



Muscle Activity in Upper-Body Single-Joint Resistance Exercises with Elastic Resistance Bands vs. Free Weights

by

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Elastic resistance bands require little space, are light and portable, but their efficacy has not yet been established for several resistance exercises. The main objective of this study was to compare the muscle activation levels induced by elastic resistance bands versus conventional resistance training equipment (dumbbells) in the upper-body resistance exercises flyes and reverse flyes. The level of muscle activation was measured with surface electromyography in 29 men and women in a cross-over design where resistance loadings with elastic resistance bands and dumbbells were matched using 10-repetition maximum loadings. Elastic resistance bands induced slightly lower muscle activity in the muscles most people aim to activate during flyes and reverse flyes, namely pectoralis major and deltoideus posterior, respectively. However, elastic resistance bands increased the muscle activation level substantially in perceived ancillary muscles, that is deltoideus anterior in flyes, and deltoideus medius and trapezius descendens in reverse flyes, possibly due to elastic bands being a more unstable resistance modality. Overall, the results show that elastic resistance bands can be considered a feasible alternative to dumbbells in flyes and reverse flyes.

Key words: electromyography, resistance training, pectoralis muscles, deltoid muscle.

Introduction

Regular resistance training provides several health benefits (Chodzko-Zajko et al., 2009; Kristensen and Franklyn-Miller, 2012; Williams et al., 2007). However, limitations associated with conventional resistance training equipment might restrain therapists, patients and the general population from using this form of exercise. Barbells, dumbbells, weight-plates and resistance training machines are heavy, stationary and require space. Moreover, many people do not have the interest or opportunity to exercise at a fitness center.

An alternative way of performing resistance training is by using elastic bands, which require little space and are light and portable. When barbells, dumbbells or conventional training machines are used, external resistance does not change during the range of motion, while elastic resistance provided by elastic bands

will increase with elongation of the band (Patterson et al., 2001).

Several studies have used surface electromyography (EMG) to compare muscle activation in resistance exercises using both elastic and conventional resistance. Some of these suggest that when relative resistance is matched – the same percentage of one-repetition maximum – similar levels of muscle activation can be achieved for the prime movers (Aboodarda et al., 2011; Andersen et al., 2010; Brandt et al., 2013; Calatayud et al., 2014; Jakobsen et al., 2012; Jakobsen et al., 2014), whereas others have found conventional resistance to be the favorable modality (Sundstrup et al., 2014; Vinstrup et al., 2015; Vinstrup et al., 2015).

The muscular activation patterns have been found to differ between elastic bands and conventional resistance training exercises, with

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higher muscle activity for conventional and elastic resistance in different phases of the contraction. Generally, muscle activity induced by conventional equipment is higher than from elastic resistance early in the concentric phase of the contraction, while towards the end – when the band is elongated - muscle activity levels are more similar. However, this is affected by the “sticking point” of the exercise in question. The sticking point is commonly known as the point in the range-of-motion (ROM) where one experiences a disproportionately large increase in the difficulty to complete the movement (van den Tillaar and Ettema, 2009), and is the performance bottleneck in a resistance exercise (Kompf and Arandjelovic, 2016). In movements where the sticking point occurs in the early phase of the concentric ROM with conventional resistance one might assume that the sticking point occurs later in the movement phase with elastic bands, due to the gradually increasing external resistance, but to our knowledge this has not been experimentally verified.

This study compares the single-joint flyes and reverse flyes exercises using dumbbells versus elastic bands. The fly primarily targets muscles in the chest, while reverse flyes primarily targets the posterior shoulder muscles. Furthermore, the fly is an exercise where the sticking point is early in the concentric phase with dumbbells, due to the high leverage created by the arms in this position. For reverse flyes the sticking point will occur towards the end of the concentric ROM for both dumbbells and the elastic band, as the leverage will be highest here. Thus, we hypothesized that overall EMG levels would be comparable between the modalities, yet higher EMG levels would be induced by elastic bands than dumbbells in the late concentric and early eccentric phase in flyes, but not in reverse flyes where we expected similar activation for dumbbells and elastic bands throughout the movement.

