ISSN: 2469-5718

Hunter et al. Int J Sports Exerc Med 2024, 10:266
DOI: 10.23937/2469-5718/1510266
Volume 10 | Issue 1
Open Access

International Journal of
Sports and Exercise Medicine

RESEARCH ARTICLE

Increases in Upper-Body Strength are Dependent on Training Modality and Independent of Initial Strength Level and Fat-Free Mass Index in Women

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Abstract

Objective: This study aimed to evaluate the effect of 3 different resistance training (RT) modalities on changes in upper-body muscular strength in women of different levels of initial strength and fat-free mass index (FFMI).

Methods: Strength was determined from one-repetition maximum (1RM) free weight and modality specific upper-body press measured before and after 12 weeks of periodized RT with each modality. From a large cohort (N = 570), the top and bottom 20% were identified for one-repetition maximum bench press with free weights (FW, n = 60), seated horizontal press (SHP, n = 80), and supine vertical press (SVP, n = 87) for low (n = 94) or high (n = 133) FFMI (FFMI = FFM/Ht2) groups. RT also included upper- and lower-body supplemental exercises (3 sets of 10RM) throughout the training period.

Results: A modality × FFMI-Str ANOVA revealed significantly greater modality specific strength improvement ($p < 0.001$) for SHP (9.7 ± 5.9 kg) and SVP (9.6 ± 5.4 kg) than for FW (5.0 ± 4.0 kg). There was no significant difference ($p = 0.19$) in modality specific strength gains between high FFMI-Str (8.7 ± 6.3 kg) and low FFMI-Str (8.0 ± 4.5 kg) groups. The modality × FFMI-Str group interaction was not significant ($p = 0.47$). For FW bench press, there was no significant difference ($p = 0.06$) in strength gain among FW (5.0 ± 4.0 kg), SHP (4.8 ± 4.3 kg), and SVP (3.7 ± 3.7 kg) groups. There was also no significant difference ($p = 0.07$) in FW strength gain between the high FFMI-Str group (4.9 ± 4.2 kg) and low FFMI-Str group (3.7 ± 3.7 kg). The modality × FFMI-Str group interaction was not significant ($p = 0.34$).

Conclusion: Specific increases in upper-body pressing strength appear to be modality dependent. Initial differences in FFMI and strength level have only minor impact on the amount of strength gain across training modalities. The carry-over from machine RT to FW strength gain was comparable to that registered by the FW training group. Therefore, for women interested in gaining upper-body strength, training with MW may offer an initial advantage over FW due to simpler technique acquisition. However, the carry-over to performance with FW strength is likely to be equivalent.

Keywords

Free weights, Machine weights, Resistance training, Bench press

Introduction

Physical activity is widely accepted as an integral part of a healthy lifestyle. The positive effects of resistance training (RT) on strength and body composition are widely recognized [1,2]. However, women may still lack the motivation to engage in RT or have negative perceptions of this form of exercise [3,4]. To the contrary, studies have noted the positive effects of resistance training (RT) on muscular strength and body composition in women, including gains in fat-free mass (FFM) [5-8] and reductions in fat mass (FM) [2].

Citation: Hunter ML, Arabas JL, Jorn L, Mayhew JL, Brechue WF (2024) Increases in Upper-Body Strength are Dependent on Training Modality and Independent of Initial Strength Level and Fat-Free Mass Index in Women. Int J Sports Exerc Med 10:266. doi.org/10.23937/2469-5718/1510266

Accepted: July 05, 2024; **Published:** July 07, 2024

Currently, the availability of a variety of RT modalities allows application of resistance loads in assorted configurations to maximize muscle force output. The oldest and most commonly utilized RT modality is free weights (FW) which gives an individual complete control to manipulate the load throughout a full range of motion by activating prime movers and synergistic muscles. Equally as popular for applying resistance is the use of machine weights (MW) that provide a specific guided path through which a resistance load is moved. These modalities rely less on contraction of synergistic muscles to control the lifting motion [9-12] and may provide easier incorporation of exercises into a first-time training program and a level of protection from accidental injury [13].

