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Isometric, Eccentric, and Concentric Strength in Trained and Untrained Older Adults: A Pilot Study

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ABSTRACT

Background: Despite an overall decrease in muscular strength, older adults maintain eccentric (ECC) strength in greater proportions compared to isometric (ISO) and concentric (CON) strength. While resistance training is promoted for older adults, the impact of resistance training on ISO, ECC, and CON strength is relatively unknown. **Objective:** The purpose of this study was to compare peak ISO, ECC and CON knee extensor moments between trained and untrained older individuals. **Methods:** A quasi-experimental design with a two-group comparison, ex post facto, was conducted. Twenty older adults (8 females, 69.6 ± 6.1 years, 80.5 ± 16.4 kg, 1.7 ± 0.1 m) were allocated to two groups, one undergoing resistance training (n =10) and one not (n = 10). An isokinetic dynamometer measured ISO, ECC, and CON knee extensor moments. Peak knee extensor moments (Nm) and ECC: ISO ratio were analyzed using a Kruskal-Wallis test ($\alpha = 0.05$). Spearman Rank-Order Correlations were run on paired combinations of peak ISO, ECC, and CON moments for both groups. **Results:** The trained group had significantly greater peak ISO moment (183.8 vs 137.1 Nm, p = 0.013, *d* = 1.3) but significantly lower ECC: ISO ratio (p = 0.028, *d* = 1.1). The trained group exhibited stronger correlations for ECC-ISO (r_s = 0.79 vs. 0.65), ECC-CON (r_s = 0.93 vs. 0.59), and CON-ISO (r_s = 0.93 vs. 0.78) compared to the untrained group. **Conclusions:** The findings demonstrate older adults maintain eccentric and concentric strength, regardless of training status. However, trained participants had a more balanced ECC: ISO ratio, due to their increased peak ISO strength possibly due to their resistance training.

Key words: Resistance Training, Muscle Strength, Aged, Knee Joint, Lower Extremity, Aging

INTRODUCTION

Older individuals are known to suffer from many debilitating changes later in life, including altered gait and reduced balance, leading to an increased risk of falling (Ambrose et al., 2013; Hackstaff, 2009; Holtzer et al., 2014; Verghese et al., 2010). In 2018, there were an estimated 35.6 million falls for adults aged 65 years or older (Moreland et al., 2020). Many of these changes stem from a reduction in muscle strength, primarily caused by cachexia and sarcopenia (Cruz-Jentoft et al., 2010; Deschenes, 2004; Rolland et al., 2011; Sadeghi et al., 2021). Cachexia is considered a metabolic disorder, involving overall weight loss in older adults, with a substantial reduction in muscle mass and increased adipose tissue infiltration into muscles (Evans et al., 2008). Cachexia is characterized by inflammation and increased protein breakdown that could cause chronic infections, potentially affecting kidneys, causing pulmonary disease and heart failure, along with the breakdown of muscle tissue during the process leading to sarcopenia (Evans et al., 2008; Rolland et al., 2011). Sarcopenia cases are multifactorial, with possible roots of the condition including: sedentary lifestyles, inactivity, immobilization, malnutrition, adverse drug reactions, inflammatory diseases, or malignancy (Rolland et al., 2011).

Muscular strength has been recognized as a highly relevant quality of life metric for elderly populations, with direct ties to sarcopenia (Sillanpaa et al., 2012). Lower extremity strength has been shown to be correlated to first time falls and subsequent recurrent falls in older populations (Moreland et al., 2004). Even though muscular strength decreases with age, eccentric (ECC) strength is maintained to a greater extent when compared to concentric (CON) and isometric (ISO) strength in older adults (Power et al., 2012b). When compared to younger counterparts, older individuals display a smaller difference in ECC in comparison to ISO and CON strength (Lindle et al., 1997; Porter et al., 1995; Pradhan et al., 2020; Thompson, 2009; Wu et al., 2016). This maintenance of ECC strength is due to increased stiffness in connective tissues, allowing for a greater capacity of elastic

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force during the lengthening of muscles (Klass et al., 2005; Lindle et al., 1997). Importantly, greater strength during ECC actions function to decelerate external and internal forces. Decelerations of external and internal forces are critical for maintaining posture and balance, which in turn aids with reducing fall risk (Gault & Willems, 2013; Hody et al., 2019; Wu et al., 2002).

