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Differences in Female Lift Quality During Back Squat, Bench Press, and Deadlift Compared to Standardized Percent of 1RM and Repetitions Allowed

Andrew A. Wolfe[1], Ruth E. Caddell[1], Gillian C. Braden[1], Emma J. Thornton[1], Jackson C. Maynard[1] Cheyenne B. Lavender[1], Micheal J Luera[1] & Aaron N. Rinehart[2]

[1]Department of Health & Human Performance, Tarleton State University, Stephenville, Texas, USA, [2]EXOS Sports Performance, Children's Health Andrew Institute for Orthopaedics and Sports Medicine, Plano, Texas, USA.

ABSTRACT

The purpose of the study was to examine the difference between the current norm repetition-intensity recommendations and the performed repetitions of females at concurrent intensities. Females (n = 20) with six-months of consistent resistance training experience completed five testing sessions. Session 1 consists of one-repetition maximum (1RM) testing for the squat (SQ), bench press (BP), and deadlift (DL). Sessions 2-5 involved repetition-maximum testing at 65, 75, 85, and 95% 1RM, in the order of SQ, BP, then DL, with 10-15 minutes of rest between exercises. A 3 (exercise) x 4 (percentage-intensity) Mixed Factorial ANOVA determined significant differences in repetitions performed between exercises at each intensity level. A series of one-sample t-tests were performed to indicate female differences between established target repetitions for each exercise across all intensities (65% = 15, 75% = 10, 85% = 6, 95% = 2). Significance level was set at $p < .05$. There was no significant main effect (p=0.14) between repetitions completed during SQ, BP, or DL at 65% (26.1±6.8, 21.3±6.8, 23.4±6.3, respectively), 75% (18.0±6.2, 14.4±4.2, 15.7±4.7, respectively), 85% (10.3±3.7, 9.0±4.6, 9.6±4.1, respectively), nor 95% 1RM (4.1±2.4, 2.5±2.0, 3.4±2.0, respectively). No significant difference was recognized (p = 0.09) between current BP norms and female BP repetitions at 95%. Significantly higher repetitions were completed by females at all other percentages during SQ, BP, and DL. These results suggest different intensity-repetition ratios should be prescribed for females in comparison to current norms during resistance training, meriting future research aimed at establishing a sex-specific intensity-repetition ratio.

Keywords: resistance training, sex-specific, exercise intensity.

INTRODUCTION

One-repetition max (1RM) testing has been used for many years by strength and conditioning coaches and health professionals to reliably establish measures of maximal muscular strength and determine load when prescribing variations of exercise intensities (28, 29, 34). During practical application, volume (number of repetitions completed) and intensity (weight lifted or percentage of maximal capacity), frequently referred to as "load", are manipulated in exercise programs in a manner that allows the body to adapt specifically to a designated training stimulus. Strength and conditioning coaches frequently rely on 1RM to determine the appropriate intensity an individual will utilize throughout a training session. Previous investigations recognize an inverse relationship between load and repetitions completed, and exercise prescriptions should be employed according to this appropriate repetition-to-load ratio. Additionally, identified within the literature, specific repetition-to-load recommendations change according to lifting experience (i.e., trained vs. untrained) and athlete event (i.e., ball players, racket sports, powerlifter, etc.). However, male participants dominate the majority of examined subjects within the literature; thus, failing to identify a sex-specific relationship between repetitions completed and load performed.