Previous research has found that training with different exercise modalities may not produce equivalent increases in muscular strength as indicated by changes in the one-repetition maximum (1RM). Some studies have noted significantly greater increases in 1RM when utilizing FW compared to MW [14-16], while others have found MW to produce a greater increase than FW [17-19]. Yet other studies have found no modality difference in strength improvement following RT [20-23]. Greater neural activation of prime movers is typically observed during FW lifts than during equivalent loading with MW, which could explain some of the difference between lifting performances [9-12].

Most studies comparing FW to MW for strength enhancement have been conducted on men [14-22]. Women without a strength training history may prefer to utilize MW for resistance exercise due to a greater feeling of control and safety when lifting the bar [13]. Thus, it may be beneficial to assess the effect of different modalities for enhancing upper-body strength to determine if one particular technique is superior to another for women. Given that differences in initial 1RM performance using either FW or MW might influence the degree of improvement following resistance training, it would be advisable to control this factor by equating groups for initial modality-specific 1RM. Furthermore, recognizing the influence of amount of muscle mass on muscular strength, it would be appropriate to control for this contingency using FFM per unit height (FFMI = FFM/Ht^2). Therefore, the purpose of this study was to determine the effects of different resistance training modalities on upper body strength in women of different initial strength levels and fat-free mass indices (FFMI).

Methods

Participants

Participants were selected from a large group of college women (N = 590) enrolled in a required university fitness course over multiple years. None of the participants had an extensive background in resistance training. The Institutional Review Board of the university approved this protocol and procedures were fully explained before obtaining written consent prior to testing. All procedures followed the directive of the Declaration of Helsinki.

Protocol

Prior to training, participants were measured for height, weight, and percent body fat (%fat) using a 3-site skinfold equation [24] (Table 1). Each participant self-selected to train with either free weight (FW) or one of two forms of machine weights (MW). Upper-body pressing strength was measured with both FW and modality-specific 1RM of their choice. Participants in the upper and lower one-third of each modality were identified as having high (HiStr) or low (LoStr) strength, respectively. Furthermore, high FFMI and low FFMI participants were also identified using the same statistical procedure. The final participant pool (n = 227) was determined by combining strength levels and FFMI levels to form low-strength, low FFMI (LoFFMI-Str) and high-strength, high FFMI (HiFFMI-Str) groups for each of the three modalities. Physical characteristics of participants by group are shown in Table 1.

Anthropometric measures: Height was measured with a wall stadiometer to the nearest 0.1 cm and body weight to the nearest 0.1 kg with a certified balance scale. Triceps, suprailiac, and thigh skinfolds were measured in triplicate at each site using Harpenden calipers by the same experienced investigator. The average of the 3 cites were summed and used to estimate % fats using the Jackson-Pollock equation [24]. Fat-free mass (FFM) was determined as body mass minus fat mass and evaluated as fat-free mass index (FFM/Ht^2).

Table 1: Physical characteristics of participants.

	FW		SHP		SVP	
Variable	LoFFMI-Str n = 20	HiFFMI-Str n = 40	LoFFMI-Str n = 37	HiFFMI-Str n = 43	LoFFMI-Str n = 37	HiFFMI-Str n = 50
Age (yrs)	19.1 ± 0.9	19.0 ± 0.8	18.8 ± 0.8	18.8 ± 0.7	19.0 ± 0.6	19.3 ± 10
Height (cm)	163.7 ± 6.0	163.3 ± 5.6	165.6 ± 6.2	165.6 ± 6.2	165.1 ± 5.4	164.5 ± 6.5
Weight (kg)	54.9 ± 5.6	73.0 ± 13.3*	54.0 ± 4.7	73.0 ± 12.4*	54.3 ± 4.5	74.6 ± 12.3*
%fat	22.3 ± 5.1	25.0 ± 4.8	21.0 ± 3.3	24.1 ± 4.4	21.5 ± 2.7	26.2 ± 4.2
FFMI (kg/Ht^2)	15.83 ± 0.71	20.30 ± 2.07	15.52 ± 0.75	20.02 ± 2.04	15.60 ± 0.61	20.19 ± 2.17

*Significantly different from LoFFMI-Str groups.

Table 2: Physical characteristics of participants.

