Journal of Strength and Conditioning Research, 2007, 21(1), 34–40

Maximal Eccentric and Concentric Strength Discrepancies Between Young Men and Women for Dynamic Resistance Exercise

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Abstract. Hollander, D.B., R.R. Kraemer, M.W. Kilpatrick, Z.G. Ramadan, G.V. Reeves, M. Francois, E.P. Hebert, and J.L. Tryniecki. Maximal eccentric and concentric strength discrepancies between young men and women for dynamic resistance exercise. *J. Strength Cond. Res. 21(1):34–40. 2007.*—Although research has demonstrated that isokinetic eccentric (ECC) strength is 20–60% greater than isokinetic concentric (CON) strength, few data exist comparing these strength differences in standard dynamic resistance exercises. The purpose of the study was to determine the difference in maximal dynamic ECC and CON strength for 6 different resistance exercises in young men and women. Ten healthy young men (mean ± *SE*, 25.30 ± 1.34 years), and 10 healthy young women (mean ± *SE*, 23.40 ± 1.37 years) who were regular exercisers with resistance training experience participated in the study. Two sessions were performed to determine CON and ECC 1 repetitions maximum for latissimus pull-down (LTP), leg press (LP), bench press (BP), leg extension (LE), seated military press (MP), and leg curl (LC) exercises. Maximal ECC and maximal CON strength were determined on weight stack machines modified to isolate ECC and CON contractions using steel bars and pulleys such that only 1 type of contraction was performed. Within 2 weeks, participants returned and completed a retest trial in a counterbalanced fashioned. Test-retest reliability was excellent ($r = 0.99$) for all resistance exercise trials. Men demonstrated 20–60% greater ECC than CON strength (LTP = 32%, LP = 44%, BP = 40%, LE = 35%, MP = 49%, LC = 27%). Women's strength exceeded the proposed parameters for greater ECC strength in 4 exercises, $p < 0.05$ (LP = 66%, BP = 146%, MP = 161%, LC = 82%). The ECC/CON assessment could help coaches capitalize on muscle strength differences in young men and women during training to aid in program design and injury prevention and to enhance strength development.

Key Words. dynamic strength, gender

Introduction

Eccentric (ECC) resistance training has been shown to increase muscular strength and produce muscle hypertrophy (4, 8, 10). Moreover, it has recently been reported that resistance training using concentric (CON) and ECC contractions, with greater ECC loading, produces specific adaptations for a stronger, faster muscle, as indicated by greater IIx myosin adenosine triphosphatase gene expression using primarily isokinetic protocols (11, 35, 42). These findings have been validated through enhanced performance in Olympic lifters who trained with loads that were between 10 and 30% above their CON 1 repetitions maximum (RMs) across 6 weeks (13). Additionally, in powerlifters, a slower ECC movement was observed in better performances in the bench press and squat exercises during competitions (28, 32). Thus, preliminary evidence in resistance exercise research suggests that ECC overload can enhance lifting performance. Despite these findings, implementation of ECC overload strength training has been lacking in traditional strength and conditioning program designs. One contributing factor may be the lack of an established method for determining dynamic ECC strength. Without a valid, standardized protocol in place for determining optimal ECC load during training, potential for injury and ineffective loading is great. Moreover, if the goals of strength and conditioning coaches are to help prevent injury and enhance athletic performance, then the development of an optimal 1RM determination to individualized dynamic ECC training protocol would be beneficial.

With a few exceptions (30, 44), previous ECC strength studies have employed isokinetic machines (6, 7, 14–19, 31, 40, 45). These studies have demonstrated a range of greater ECC relative to CON isokinetic strength. It is not currently known whether these strength differences exist for dynamic constant external resistance exercises. If these values can be determined, it is possible that training loads of ECC and CON portions of resistance training could be optimized for more rapid training adaptation and injury prevention.