A study completed by Hoeger and colleagues (12) established the initial correlation between repetitions completed and selected percentage of 1RM. Hoeger et al. (12) collected repetitions completed at 40%, 60%, and 80% of 1RM for untrained male athletes across seven different resistance training exercises. These results indicated significant difference in repetitions completed for different exercises and across all percentages of 1RM. Moreover, predicting 1RM at different percentages should rely on different repetitions and be dependent on exercise selection (34). Since, several studies have investigated varying percentage-1RM (%1RM) to repetition with different populations and different resistance exercises. Richens and Cleather (29) reported differences between repetitions completed for endurance and strength training athletes at 70%, 80%, and 90% 1RM for leg press, with endurance athletes performing significantly more repetitions at each intensity level. According to Shimano et al. (32), no difference in repetitions completed were found between trained and untrained males at 60% and 80% 1RM for bench press, back squat, and arm curl. However, at higher intensity (90%), trained participants significantly outperform untrained participants, indicating training status minimally influences lift quality as quantified by repetitions completed (32). Marginally different, Hoeger et al. (13) reported trained males significantly outperformed untrained males at 40%, 60%, and 80% for arm curls, sit-ups, and knee extension, leg curls at 60%, and lat pull down at 60% and 80%. These findings further suggest higher intensities create differences in performance between untrained and trained athletes. Likewise, when assessing a variety of sports, differences in repetitions completed surfaced, yet again, for male powerlifters, racquet sports players, ball players, swimmers, and rowers (3). Significant differences in repetitions completed for the sports previously listed occurred at 20%, 40%, 60%, and 75% for bench press. Furthermore, these investigations suggest a group specific regression model may be the best approach for establishing predicted 1RM formulas, based on repetitions completed (3).

As stated, previous studies establishing and investigating %1RM-repetition ratios predominantly utilized male participants, although a substantial quantity of reports indicate physiological differences between males and females. In fact, reports of sex differences in muscle mass, substrate utilization, and muscle morphology are prevalent, with results indicating females possess higher fatigue resistance when compared to males (10, 11). Mayhew and colleagues (23) investigated the accuracy of current predictive equations for repetition to failure for females when performing bench press and determined accuracy in the prediction equations remained intact when fewer than 10 repetitions were completed. These findings indicate slight, yet inconclusive similarities (23). Hoegen et al. (13) reported differences in repetitions completed between trained and untrained females at 40% intensity for leg press, lat pulldown, bench press, knee extension, sit-up, leg curl, and arm curl, 60% for knee extension, and 80% for bench press, sit-ups, and leg press. These results suggest training status influences fatiguability; however, these findings provided no distinctions between the sexes.

The current literature clearly recognizes an inverse relationship between the weight lifted and repetitions completed; however, the current NSCA recommendations utilize a single %1RM-repetition ratio for the prescription of resistance training, regardless of sex differences (6, 8). These inaccuracies in intensity prescription (too heavy or too light of loads) disallow athletes enough stimulus or sufficient recovery to receive optimal adaptation from the intended resistant training stimulus (25). Therefore, the purpose of the current investigation was to examine the difference in repetitions completed by females at incremental %1RM loads compared to the current %1RM norms.

METHODS

Experimental Approach to the Problem

To examine the difference in repetitions completed by females at different %1RM (65, 75, 85 and 95%), participants performed 5 sessions consisting of squat (SQ), bench press (BP) and deadlift (DL). Session 1 was 1RM testing and sessions 2 - 4 served as repetition maximum (RM) testing. Forty-eight hours rest was required between testing sessions (2, 18, 24, 26, 36). All participants were required to have at least 6 months of consistent resistance training to be included in the study. This investigation was reviewed and approved by the Institutional Review Board (IRB) of Tarleton State University.

Subjects

Study subjects consisted of 20 females (20.65 ± 1.93 years) recruited from a midsize university in the southwest region. Inclusion criteria required participants to be asymptomatic, free of injury, with at least 6 months, minimum of 2 days per week, of consistent recreational resistance training (maintenance stage of the transtheoretical model of behaviour change) (27). Participants were recruited via oral advertisement at kinesiology department classes and female recreational sports team meetings. All subjects were informed of study procedures and regulations prior to signing the Institutional Review Board approved written informed consent form. Prior to beginning testing, participants were required to fill out a physical activity readiness questionnaire to assess activity level and ensure no underlying/pre-existing conditions would alter subjects' performance. An application-based approach was taken regarding the control of menstrual cycle status among participants. Strength coaches experience undulation in their athletes' menstrual cycles and differences in cycle status among athletes on a day-to-day basis. Therefore, allowing variability in menstrual cycle status enhanced the ecological validity of the study design.