One strategy that is regularly employed to increase and maintain muscular strength is participation in resistance training programs (Correa et al., 2013; Englund et al., 2019; Reeves et al., 2006) which subsequently improve gait velocities (Hortobagyi et al., 2015). Following twelve weeks of resistance training, elderly women saw increases in knee extensor strength and quadriceps muscle volume by 33% and 26%, respectively (Correa et al., 2013). Further, following resistance training, older adults display increases in their ISO (+9%) and CON (+37%) moments (Reeves et al., 2006). Others found increases of CON moment of 22-37% following resistance training but accompanied with no changes in ECC moments (Reeves et al., 2005). Compared to a home-based flexibility program, a twelve-week progressive resistance training program showed increased peak isokinetic knee extensor moment (mean difference = 7.54 Nm [95% CI: 1.46,13.63 Nm]) for adults aged 70-92 years old (Englund et al., 2019). While there have been numerous studies displaying the differences between training paradigms and benefits of resistance training, the comparison between those who are resistance training in community-based programs and those who are untrained remain relatively unknown. Comparing these two distinct groups of older individuals may provide valuable insight into whether regular resistance training elicits benefits compared to a lack of resistance training, and whether benefits varying depending on contraction type (e.g., ISO, ECC, and CON). Additionally, examining ISO, ECC, and CON strength gives practical viewpoints relating to quality of life and fall risk for aging populations.

Therefore, the purpose of this study was to compare peak ISO, ECC, and CON knee extensor moments between trained and untrained older individuals. Additionally, we aimed to quantify the relationship between the differing contraction moments between trained and untrained individuals, examining whether training status impacted these relationships. Our hypothesis was that there would be no significant difference in peak ECC knee extensor moment and ECC: ISO moment ratio, but that the trained group will display greater peak ISO and CON knee extensor moments compared to the untrained group.

MATERIAL AND METHODS

Participants and Study Design

This study implemented a quasi-experimental study design to compare two-groups, ex post facto. Twenty older adults were recruited into the current study (Table 1). Post-hoc analysis of our reported results showed that our key significant variables of interest reached a statistical power of $\beta = 0.66 – 0.83$ with an alpha of 0.05 and n=20 (Faul et al., 2007). Participants were included in the study if they were 60 years of age or older. Participants were excluded from the study if they had any lower limb injuries or neuromuscular disorders that would affect their ability to participate. The independent variable used to compare groups is the participants' current resistance training status. Recruited participants were allocated to the trained or untrained group based on their training status. Those placed in the trained group were active participants in the mature adult resistance training program for at least six-months at the Bellingham Senior Center, Blaine Senior Center, or Western Washington University with a frequency of 2-3 times per week. The mature adult resistance training program consisted of 8-10 exercises with 10-15 repetitions each per day. Those allocated to the untrained group were not currently and had not participated in any resistance training programs with a frequency of twice per week in the last six months. Dependent variables included maximal ISO, ECC, and CON knee extensor torques using an isokinetic dynamometer. All testing procedures were approved by the University Institutional Review Board (14-028) and all participants read and signed an informed consent form.

Instrumentation

An isokinetic dynamometer (System 2, Biodex, Shirley, NY, USA) was utilized to measure peak knee extensor moment at preset constant angular velocities. The isokinetic dynamometer was calibrated per manufacturers specifications prior to each testing session. Participants were seated to elicit an 80° hip angle, measured by the trunk and thigh. Participants were secured to the dynamometer seat using Velcro straps across the thorax, pelvis, and distal thigh. The center of rotation for the dynamometer shaft was set to be aligned with lateral femoral epicondyle of the testing limb. Peak ISO knee extensor moment was measured at a knee flexion angle of 50°, corresponding to the mid-range of motion (Babault et al., 2001). Peak ECC and CON knee extensor moments were assessed at preset constant angular velocities of 120°/sec, which has been used to simulate real life events such as sitting, lowering groceries, and resisting a fall after tripping (Hartmann et al., 2009).

Experimental Protocol

Participants took part in a single testing session lasting

Table 1. Participant characteristics for the trained and untrained groups (mean ± STD) as well as statistical results from the Kruskal-Wallis test assessing group differences for height, mass, and age

	Trained	Untrained	p-value
N (males, females)	10 (6M, 4F)	10 (6M, 4F)	-
Height (m)	1.69 ± 0.08	1.70 ± 0.09	0.939
Mass (kg)	77.94 ± 16.97	83.15 ± 16.36	0.449
Age (yrs)	69 ± 8	71 ± 4	0.425

approximately 40 minutes. Upon arrival, participants performed a 5-min warm up on a stationary cycler ergometer at a self-selected cadence and with no resistance. Following the warm-up, participants were introduced and instructed by a researcher how to use the isokinetic dynamometer to become familiar with its use. The three testing conditions (ISO, ECC, and CON) were randomized. Testing procedures were completed on participants' dominant limb, which were determined by kicking a ball, with their kicking limb defined as their dominant (Hartmann et al., 2009).

