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Drop set versus traditional strength training protocols equated in volume on muscle thickness in women

Drop set versus protocolos de entrenamiento de fuerza tradicionales de igual volumen en el grosor muscular en mujeres

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Abstract. Purpose: The aim of this study was to investigate the effects of two strength training protocols, equated in volume, on the elbow flexor muscle thickness (MT) in women. Methods: Twenty-seven women (mean±sd, age 21.89±2.85 years; stature,167.82±5.90 cm; body mass 63.01±7.20 kg; estimate of body fat mass, 19.19±2.88%) were divided in three experimental groups: a drop-set (DS), a traditional (TR), and a control group (CG). The CG maintained regular strength training without perform any upper body exercises. The DS group performed a dumbbell biceps curl for two days/week, 12 weeks, 4 sets of 3 blocks of 10 repetitions at 75%, 55%, and 35% of their 1 Repetition Maximum (RM), and 8 sets of 11 repetitions at 75% of the 1RM for the TR protocol. Rest interval between sets was 120 seconds. The MT was acquired in the anterior face of both upper arms at 50% and 60% of the distance between the lateral epicondyle of the humerus and the acromial process of the scapula before (T0) and after the 24 training sessions (T1). Results: There was a significant increase in all MT measurements between T0 and T1for the training groups($p<0.05$). In addition, significantly higher values of MT were found in the training groups compared to the control group for all local measurements in T1 ($p<0.05$). No significant differences were found between training the groups for MT. Conclusion: It appears that both training groups (DS and TR), were effective in promoting MT of the elbow flexors muscles of young women with no differences between training strategies.

Keywords: Hypertrophy, Ultrasonography, Training method, Female

Resumen. Objetivo: el objetivo de este estudio fue investigar los efectos de dos protocolos de entrenamiento de fuerza, equiparados en volumen, sobre el grosor del músculo flexor (MT) del codo en mujeres. Métodos: Veintisiete mujeres (media ± DE, edad 21,89 ± 2,85 años; estatura, 167,82 ± 5,90 cm; masa corporal 63,01 ± 7,20 kg; estimación de la masa grasa corporal, 19,19 ± 2,88 %) se dividieron en tres grupos experimentales: a drop-set (DS), un tradicional (TR) y un grupo de control (CG). El GC mantuvo un entrenamiento de fuerza regular sin realizar ningún ejercicio de la parte superior del cuerpo. El grupo DS realizó un curl de bíceps con mancuernas durante dos días a la semana, 12 semanas, 4 series de 3 bloques de 10 repeticiones al 75 %, 55 % y 35 % de su 1 Repetición Máxima (RM), y 8 series de 11 repeticiones al 75% del 1RM para el protocolo TR. El intervalo de descanso entre series fue de 120 segundos. El MT se adquirió en la cara anterior de ambos brazos al 50% y 60% de la distancia entre el epicóndilo lateral del húmero y el proceso acromial de la escápula antes (T0) y después de las 24 sesiones de entrenamiento (T1). Resultados: Fue verificado un aumento significativo en todas las mediciones de MT entre T0 y T1 para los grupos de entrenamiento ($p<0,05$). Además, se encontraron valores significativamente más altos de MT en los grupos de entrenamiento en comparación con el grupo control para todas las mediciones locales en T1 ($p<0,05$). No se encontraron diferencias significativas entre los grupos de entrenamiento para MT. Conclusión: parece que ambos grupos de entrenamiento (DS y TR) fueron efectivos para promover la MT de los músculos flexores del codo de mujeres jóvenes sin diferencias entre las estrategias de entrenamiento.

Palabras clave: Hipertrofia, Ultrasonografía, Método de entrenamiento, Mujer

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Introduction

Is clear that strength training (ST) is an excellent training approach that can increase skeletal muscle size and strength including in women (Hagstrom et al., 2020; Fernández & Hoyos, 2020;Vila Suarez et al., 2023; Marcos-Pardo et al., 2024). Hence, coaches and practitioners use several strategies to prevent the stagnation of gains in muscle mass with the manipulation of several ST variables including selection and order of exercises, manipulation of load and repetitions, rest interval between sets and exercise, and the time under tension (Angleri et al., 2017, 2020; Charro et al., 2010; Fleck & Kraemer, 2014; Ribeiro et al., 2016; Schoenfeld, 2011). The manipulation of the ST variables to improve muscle mass led to the design of a set of various techniques such as drop-sets, cluster sets, crescent and inverse pyramid, and German volume training (Fleck & Kraemer, 2014; B. Schoenfeld, 2011). However, the superiority of these techniques in relation to the traditional ST (TST) is not well established (Grgic et al., 2022).