Additionally, the potential moderating factor of gender remains relatively understudied with regard to dynamic resistance exercise. Several studies have attempted to quantify the relation between isokinetic ECC and CON strength between men and women; however, no investigations have been identified that compare maximal ECC/CON dynamic strength ratios across gender. There is some evidence that these differences may be affected by the gender of the participants being examined, with greater isokinetic ECC/CON torque ratios in women than in men between the ages of 20 and 93 years. (26, 27). Griffin et al. (12) further supported gender discrepancies when comparing ECC and CON strength differences in elbow and knee joint exercises. Although the use of isokinetic ECC strength data may be very helpful in rehabilitation settings, the translation of this research into functional recommendations for athletes who normally train on dynamic resistance machines such as weight-stack equipment, plate-loaded equipment, or free weights is lacking. Investigators are challenged to explore the

FIGURE 1. Lat pulldown.

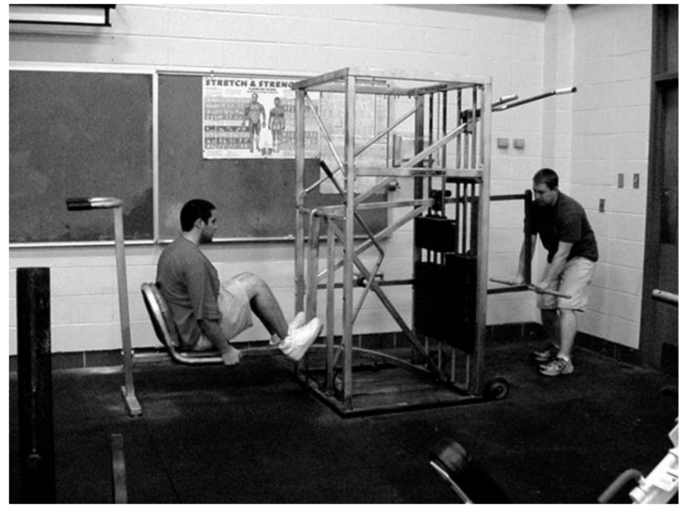

FIGURE 2. Leg press.

paradigm of dynamic resistance exercise, as the lack of control for range of motion, speed of movement, and consistency of levers across equipment manufacturers often impedes ecologically valid or comparable data. Moreover, although Kraemer and Ratamess (25) have provided some guidance with regard to the fundamentals of resistance training, there are very few data concerning maximal ECC/CON strength differences for different resistance exercises. Thus, description of the differences in maximal strength for different ECC and CON dynamic resistance exercises could be very applicable to typical exercise programs for athletes and noninjured exercisers.

Thus, the purpose of the present investigation was to determine the difference in maximal dynamic ECC and CON strength for 6 resistance exercises in young men and women using elements of previously reported protocols for determining maximal CON strength (14, 24, 34). Because previous studies have demonstrated equivocal results when comparing isokinetic ECC and CON strength between samples of men and women (14, 24, 34, 36), it was hypothesized that dynamic ECC/CON strength ratios using a constant load would be greater in young women than in young men, but that the strength ratios would be within previously reported ranges for isokinetic strength. The isokinetic strength in 654 individuals documented by Lindle and colleagues supports this hypothesis. Specifically, maximal ECC strength would be roughly 20–60% greater than CON maximal strength in both young men and young women (20, 24).

METHODS

Experimental Approach to the Problem

We determined CON and ECC strength for 6 conventional resistance exercises in 2 counterbalanced and randomized trials on separate days. During the trials, either a CON or an ECC 1RM was established for each subject. Within 2 weeks, subjects returned and completed a retest trial to establish reliability. The main outcome measures were ECC and CON 1RMs and ECC/CON strength ratios. The ECC/CON strength ratios for young men and women were contrasted with the previously reported isokinetic strength ratios (120–160%). In addition, we compared these values between young men and women.