Table 1. Descriptive characteristics of female subjects (mean ± SD)

Variable	**Mean ± SD (*N* = 20)**
Age (y)	20.65 ± 1.927
Height (cm)	163.13 ± 7.06
Weight (kg)	65.10 ± 9.83
BMI	24.44 ± 3.18
%BF	24.24 ± 4.83
1RM SQ	191 ± 49.11
1RM BP	103.5 ± 22.89
1RM DL	181.75 ± 27.06

BMI = Body Mass Index; %BF = % body fat; 1RM = 1 repetition maximum; SQ = Squat; BP = Bench Press; DL = Deadlift

Participants were numerically coded to ensure confidentiality was maintained and all data was stored on a university computer, within an encrypted Microsoft Excel file to prevent unauthorized access. Additionally, it was required that participants refrain from alcohol and caffeine consumption for 24 hours prior to each session.

Experimental Design and Procedures

Prior to beginning of testing, all participants were familiarized with the testing procedures, session order, exercises order, and proper exercise technique in accordance with NSCA testing protocol and exercise technique (8). Subjects' characteristics (height, weight, and age) were obtained during familiarization. Following, body composition (i.e., body fat percentage) measurements were collected utilizing the Jackson-Pollock 3 site (triceps, suprailiac, and mid-thigh) skinfold method (16).

One-Repetition Maximum Testing

One-repetition maximum (1RM) testing was administered in the order of SQ, BP, and DL allowing for 10-15 minutes rest between exercises. The researchers utilized the National Strength and Conditioning Association (NSCA) (8) standardized 1RM testing protocol. To begin the testing protocol participants were instructed to perform 10 repetitions with the empty barbell (45lbs). Following this set they were instructed to perform 5-10 repetitions with a light weight, followed by a set of an added 30-40 pounds for lower body exercises and 10-20 pounds for upper body exercises. Participants were instructed to perform 3-5 repetitions. After 2 minutes of rest, participants increased load again following the same instructions for upper and lower body, performing 2-3 repetitions. Following a 2-minute rest, participants were instructed to increase load again and attempt a 1RM. This final step was repeated either adding or subtracting weight until participant achieved the maximum amount of weight they could lift for 1 repetition, thus establishing a 1RM.

Repetition Maximum Testing

Participants performed four sessions to failure (RM) at randomly selected 65, 75, 85, and 95% load of participants' session 1 established 1RM. Prior to beginning the session individuals completed 2 mins cycling at ~50% effort, followed by a full body dynamic warm up. The dynamic warm up included 1 set of 10 repetitions for the following exercises: body weight squat, inchworm, lunge with overhead side reach, walking knee lift, and inverted hamstring stretch. The RM session exercise order was SQ, BP, and DL. Three warm up sets with 10% load increases and incremental decreases in repetitions were performed before completing the RM set. For example, 65% testing session sets adhered to the following protocol: Set 1: 5-10 repetitions at 35%; Set 2: 3-5 repetitions at 45%; Set 3: 2-3 repetitions at 55%; and Set 4: as many repetitions as possible at 65% (testing/RM set). A 10–15-minute recovery period was required between exercises.

Statistical Analyses

A Mixed Factoral ANOVA was performed to determine significant differences in repetitions performed between exercises at each intensity level. A series of one-sample t-tests were performed to indicate significant differences between established target repetitions for each exercise across all intensities (current recommendations: 65% = 15, 75% = 10, 85% = 6, 95% = 2). Cohen's *d* indicated statistical power ranging from 0.66 to 1.70 (medium to large effect) for the n size used. Statistical significance was set at $p < .05$.

RESULTS

A Mixed Factoral ANOVA indicated no significant main effect ($p = 0.14$) in repetitions completed during SQ, BP, nor DL at 65% (26.1 ± 6.8, 21.3 ± 6.8, 23.4 ± 6.3, respectively). Similarly, no significant main effect was found at 75% ($p = 0.15$) across SQ, BP, and DL (18.0 ± 6.2, 14.4 ± 4.2, 15.7 ± 4.7, respectively). At 85% there was no significant main effect ($p = 0.7$) found for repetitions completed during SQ, BP, and DL (10.3 ± 3.7, 9.0 ± 4.6, 9.6 ± 4.1, respectively). Finally, no significant main effect ($p = 0.30$) was present at 95% during SQ, BP, and DL (4.1 ± 2.4, 2.5 ± 2.0, and 3.4 ± 2.0, respectively). Figure 1 depicts no significant main effect in repetitions completed during SQ, BP, nor DL at the various intensities.

