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Establishing Normative Data for 10RM Strength Scores in College-Aged Females

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ABSTRACT

Training recommendations for novice to intermediate lifters include loads that correspond to a 10RM, yet there has not been normative data established for college aged females. Therefore, the purpose of this study was to provide 10RM normative reference values for various strength exercises for 18 to 25-year-old females. The exercises for this study included were the Lat Pulldown, Bench Press, Seated Front Press, Preacher Curl, and the Leg Press. Every testing and training occurred using the same equipment and in the same facility. Testing occurred prior to the structured training program began and then again upon completion of 12 weeks of training. A total of 371 subjects (age = 19.86 ± 1.43years; height = 64.51 ± 2.90 inches; pre-test bodyweight = 151.19 ± 36.05 pounds; pre-test body fat percentage = 29.20 ± 8.89 percent body fat; post-test bodyweight = 153.66 ± 36.80 pounds; post-test body fat percentage = 30.76 ± 8.44 percent body fat; years of strength training experience = 2.28 ± 2.38 years), participated in the study. Bodyweight categories were derived based upon two established classification systems used in competitive lifting sports. Percentiles and performance rankings for each weight category were reported, where the weighted average method was used to determine the percentile break points. These norms provide a range of possible 10RM loads as well as a reference to the strength levels, which could be useful to more effectively assess and design resistance training programs.

Key Words: 10RM, Leg Press, Bench Press, Lat Pulldown, Bicep Curl, Seated Overhead Press

INTRODUCTION

Muscular strength has been recognized as being an integral part of health, activities of daily living, and athletic performance. Individuals lacking the requisite strength may not be able to perform physical tasks that coincide with activities of daily living (6, 22) Lower body and upper body strength have been suggested as a predictor of mortality in older females and men respectively (32). Greater muscular strength also has the potential to improve the performance of a wide range of both general and sport specific skills and can be seen as the foundation in many fitness related programs. The metanalysis (40) involving the importance of strength in athletic performance found that there is a strong relationship between strength and superior jumping, sprinting, change of direction, and sport specific performance. It is clear that strength is an important aspect for both health and performance.

According to the American College of Sport Medicine (ACSM), the general healthy adult population (> 18 years) is recommended to begin resistance training programs with loads that can be achieved for 8-12 repetitions, 2 or more days a week to improve muscular strength (2). However, research has shown that women have reported not meeting these recommendations as often as men despite acknowledging the potential benefits resistance training can offer (18, 26). Research amongst women has suggested that women are less likely to participate in resistance training due to perceived time and effort, comfort of using the equipment, presence of men, perceived lack of skill, and self-consciousness/judgement (23, 33). Contrary to these potential barriers to participation, there has been copious amounts of evidence that supports that resistance training can be beneficial to women.

Noticeable health related benefits of resistance training for women include improved body composition, increased muscular strength and endurance, and bone density (24, 29, 35, 37). Sport scientists have also promoted the importance of resistance training for improving athletic performance in females as well. These benefits can include improvements in speed, vertical jump height, and agility. (17, 25, 39). These benefits should highlight the importance of female athletes to engage in resistance training on a regular basis to supplement the training in their respective sport. Injury prevention is also an important part of training for coaches and athletes, and with the increased prevalence of knee injuries in females as opposed to men who participated in the same sport suggest the importance of increasing leg strength (20). Non-contact injuries can be significantly reduced using a structured strength and conditioning program. For example, Hewett et al. found that female athletes who did not participate in a strength and conditioning program that consisted of resistance training, jump training, and stretching had a 3.6 times higher knee injury rate than the females that had participated in a structured strength and conditioning program (19). Another consideration for increased risk of a knee injury is that when the quadriceps muscle group are significantly stronger than the hamstrings muscle group, more anterior translation of the of the tibia on the femur can occur and thus puts the ACL at higher risk for injury (5). Thus, increasing the strength of the hamstrings muscle group through resistance training could theoretically reduce the risk of ACL injury (14).

Lastly, besides the reduction of non-contact injuries from resistance training it has also been shown to have positive psychological benefits in women (12, 30, 42) . Furthermore, women have reported "increased feelings of vigor, physical self-concept, self-esteem, and self-efficacy, as well as decreased total mood disturbance" following regular resistance training workouts (42). Depression and anxiety levels in women over 60 years of age were reduced after a structured resistance training program lasting 12 weeks (12). Psychological benefits have been shown to be especially important in typical college age women as they transition from living away from home for the first time can be difficult (15).