Subjects

The study was approved by the Southeastern Louisiana University Institutional Review Board. Ten healthy young men and 10 healthy young women volunteers participated in the study. The subjects were recreational, noncompetitive exercisers with resistance training experience for a minimum of 1 year and were between 18 and 30 years of age. A health history questionnaire was administered to rule out (a) participation in competitive bodybuilding or weightlifting for the previous year, (b) smoking, (c) taking medications that could alter test results (e.g., anabolic steroids or sympathoadrenal drugs), (d) history of pituitary, renal, hepatic, cardiovascular, or metabolic disease, (e) adherence to a reduced-calorie, low-fat, or ketogenic diet that could affect hormone levels, and (f) use of commercial ergogenic aids in the past 6 months, such as creatine monohydrate, androstenedione, dehydroepiandrosterone, or ephedra.

The subject sample represented young healthy subjects whose strength data were greater than those of novice lifters but not quite as high as strength data reported for collegiate athletes (2, 29, 38, 39). Our sample represented a median strength sample that was neither hindered by lack of training nor limited by advanced training such that application of results could be considered for a greater strength range of individuals.

Concentric and Eccentric Trials

We employed conventional resistance exercise that involved the performance of dynamic, full range-of-motion contractions against a constant external load. Two separate sessions were performed to establish CON and ECC 1RMs for lat pull-down (LTP), leg press (LP), bench press (BP), leg extension (LE), seated military press (MP), and leg curl (LC) on weight stack machines (Master Trainer, Rayne, LA). The exercises selected included multi-joint and single-joint exercises that have been employed in many resistance training regimens and have been determined to be effective in increasing muscular strength and power (24). Equipment was modified to isolate ECC and CON contractions using steel bars and pulleys. The trials began with a 3-set warm-up followed by a counterbalanced and randomized trial of determining the CON and

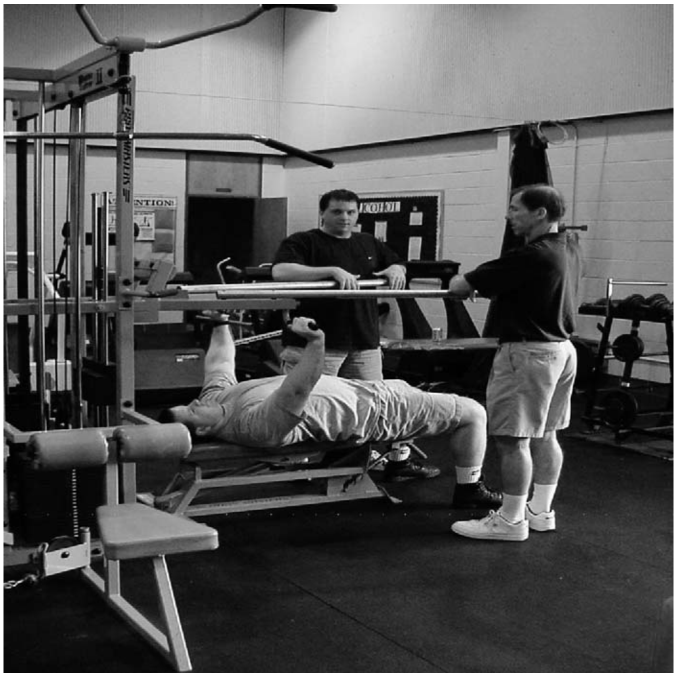

Figure 3. Bench press.

ECC 1RM. Before each subject was tested, two 48-in. (10 lb each) steel pipes were bolted on top of the machine bench and military press. The steel rods were placed on the machine before the 1RM to simulate the conditions of the CON and ECC trials. For the lat pull-down and the leg extension, a spotting mechanism was designed so that the subject only performed either ECC or CON movements, while the spotter(s) performed the other half of the lift (Figures 1–6). The protocol to determine CON or ECC 1RMs employed elements of previously published protocols (14, 24, 34).

Briefly, a 2–3 set warm-up was performed with 5–10 repetitions that represented 40–60% of a perceived maximal exertion. Each warm-up set was performed in a linear progression. Subjects were instructed to perform the next 1–2 sets for 5 repetitions at a weight that was approximately 80% of perceived 1RM. Following these sets, subjects were instructed to perform a 1RM for ECC or CON actions; if the 1RM was not achieved, a lighter weight was chosen. Rest periods between all sets were 3–5 minutes. The CON and ECC contractions were performed to a 3-second cadence (14, 34) and failure was determined as inability to maintain the 3-second cadence throughout the range of motion.