A series of one-sample t-tests indicated significantly higher repetitions completed by females for SQ at 65, 75, 85, and 95% 1RM in comparison to the standardized repetition to intensity ratio (see figure 2). Likewise, one-sample t-tests indicated significantly higher repetitions completed by females during the BP at 65, 75, 85, and 95% 1RM in comparison to the standardized repetition to intensity ratio (see figure 3). Finally, and again, a series of one-sample t-tests indicated significantly higher repetitions completed by females for all DL at 65, 75, 85, and 95% in comparison to the standardized repetition to intensity ratio (see figure 4).

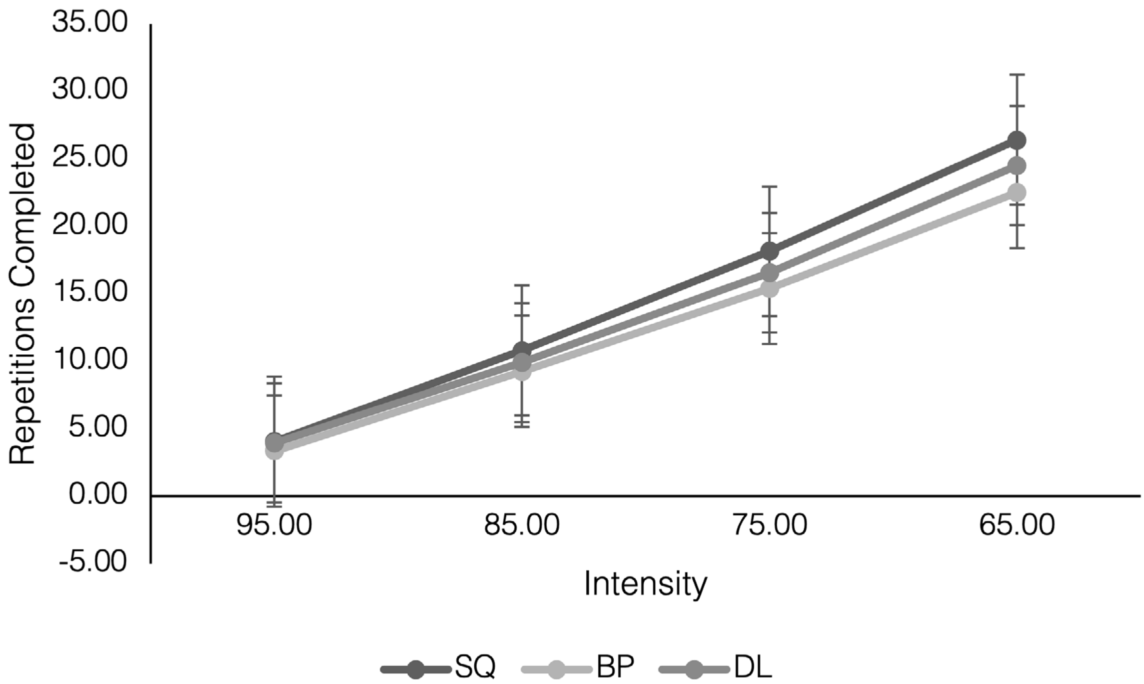

Figure 1. The mean difference of repetitions completed during squat (SQ), bench press (BP), and deadlift (DL) at 65, 75, 85, and 95% of subjects 1RM.