The literature is clear that resistance training can be a valuable component to a women's overall fitness routine. Thus, it is important that if women do decide to partake in resistance training, they have a point of reference for developing an training program for improving their performance. This reference is equally important for the fitness professional to provide objective feedback to the client in regard to their strength performance. Normative value resources have been available for a wide array of resistance training exercises for multiple age groups, and populations (2, 4, 21, 36). Although these resources exist, much of the normative and referenced data are based upon smaller sample sizes or were established in the 1990's which likely does not represent the current fitness levels for various populations. Recent work by Piper et al .,2021, has determined normative values for the 10RM in resistance training exercises in over 1000 college aged males (33). This study was the first to establish 10RM norms for multiple resistance training exercises (i.e. bench press, leg press, seated front press, lat pulldown, and preacher curl). Establishing normative values for the 10RM in females however is non-existent. This lack of data can be detrimental due to the fact novice participants in resistance training have been recommended to do sets between 8-12 reps but may not have a reference to base their performance on (2) without a performance related goal or benchmark. The development of normative data could enhance program design and efficacy in the female population. Using a 10-repetition maximum (10RM) allows for the loads to be submaximal and could provide a better representation of the weights more commonly recommended for the novice client. While the 10RM is commonly used in programming and in research, no study has been conducted with the purpose of establishing 10RM normative data for college aged females. Therefore, the purpose of this study is to provide 10RM normative reference values for various resistance training exercises for 18 to 25-year-old females.

METHODS

Experimental Approach to the Problem

Cross-sectional performance and anthropometric data were obtained over the course of five years as part of a college basic strength training course. Data and training were conducted by twelve graduate students who were under the direct supervision and training from a National Strength and Conditioning Association (NSCA) Certified Strength and Conditioning Specialist (CSCS). Exercises were performed according to NSCA established guidelines (4, 9). Each testing and training session occurred in the same facility and utilized the same equipment. Testing occurred prior to the structured training program began and then again upon completion of 12 weeks of training.

All data from these strength tests were analyzed using IBM SPSS version 24. Following the same procedures as prior research (33) bodyweight categories were established by utilizing two established classifications from two lifting organizations: the International Weightlifting Federation (IWF) weight classes and the World Drug Free Powerlifting Federation (WDFPF) weight classes. These derived weight categories were: 110 lbs. or less, greater than 110-120 lbs., greater than 120-130 lbs., greater than 130-140 lbs., greater than 140-155 lbs., greater than 155-175 lbs., greater than 175-200 lbs., and greater than 200 lbs.

Subjects

Subjects included a sample of N=371 of female, college students. The Western Illinois University Institutional Review Board (IRB) in the Office of Sponsored Projects approved the study.

Operational definition of 10RM

For consistency with prior research (33) the same operational definition of 10RM was utilized. In the same manner as the aforementioned study a 10RM is defined as: the most weight that could be lifted for 10 repetitions with good technique. Reaching complete failure on each set was not the goal, but lifters were instructed to lift the highest load possible while maintaining proper form on each repetition. Speed of each repetition was under the discretion of the participants but they were encouraged to complete the concentric phase as quickly as possible and use a controlled eccentric phase. All subjects were required to follow the NSCA established lifting technique guidelines (4, 9) and any attempts that were deemed incongruent with these guidelines resulted in those subjects re-testing for the given exercise until they achieved a full set, with proper technique, of a 10RM.

Procedures

The exact same procedures and techniques utilized by Piper et al., (2021) were repeated in the present study. The following procedures are verbatim copies of the exact same procedures of testing and training. Piper et al., (2021) procedures included:

Prior to each testing session, subjects performed a general total body warm-up by performing five to 10 minutes of calisthenics, in addition to dynamic and static stretches. After the warm-up, subjects were tested on each of the exercises, with the exercises performed in random order. Exercises were performed according to the guidelines established by the NSCA (4, 9). All exercises were demonstrated and then supervised by researchers under the direct supervision and training of the primary investigator, who holds the title of NSCA-CSCS*D. This strict adherence to the NSCA guidelines was maintained to ensure that the specifications of the testing battery and exercise technique were properly followed. Any technique modifications are indicated with each respective exercise. Verbal encouragement was provided during each testing attempt. Spotters were available for lift-offs and for any needed assistance for safety purposes. Any test attempt in which spotters assisted in the performance of the exercise were considered unsuccessful and were not included in the data analysis.

For each test performed, subjects were instructed to self-select initial loads that they were confident they could perform for five to eight repetitions. After they completed one set with their starting load, they rested for approximately three minutes, and then performed another set with more weight. This procedure was repeated for at least five sets, but not more than eight sets. When subjects felt they had found a load they perceived was the most they could lift for 10 repetitions with good technique, they were directly observed by at least one researcher who evaluated each test attempt to ensure that lifting techniques met the prescribed requirements. If test sets were evaluated to be too heavy or were performed with poor technique, subjects were instructed to rest, lower the weight, and perform another test attempt. If the test was successful but deemed to be under the true 10RM, subjects were instructed to rest, add weight, and perform another test attempt. These procedures were repeated until a 10RM was achieved for each strength measure.