Methods

Participants

Twenty-nine healthy subjects including 17 men (age 26 ± 3 years, body height 180 ± 7 cm, body mass 75.6 ± 11.2 kg) and 12 women (age 25 ± 2 years, body height 168 ± 7 cm, body mass 60.2 ± 7.4 kg) were enrolled in the study. Ten of the

participants reported to have previous experience with structured strength training. The study conformed to the Declaration of Helsinki and the study protocol was approved by the Regional Committee for Medical and Health Research Ethics in central Norway (project no: 2014/1157). All subjects signed informed consent before participating in the study.

Measures

10-RM

All participants attended two familiarization and strength assessment sessions. In these sessions, they performed a 10-RM test protocol, where we identified the load the participants were able to perform 10 repetitions with but not more, in order to match the load from the elastic bands with that of the dumbbells for subsequent muscle activation comparisons.

EMG

EMG signals were sampled using self-adhesive, gel-coated electrodes with a centre-to-centre distance of 25 mm (Blue Sensor, M-00-S, Ambu A/S, Ballerup, Denmark). Before electrode placement, the skin was abraded and washed with alcohol. Electrodes were placed on the participant's dominant side, and placement followed Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM) recommendations (<http://www.seniam.org>). For the pectoralis major, the electrodes were placed ~4 cm medial to the axillary fold (Schick et al., 2010), and for the latissimus dorsi, the electrodes were placed ~1 cm lateral to the inferior border of the scapula (Lehman et al., 2004). The EMG signal was recorded through shielded wires to the EMG system (MuscleLab 4020e, Ergotest Technology AS, Langesund, Norway). A pre-amplifier near the recording site was used to minimize external noise, with a common mode rejection ratio of 100 dB. The signal was filtered using a fourth-order Butterworth band-pass filter with a bandwidth of 8-600 Hz. A hardware circuit network was used to convert the filtered EMG signals, with a frequency response of 0-600 kHz, averaging constant of 100 ms, and total error of $\pm 0.5\%$. The root-mean-square (RMS) signal was then sampled at 100 Hz with a 16-bit A/D converter (AD637).

EMG was recorded during the exercises and maximal voluntary isometric contractions for the following muscles: biceps brachii, deltoideus anterior, deltoideus medius, deltoideus posterior,

trapezius descendens, latissimus dorsi, and pectoralis major. The procedure for maximal voluntary contraction testing was standardized, and two tests were performed for each muscle. Participants were instructed to gradually increase force to a maximal level within 2-3 s and exert maximal force until told to stop. Each test lasted 5 s. Standardized strong verbal encouragement was given to all participants. A second maximal voluntary contraction was performed 1 min after ending the first one, and the test with the highest recorded EMG signal for each muscle was used for normalization of the EMG signals during the exercises.

To measure EMG in the different phases of contraction, a linear encoder was used and synchronized with the EMG signals (sampling frequency of 100 Hz, resolution of 0.075 mm; ET-Enc-02, Ergotest Technology AS, Langesund, Norway). The linear encoder was placed on the floor during flyes and reverse flyes when performed with free-weight resistance. During flyes and reverse flyes performed with elastic resistance, the linear encoder was attached to the wall close to the attachment point of the elastic band.

Commercial software was used for analyzing the RMS EMG and position signals (MuscleLab v8.13, Ergotest Technology AS, Langesund, Norway). The start and the end of each contraction was identified from the position data. The range of motion of 10-90% in the concentric and eccentric phases was used in EMG analysis. This time window was then split in two equal phases constituting the first and the second half of the concentric (denoted as CON1 and CON2) and eccentric (denoted as ECC1 and ECC2) phase of a contraction. Mean RMS EMG values in these time windows were calculated and averaged from two contractions in each series of three. For the concentric phase, the last two contractions were used, while for the eccentric phase the first two contractions were considered. The reason for such proceeding was that the start/stop point was difficult to identify in the concentric and eccentric phase of the first and last repetition, respectively. The mean RMS EMG obtained during CON1, ECC1, CON2, and ECC2 was then normalized to the maximal EMG signal obtained during the maximal voluntary contraction tests for all muscles, yielding

%EMGmax.