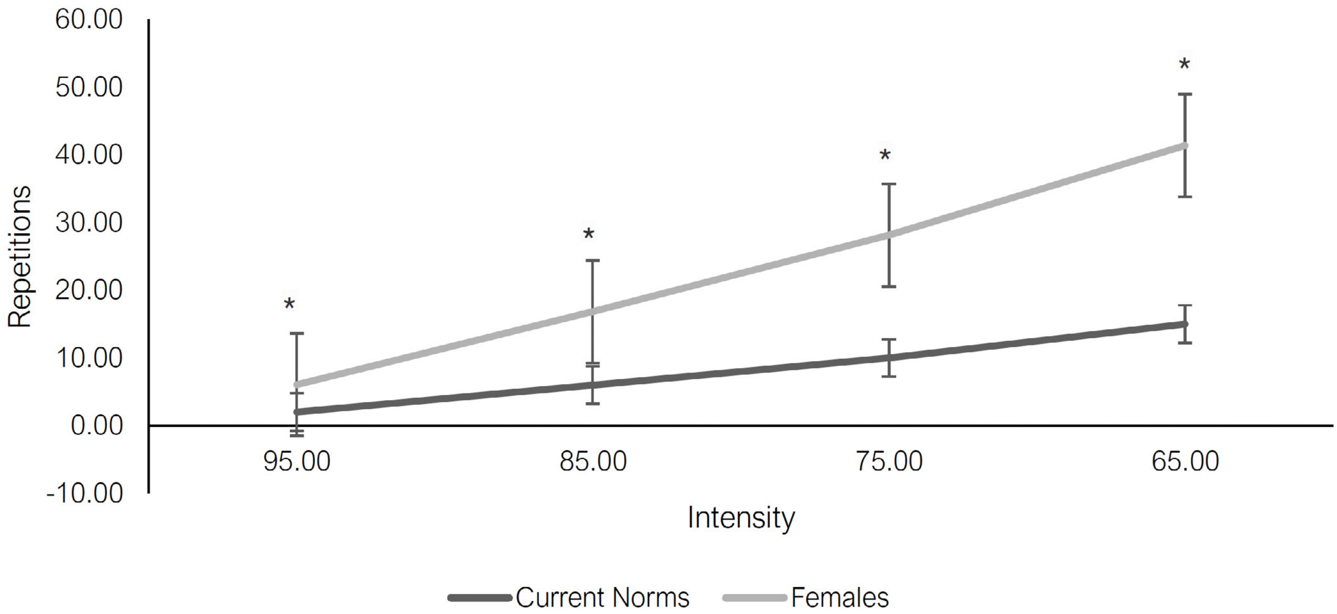

Figure 2. The mean difference between repetitions completed by females and the standard repetition per intensity at 65, 75, 85, and 95% 1RM during the squat (SQ) exercise.
*Significantly greater repetitions completed than current standardized repetition to intensity norm.