Every effort was made to ensure that speed of movement was maintained throughout the maximal lifting attempt. An external metronome recording of the 3-second cadence was played during the lift. Based on the warm-up trials, distance traveled by the weight stack was recorded and grommets were placed as external markers on

Table 1. Demographic characteristics of the sample.*

	Age (y)	Height (cm)	Weight (kg)
Men (N = 10)	25.30 (1.34)	177.54 (1.98)	88.91 (4.42)
Women (N = 10)	23.40 (1.37)	164.34 (3.39)	66.45 (5.19)

* Data are expressed as mean (± *SE*).

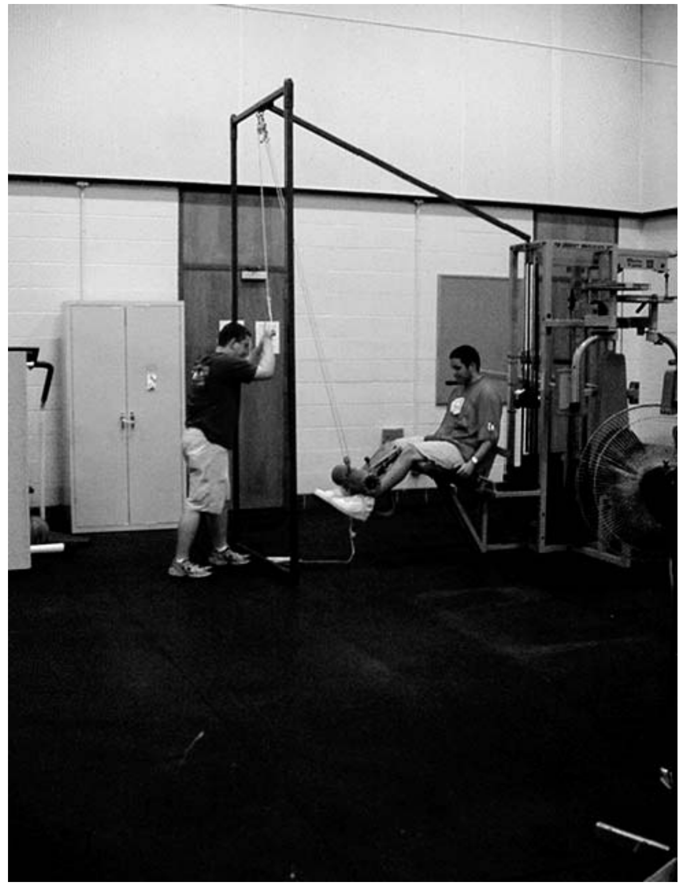

Figure 4. Leg extension.

the machine to designate when the weight had traveled each third of the full distance. A measuring yardstick was placed on the machine as well as an arrow on the weight stack to keep measurements accurate. An observer watched the range of motion to determine that the weight passed along each predesignated range throughout the 3 seconds so that adherence to the 3-second cadence at the specified range of motion was maintained. This was to

Table 2. Concentric (CON) and eccentric (ECC) strength values for young men and women.*

	Men		Women	
Exercises	Mean	*SE*	Mean	*SE*
LTP CON	100.68	3.46	59.55	2.08
LTP ECC	132.05	5.64	76.82	3.48
LP CON	188.64	8.77	107.05	7.49
LP ECC	270.23	8.02	174.32	11.35
BP CON	148.41	12.74	30.91	4.00
BP ECC	203.18	14.73	69.09	5.58
LE CON	74.09	3.64	39.77	2.63
LE ECC	99.09	4.38	61.82	5.43
MP CON	84.55	7.40	20.23	3.22
MP ECC	124.55	10.61	44.55	3.44
LC CON	35.00	1.18	13.18	1.43
LC ECC	44.09	1.36	22.27	2.08

* Data are values in kg for absolute 1 repetition maximum ECC and CON strength. LTP = lat pulldown; LP = leg press; BP = bench press; LE = leg extension; MP = military press; LC = leg curl.