Training protocol

The entire program consisted of 2 weeks of pre-testing, 12 weeks of structured training, and concluded with 2 weeks of post-testing. Daily training sessions were led by NSCA-CSCS professors and trained graduate assistants who taught each exercise technique according to NSCA guidelines (4, 9). Each 50-minute training session included at least two multi-joint exercises for variations of squatting, pushing, and pulling exercises for a total of 18 sets minimum per session. Each session was concluded with some form of abdominal exercises for 1-3 sets of 10-20 reps or 30-60 seconds.

Daily workouts were recorded on training logs that were monitored for adherence and effort. This close monitoring helped to ensure that participants were compliant with total-body training requirements.

The set and rep scheme followed a traditional periodization model using three sets per exercise of varying RM loads. The first 6 weeks consisted of three sets of 8-10RM loads, followed by three weeks of three sets of 5RM loads, and concluded with three weeks of three sets of 3RM loads. Regardless of which rep scheme was being performed, sets one and two acted as warm-up sets prior to the most intense third set. Loads were adjusted daily to levels that allowed each exercise to be performed with proper technique up to, but not surpassing, a repetition maximum (RM) load on the final set.

Lat Pulldown

A lat pulldown station on a multi-station machine was used for all lat pulldown testing, (MuscleMaxx, multi-station compact gym).

Bench Press

The equipment used for bench press testing included a Legend 3-way adjustable bench (model 3103), a 45 lbs. York barbell, and York iron pound weight plates.

Seated Barbell Shoulder Press

The equipment used for seated front press testing included a Legend 3-way adjustable bench (model 3103), a 45-pound York barbell, and York iron pound weight plates. The seat back was inclined to 75o while subjects were seated in the five-point body contact position. The procedures for this lift were modified from the technique described in the literature (10), adopted under advisement of school athletic training staff to decrease the stress on the acromioclavicular joint. The modification included lowering the barbell in front of the face until it was immediately below the chin instead of to the clavicles.

Preacher Curl

The preacher curl was performed on a seated preacher curl station (Body Masters BE 207) with the arm pad angle of 40o, a standard 22-pound EZ curl barbell (York Barbell Olympic EZ curl bar, model 32042) and York iron pound weight plates. This exercise protocol was specifically developed for this study with collaboration from the CSCS researchers and athletic training staff. Subjects were seated on the bench with both feet flat on the floor. The height of the preacher bench pad was adjusted so that the posterior aspect of the upper arms rested flat on the arm pad. Using a supinated grip, subjects grasped the curling bar with the webbing of the thumbs resting in the narrowest portion of the curved portion of the EZ curl bar, with the hands between seven and 10 inches apart depending on hand size. The hands were held in approximately 25o of supination in line with the angle of the barbell. Subjects started in a fully flexed position (A point of contact between the forearms and biceps brachii). Once starting positioned was assumed, subjects then performed the eccentric portion of the exercise until the elbow joints reached a position of approximately 5-10 degrees of flexion in the elbow as measured by a goniometer (this procedure was adopted under advisement of the IRB and school athletic training staff to decrease the stress on the elbow joint). Subjects lifted the bar upward to the starting position by contracting the elbow flexors until the elbow joints were fully flexed while maintaining foot contact with the floor and buttocks in contact with the bench pad. No forward torso movement or backward rocking was allowed throughout the exercise.

Leg Press

The equipment used for leg press testing included a 45° leg press (ProMaxima, model P-118, height 63" Width-68", length 60") and York iron pound weight plates.

Subjects sat in the inclined leg press machine while having their lower back, hips, and buttocks in contact with the pads of the seat and back rest. Subjects then positioned their feet flat, hip-width apart on the leg press sled platform. Subjects then pressed the sled upwards, removed the support/

safety mechanisms and allowed the hip and knee joints to flex until the thighs were parallel with the foot platform and the knee joint was flexed past 90°, assessed via a 90° reference guide. Once the thighs and knees reached the parallel position, the subjects then pushed the platform up until the knee joints were fully extended. The sled support mechanisms were then reset.

Statistical Analyses

IBM SPSS Statistics version 24 for Windows (IBM corporation, Armonk, New York) was used for statistical analysis. Within each age group, extreme values (either very low or very high values) that exceeded 2 × IQR were Winsorized. A paired-samples t-test was used to determine whether there was a statistically significant mean difference between the pre-training and post-training strength measures. Further exploratory analysis of percentage increase for each lift was also calculated.

To generate standards for each strength measure, the 5th, 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, 90th, and 95th percentiles (37) were reported, where the weighted average method (39) was used to determine the percentile break points.