Typically, the TST technique uses the multisets system, performing multiple sets with the same load (Fleck & Kraemer, 2014). In turn, the Drop-sets (DS) technique (also known as descending sets or breakdown sets) consists of performing a set of one exercise, and consequently in the same set, decrease (drops) the load (e.g., 20%) performing more repetitions without or with very little, interval rest between drops (Angleri et al., 2017; Fink et al., 2018; Fleck & Kraemer, 2014; Bentes et al., 2012). Both of these techniques are very popular with ST practitioners, especially the DS for the more experienced. Techniques like drop sets, for example, can be justified by a physiological principle known as the Henneman size principle. This principle establishes that motor units (MUs) follow a recruitment order, where lower-threshold MUs, typically composed of type I fibers, are recruited before higher-threshold MUs, which mainly innervate type II fibers, fibers with greater hypertrophic capacity (Henneman et al., 1965, 1974). Therefore, methods aiming to increase muscular fatigue would have a greater potential for MU recruitment, causing lower-threshold MUs to fatigue and higher-threshold MUs to be recruited in order to maintain force levels and complete the task, such as exercise execution (Fisher et al., 2011; Grgic et al., 2022).

Moreover, the mechanical stimulus and the consequent metabolic stress of the predominantly anaerobic lactic metabolism (MALS) is assumed as essential to promote muscle hypertrophy (Schoenfeld et al., 2017). The DS technique idealizes an underlying fatigue mechanism and is effective in promoting mechanical stimulus and MALS because of the necessity to perform the set to the momentary muscular failure, causing a higher MALS (Goto et al., 2016; Schoenfeld, 2011), more activation of high-threshold motor units (Goto et al., 2016), higher muscular hypoxia (Goto et al., 2016), and a higher blood concentration of grow hormone. However, little is known about the efficiency of DS on improving muscle thickness in women, which suggests the need for further research. Thereby the purpose of the present study was to compare the influence of including the DS or TST protocols, equated in volume, on muscle thickness (MT) of the elbow flexors muscles in women.

Materials and Methods

Design

To evaluate the effects of two strength training (ST) protocols, matched for volume, on the muscle thickness of elbow flexors in women, twenty-seven participants were randomly allocated into three experimental conditions: DS, TST, and a control group (CG). The randomization was performed using Excel 365 software, generating a list of numbers using the "RAND" function for simple data randomization. The DS and TST performed the biceps curl exercise seated in the Scott bench with dumbbells (BCSD), with a weekly frequency of two days for 12 weeks. Conversely, the CG maintained their daily activities for the same period.

Participants

Twenty-seven active young women, with a maximum of 3 months of strength training experience and thus considered beginners, were divided into a DS (n=9), TST (n=9), and CG (n=9) groups. The DS and TST experimental groups performed their respective training protocols and the CG maintained regular training without upper body exercises. The anthropometric measurements, age, and percentage of estimated body fat are displayed in Table 1. Each subject had been strength training for the previous three months. All participants filled a medical history questionnaire and it was checked whether participants had any orthopaedic, endocrine, or other medical problems. In addition, it was examined whether they used any medications or dietary supplements that might influence the results of this investigation. After being briefed on the possible risks and benefits of participating in this investigation, all participants provided written informed consent. The procedures were designed according to the recommendations of the World Medical Association's Declaration of Helsinki of 1975, as revised in 2013, for human studies and were approved by the Research Ethics Committee of the Institution (Doc46-CE-UTAD-2020).