	FW		SHP		SVP	
Variable	LoFFMI-Str n = 28	HiFFMI-Str n = 35	LoFFMI-Str n = 31	HiFFMI-Str n = 40	LoFFMI-Str n = 47	HiFFM-3Str n = 36
Age (yrs)	19.5 ± 1.2	19.9 ± 2.9	19.0 ± 0.8	19.3 ± 1.0	19.1 ± 0.9	18.8 ± 0.7
Height (cm)	167.5 ± 4.9	164.8 ± 6.5	166.8 ± 7.0	167.8 ± 5.9	168.3 ± 7.4	165.6 ± 6.2
Weight (kg)	54.4 ± 4.1	74.4 ± 16.4*	52.8 ± 5.2	74.9 ± 11.7*	55.1 ± 5.1	80.9 ± 17.4*
%fat	20.7 ± 3.7	24.7 ± 4.6*	19.7 ± 3.1	26.6 ± 4.0*	21.0 ± 3.5	26.5 ± 4.8*
FFMI (kg/Ht^2)	15.36 ± 0.71	20.53 ± 2.54*	15.19 ± 0.83	20.53 ± 1.86*	15.32 ± 0.71	21.34 ± 3.48*

Note: FW: Free Weights; SHP: Seated Horizontal Press; SVP: Supine Vertical Press; FFMI: Fat-Free Mass Index
*Significantly different from LoFFMI-Str group ($p < 0.05$)

Upper-body 1RM: Maximum upper-body strength was evaluated initially for all participants using free weights (FW). A standard weight bar and metal plates were utilized. The 1RM procedure utilized the 'touch and go' method. After assuming a slightly wider than shoulder-width grip on the bar, the lifter lowered the bar to their chest and immediately returned it to full extension. Head, shoulders, and buttocks remained in contact with the bench throughout the lift. Following several warm-up sets using light weights (50-70% of projected 1RM), an initial weight was lifted for one repetition. Dependent upon the ease of completing that repetition, weight was added for the next attempt and another single repetition was completed. A 3-5 minute recovery was given between attempts. 1RM was reached within 3 to 5 attempts for each participant.

On a separate day, those participants who selected to train with a different modality were evaluated for a 1RM on either a seated horizontal press (SHP, n = 80) weight-stack apparatus or a plate-loaded supine vertical bench (SVP, n = 87). The general procedure to reach a modality- specific 1RM was the same as used to determine a FW 1RM. For SVP, participants began the lift in the bottom position and pressed the handles of the device to full-arm extension in a shallow convex upward arc. For SHP, participants were in a seated position and pressed the handles of the device from a flexed position to full-arm extension in a forward movement. For both the SVP and SHP, the hand position was slightly wider than shoulder width.

Training program: Typical training programs for all participants included seated overhead press, biceps curls, lat-pulls, squats or leg presses, and calf raises in addition to the specific chest press modality. Each group underwent a similar linear periodization resistance training program three times per week for 12 weeks. Core lifts were performed using 3 × 10-12RM during the first five weeks, 3 × 6-8RM during the next four weeks, and 3 × 3-5RM during the final three weeks. Auxiliary lifts were performed in three sets of 10-RM, with weight being added when the participant could consistently perform three sets of 12RM with ease. Abdominal curl-ups were also performed for one set of 20-30 repetitions.

Statistical analysis: Power analysis indicated that 199 participants were required for a power of 0.80, with an effect size of 0.5, and α = 0.05 [25]. Difference among groups was determined by a training modality × FFMI-Str group (3 × 2) analysis of variance. *Post hoc* differences were assessed using the Bonferroni comparison.

Results

A modality × FFMI-Str level ANOVA on pre-training FW 1RM indicated that the FW group (35.4 ± 5.3 kg) had a significantly greater FW 1RM than either SHP (32.5 ± 5.3 kg) or SVP (32.7 ± 5.3 kg); the latter two groups did not differ significantly. The HiStr-HioFFM group (40.0 ± 5.3 kg) had a significantly greater ($p < 0.001$) FW 1RM than the LoStr-LoFFM group (26.1 ± 5.4 kg). The training modality group by tr.grp-FFMI group interaction was significant ($p = 0.05$) suggesting that the LoStr-LoFFM in each corresponding modality was significantly different from the HiStr-HioFFM.