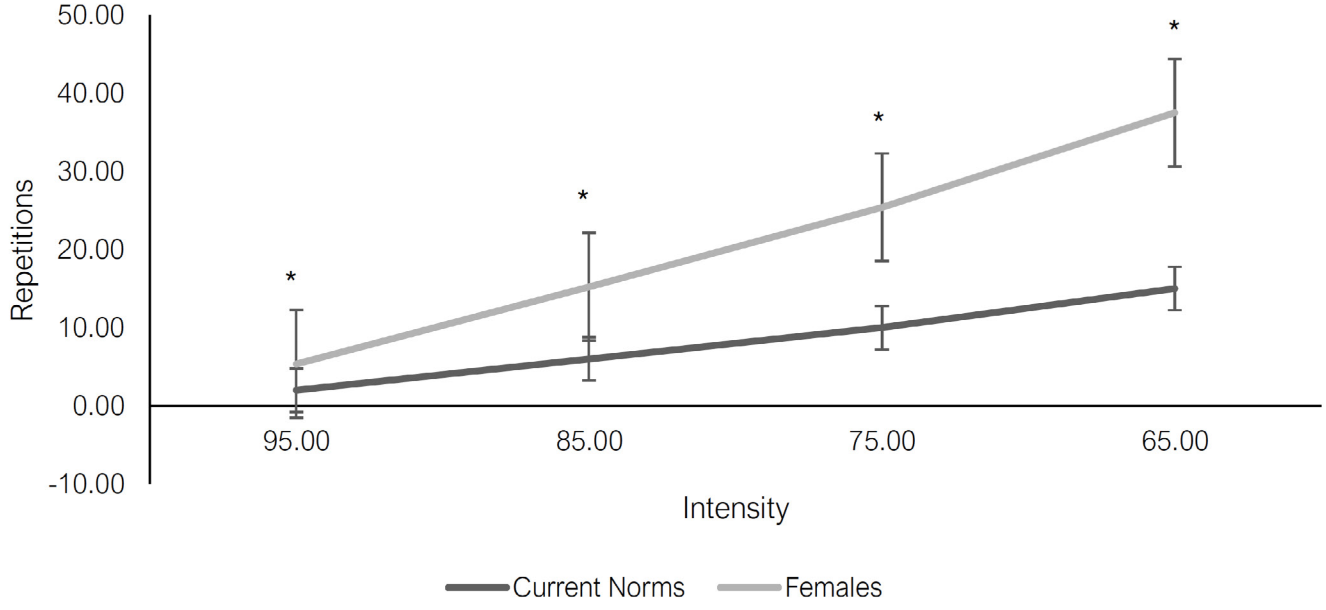

Figure 3. The mean difference between repetitions completed by females and the standard repetition per intensity at 65, 75, 85, and 95% 1RM during the bench press (BP) exercise.
*Significantly greater repetitions completed than current standardized repetition to intensity norm.

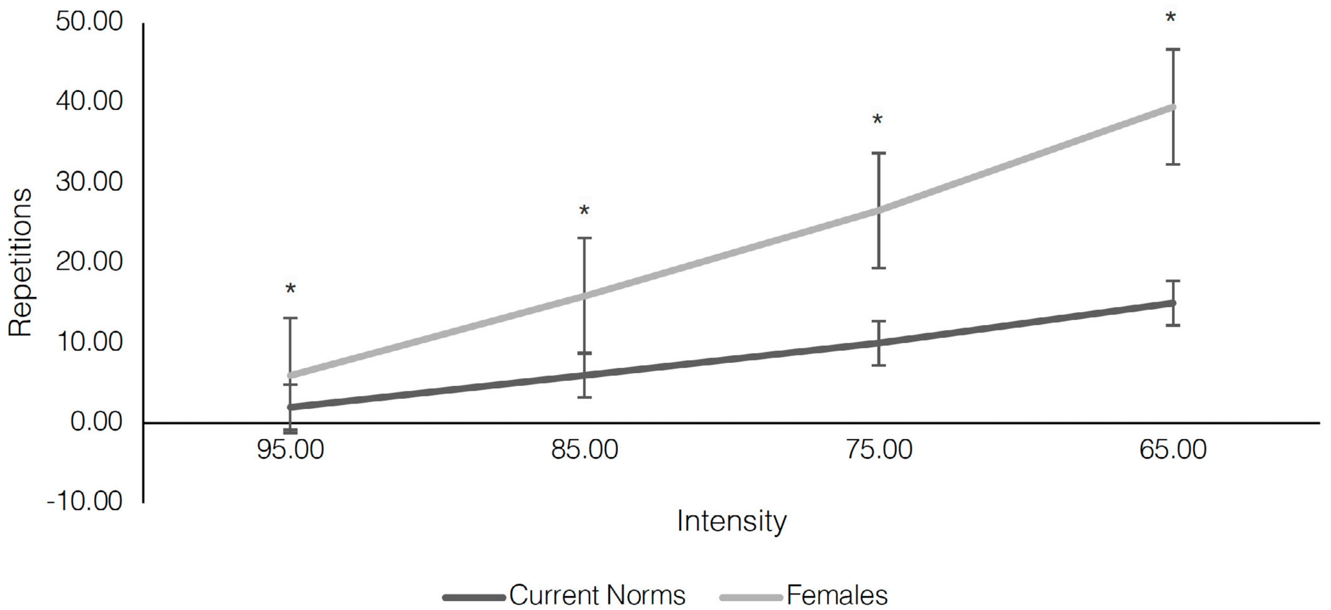

Figure 4. The mean difference between repetitions completed by females and the standard repetition per intensity at 65, 75, 85, and 95% 1RM during the deadlift (DL) exercise.
*Significantly greater repetitions completed than current standardized repetition to intensity norm.