Participants then sat in the isokinetic dynamometer, and the seat and straps were adjusted to properly fit each participant (Hartmann et al., 2009). Next, participants underwent a specific warm-up on the isokinetic dynamometer consisting of three submaximal ISO knee extension contractions. Participants were instructed to contract at approximately 60-70% of their perceived maximal effort. Following the warm-up, participants completed three trials of each condition, in the randomly selected order, with 2-min of rest between each trial to minimize the risk of fatigue. For the ISO condition, participants attempted to extend their knee with maximal effort for 5-s while the dynamometer was set to 50° knee flexion (Babault et al., 2001). For the ECC condition, participants were instructed to maximally resist the dynamometer as it eccentrically moved the knee into flexion at a constant angular velocity of 120°/sec (Hartmann et al., 2009). For the CON condition, participants extended their knee with maximal effort into the dynamometer moving into knee extension at a constant angular velocity of 120°/sec. Following testing, participants underwent a five-minute cycling cool-down at a self-selected cadence and no resistance.

Data Analysis

Peak knee extensor moments for the three successful trials per condition were recorded and the average was taken for data analysis. Peak ISO, ECC, and CON knee extensor moments (Nm) were reported and analyzed. The ratio of ECC to ISO peak knee extensor moments (ECC: ISO) were calculated to assess the participants' ECC strength in relation to their maximal strength (Power et al., 2012a).

Statistical Analysis

All statistical analyses were implemented using IBM SPSS Statistics Software (version 26, IBM, Armonk, NY, USA). Descriptive statistics were calculated for ISO, ECC, and CON peak knee extensor moments and the ECC: ISO ratio for each group. To determine significant differences between the trained and untrained groups, Kruskal-Wallis Tests were run for each dependent variable with group allocation as the between-subjects grouping factor. The Kruskal-Wallis Test was conducted to ensure that the sample size (n = 20) or statistical power ($\beta = 0.66 – 0.83$) did not influence the potential results, as this nonparametric statistical model may be better suited than parametric counterparts. Additional analyses were run on participant characteristics (age, height, and mass) to assess whether the groups differed from one another. Finally, Spearman Rank-Order Correlations were run for paired combinations of peak ISO, ECC, and CON knee extension moments for each group to assess potential relationships between the differing contraction types. Cohen's d effect sizes were calculated to examine the effect sizes of differences between groups and were interpreted as small ($d \leq 0.20$), medium ($0.21 < d \leq 0.50$) and large ($0.51 < d \leq 0.80$) (Cohen, 2013).

RESULTS

There were no significant differences between the trained and untrained groups for age ($p = 0.425$), height ($p = 0.939$), or mass ($p = 0.449$). There was also an equal distribution of six males and four females in both the trained and untrained groups (Table 1).

Peak ISO knee extensor moment was significantly higher in the trained compared to untrained group (H[1] = 6.223, $p = 0.013$, d = 1.3, (Figure 1 and Table 2). The trained and untrained groups did not show any significant differences for peak ECC (H[1] = 1.120, $p = 0.290$, d = 0.57) or peak CON (H[1] = 2.520, $p = 0.112$, d = 0.81) knee extensor moments (Table 2). Finally, there was a significant group difference for the ECC: ISO ratio, with the trained group showing a lower ECC: ISO ratio compared to the untrained group (H[1] = 4.806, $p = 0.028$, d = 1.07), Table 2).

The trained group showed significant correlations between peak ECC and peak ISO ($r_s = 0.79$, $p = 0.006$), peak ECC and peak CON ($r_s = 0.93$, $p < 0.001$), and peak CON to peak ISO ($r_s = 0.93$, $p < 0.001$). However, the untrained group only showed significant correlations between peak ECC to peak ISO ($r_s = 0.65$, $p = 0.043$) and peak CON ($r_s = 0.78$, $p = 0.008$) (Figure 2).