Rating of perceived exertion

Before testing, the participants were explained how to use the Borg CR10 scale (Saeterbakken and Fimland, 2013). Immediately after performing 10-RM, the participants were asked to rate their perceived exertion. It had previously been demonstrated that a moderate to strong relation existed between ratings on the Borg CR10, actual loading, and muscle activity levels from elastic bands and dumbbells (Andersen et al., 2010).

Procedures

All participants attended four sessions in total. The 10-RM protocol was performed in session one and two, using elastic bands on one day and dumbbells the other day. The participants were instructed to abstain from strength exercise for at least three consecutive days before the 10-RM tests. Prior to the 10-RM test, a demonstration of correct execution was given, and the participants practiced the technique until it could be performed properly. Subsequently, the load was gradually increased. Before making larger increments, at least two sets at relatively low resistance had to be performed. To avoid muscle fatigue, participants were encouraged to stop if the load felt easy enough to perform more than 10 repetitions. With elastic resistance, the load was manipulated by changing and/or increasing the number of bands and/or by changing the distance between the participant and the anchor point. The combination of bands and distance was recorded for all participants so that the load could be replicated for the EMG and motion sampling. As the manufacturer recommended, the elastic bands were pre-stretched and never stretched to >300% of resting length.

In sessions three and four, the participants performed maximum voluntary contractions, before proceeding with EMG measurements during exercise. As a warm-up, they performed a set of 10 repetitions at 50% of the 10-RM load. A linear encoder was attached to the participants' dominant hand, and the metronome was set to 60 beats per minute. Participants then performed three repetitions with the 10-RM load, using 2 s each on the concentric and eccentric phase. Flyes were tested before reverse flyes, and exercises with dumbbells were performed before the ones

with elastic bands. When performing flyes and reverse flyes with dumbbells, the participant lay on a bench (Impulse Sterling FID bench, Impulse Fitness, Newbridge, Midlothian, Scotland). The dumbbells used were rubber coated iron dumbbells ranging from 1 to 25 kg, with intervals of 1 kg from 1 to 10 kg, and of 2.5 kg from 10 to 25 kg. TheraBand® elastic bands and TheraBand® exercise handles were used as elastic resistance (Hygenic Corporation, Akron, OH, USA). Levels of resistance used were indicated by different colours i.e. yellow, red, green, blue, black, silver and gold, which at 200% elongation corresponded to 2, 2.5, 3, 3.9, 4.6, 6.9 and 9.5 kg, respectively. A metronome application on a smartphone was used to standardize the lifting time.

In flyes, the participant lay on the bench in a supine position, holding one dumbbell in each hand with arms erect in a straight vertical line towards the ceiling. The participants were instructed to keep their elbows slightly bent throughout the movement. When starting, the dumbbells were lowered in an arc to the sides and the movement stopped when the upper arms were parallel to the floor. The dumbbells were then returned to the starting position.

Elastic bands were attached to a wall-bar at shoulder height. Handles were connected to each end of the band, and the participant started the exercise facing away from the wall-bar, in a position where the arms were kept extended in a forward horizontal line, while leaning the upper body slightly forward for balance. The non-dominant foot was placed in front of the other for support. With slightly bent elbows, the arms were then moved out in an arc to the sides until the upper arms formed a straight line through the torso. The movement was completed by pressing the handles toward each other.

For reverse flyes, the participant lay on the bench in a prone position, with one dumbbell in each hand, keeping the arms erect in a straight vertical line towards the floor. The participants were instructed to keep their elbows slightly bent throughout the movement. The movement started by lifting the dumbbells in an arc out to the sides, returning them when the upper arms were elevated to a position parallel to the floor.

Elastic bands were attached to a wall-bar at shoulder height. Handles were connected to each end of the band, and the participant started

the exercise while facing the wall-bar with arms in a forward horizontal line, parallel to the floor. The handles were then pulled in an arc out to the sides until the upper arms formed a straight line through the torso. The handles were then returned to the starting position. Elbows were slightly bent throughout the movement.