RESULTS

A total of 371 subjects completed the study. The overall means, standard deviations (SDs), minimum and maximum levels for age, years of training experience, height, weight, and body fat percentage are presented in table 1. Subject age ranged from 18 to 25 years old, with a mean age was19.86 +1.43 years. The mean height was 64.51 +2.90 inches. Years of experience ranged from none to 12 years, with a mean of 2.28 +2.38 years. Pre-test results for weight ranged from 88 to 311.8 pounds, with a mean of 151.19 +36.05 pounds. Pre-test body fat percentage ranged from 7 to 53.9 percent fat, with a mean of 29.20 +8.89 percent body fat. Post-test weight ranged from 88 to 318.6 pounds, with a mean of 153.66 +36.80 pounds. Post-test body fat percentage ranged from 7.5 to 55.8 percent fat, with a mean of 30.76 +8.44 percent body fat.

The descriptive statistics can be found in Table 1.

Table 1. Descriptive statistics of entire sample

	N	Minimum	Maximum	Mean	SD
Age (yrs)	371	18	25	19.86	1.43
Years of Experience	350	0	12	2.29	2.38
Height (in)	365	54	74	64.52	2.90
Pre-test Bodyweight (lbs.)	366	88	311.80	151.19	36.05
Pre-test Bodyfat %	364	7	53.90	29.20	8.90
Post-test Bodyweight (lbs.)	365	88	318.60	153.66	36.80
Post-test Bodyfat %	365	7.50	55.80	30.76	8.44
Valid N (listwise)	336				

Table 2. Pre-training weight (lbs.) categories

		Frequency	Percent	Valid Percent
Valid	110 or less	20	5.4	5.5
	110.1-120	43	11.6	11.7
	120.1-130	49	13.2	13.4
	130.1-140	59	15.9	16.1
	140.1-155	61	16.4	16.7
	155.1-175	62	16.7	16.9
	175.1-200	39	10.5	10.7
	200 or more	33	8.9	9.0
	Total	366	98.1	100.0
Missing	System	7	1.9	
Total		371	100.0	

Table 3. Post-training post weight (lbs.) categories

		Frequency	Percent	Valid Percent
Valid	110 or less	17	4.6	4.7
	110.1-120	31	8.4	8.7
	120.1-130	47	12.7	13.1
	130.1-140	60	16.2	16.8
	140.1-155	61	16.4	17.0
	155.1-175	64	17.3	17.9
	175.1-200	38	10.2	10.6
	200 or more	40	10.8	11.2
	Total	358	96.5	100.0
Missing	System	13	3.5	
Total		371		

Table 4. Pre-training and post training comparisons (all scores in pounds)

	Pre-Training Score Mean +Std. Deviation	Post-Training Score Mean +Std. Deviation	% increase between pre- and post-training
Lat Pulldown	74.63 +13.11	89.91 +12.91	20.5%
Bench Press	55.54 +13.11	68.39 +13.83	23.1%
Seated Front Press	44.77 +8.31	54.22 +10.10	21.1%
Preacher Curl	30.68 +7.36	40.12 +8.45	30.8%
Leg Press	166.10 +58.74	265.87 +80.75	60.1%

Upon further exploration the expected increases in strength for each exercise was found to vary for each exercise. T-test results revealed that each lift comparison pre-training to post-training scores all possessed a statistically significant increase (p>.001), are displayed in table 4, and include the mean score +standard deviation, and approximate percentage increase. The percentage increase between pre- and post-training was calculated by dividing the increase score by the original score and multiplying by 100.

Percentile ranks, performance ranks, sample size (n), mean, and standard deviation for pre-training and post-training for each weight class for the lat pulldown, bench press, seated front press, preacher curl, and leg press, are reported in tables 5-14, respectively.
To further enhance the utility of the data performance rankings were determined on both the pre-training and post-training data. The methodology for determining the normative data performance rankings was adopted from prior research (33) and is as follows: Excellent= Highest 5%, Good= next highest 15%, Regular= middle 60%, Poor=next lowest 15%, Very Poor= next lowest 5%. The rankings are displayed using gradients of grayscale highlights for each level of performance within tables 5-14. By designating the normative data with performance rankings practitioners can better explain an athlete's current strength level compared to this sample of college-aged students. This method of performance ranking is a common practice with a variety of other fitness measures and can be found in numerous resources (4, 11, 16, 21).

Table 5. Percentile ranks and descriptive statistics for Lat Pulldown Pre-Training

	Body Weight Class (lbs)							
Percen-tile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	99.50	88.00	90.00	90.00	100.00	98.50	100.00	120.00
90%	89.00	80.00	90.00	80.00	97.00	90.00	90.00	103.00
80%	80.00	70.00	80.00	80.00	90.00	90.00	90.00	100.00
70%	78.50	70.00	80.00	80.00	80.00	80.00	80.00	90.00
60%	70.00	70.00	75.00	80.00	80.00	80.00	80.00	90.00
50%	70.00	70.00	70.00	70.00	77.50	80.00	80.00	85.00
40%	60.00	66.00	70.00	70.00	70.00	70.00	70.00	80.00
30%	60.00	60.00	70.00	70.00	70.00	70.00	70.00	80.00
20%	52.00	60.00	60.00	60.00	70.00	70.00	70.00	80.00
10%	41.00	50.00	60.00	50.00	60.00	60.00	60.00	70.00
5%	40.00	50.00	50.00	50.00	60.00	60.00	60.00	70.00
n	20	43	49	59	62	62	39	33
Mean	67.25	66.57	72.04	71.69	76.45	77.10	77.82	87.12
SD	15.68	10.24	10.99	13.51	12.69	11.36	12.61	12.50