DISCUSSION

The purpose of the current study was to compare the ISO, ECC, and CON peak knee extensor moments between trained and untrained older adults and to quantify if training status impacted the relationship between contraction type

Table 2. Knee extensor moment results for the trained and untrained groups (mean ± STD)

	Trained	Untrained	p-value	Cohen's D
Peak ISO (Nm)*	183.77 ± 36.43	137.12 ± 35.17	**0.013**	1.3
Peak ECC (Nm)	226.37 ± 51.91	198.74 ± 45.06	0.290	0.6
Peak CON (Nm)	119.50 ± 20.41	101.11 ± 24.96	0.112	0.8
ECC:ISO*	1.23 ± 0.18	1.48 ± 0.27	**0.028**	1.1

*Significant difference between trained and untrained groups ($p < 0.05$), ISO: isometric, ECC: eccentric, CON: concentric moments. Participants in the trained and untrained groups were similar based on their age, height, and mass, indicating these participant characteristics should have minimal influence. We hypothesized that there would be no significant differences between the trained and untrained groups in peak ECC knee extensor moment and ECC: ISO ratio, but that the trained group would have greater peak ISO and CON knee extensor moments.

Our hypothesis was partially supported, with a 34.1% greater peak ISO knee extensor moment in the trained group compared to the untrained group. Comparatively, following a twelve week concentric resistance training program, older adults displayed a 17.3% increase in peak ISO knee extensor moment (Symons et al., 2005) with others reporting a 9% improvement (Reeves et al., 2006). While the results from the current study show a larger difference, this may be due to the duration of the resistance training intervention. Following a 24-week strength training intervention, older adults saw a 23.3% greater peak ISO knee extensor moment compared to baseline (Henwood et al., 2008). The duration of 24-weeks is the same as the minimum requirement for the trained group, meaning participants in said group may have been participating in resistance training much longer. In addition, improvements in peak ISO strength is directly related to the physiological cross-sectional area (PSCA) of a muscle, and is a strong indicator of basal strength (Morse et al., 2005). Regular resistance training has shown significant effects on quadriceps muscle volume and maximal strength (Correa et al., 2013). A twelve-week resistance training program elicited a 26% increase in quadriceps muscle volume accompanied with a 33% increase in maximal strength. These gains were subsequently lost following a twelve-week detraining period (Correa et al., 2013). Therefore, participants in the trained group may have seen increases in muscle volume, leading to the significantly greater peak ISO compared to their untrained counterparts. In older healthy individuals, resistance training status appears to play a key role in increasing peak knee extension ISO moment.

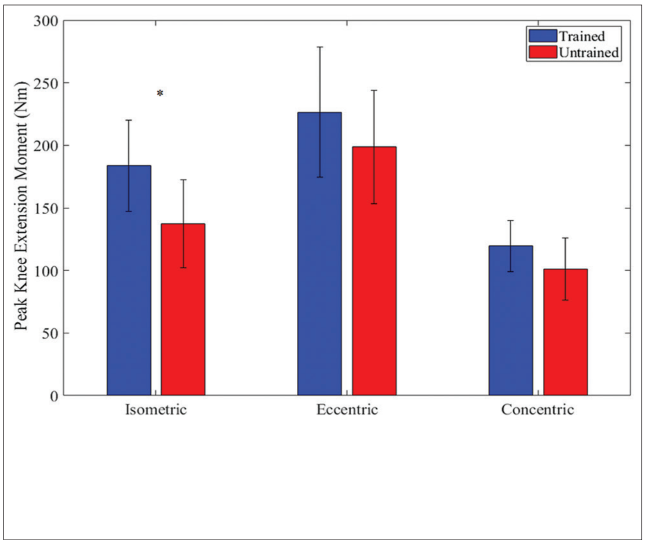

Figure 1. Mean and standard deviation plots for peak isometric, eccentric, and concentric knee extensor moments for the trained (blue) and untrained (red) groups, *significant difference between groups ($p < 0.05$)

While the trained group displayed a significantly greater peak ISO knee extensor moment, no difference between groups were found for peak ECC knee extensor moment. The non-significant group difference for peak ECC knee extensor moment was 13.9%, favoring the trained group. The lack of difference based on training status may be due to the general preservation of ECC strength that comes with aging. When compared to younger adults, older individuals only had a 6.5% lower peak ECC strength in contrast to peak CON strength (-38.6%) and peak ISO strength (-20.5%)