Statistical analyses

Statistical analyses were performed using SPSS for Windows (v. 21.0). A two-way (2x4) repeated measures analysis of variance (ANOVA) was used to assess the effect of the exercise modality (elastic band vs. dumbbells) and interaction with the contraction phase (CON1, CON2, ECC1, and ECC2) on muscle activity. Significant interaction effects were investigated within the concentric and eccentric phases, i.e., between CON1 and CON2, and ECC1 and ECC2, respectively. When significant main effects or interactions were detected ($p < 0.05$), post-hoc tests were performed within each contraction phase to assess differences in muscle activity between dumbbells and elastic bands. For post hoc tests, p -values lower than 0.01 were considered significant, and p -values up to 0.05 were considered trends toward significance to account for multiple testing. The dependent variable was %EMGmax. For the rating of perceived loading on the Borg CR10 scale, a paired samples t-test was used and a p -value of 0.05 was considered significant. The data was checked for normality with a Shapiro-Wilk test. A log transformation was performed on all EMG variables.

Results

For flyes, there were significant main effects of the exercise modality on muscle activity levels for all muscles ($p \leq 0.026$ for all comparisons) and also significant interactions between muscle activity and the exercise modality in both the concentric and eccentric phases ($p \leq 0.001$ for all comparisons). For the pectoralis major, muscle activity was highest when using dumbbells, whereas for the deltoideus anterior, biceps brachii and latissimus dorsi, elastic bands induced the highest levels of muscle activity. Figure 3 shows results of post hoc comparisons for muscle activity in the different contraction phases of flyes with elastic bands versus dumbbells.

For reverse flyes, there were significant

main effects of the exercise modality on muscle activity levels for all muscles ($p \leq 0.001$ for all comparisons). Significant interactions were found for the deltoideus medius and trapezius descendens in both the concentric and eccentric phase ($p \leq 0.011$ for both comparisons). Higher muscle activity was observed when using elastic resistance compared to free-weight resistance for the trapezius and deltoideus medius. In contrast, the deltoideus posterior and latissimus dorsi displayed higher muscle activity when using free-

weight resistance. Figure 4 shows results of post hoc comparisons for muscle activity in the different contraction phases of reverse flyes with elastic bands versus dumbbells.

Table 1 shows the perceived exertion rated on the Borg CR10 scale after performing the 10-RM tests with elastic bands and dumbbells. Elastic bands were rated heavier compared to dumbbells for both flyes and reverse flyes; yet statistical significance was only reached for reverse flyes.

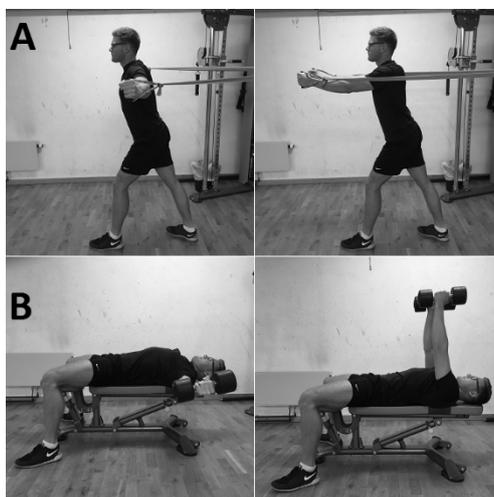


Figure 1

Start- and end position of flyes with elastic bands (A) and dumbbells (B)