Table 1.
Mean and SDs of age, stature, body mass, and estimated body fat of the participants

Variables	Drop-Set n=9	Traditional n=9	Control n=9
Age (years)	21.33±2.78	21.89±3.06	22.44±2.70
Stature (cm)	168.61±4.66	164.67±6.39	170.17±6.65
Body mass (kg)	63.28±3.44	60.27±6.12	65.49±12.03
Estimate body fat mass (%)	19.19±2.32	18.30±2.92	20.07±3.40

Strength Training Protocols

The experimental strength training protocols used only the BCSD exercise (1HP215, Pannatta, Apiro, Italy). The DS consisted of four sets of 3 blocks of 10 repetitions at 75%, 55%, and 35% of 1RM, respectively. The TST consisted of 8 sets of 11 repetitions at 75% of 1RM. The adjustment in the number of sets for TST allows for the equalization of total volume between the protocols. Both protocols used 120 seconds of rest between sets. The exercise load was increased by 5% every two weeks in both protocols, always maintaining the total volume equalized. All routines were directly supervised by an experienced strength training professional and the research team.

Measurements

Repetition Maximum testing. The 1RM testing protocol has been described previously by (Kraemer & Fry, 1995). The 1RM of the BCSD exercise was measured in two sessions separated by 72 hours. Standardized instructions concerning the testing procedures and exercise technique were given to minimize error during the 1RM tests, and verbal encouragement during the testing procedure was provided. The 1RM was determined in less than five attempts with a rest interval of five minutes between attempts. The heaviest load lifted in the two sessions was considered the 1RM load and intraclass correlation coefficient of the 1RM testing was r=0.92.

Volume load. Volume load was calculated as relative load × reps × sets for the BCSD exercise.

Muscle Thickness. Ultrasound imaging (US) was used to obtain measurements of MT. The same trained technician performed all testing using a portable US SonoScape A6 portable B&W (Shanghai, China) with an electronic linear transducer of 7.5 MHz (Linear L745 Sonoscope) wave frequency, used for a transverse scan. The linear transducer was placed perpendicular to the tissue interface without depressing the skin. The equipment settings for image quality were optimized and maintain between testing sessions. The technician saved the US image and obtained the MT dimensions by measuring the distance from the bone to the adipose tissue of the elbow flexors (Biceps Brachii; Brachialis) of left and right upper arms at 50% (L50 and R50, respectively) and 60% (L60 and R60, respectively) distal between the lateral epicondyle of the humerus and acromion process of the scapula as define by Abe et al. (1). For each measurement, the examined limb was secured to minimize movements. MT was measured before the 1st session of intervention (T0) and after the 24 sessions, consecutively for 24 hours intervals, until there was no decrease in MT (T1). In T1, the lowest value measured was registered for analyzing.

Statistical Analysis

An exploratory analysis was performed to characterize the values of the different variables in central tendency and dispersion. The Intraclass Correlation Coefficient was used to test the reliability of the 1RM measurement. All parameters were normally distributed (Shapiro–Wilk test), variances were homogeneous (Levene test), and sphericity was tested using the Mauchly test. ANCOVA for repeated measures was used with the model: 3 groups (DS, TST, and CG) × 2 times (T0 and T1), with the T0 values has covariable, to analyze differences in MT before and after the 12-week intervention protocol. The significance analysis between sessions and moments was carried out using the Bonferroni adjustment posthoc. T-test for paired samples was used for analyzing the differences between T0 and T1 within-group. Effect size (ES) was calculated using partial eta squared (ηp2) and small, medium, and large ES would be reflected for ηp2 in values greater than 0.0099, 0.0588, and 0.1379, respectively (Cohen, 1988). Statistical analyses were conducted using IBM SPSS Statistics for Macintosh, (Version 22.0. Armonk, NY, USA), for. The level of significance was maintained at $p < 0.05$.