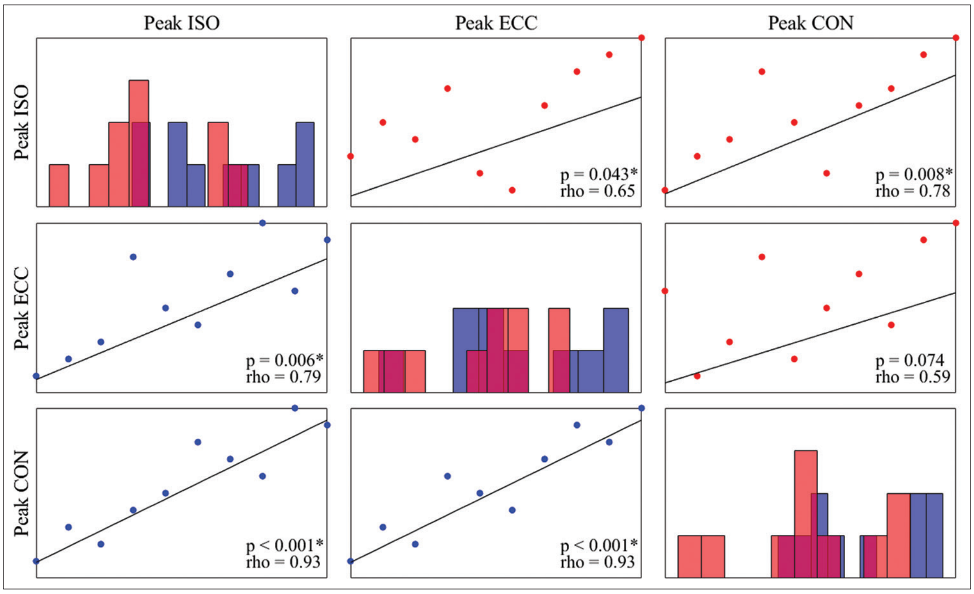

Figure 2. Spearman Rank-Order Correlation analyses results for the trained (Blue) and untrained (Red) groups. Histogram plots of both groups data along the diagonal, and rank-order scatter plots for the trained (Blue, lower triangle) and untrained (Red, upper triangle) with statistical results

(Klass et al., 2005). These age-related differences in peak CON and ISO knee extensor torques were later confirmed (Pradhan et al., 2020). The attenuated loss of ECC strength with age has been attributed to the increased connective tissue stiffness, returning a greater amount of stored elastic, passive energy (Poulin et al., 1992; Schwartz, 2010). Additionally, the specificity of the resistance training program could influence peak ECC strength. Older adults undergoing an 24-week ECC based resistance training program had greater increases in peak ECC knee extensor moment (+26%) compared to a CON resistance training group (+10%) (Symons et al., 2005). Despite our study displaying a 13.9% difference in peak ECC knee extensor moment between groups, the lack of statical significance could contributed to the increase variance (standard deviation) in our group. Our results indicate that the training status of our participants did not significantly alter their peak ECC knee extensor moments.

Similarly, to peak ECC, peak CON knee extensor moment was similar between the trained and untrained groups, with a non-significant difference of 18.2%. Previous resistance training studies have found benefits for peak CON strength following twelve-weeks (Correa et al., 2013; Englund et al., 2019; Reeves et al., 2006; Symons et al., 2005). Reported increases of peak CON knee extensor moment ranged from 7.7% (Englund et al., 2019) to 33% (Correa et al., 2013). While no group difference was present in our current study, one potential cause could be the angular velocity of 120°/sec. Others have assessed peak CON knee extensor moment at 60°/sec to 90°/sec (Englund et al., 2019; Symons et al., 2005). Since force is dependent on velocity, via the force-velocity relationship, a greater angular velocity may have some impact on our findings (Zajac, 1989). Peak CON strength has been previously found to have the largest degradation due to the aging process (Klass et al., 2005). Older individuals display 38.6% lower peak CON strength compared to younger counterparts. It is unknown if those in the trained group would outperform their untrained counterparts if the CON condition were done at varying angular velocities, including those slower than 120°/sec. While our results provided a non-significant result, the small inter-group difference was accompanied by a large effect size ($d = 0.8$). This may indicate a clinically relevant difference (>10%) that merits further investigation.