FIGURE 5. Military press.

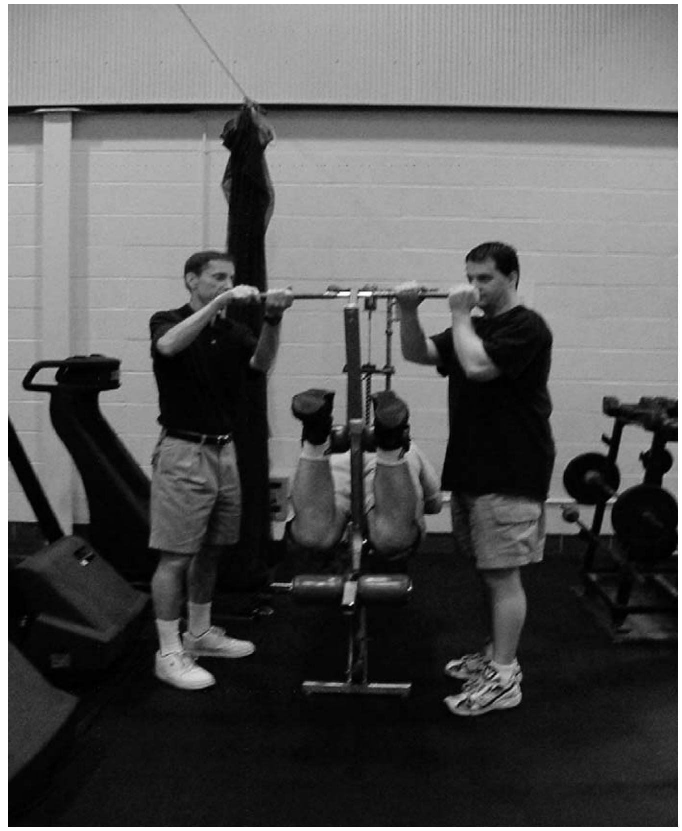

FIGURE 6. Leg curl.

ensure that neither gravity nor inconsistent effort hampered results. The 3-second cadence selection was an important aspect of this study because recommendations for ECC and CON exercise have traditionally used an isokinetic protocol. Two recent studies have demonstrated a comparable cadence of 3 seconds for determining CON and ECC differences for isokinetic contractions (14, 34). Kraemer and Ratamess (25) noted research that in a 5RM for bench press, the speed of the repetitions varied from 1.2 to 3.3 seconds, depending on fatigue (33). Thus, the speed of our protocol was consistent with documented speeds during dynamic resistance exercise. Within 2 weeks, subjects returned and completed a retest trial.

Statistical Analyses

Resistances were recorded and data were reduced into percentage of CON for ECC maximal lifts to compare ECC strength to CON strength in young men and women. All results were considered significant at $p \leq 0.05$. To compare ECC and CON strength ratio between genders for each resistance exercise, *t*-tests were used. Test-retest reliability was determined using intraclass correlations (43).

RESULTS

Demographic data are presented in Table 1. Height and weight were significantly greater for the men ($p < 0.01$), whereas age was not. When comparing test-retest reliability between the first and second maximal attempts, correlations were $r = 0.99$ or better for all resistance exercise trials. Maximal ECC and CON values are presented in Table 2.

Independent *t*-tests revealed that women, on all exercises except the LTP and LP, had a significantly higher ECC to CON difference when compared to men ($t = -3.98$, -2.38, -2.97, and -2.91; $p < 0.05$). As shown in

TABLE 3. ECC/CON strength ratios and effect sizes (ES).*

	LTP	LP	BP	LE	MP	LC
Men	1.45 (5.09)	1.46 (2.76)	1.40 (4.58)	1.38 (4.42)	1.51 (5.09)	1.30 (3.63)
Women	1.57 (5.20)	1.71 (6.98)	2.40 (0.16)	1.57 (4.23)	2.87 (0.36)	1.83 (0.12)
ES	0.52	1.06	2.68	0.97	1.18	1.33

* All strength ratios are reported in mean (± *SE*) increments. LTP = lat pulldown; LP = leg press; BP = bench press; LE = leg extension; MP = military press; LC = leg curl.