Results

At T0, it was observed significant higher values of MT in the CG in relation to TST in the R50 (p=0.03), R60 (p=0.03) and L60 (p=0.03). The elbow flexors' MT showed: i) at R50 a significant group-time interaction ($F_{(2,23)}$=11.573; p<0.00; η_p^2=0.502), a main time effect ($F_{(1,23)}$=5.229; p=0.03; η_p^2=0.185) and a main group effect ($F_{(1,23)}$=5.229; p=0.032; η_p^2=0.185). It was observed a significant increment between T0 and T1 in the DS (p<0.00, CI95% [4.29, -8.86]) and TST (p=0.00, CI95%[3.10, 9.43]). No significant changes were observed in the CG. In the T1 the CG presented fewer values in relation to DS and TST (p<0.00, CI95%[-5.7, -1.90] and p=0.00, CI95%[-4.82, -1.47]), DS and TST, respectively); ii) at R60 a significant group-time interaction ($F_{(2,23)}$=11.934; p<0.00 η_p^2=0.509), a main time effect ($F_{(1,23)}$=10.239; p=0.00; η_p^2=0308) and a main group effect ($F_{(1,23)}$=11.934; p<0.00; ηp^2=0.509). It was observed a significant increment between T0 and T1 in the DS (p=0.00, CI95%[2.38, 8.08]) and TST (p=0.00, CI95%[4.22, 10.69]). Contrarily in the CG it was observed a significant decrease (p<0.01, CI95%[-2.32, -0.52]). In the T1 the CG presented fewer values in relation to DS and TST (p=0.00, CI95%[-4.39, -1.37] and p<0.0001, CI95%[-5.22, -1.97], DS and TST, respectively); iii) at L50 a significant group-time interaction ($F_{(2,23)}$=30.177; p<0.00; η_p^2=0.724) a main time effect ($F_{(1,23)}$=22.136; p<0.00; η_p^2=0.490) and a main group effect ($F_{(1,23)}$=30.177; p<0.00; ηp^2=0.724). It was observed a significant increment between T0 and T1 in the DS (p=0.00, CI95%[1.62, 6.07]) and TST (p<0.00, CI95%[4.58, 8.40]). Contrarily in the CG it was observed a significant decrease (p=0.024, CI95%[-1.55, -0.14]). In the T1 the CG presented fewer values in relation to DS and TST (p<0.00, CI95%[-3.16, -1.34] and p<0.00, CI95%[-4.30, -2.47], DS and TST, respectively); iv) at L60 a significant group-time interaction ($F_{(2,23)}$=15.534; p<0.00; η_p^2=0.575) a main time effect $F_{(1,23)}$=11.642; p=0.00; η_p^2=0.336) and a main group effect ($F_{(1,23)}$= 15.534; p<0.00; ηp^2=0.575). It was observed a significant increment between T0 and T1 in the DS (p=0.00, CI95%[2.87, 6.98]) and TST (p<0.00, CI95%(4.19, 9.50]). Contrarily in the CG it was observed a significant decrease (p=0.04, CI95%[-3.77, -0.12]). In the T1 the CG presented fewer values in relation to DS and TST (p<0.00, CI95%[-4.08, -1.39] and p<0.00, CI95%[-4.97, -2.23, DS and TST, respectively). The mean values can be seen in the table 2 and the graphic visualization in the figure 1.