Table 6. Percentile ranks and descriptive statistics for Lat Pulldown Post-Training

	Body Weight Class (lbs)							
Percen-tile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	102.00	100.00	105.00	109.50	110.00	110.00	110.00	130.00
90%	102.00	90.00	100.00	100.00	107.00	105.00	110.00	129.00
80%	90.00	85.00	90.00	93.00	100.00	100.00	106.00	120.00
70%	86.00	80.00	90.00	90.00	92.75	100.00	100.00	110.00
60%	80.00	80.00	85.00	90.00	90.00	100.00	100.00	106.00
50%	80.00	80.00	80.00	80.00	90.00	90.00	95.00	100.00
40%	70.00	80.00	80.00	80.00	90.00	90.00	90.00	100.00
30%	70.00	80.00	80.00	80.00	89.41	90.00	90.00	100.00
20%	68.00	80.00	80.00	72.00	80.00	90.00	80.00	90.00
10%	60.00	70.00	70.00	70.00	80.00	80.00	74.50	90.00
5%	60.00	70.00	70.00	70.00	70.75	80.00	70.00	80.25
n	17	31	49	61	62	64	38	40
Mean	78.53	81.13	84.03	84.88	90.44	94.10	94.01	104.25
SD	13.89	7.15	10.79	11.20	10.14	9.11	12.62	14.17

Index to Performance Rankings
Excellent =highest 5%
Good= next highest 15%
Average= middle 60%
Below average=next lowest 15%
Poor=lowest 5%

Table 7. Percentile Ranks and Descriptive Statistics for Bench Press Pre-Training

	Body Weight Class (lbs)							
Percentile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	74.25	65.00	70.00	75.00	84.00	84.25	90.00	115.00
90%	59.50	65.00	65.00	70.00	74.00	75.00	85.00	91.00
80%	55.00	55.00	65.00	65.00	65.00	65.00	70.00	76.00
70%	45.00	55.00	60.00	55.00	65.00	65.00	65.00	65.00
60%	45.00	50.00	55.00	55.00	60.00	59.00	65.00	65.00
50%	45.00	45.00	50.00	50.00	55.00	55.00	60.00	55.00
40%	45.00	45.00	45.00	45.00	55.00	55.00	55.00	55.00
30%	45.00	45.00	45.00	45.00	50.00	45.00	55.00	55.00
20%	40.00	39.00	45.00	45.00	45.00	45.00	45.00	49.00
10%	26.50	35.00	40.00	45.00	45.00	45.00	45.00	45.00
5%	25.00	30.00	35.00	45.00	45.00	45.00	35.00	45.00
n	20	43	49	59	61	62	39	33
Mean	46.00	48.26	52.24	53.19	57.55	57.42	59.74	63.33
SD	10.95	11.39	10.61	10.46	11.42	12.14	14.82	18.01

Table 8. Percentile Ranks and Descriptive Statistics for Bench Press Post-Training

	Body Weight Class (lbs)							
Percentile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	76.00	80.00	78.00	89.75	90.00	105.00	95.00	105.00
90%	76.00	75.00	75.00	84.50	85.00	90.00	95.00	95.00
80%	64.00	73.00	70.00	75.00	80.00	85.00	85.00	94.00
70%	58.00	65.00	70.00	70.00	75.00	77.50	81.50	85.00
60%	55.00	61.00	65.00	70.00	70.00	75.00	75.00	80.00
50%	55.00	60.00	65.00	65.00	68.33	70.00	75.00	75.00
40%	51.00	59.00	56.00	65.00	65.00	65.00	70.00	70.00
30%	50.00	55.00	55.00	60.00	65.00	65.00	65.00	65.00
20%	45.00	55.00	50.00	60.00	60.00	60.00	60.00	65.00
10%	43.00	55.00	45.00	55.00	55.00	55.00	54.50	60.00
5%	35.00	51.00	45.00	45.00	55.00	55.00	39.75	55.25
n	17	31	47	60	61	64	38	40
Mean	55.29	62.10	61.38	67.00	69.48	72.11	72.89	77.13
SD	11.38	8.73	9.87	12.15	11.10	13.62	15.45	14.05

Index to Performance Rankings
Excellent =highest 5%
Good= next highest 15%
Average= middle 60%
Below average=next lowest 15%
Poor=lowest 5%

Table 9. Percentile Ranks and Descriptive Statistics for Seated Front Press Pre-Training