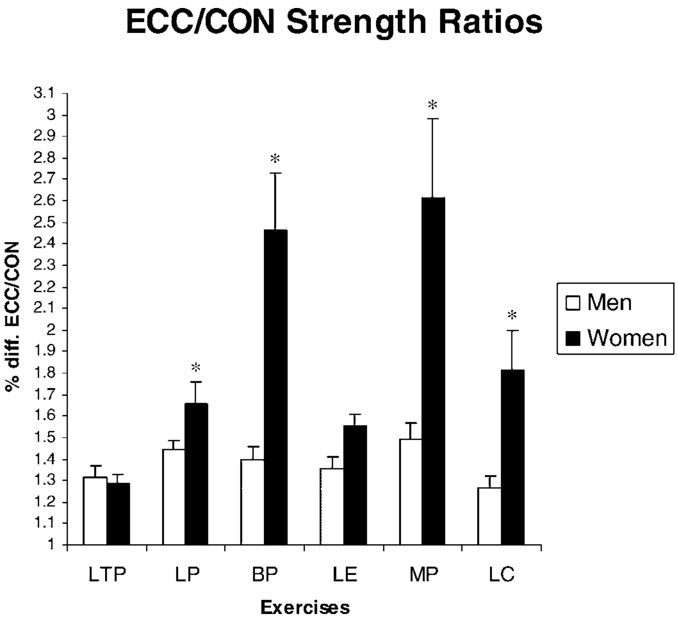

FIGURE 7. Eccentric (ECC) 1 repetition maximum (1RM) values represented as percentage of concentric (CON) 1RMs in young men and women. LTP = lat pulldown; LP = leg press; BP = bench press; LE = leg extension; MP = military press; LC = leg curl. Significant difference for ECC to CON strength ratios for women when compared to men, $p < 0.05$.

Figure 7, men demonstrated greater ECC than CON strength within previously proposed parameters of 20–60% of 1RM (LTP = 32%, LP = 44%, BP = 40%, LE = 35% MP = 50%, LC = 27%), but women did not. Women'sstrength exceeded the proposed parameters for greater ECC than CON strength in 4 exercises (LP = 66%, BP = 146%, MP = 161%, LC = 82%).

Table 3 indicates the average ECC/CON 1RM ratio for men and women for each strength exercise. This table also provides the effect size statistic for each exercise, indicating the magnitude of the difference between men and women. Women's ratios were higher than those of men for all exercises, and effect sizes ranged from 2.68 to 0.52. The largest gender differences were for the BP, LC, MP, and LP, with mean effect sizes for these exercises all over 1.0; the smallest difference was for the LTP exercise, with this effect size at 0.52. Post hoc power estimates were conducted using the given study parameters (e.g., N = 20) and effect sizes observed (23). It was determined that power to detect differences with effect sizes as large as those found to be significant (effect size ≥ 1.0) was approximately 0.60. However, with the number of subjects in the study, power to find the difference between women and men for LTP as significant was approximately 0.20. Overall, the effect size calculations and the power comparison indicated that the number of subjects to detect differences with the current design was adequate for all but the LTP exercise.

DISCUSSION

The findings revealed large interexercise variability for the ECC/CON strength ratios among different exercises. It also demonstrated that dynamic ECC compared with CON strength was greater in young women than in young men for some resistance exercises and that these strength ratios in women exceeded previously described isokinetic ECC/CON strength ratios (14, 17). Moreover, upper-body movements of the bench press and the military press demonstrated considerably larger ECC/CON ratios (BP = 146%, MP = 161%) than leg movements (LP = 66%, LC = 82%) for women.

