and medial heads than the posterior deltoid during HG. STD demonstrated more muscle activity at the posterior deltoid eccentric phase of DRDR exercise than HG.

To the authors' knowledge, this is the first study to investigate differences in muscle activity of the deltoid heads during the concentric and eccentric phases of different exercises with different handgrip and ROM variations. Knowing the muscle activity levels of different exercises on the three heads of the deltoid muscle can assist in choosing the most appropriate exercise for strengthening and rehabilitation. The results of the present study showed that different deltoid exercises demonstrated different activation levels for each head of the deltoid muscle. This finding is consistent with the results of previous studies that reported each head of the deltoid is activated differently per specific exercise (Botton et al., 2013; Coratella et al., 2020; Raizada & Bagchi, 2017). In particular, Coratella et al. (2020) reported similar results with the present study. They found that the muscle activity in the anterior deltoid was greater during the frontal raises concentric phase, and the medial deltoid was more active during the lateral raises. These results can be explained by the primary functions of the deltoid heads in different movements. For example, in horizontal shoulder flexion movements, the anterior deltoid is defined as the main agonist head (Brum et al., 2008). Shoulder abduction is the primary function of the medial deltoid (Kronberg et al., 1990; Reinold et al., 2004). In addition, the posterior deltoid is considered the prime mover during horizontal shoulder extension (Knudson, 2007).

Another main finding of the present study is that dumbbell grip variations in deltoid exercises cause different degrees of muscle activation on deltoid heads. Past studies on different body parts and with different exercises have revealed that muscle activation is affected by grip variations (Pratt et al., 2020; Signorile et al., 2002). One of the limited numbers of studies on the shoulder muscle group supporting the results of our study reported that different hand positions cause differences in posterior deltoid activation in the horizontal abduction movement exercise (reverse fly machine) (Schoenfeld et al., 2013). In the studies examining how grips and hand positions as a result of grips affect local muscle activation, it can be explained by length tension. For example, grips that require an internally rotated and horizontally addicted start position have the potential to stretch the posterior deltoid. Therefore, this situation may prevent the development of local strength in such exercises (Hung et al., 2010; Kolber & Hanney, 2010; Schoenfeld et al., 2013). It is thought that the grips versions of the exercises used in this study and performed in different planes affect muscle activation because they cause length tension in different parts of the deltoid.

In our study, two different ROMs (Limited, Full) were used in the lateral raise exercise. No research has been found in the literature examining deltoid activation in the lateral raise exercise performed in different ROMs. The present results showed that only LTR caused higher activation in the concentric phase of anterior deltoid muscle activation. Contrary to our results, Paoli et al. (2010) stated that the wider the ROM in the military press exercise, which is an overhead exercise, the higher the activation in the deltoid sections. However, we do not find it appropriate to compare the results because the type of exercise used in this study and the exercise used in our study are biomechanically different. Especially due to the different starting positions and directions of the exercises, the muscle activation of the deltoid heads may also differ. Some limitations are present in this study and should be considered prior to exercise applications. In this study, the effects of grips and ROM variables only on the deltoid muscle were examined and exercises for this muscle area were selected. Participants were well-trained athletes with at least 5 years of resistance training history. Therefore, the variables selected in the study may show different muscle activations in inexperienced and recreational athletes.

CONCLUSION

In conclusion, for the heads of the deltoid muscle, the use of the different grip and ROM variations may increase or decrease the neuromuscular activity. Especially HG for anterior deltoid in dumbbell front raise, LTR for anterior deltoid in lateral raise, and STD for posterior deltoid in dumbbell rear delt raise exercise are the grip and ROM variations that increase muscle activation. The results of this research may be effective for competitive athletes rather than recreational athletes. Especially for experienced fitness and bodybuilding athletes, using hand grips and ROM that provide more muscle activation in the development of hypertrophy for specific body regions can achieve their goals. It can also assist trainers who aim for optimum load and impact in their training in choosing the most appropriate hand grip and ROM.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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