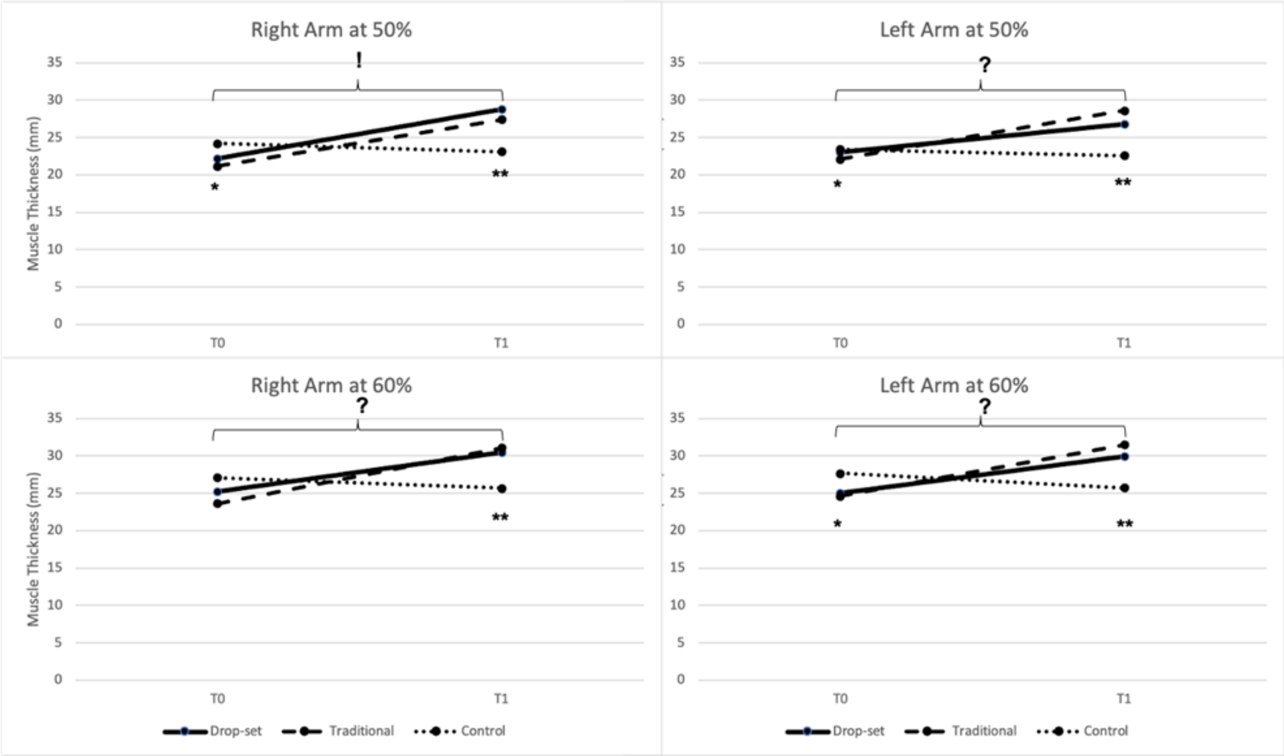

Figure 1. Muscle Thickness measures of the elbow flexors muscles in the times pre (T0) and post (T1) intervention in right and left arms at 50% and 60%. "!" p<0.01 between T0 and T1 in the drop-set and traditional groups; "?" p<0.01 between T0 and T1 in all groups; * p<0.05 between control and traditional group; ** p<0.01 between the control and the drop set and traditional groups

Table 2.
Mean values and SDs of Muscle Thickness measures of the elbow flexors muscles in the times pre (T0) and post (T1) intervention

Variables	Drop-Set	Traditional	Control
		T0	
R50	22.19±2.50	21.16±2.04	24.21±3.56*
R60	25.23±2.80	23.61±2.78	27.08±3.65
L50	22.98±3.92	22.10±2.46	23.43±3.07*
L60	25.03±3.33	24.64±2.19	27.66±2.49*
		T1	
R50	28.77±2.98!	27.42±3.17!	23.11±4.30**
R60	30.47±3.11!	31.07±2.70!	25.66±4.07!**
L50	26.82±2.30!	28.59±2.04!	22.59±3.29!**
L60	29.96±2.35!	31.49±2.27!	25.71±3.58!**

*$p<0.05$ between the control and traditional groups; **$p<0.01$ between the control and the drop set and traditional groups; ! $p<0.01$ between T0 and T1; R50 Muscle Thickness of right arm at 50%; R60 Muscle Thickness of right arm at 60%; L50 Muscle Thickness of left arm at 50%; L60 Muscle Thickness of left arm at 60%

Discussion

The aim of this study was to investigate the effects of two strength training protocols (DS and TST), matched for volume, on the thickness of the elbow flexor muscle in women. The results show a significant time effect on changes in elbow flexor muscle thickness in all DS and TST measurements. These results were expected because, although the participants were active, they did not have a long history of strength training, and the training program was specific to promote adaptations at the two measurement sites of elbow flexor muscle thickness (Mannarino et al., 2021). The results seem to indicate that both interventions are optimized training programs, based on scientific principles that govern the prescription of different training variables.

Several techniques commonly used by fitness practitioners include DS, but the influences of these techniques are relatively unknown in terms of hypertrophy. One advantage presented by some non-scientific literature and practitioners is that DS is an efficient technique for making progress while spending less time in the gym, being an easy technique to manipulate for increasing the total training volume. In the scientific literature on strength training, the rationale for using DS is the increased recruitment of motor units during fatigue, resulting in greater muscle activation (Costa et al., 2021; Gentil et al., 2007; Schoenfeld, 2011; Schoenfeld, 2010). Even when a practitioner trains to muscle failure, there are still muscle fibers that are not fully fatigued, and DS could, hypothetically, fatigue the muscle to a greater extent since recruitment tends to increase to complete the training task (Ozaki et al., 2018; Schoenfeld & Grgic, 2018).