A modality × FFMI-Str level ANOVA on pre-training modality-specific strength (1RM) noted a significantly greater ($p < 0.001$) SVP (41.3 ± 5.7 kg) than for SHP (35.8 ± 5.7 kg) and FW (34.5 ± 5.7 kg) which did not differ significantly. The HiStr-HioFFM group (46.5 ± 5.6 kg) had a significantly greater ($p < 0.001$) than the LoStr-LoFFM group (27.8 ± 5.8 kg). The training modality group by tr.grp-FFMI group interaction was significant ($p < 0.008$) suggesting that the LoStr-LoFFM in each corresponding modality was significantly different from the HiStr-HioFFM.

A modality × FFMI-Str level ANOVA on modality-specific strength improvement revealed that SHP (12.5 ± 4.8 kg) made significantly greater gains ($p < 0.001$) than SVP (8.5 ± 4.8 kg) which made greater gain than the FW group (5.5 ± 4.8 kg) (Table 2). There was a significant difference ($p = 0.02$) in modality-specific strength gain between high FFMI-Str (9.6 ± 4.8 kg) and low FFMI-Str (8.0 ± 4.9 kg) groups. The modality group by FFMI-Str group interaction was also not significantly different ($p = 0.13$) (Figure 1).

A modality × FFMI-Str level ANOVA on FW strength improvement noted that FW (5.5 ± 4.2 kg) made significantly greater gain than SHP (3.5 ± 4.3 kg), and

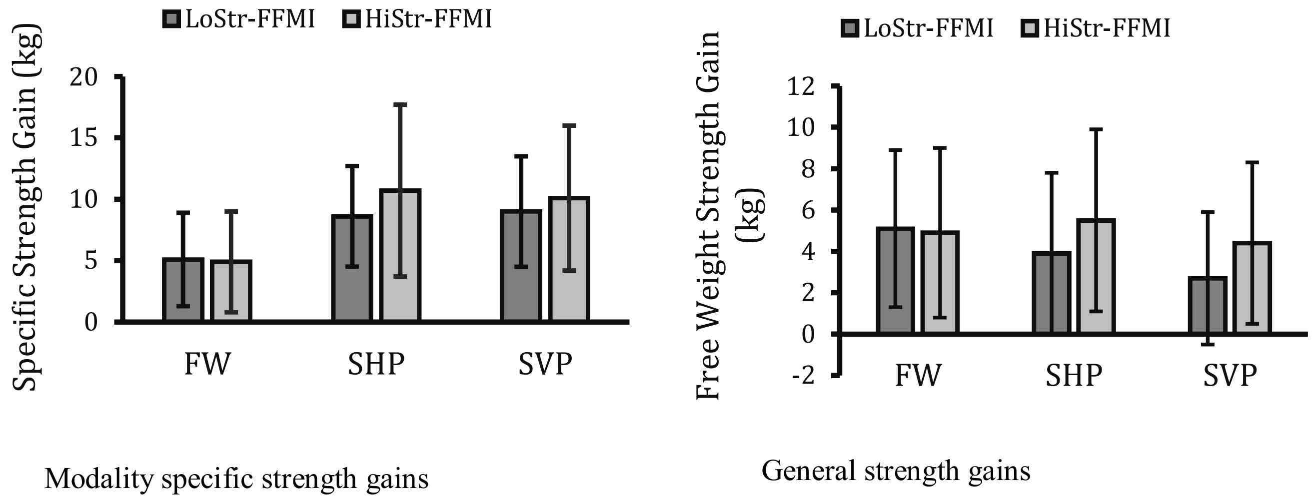

Figure 1: Machine weight strength gain.