DISCUSSION

The purpose of this investigation was to examine the difference between the repetitions completed by females during the SQ, BP, and DL at incremental %1RM (65, 75, 85 and 95%) in comparison to the current %1RM-repetition recommendations. Additionally, this study aimed to recognize differences in repetition performance by females at distinct %1RM when performing different exercises (SQ, BP, and DL). These data provided both contradicting and complimentary results to previous investigations examining %1RM-repetition outcomes, and additionally, provide a novel perspective for trained females resistance training performance.

No significant repetition completion differences were found at 65, 75, 85, nor 95% 1RM between SQ, BP, nor DL. These findings suggest multi-joint, large muscle mass exercises produce similar repetition completion, which contradicts previous reports (12, 13, 14, 33). Among the 7 exercises examined by Hoeger et al. (12, 13), repetitions completed during leg press significantly exceeded all exercises, including BP. Shimano and colleagues (32), additionally, reported similar findings for repetitions completed during SQ and BP, with SQ %1RM-repetitions significantly exceeding that of BP for both trained and untrained males. Differing from the current investigation, these reports produced resistance training findings for male subjects. However, within a previous investigation conducted by Hoeger et al. (13), when examining repetitions completed by trained females, significant differences were not observed across 7 machine-based exercises, complementing the current investigation and suggesting a standard %1RM-repetitions recommendations for trained females may be appropriate for a variety of exercises.

A statistically significant difference was recognized between females' RM performance and current %1RM recommendations across all examined %1RM for SQ, BP, and DL. These findings suggest the current %1RM recommendations do not align with the physiological capacity of females. Complementary findings were expressed when Thomas and colleagues (33) investigated the difference in maximal power output at incremental %1RM for males and females. Maximal power output was executed at 30-40% 1RM during the squat jump for males, whereas 30-50% 1RM, a broader range, was superlative for females (33). Additionally, during speed bench press, males produced maximal power output at 30% 1RM, with females, again producing power throughout a wider range of 30 - 50% 1RM (33). Subsequently, previous investigations recommend male lifters' prescriptions follow lower %1RM when striving to maintain velocity capacity (21). Likewise, Wilmore (37) conducted a 10-week resistance training study, with equivalent relative volume parameters for males and females. The female group percentage strength improvement for forearm flexion was significantly lower than males (10.6% vs 18.9%, respectively), suggesting the prescribed relative volume underestimated the work capacity needed for females to achieve comparable adaptation to males (37). Additionally, and lastly, when working at relative intensities, neuromuscular fatigue and recovery differ between males and females (9). Häkkinen (9) examined maximal voluntary neural activation and force-time curve of the leg extensor muscles, immediately after and 1 hour after a bout of equally staining exercise (20 sets of 1 repetition for squat at 100% 1RM) (9). Again, corresponding results occurred, as lifting %1RM increased, a greater decrease in maximal force production was observed for males immediately and 1 hour after exercise in comparison to females; thus, indicating females' fatigue less and recover faster than males when equivalent relative exercise volumes are prescribed (9).

Several investigations have attempted to explain the results found within the current study and complementary investigation (4, 7, 17, 20, 31). Differences in male and female muscle fiber type profile may best explain higher levels of fatigue resilience among females (31). Miller and coworkers (25) recognized lower fatigable type II fiber proportions in female vastus lateralis in comparison to males; thus, potentially enabling increased repetition completion during exercises involving the lower extremity (i.e. SQ and DL). Additionally, concerning body composition, females consist of proportionately less skeletal muscle, producing lower absolute velocity during voluntary contraction, with shortened time under tension during dynamic exercise repetitions in comparison to males (14, 30). Furthermore, compared to males, lower oxygen demands are needed and the local vasculature experience less mechanical compression for females to complete similar tasks (22, 25). Additionally, supporting these claims, Barnes (1) investigated maximal voluntary contraction (MVC) strength and intramuscular vascular occlusion during an isometric handgrip exercise and found a significant negative correlation between the percentage MVC needed to generate intramuscular vascular occlusion and absolute MVC strength of male subjects. Although Barnes (1) examined only males, these findings theoretically support that females would possess increased availability of oxygen and improved metabolic byproduct clearance during exercises due to minimal occlusion at submaximal MVC percentages in comparison to stronger male counterparts (1). However, comparing contractile and activation mechanisms of males and females with similar anthropometrics has yet to be examined, and therefore, this should be interpreted with a degree of caution. Lastly, female estrogen level may possibly be a contributing factor to increased fatigue resilience. Estrogen may provide a protective effect on skeletal muscle, according to previous studies, and therefore, mediating resistance to fatigue and inflammation during and after exercise (5, 15, 19, 35). These positive protective effects should, however, again be interpreted cautiously based on conclusion of Hunter (15) – the influence of estrogen on younger females appears negligible compared to older females. That notwithstanding, the influence of estrogen on females, holistically, appears to be a plausible explanation for sex-specific fatigability difference (19).