As Gentil et al. (2007) state, the fatigue of some muscles can be compensated by increasing motor unit recruitment of other muscles in an attempt to maintain the required performance. Another effect of using DS reported by the literature is an increase in the time under tension and mechanical tension (Campos et al., 2002; McDonagh & Davies, 1984), which could increase hypertrophy (Schoenfeld & Grgic, 2018). Increased motor unit recruitment, muscle failure, fatigue, and time under tension all contribute to increased metabolic stress, considered to promote hypertrophy (Ozaki et al., 2018; Schoenfeld & Grgic, 2018). On the other hand, it should be said that going to failure would not necessarily give greater hypertrophy, however, a high volume seems to enhance hypertrophy (Schoenfeld et al., 2019). Research has already demonstrated the superiority of performing multiple sets vs. single sets for increases in maximal strength (Kemmler et al., 2004; Rhea et al., 2002). Although, there is little direct evidence to decide conclusively whether or not multiple sets should be performed to failure (Willardson, 2007; Martins et al.,2020).

The DS may enable greater amounts of muscle work by providing short rest periods between work bouts and some studies (Ozaki et al., 2018) suggest that DS are equivalent to regular sets for gaining muscle mass but in untrained young men. In the present study, despite having female participants the results between the two strength training protocols (DS and TST), equated in volume, showed no differences.

Five studies with a design similar to the present study were found. Four of them directly assessed muscle hypertrophy using magnetic resonance imaging or ultrasound (Angleri et al., 2017; Fink et al., 2018; Giessing et al., 2016; Ozaki et al., 2018), and one assessed hypertrophy indirectly using the Bod Pod (Fisher et al., 2016). We identified two studies that used a within-subjects design (Angleri et al., 2017; Ozaki et al., 2018), meaning they randomized the participants' arms or legs. In our study, we used a between-subjects design; despite the difference in group design, the results were similar.

In Angleri et al. (2017) and Ozaki et al. (2018) participants increased their muscle cross-sectional area (CSA) but the between-group effect sizes were small, and the confidence intervals were wide. Mean changes were neither statistically significant nor clinically significant between groups. Both of these studies used within-subject design where each limb was randomized to DS or TR. In Angleri et al. (2017) the CSA increased significantly and similarly for all protocols (TST: 7.6%; crescent pyramid: 7.5%; and DS: 7.8%). In the Ozaki et al. (2018) study, there were however a main effect of time ($p < 0.001$, ES: 0.830) with the CSA increasing from PRE to MID and from MID to POST.

The Fink et al. (2018) study had a smaller absolute gain in muscle CSA than Angleri et al. (2017) and Ozaki et al. (2018) studies. It is unclear why, but we speculate that perhaps the training protocol was not enough of a stimulus. It is also the study with the largest between-group effect size favouring DS group.

Our results are corroborated by the studies mentioned above, despite showing significant main group effect, group-time interaction and time effect for all MT measurements and higher effect size values.

In the present discussion we did not analyze the studies by Giessing et al. (2016), Johannsmeyer et al. (2016), Bentes et al. (2012), and Goto et al. (2016) since the methodologies followed did not allow comparison, as some studied older participants doing supplementation (Johannsmeyer et al., 2016), or circuit training in combination with DS (Giessing et al., 2016), or pre-exhaustion exercise (Bentes et al., 2012), or analyzed different outcome measures (Goto et al., 2016).

In conclusion, we can affirm that the results reported by studies conducted with similar methodologies are consistent with those found in our study. The high level of mechanical and metabolic stimuli in an exercise protocol appears to maximize muscle hypertrophy. However, it is necessary to emphasize that different training methods can and should be used in phases that align with the specific training goal. DS, for example, is a methodology that efficiently allows for an increase in volume, while in traditional sets, the load can be more easily manipulated (Schoenfeld et al., 2017). As cited by Schoenfeld et al. (2019), in terms of strength increase, DS may not be ideal because adaptations in muscle strength and endurance are consistent with the principle of specificity. The research methodological model implies equalizing the total volume; however, each method has its particularities and should be conceptualized in planning based on the specific objectives around it.

Conclusions

We can conclude that the two strength training protocols (DS and TST), equated in volume, are equally effective in increasing the muscle thickness of elbow flexors muscles in women. The results seem to indicate that both interventions are optimally designed training programs to promote muscle growth. Furthermore, the DS are a good way to allow the practitioners to have a greater volume of training in less time.

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