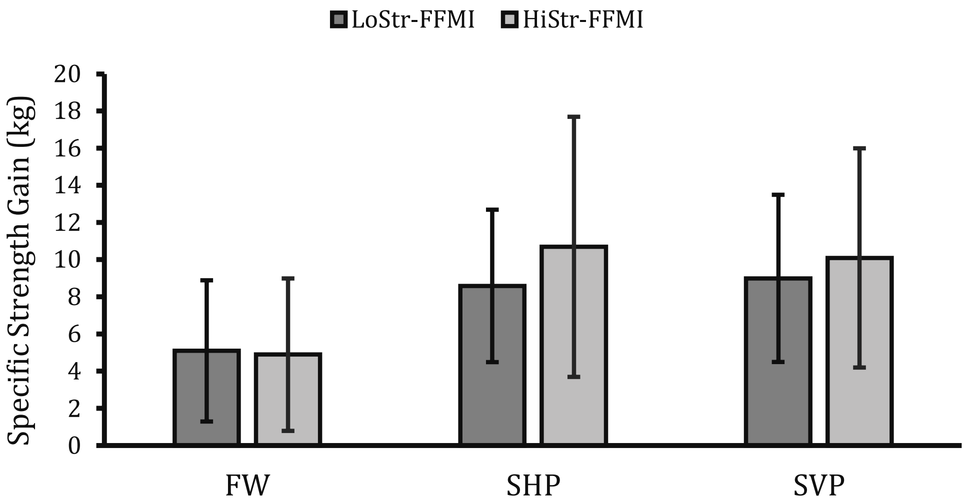

Figure 2: Relative Strength gain for loFFM-Str and HiFFM-Str groups.

SVP (3.6 ± 4.3 kg) training groups which did not differ significantly (p = 0.06). The high low FFMI-Str groups (3.6 ± 4.3kg) and high FFMI-Str groups (4.7 ± 4.3 kg) were not significantly different (p = 0.06) across the three modalities. The modality × FFMI-Str interaction was significant (p = 0.03), again suggesting that the HiStr-HioFFM performed better than the low FFMI-Str groups in each training modality (Figure 2).

Discussion

The major findings of this study suggest that training with either FW or MW can produce significant absolute and relative upper-body strength gains in young women of differing muscle masses and initial strength. The gains made by young women of different FFMI and strength levels are likely to be greater in their specific training modality. However, there is likely to be good carryover strength gain in FW when training with a MW modality. This agrees with studies on novice men [16-18] and women [26-28] that found similar RT bench press strength gains regardless of training modality. Therefore, young women wishing to begin a strength training program should be free to select a RT modality they will be most comfortable utilizing [29,30].

It should be noted that previous studies comparing FW and MW have found differing results. An early study by Stone, Johnson, and Carter [23] observed FW 1RM squats to be significantly greater than Universal machine squats in men in a beginning RT class. Additional research comparing FW and MW bench press training in a group of untrained women found a non-significantly higher 1RM for MW bench press compared to FW bench press [22]. Due to the high correlation between participants' FW and MW 1RM, Simpson, et al. [22] concluded that strength measurement may be considered independent of testing modality. In a recent study on the effects of MW verses FW training on motor performance skills, it was noted that MW squats might provide equal or better performance-enhancing benefit than FW in women [27]. In an earlier study, women who were assigned to train with FW made significantly greater gains I strength than either SHP or SVP groups [26]. However, when evaluated for modality-specific 1RM strength gains, SHP and SVP groups made significantly greater gains than the FW group. Furthermore, low correlations between FW and modality-specific 1RM gains prompted researchers to suggest that gains made by modality-specific groups might not transfer directly when lifting FW. In a separate study conducted on college men, researchers comparing different weekly training frequencies found significantly greater gains with MW than with FW regardless of training frequency [18]. However, it is interesting to note that the relative gains made by men using SHP (21.2%), SVP (15.7%), and FW (11.4%) in that study [18] were comparable to those for women in the current study (24.5%, 27.5%, and 14.5%, respectively). In addition, high and low strength groups in that study were not significantly different in strength gains, which are supported by the current study.

An important aspect of RT which has received little attention is the enjoyment and sense of reward of participants following training. Carraro, Paoli and Gobbi [4] found that RT with FW produced a greater increase in enjoyment and perceived exertion than MW in a sample of recreationally trained men. However, they further noted that beginners might utilize diverse modalities to gain greater enjoyment from RT. No such studies have been performed on women to determine their perception of training with different modalities, but anecdotal evidence would suggest that women feel more comfortable using MW than FW, at least initially.

Limitations

Participants in this study were free to select the lifting procedure of their choice rather than being assigned to a specific procedure. Training was limited to a semester schedule, which restricted it to 10 weeks of exercise 3 days per week. Despite direct supervision of all training sessions, it was difficult to identify the motivational level of all participants.

Conclusion

This study suggests that women wishing to begin a RT program should be free to select a training modality that suits their preference and comfort. The greater the invested interest and enjoyment perceived by participants, the more likely they will be to continue training and benefit both physiologically and psychologically. Additional investigation is warranted to assess the carry-over potential for strength from MW training to FW performance in both men and women.

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