	Body Weight Class (lbs)							
Percentile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	54.75	55.00	55.00	60.25	55.00	55.00	45.00	65.00
90%	49.50	45.00	55.00	55.00	55.00	55.00	40.00	65.00
80%	45.00	45.00	50.00	45.00	50.00	55.00	40.00	59.00
70%	45.00	45.00	45.00	45.00	45.00	50.00	40.00	55.00
60%	45.00	45.00	45.00	45.00	45.00	46.00	35.00	49.00
50%	42.50	45.00	45.00	45.00	45.00	45.00	35.00	45.00
40%	37.00	35.00	40.00	40.00	45.00	45.00	30.00	45.00
30%	35.00	35.00	38.50	35.00	45.00	45.00	30.00	45.00
20%	35.00	35.00	35.00	35.00	40.00	42.00	20.00	45.00
10%	26.00	35.00	35.00	34.50	35.00	35.00	20.00	41.50
5%	20.25	27.75	25.00	25.00	35.00	35.00	20.00	35.00
n	20	42	48	58	61	61	37	32
Mean	40.00	40.60	42.81	42.33	45.49	46.89	47.84	50.00
SD	8.27	7.42	8.18	9.00	7.05	7.26	7.41	8.89

Table 10. Percentile Ranks and Descriptive Statistics for Seated Front Press Post-Training

	Body Weight Class (lbs)							
Percentile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	72.00	70.00	65.00	65.00	75.00	75.00	85.00	94.50
90%	72.00	59.50	65.00	60.00	70.00	72.50	75.50	80.00
80%	54.00	55.00	55.00	55.00	60.00	65.00	66.00	65.00
70%	45.00	55.00	55.00	55.00	60.00	60.00	65.00	65.00
60%	45.00	50.00	51.00	50.00	55.00	55.00	60.00	65.00
50%	45.00	47.50	50.00	50.00	55.00	55.00	57.50	65.00
40%	45.00	45.00	50.00	50.00	55.00	50.00	55.00	57.00
30%	40.00	45.00	45.00	45.00	50.00	50.00	55.00	55.00
20%	35.00	45.00	45.00	45.00	50.00	45.00	50.00	55.00
10%	34.00	40.00	38.50	40.00	45.00	45.00	45.00	45.00
5%	30.00	40.00	35.00	40.00	45.00	45.00	45.00	45.00
n	17	30	46	60	60	64	38	40
Mean	46.47	49.67	50.22	50.25	55.99	56.01	59.61	61.88
SD	12.84	7.98	8.23	7.78	8.48	9.86	10.61	12.34

Index to Performance Rankings
Excellent =highest 5%
Good= next highest 15%
Average= middle 60%
Below average=next lowest 15%
Poor=lowest 5%

Table 11. Percentile Ranks and Descriptive Statistics for Preacher Curl Pre-Training

	Body Weight Class (lbs)							
Percentile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	40.00	40.00	42.75	40.25	45.00	45.00	45.00	50.00
90%	39.50	35.00	40.00	40.00	40.00	45.00	40.00	48.50
80%	30.00	30.00	35.00	35.00	35.00	40.00	40.00	40.00
70%	30.00	30.00	30.00	30.00	32.38	40.00	40.00	40.00
60%	30.00	30.00	30.00	30.00	30.00	35.00	35.00	35.00
50%	25.00	25.00	30.00	30.00	30.00	30.00	35.00	35.00
40%	25.00	25.00	25.00	30.00	30.00	30.00	30.00	30.00
30%	25.00	25.00	25.00	25.00	30.00	30.00	30.00	30.00
20%	21.00	25.00	20.00	20.00	25.00	27.00	20.00	30.00
10%	20.00	20.00	20.00	20.00	20.00	25.00	20.00	30.00
5%	10.50	20.00	20.00	20.00	20.00	20.00	20.00	23.25
n	20	43	48	58	61	61	39	32
Mean	27.00	27.09	28.96	29.48	30.83	33.49	32.44	35.47
SD	6.96	5.48	7.29	7.47	6.47	7.37	7.85	7.34

Table 12. Percentile Ranks and Descriptive Statistics for Preacher Curl Post-Training

	Body Weight Class (lbs)							
Percentile	**<110**	**110<-120**	**120<-130**	**130<-140**	**140<-155**	**155<-175**	**175<-200**	**200>**
95%	40.50	50.00	55.00	50.00	50.00	55.00	60.00	65.00
90%	40.50	48.50	51.00	45.00	50.00	55.00	55.00	59.50
80%	40.00	42.00	45.00	45.00	45.00	50.00	50.00	54.00
70%	38.25	40.00	40.00	40.00	45.00	50.00	50.00	50.00
60%	35.00	35.00	40.00	40.00	40.00	45.00	45.00	45.00
50%	35.00	35.00	40.00	40.00	40.00	45.00	45.00	45.00
40%	30.00	35.00	35.00	37.00	40.00	40.00	40.00	40.00
30%	28.50	30.00	30.00	35.00	35.00	40.00	40.00	40.00
20%	25.00	30.00	30.00	30.00	35.00	35.00	38.00	40.00
10%	24.50	25.00	29.00	30.00	30.00	30.00	35.00	35.00
5%	20.00	23.25	25.00	25.00	30.00	26.25	34.00	35.00
n	18	32	47	60	62	64	37	40
Mean	32.91	35.70	37.87	38.00	39.83	43.17	44.53	45.30
SD	6.98	7.71	8.52	7.38	6.51	9.31	7.90	8.86