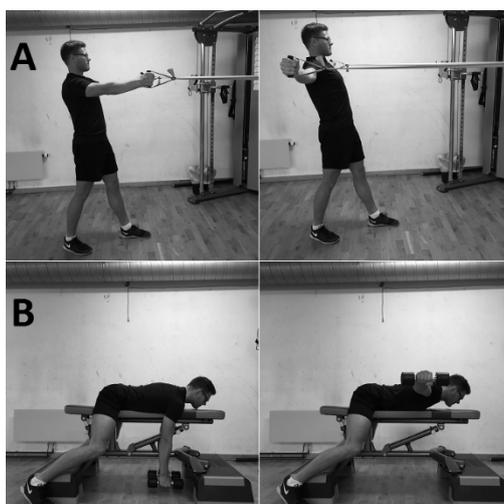
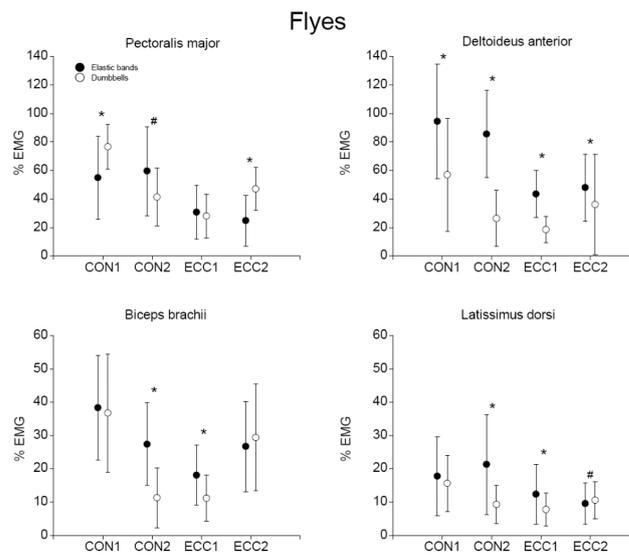
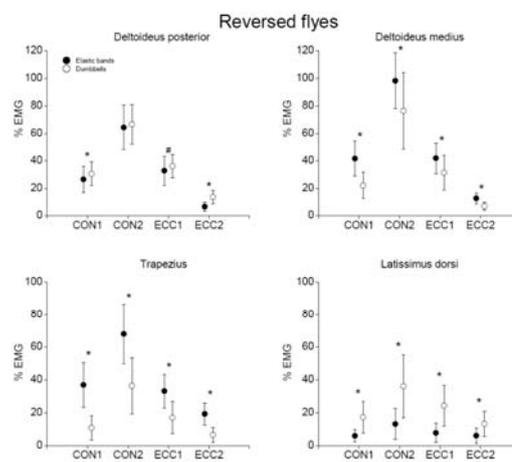


Figure 2

Start- and end position of reversed flyes with elastic bands (A) and dumbbells (B).

**Figure 3**

EMG data for flies with elastic bands and dumbbells in the first and second half of the concentric (CON1 and CON2) and eccentric (ECC1 and ECC2) phases for the pectoralis major (A), deltoideus anterior (B), biceps brachii (C) and latissimus dorsi (D). Means and standard deviations. * $p \leq 0.01$; # $p \leq 0.05$

**Figure 4**

EMG data for reverse flies with elastic bands and dumbbells in the first and second half of the concentric (CON1 and CON2) and eccentric phases (ECC1 and ECC2) for the deltoideus posterior (A), trapezius descendens (B), deltoideus medius (C), and latissimus dorsi (D). Means and standard deviations. * $p \leq 0.01$; # $p \leq 0.05$

Table 1
Perceived exertion rated on the Borg CR10 scale after performing the 10-RM tests with elastic and free-weight resistance. Values are mean (SD).

Exercises	Elastic	Free-weight	<i>p</i> -value
Flyes	8.2 (1.2)	7.8 (1.3)	0.073
Reversed flyes	7.9 (1.4)	7.1 (1.9)	0.040

Discussion

The main objective of this study was to assess differences in muscle activity levels induced by elastic bands and dumbbells in flyes and reverse flyes. In flyes, elastic bands generally induced lower levels of muscle activation for the pectoralis major than dumbbells, but higher for the deltoideus anterior. In reverse flyes, elastic bands generally induced lower levels of muscle activation for the deltoideus posterior, but higher for the deltoideus medius and trapezius descendens.

Flyes are primarily used to target chest muscles. Overall, dumbbells were slightly more effective for this muscle group. However, the results showed that elastic bands activated the deltoideus anterior substantially more, and that flyes, performed with elastic bands in particular, could be effectively used to train the deltoideus anterior as well.