Previous studies have shown greater ECC relative to CON isokinetic strength (17). In an early investigation of ECC and CON strength employing a manual isokinetic dynomometer, Doss and Karpovich found that ECC force was 39.7% greater than CON force of elbow flexors (7). Singh and Karpovich (41) reported isokinetic ECC forces of flexors and extensors to be 32.65% and 14.22% greater than CON forces employing an electronically-operated dynamometer, respectively. Using a Cybex isokinetic dynamometer, Rodgers and Berger (37) found approximately 80% greater torque produced with ECC than with CON contractions. Hortobagyi and Katch (16) reported that ECC isokinetic strength was 22–60% greater than isokinetic CON strength when testing subjects on a Biodex dynamometer. Both upper-body (primarily the biceps brachii in elbow extension and flexion) and lower-body strength (primarily the quadriceps in knee flexion and extension) have been evaluated (12). Thus, research has established isokinetic ECC strength ranging from 14 to 89% above CON strength (17, 41) with results of the majority of studies ranging from 22 to 60% (16, 20). The present study adds to our understanding of strength ratios, demonstrating dynamic ECC/CON strength ratios for men and women that were dissimilar.

The gender differences in the present study were consistent to some extent with previous isokinetic research. Specifically, past research demonstrated that women generated greater isokinetic ECC compared with CON torque than men for upper- and lower-body muscle groups (12, 26). A similar result in greater strength ratios in women than men was reported by Colliander and Tesch who found that knee flexion extension at 90 to 150°·s^{-1}, but not at a lower velocity of 30°·s^{-1}, were greater for women (5). Our data demonstrated greater dynamic (as opposed to isokinetic) ECC /CON ratios for young women across upper- (BP and MP) and lower-body (LE and LC) exercises. Previous research has supported the notion that gender differences could be a result of differences in stored and elastic energy of muscles, central nervous inhibition of maximal voluntary muscle actions, and the ability to recruit motor units during contractions in upper- and lower-body muscle actions (5, 12, 21, 46).

A secondary explanation of why our results did not match those of past isokinetic strength ratios can be seen in the work of Lindle et al. (26). Lindle et al. reported a decline in muscle quality as well as in peak torque in the knee extensors from a sample of 654 men and women across the ages of 20–93 years. Interestingly, although muscle quality declined for both sexes, the men demonstrated a significantly greater decline across age for ECC peak torque, and women seemed to decline to a lesser degree (26). Furthermore, these investigators concluded that older women had an enhanced capacity to store and utilize elastic energy when compared to men. Collectively, these data may point to the need for specific strength training protocols for young men and women, as 1RM comparisons for dynamic ECC/CON strength may be different.

Because sample size was low, a power analysis was warranted. This analysis demonstrated that with the balanced, within-subjects design, the sample was able to capture the ECC/CON strength differences with reasonable power for most of the lifts performed. Moreover, the effect sizes were relatively large (ranging from 0.97 to 2.68 in 5 lifts), which further supports the validity of the comparison made in the present study between genders.

PRACTICAL APPLICATIONS

The results of the study may help strength and conditioning professionals understand the potentially large ECC/CON strength ratio differences in young women compared with young men who are not competitive weightlifters. Moreover, data from the present study may eventually allow more precise development of ECC overload resistance training protocols to improve strength and performance as well as rehabilitate athletes from injury, because our data provide a protocol for determining ECC 1RMs. In addition, a challenge when training eccentrically has been delayed onset muscle soreness accompanying ECC movements, and this has been attributed to fewer motor units recruited compared to CON movements (1, 3, 9). Although soreness has been shown to dissipate within 1–2 weeks of the initial bout (22), caution in applying ECC overload training is still warranted because ECC 1RM determination and ECC overloading have received limited attention. Careful implementation of ECC overloading periodically throughout a training cycle with DOMS monitoring could potentially complement a traditional periodized strength and conditioning program for young men and women. Thus, an accurate ECC 1RM can become useful in determining proper resistance training loads and evaluating specific muscular contraction (ECC/CON) deficits. This study presents a protocol for testing maximal ECC strength so that optimal training loads can be determined and applied.

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Acknowledgments

Financial support was provided by the Center for Faculty Excellence, Faculty Development Grant, Southeastern Louisiana University.

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