Although significant differences were identified, showcasing female workload appears to significantly surpass the current repetition to intensity recommendations, a few limitations to the study exist. The current investigation did not account for menstrual cycle during 1RM session nor RM testing sessions. A participant may experience a change in strength based on hormonal contraceptive use, differing cycle phases, or menstrual cycle irregularities. The researchers assumed and expected a variety of menstrual cycle differences among subjects would exist. Aligning the methodological approach with a practitioner's exposure to daily menstrual cycle fluctuations (i.e., ecological validity) was the justification for examining females without controlling menstrual cycle variability. These results provide a generic perspective of female exercise capacity. However, to establish repetition to load percentage during different phases of menstrual cycles merits further investigation and may yield greater exercise programming specificity for females. The females examined were simply one subcategory of physically active females. Examining one category instead of various female sport athletes, different types of resistance trained females (i.e., powerlifters, CrossFit, high intensity interval training), and a wider range of age groups, limits the researchers' ability to suggest holistic interpretations and recommendations regarding females' workload capabilities. Additionally, the current investigation did not compare female workload directly to male performance. Another limitation, this investigation provides no information regarding the effectiveness of training for females at adjusting repetitions to %1RM recommendations. Therefore, future research should explore the efficacy of an updated female %1RM-repetition recommendation for strength, power, hypertrophy, and endurance training goals. Future investigations should include various populations of females and males to comprehensively examine sex- and sport-specific lift capacities and the potential performance enhancements associated with an updated lifting recommendations for females.

In conclusion, the findings from previous investigations and those expressed in the current study showcase sex-differences when performing and adapting from resistance training exercise. Specifically, the results from the current investigation suggest females perform significantly more repetitions than the current %1RM-repetition recommendations at all examined incremental %1RM for all exercises, and furthermore, necessitates further research oriented towards re-establishment of repetition-to-intensity norms for females.

PRACTICAL APPLICATIONS

Varying the acute variables (i.e., sets, repetitions, intensity, etc.) during resistance training directly affects the elicited adaptation and therefore, specific and appropriate programming is essential to achieve the desired physiological change. The results of the current investigation and previous research (29) recognized an underestimation of repetitions completed potential at various %1RM. The results of the current investigation suggest an altered prescription in repetition-to-intensity ratios is needed for females to gain desired adaptations more proficiently.

Several innovative strength and conditioning training concepts can be employed to accommodate female specific lifting abilities. For simplicity purposes, strength coaches may consider increasing the traditional %1RM by 2-5% for females to account for females enhances lift capacity. Similarly, with fixed intensity, coaches may simply instruct females to perform the programmed exercises to failure (i.e., repetition maximum). Slightly more complex, strength coaches may explore autoregulatory approaches to resistance training where sets, repetitions, and intensity is governed by daily performance capacities (i.e., velocity-based training). These daily titration methods may permit female athletes to extend repetitions completed beyond the traditional fixed repetition scheme, while training at the required intensity level for various adaptations. Each of these non-traditional, customizable forms of resistance training provide lifters a degree of programming autonomy; thus, better aligning with females lifting capacity.

These recommendations are suggested for large muscle groups, upper and lower body exercises as no differences were found between repetitions completed for SQ, BP, and DL. Implementing these recommendations may assist in improving the effectiveness of resistance training programs for recreationally trained females.

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