Index to Performance Rankings
Excellent =highest 5%
Good= next highest 15%
Average= middle 60%
Below average=next lowest 15%
Poor=lowest 5%

Table 13. Percentile Ranks and Descriptive Statistics for Leg Press Pre-Training

	Body Weight Class (lbs)							
Percen-tile	<110	110<-120	120<-130	130<-140	140<-155	155<-175	175<-200	200>
95%	272.50	323.00	347.50	367.00	365.00	405.00	435.00	495.00
90%	225.00	309.00	315.00	315.00	315.00	365.00	405.00	487.00
80%	225.00	245.00	285.00	279.00	315.00	323.00	365.00	406.00
70%	225.00	225.00	240.00	275.00	286.00	315.00	315.00	393.00
60%	200.00	225.00	225.00	245.00	270.00	280.00	300.00	315.00
50%	185.00	215.00	225.00	225.00	245.00	240.00	275.00	305.00
40%	171.00	187.00	200.00	225.00	225.00	225.00	275.00	275.00
30%	150.00	185.00	160.00	202.00	225.00	194.50	270.00	234.00
20%	146.00	175.00	150.00	180.00	185.00	175.00	225.00	225.00
10%	113.50	126.50	135.00	145.00	150.00	139.50	185.00	190.00
5%	62.50	106.50	87.00	127.00	130.75	120.00	160.00	148.50
n	20	42	49	57	62	62	39	33
Mean	182.50	210.36	215.41	232.98	249.28	251.13	289.74	315.90
SD	49.51	60.97	73.68	66.12	69.47	86.44	74.98	102.75

Table 14. Percentile Ranks and Descriptive Statistics for Leg Press Post-Training

	Body Weight Class (lbs)							
Percen-tile	<110	110<-120	120<-130	130<-140	140<-155	155<-175	175<-200	200>
95%	317.00	443.00	405.00	455.00	423.00	538.00	548.00	855.00
90%	317.00	351.00	405.00	429.00	394.00	490.00	506.00	677.00
80%	299.00	335.00	360.00	347.00	365.00	417.00	496.00	558.00
70%	251.00	315.00	328.00	315.00	350.00	405.00	461.00	467.00
60%	237.00	315.00	315.00	305.00	333.15	382.00	409.00	425.00
50%	225.00	300.00	295.00	295.00	305.00	350.00	390.00	405.00
40%	225.00	275.00	275.00	275.00	300.00	321.00	365.00	367.00
30%	204.00	248.00	245.00	254.00	275.00	315.00	343.00	345.00
20%	185.00	239.00	225.00	245.00	269.00	285.00	315.00	315.00
10%	164.00	213.00	169.00	209.00	233.00	262.00	249.00	272.00
5%	100.00	187.00	160.00	198.00	225.00	246.00	214.00	233.00
n	17	31	48	57	61	63	38	38
Mean	233.53	291.45	289.38	300.18	317.99	360.38	394.08	434.74
SD	60.87	64.22	76.94	74.43	74.51	85.02	96.79	155.22

Index to Performance Rankings
Excellent =highest 5%
Good= next highest 15%
Average= middle 60%
Below average=next lowest 15%
Poor=lowest 5%

DISCUSSION

This study aimed to develop normative 10RM strength measures for healthy college-aged females, based on a large sample (n = 371 subjects) that is separated into eight meaningful weight categories, and percentile ranks. These results are important because they provide the first published 10RM normative values and performance rankings for common strength exercises for healthy college-age females.

Although other studies have generated mean or normative data for grip strength (3, 21), relative strength measures for supine bench press (11), muscle endurance for push-ups (3), no current literature is available for 10RM normative data in females. Prior research has produced strength ratios based upon bodyweight and 1RM loads lifted (21) and equations to estimate RM loads (7, 13, 27, 28). However, the 10RM normative data from the present study offers a quick reference guide for practitioners. While the estimations of loads or strength ratios have their place in testing and training applications, the use of normative data comparison is an easier way to assess 10RM strength measures.