The untrained group displayed a larger (+19.9%) ratio of ECC: ISO compared to the trained group. This finding suggests that those in the untrained group display greater ECC strength relative to peak ISO strength, demonstrating a conservation of ECC previously seen in older adults (Porter et al., 1995; Poulin et al., 1992; Power et al., 2012a). This difference in ECC: ISO ratio appears to be driven by the significant differences in peak ISO knee extensor moments between the trained and untrained groups. The trained and untrained groups did not differ in peak ECC moments, therefore the increased peak ISO in the trained group would have the greatest impact in shifting the ECC: ISO ratio. This observation further confirms that ECC strength is maintained regardless of training status, but ISO strength is increased due to resistance training (Henwood et al., 2008; Power et al., 2012a; Reeves et al., 2006). These findings should be viewed in conjunction with the type of training paradigm that was implemented. The training program did not specifically train ECC contractions, but rather incorporated typical CON activities. Trained older adults have a more balanced ECC to ISO strength ratio, due to improvements in their ISO strength due to resistance training. These improvements may be beneficial for activities of daily living and function (Hortobagyi et al., 2015).

Finally, the Spearman Rank-Order Correlation analyses found that the trained group had stronger correlations for every contraction type pair (ISO-ECC, ISO-CON, ECC-CON) compared to the untrained group. ISO-CON and ECC-CON showed the largest correlation (both $r_s = 0.93$) in the trained group followed by ISO-ECC ($r_s = 0.79$). Based on these findings, the resistance training status of older individuals influenced the correlations between contraction type knee extensor moments. In the training group, participants who ranked stronger for peak CON also ranked higher for peak ISO and peak ECC (Figure 2). Interestingly, the untrained group did not show a significant correlation for ECC-CON ($p = 0.074$). While participating in a resistance training program only showed a significant difference in peak ISO, their participation may influence intra-subject differences in knee extension moments. Older individuals participating in resistance training may produce a more homogeneous sample in ranking knee extensor contraction strengths (e.g., those who are the strongest in peak CON will more than likely be the strongest in peak ISO and ECC).

This study is not without its limitations. First, we included a sample size of n=20, which may be considered small, limiting the statistical power of our results ($\beta = 0.66$-0.83). However, we analyzed our data using nonparametric statistical models (Kruskal Wallis and Spearman Rank-Order Correlation), which is suitable for analyses with non-normal distributions and small sample sizes. Additionally, we accompanied the statistical results with calculated effect sizes to provide further detailed information on the differences between the two groups. Second, the trained group used in this study underwent a resistance training protocol that was machine-based. This protocol did not include ECC specific exercises, which could impact the group comparison. Future research should aim to compare the untrained group to a trained group undergoing ECC based resistance training (Symons et al., 2005). Third, only the dominant limb of each participant was assessed. Any individual with a total knee arthroplasty was excluded from this study to reduce the impact of lower limb arthroplasties. Fourth, isokinetic muscle actions (ECC and CON) were only recorded at an angular velocity of 120°/sec. While this angular velocity is similar to real life activities during ECC contractions (Hartmann et al., 2009), different angular velocities may impact the comparison for CON strength (Zajac, 1989). Inclusion of more angular velocities may present a wider picture of potential group differences. Fifth, we only examined the differences of the knee extension moments between the trained and untrained group, due to the quadriceps role in balance and fall risk. The hip extensors and trunk musculature also play a crucial role in balance and their inclusion in testing would improve the direct results relating to functionality and fall risk for older adults. Finally, group allocation was based on participant reported activities. Including more objective measures of control for group allocation could improve the homogeneity of the two groups.

Strengths and Practical Implication

This study provides key insights into the effect of resistance training on knee extensor moments in older adults. Specifically, we examined the effect of resistance training being undertaken at community centers which is representative of resistance training paradigms older adults are typically exposed too. Increases in lower extremity strength are known to benefit older adults aiding in everyday function, especially in reducing fall risk. However, prior to this study, it was unknown what differences exist between older adults currently undergoing resistance training and those who are not. The results of this study suggest that resistance training in older adults' aids in improving peak ISO knee extensor strength but does not significantly alter peak CON or ECC knee extensor strength. These results exemplify the increases in ISO strength from resistance training for older adults, which leads to a more balanced ratio between ISO and ECC knee extensor strength. These increases in strength could prove to be beneficial for older adults.

CONCLUSION

The current study examined the peak knee extensor moments during ISO, ECC, and CON contractions to compare older adults who are currently resistance training to those who were not. The training status of older adults appears to not have a significant impact on peak ECC and CON knee extension moments. The maintenance of ECC strength that has been previously observed is consistent regardless of participation in traditional resistance training. However, older adults who are resistance training exhibit larger peak ISO knee extension moments, resulting in a more balanced ECC: ISO ratio. Promotion of resistance training in older adults should continue to maintain and improve ISO strength variables that are more greatly affected by training status in comparison to ECC strength, which is typically maintained with age.

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