Partly in accordance with our expectation that higher EMG levels would be induced during exercises with elastic bands than dumbbells in the end ranges in flyes, muscle activity for the pectoralis major in flyes was lower with elastic bands in CON1 and ECC2, but higher in CON2, and similar in ECC1. This may be explained by the very high leverage provided by dumbbells in the beginning of the concentric phase. When the sticking point is passed, a pronounced decline in muscle activity is seen for dumbbells. In contrast, muscle activity induced during exercises with elastic bands increases from the beginning towards the end of the range of motion, mirroring the increasing external resistance caused by elongation of the band. In ECC1 there was no difference between the modalities, whereas when the dumbbells were lowered out to the sides in

ECC2, the dumbbells again induced a higher pectoralis major activation level.

Reverse flyes are primarily utilized for deltoideus posterior training. Overall, dumbbells were slightly more effective in activating this muscle, more or less in all phases of the contraction. However, the activation level of the deltoideus medius and trapezius descendens during exercises with elastic bands was substantially higher than with dumbbells, and reverse flyes with elastic bands appear to be a very effective exercise for these muscles. As expected, when the sticking point occurred at the end of the concentric range of motion for both elastic bands and dumbbells, we did not observe the differential development in reverse flyes for the deltoideus posterior that we observed in flyes for the pectoralis major, in which the sticking point was in the early concentric phase (Figure 3A and 4A).

A similar pattern was observed from both single-joint exercises in the sense that elastic bands were slightly less effective in activating the muscles usually perceived to be the prime movers (i.e. pectoralis major for flyes and deltoideus posterior for reverse flyes). However, elastic bands induced substantially higher activation levels in muscles perceived to be ancillary. It could be that performing these exercises with elastic bands instead of dumbbells made them more unstable. Increased stability requirement could possibly elicit higher neural drive to stabilize the shoulder joint, which had been suggested previously for dumbbells versus the barbell chest press (Saeterbakken et al., 2011). However, it is also possible that the different postures contributed to these effects, as participants were lying on a bench when the

exercises with dumbbells were performed, but standing during execution with elastic bands, which is another way of inducing higher instability and to increase muscle activation of the deltoideus anterior (Saeterbakken and Fimland, 2013)

The increased stability requirement possibly induced by a standing posture, involving more stabilizing muscles, could also explain why higher ratings of perceived effort on the Borg CR10 scale were reported for elastic bands compared to dumbbells. Partly in agreement with our finding, Jakobsen and coworkers found a higher rating of perceived effort when performing knee flexions with elastic bands versus a conventional training machine (Jakobsen et al., 2014).

A limitation of this study is the use of EMG to measure dynamic contractions. The interpretation of the EMG signal during movement can be complicated by issues such as signal nonstationarity, the relative shift of the electrodes, and fluctuations in conductivity properties of the skin (Farina, 2006). Importantly, the EMG measurements were performed in the same session, thus there was no need to replace electrodes. Furthermore, we measured EMG on one side of the body only. In our study, we used an 8-channel EMG system, so measuring on one side only allowed us to measure more muscles at

the same time. The decision to measure the dominant vs. non-dominant side was arbitrary. However, we do not expect that the activation patterns would be different on the non-dominant side.

Another limitation is the 10-RM protocol used for matching the loads between the modalities. It is challenging to find the true 10-RM, particularly with elastic bands. However, the test leader was experienced in resistance training, ensuring that 10-RM could be identified within 5 attempts and we are unaware of a better procedure to match relative resistance. Furthermore, to fine-tune resistance with elastic bands, it was necessary to change the distance between the participant and the anchor point individually. Hence, we are unable to report a standardized pre-stretch of the elastic bands for each exercise.

In conclusion, elastic resistance bands induced slightly lower muscle activity in the muscles most people aim to activate during flyes and reverse flyes, i.e., pectoralis major and deltoideus posterior, respectively. However, elastic resistance bands increased the muscle activation level substantially in the deltoideus anterior in flyes, and deltoideus medius and trapezius descendens in reverse flyes, possibly due to elastic bands being a more unstable resistance modality.

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