Another positive aspect of the present study is that it spans from novice to intermediate training status of the participants. The ACSM definition of a novice trainer is someone who possesses less than several years of resistance training experience (2) while NSCA defines a novice or beginner as a person who has not been trained or has just begun resistance training with less than 2 months of experience (9) or zero to six months of training (10). The normative data developed from this study is useful for both the novice, according to the ACSM definition or the beginner to intermediate level individual, according to the NSCA definitions. The performance ratings provide the athlete and coaches with feedback on strength levels, establish training goals, aids in modifying training programs, and provides objective data for tracking of progress.

Based upon the current data, expected strength gains for a beginner can be estimated as they progress over a 12-week period of consistent resistance training. The findings of the present study indicate a typical percentage strength increase between 20-30% for upper body exercises and a 60% increase in lower body strength. The results of this exploratory analysis of mean strength scores follows a similar trend to that of the male counterparts in previous research (33) but shows a much larger overall change in strength from pre-test compared to post-test. While the testing and training protocol was identical in both the present study and the aforementioned study, the percent of increase is much more dramatic. Whereas male upper body strength scores increased by approximately 10-16% for upper body strength scores, the female scores increased by approximately 20-30% in the same exercises. For the leg press the males increased by approximately 19% while the females increased their strength by 60% in the present study.

While amount of increased strength and rate of increase may vary based upon physical maturity, training experience, genetics, hormonal levels, etc., the present study helps with making realistic predictions of strength based upon starting levels. Moreover, the current study's resistance training program was under a certified professional and the increases may not be the same if performed unsupervised. Future research should examine the difference between supervised and unsupervised resistance training programs for this population, along with the effects of percentage increases as a person becomes experienced. While further strength improvements are likely to occur these percentage of strength gains after a lifter has reached the intermediate level of training and reaches the level of an advanced lifter will probably be blunted.

When beginning a training program, it is common to find recommendations for starting at 8-12RM or 10RM loads (1, 9, 10) but without any form of normative data a lifter is left without a point of reference for standards of performance. The tables developed from this data give the practitioner a means of comparing current 10RM loads to lifters of similar age, gender, and training status. Being the first study to establish 10RM normative data for female participants is useful to help determine levels of performance for the novice lifter, based upon pre-training findings (tables 5,7,9,11,13) based on 12-weeks of structured resistance training.

In addition to the application of 10RM normative data to training program design the data is also of value to many occupations. Training someone for a given occupation to perform job-specific tasks, in the most optimal manner and with appropriate loads, could reduce the chance of training related injuries due to overexertion. Although maximal lifts may be needed in some occupations, there is typically a physical exertion demand level that follows the U.S. Bureau of Labor Statistics that is complemented with the employer's job description. Pushing, pulling, lifting, and carrying are occupational specific tasks that are performed during work shifts requiring either maximal or repetitive displays of strength. The physical fitness assessment of tactical occupations has testing to be accepted into and graduate from training (e.g. U.S. Army basic training). Although the strength tests can vary from dynamic (e.g. pull-up), isometric (e.g. hip-leg dynamometer), to isokinetic (e.g. knee extension) these all can provide an assessment that correlates to some occupational task performance (8, 31). The use of dynamic strength tests may have a greater application to occupational task performance thus testing a person's 10RM capabilities can be used a way to classify a person's strength level prior to their entry to training. Testing a person to meet a criterion for a job provides only an assessment of what they are physically capable of for a single attempt or time. Using the 10RM as a testing method on subsequent days provides a more robust assessment of the person's capabilities of having to repeat strength tasks that are experienced in daily work shifts.

While future research should explore the 1RM scores of males and females, the preparation for testing a single maximal effort is not necessarily practical as this requires a person to have confidence to be placed under physical stress for this strength test. On the other hand, a 10RM that is commonly used in training and would be more practical and efficient to occupational task assessment as person can more easily stop as technique begins to deteriorate. Daily tasks are not always performed at a single maximal strength output (e.g. 100% 1RM), but these occupational tasks are instead repeated strength actions with submaximal loads performed throughout a typical day. Testing a person's 10RM on subsequent training days provides a more robust assessment of the person's capabilities of having to repeat daily tasks. The ability to rank a person's repeated strength, based on a 10RM, can provide practitioners the ability to develop the most effective plan and programs to address physical abilities that may need improvement or others to be maintained for work, sport, or recreation.

PRACTICAL APPLICATIONS

The application of 10RM training has a long history and is a convenient, safe, and effective method for beginners undertaking a strength training program. Evaluation of strength is a common concern of lifters, athletes, coaches, and trainers. Due to the recommendations that novice lifters begin training programs with 10RM loads it is beneficial to have a reference point to a lifter's current strength levels for realistic comparisons and programming.

The use of normative data for evaluation is only useful if it matches the sample of reference. The specific pre-test data provided in the present study will be useful for assessment of novice college-age females. The post-test data in the present study will be useful for application to the novice or intermediate lifter with 12 weeks of training experience. In both cases, some may choose to use the percentile rankings or performance ratings to establish a lifter profile. This kind of profiling can be useful for lifter grading, ranking, and programming.

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