HUMAN MOVEMENT

2014, vol. 15 (3), 147–151

THE EFFECTS OF LOAD AND EFFORT-MATCHED CONCENTRIC AND ECCENTRIC KNEE EXTENSION TRAINING IN RECREATIONAL FEMALES

doi: 10.1515/humo-2015-0004

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ABSTRACT

Purpose. The purpose of this study was to compare the effects of load and intensity of effort-matched concentric and eccentric knee extension training on isometric strength. **Methods.** Unilateral isometric torque was measured using a MedX knee extension after which eleven recreationally trained females performed both concentric-only (CONC) and eccentric-only (ECC) unilateral knee extension exercise once per week for 8 weeks. Participants performed a single set of both CONC and ECC exercise load-matched at 80% of maximum isometric torque for each condition. All participants exercised to repetition maximum in both CONC and ECC conditions at a pace of ~3 s duration for each muscle action. This ensured that participants exercised to the same intensity of effort for both CONC and ECC training interventions. **Results.** Analyses revealed significant increases in isometric torque for both CONC (14.8%) and ECC (13.0%) conditions ($p < 0.05$). Absolute change from pre- to post-intervention was compared for CONC and ECC training conditions revealing no statistically significant differences ($p > 0.05$). Effect sizes are reported as 0.60 (CONC) and 0.53 (ECC). In addition, analyses revealed significantly greater mean total training volume for ECC compared with CONC conditions (15903 vs. 8091, respectively; $p < 0.001$). **Conclusions.** The present findings indicate that, when matched for intensity of effort, both CONC and ECC knee extension exercise can significantly improve strength to the same extent. This supports previous research that load and repetitions are not as important as intensity of effort in resistance exercise.

Key words: resistance exercise, isometric, repetition maximum, unilateral training

Introduction

The health benefits of resistance training (RT) have been well documented [1, 2]. It is generally considered the most effective way to increase muscular strength [3] and size [4], which in turn can reduce risk of all-cause mortality [5]. Whilst the American College of Sports Medicine have previously recommended specific load and repetition ranges as optimal for increasing strength [6], recent reviews have reported that the evidence does not support a particular load or repetition range and that equivocal results can be obtained so long as persons train to a high intensity of effort, e.g. momentary muscular failure (MMF) [3].

Human movement is made possible by the relative contributions of eccentric (ECC), isometric (ISO) and concentric (CONC) muscle actions. However evidence has suggested that persons are 20–60% stronger through ECC compared with CONC actions [7, 8] and, as a result, that CONC actions require greater motor unit recruitment and muscle fibre activation than ECC actions [9]. Since observing this disparity in strength, many research studies have considered the training effects of different muscle actions. Whilst some research using isokinetic dynamometers has suggested favourable results for ECC compared with CONC training [10, 11], we should be cautious to consider the practicality of isokinetic training. An isokinetic ECC action might best be thought of as an intended CONC contraction by the participant, where a mechanical force decreases the joint angle whilst the participant resists this movement [4, 12]. This has previously been likened to supramaximal (e.g. > one repetition maximum [1RM]) negative repetitions and used as an advanced technique by experienced trainees [4]. Since supramaximal training holds inherent risks (e.g. training with a load that a person is unable to lift) and isokinetic equipment is not accessible to many trainees, we should consider a more pragmatic approach to isoinertial exercise.

Surprisingly, there is limited research that has compared CONC and ECC training for the knee extensors using load and intensity-of-effort matched isoinertial contractions. Multiple studies have considered training conditions with a heavier load for ECC compared with CONC training. For example, Jones and Rutherford [7] considered ISO strength following unilateral isoinertial training with 80% 1RM for CONC and 145% 1RM for ECC training. Their results reported no statistically significant differences in strength gains between conditions. However, we might consider that whilst volume-matched, the conclusions are limited by conditions that were not equated for load or intensity of effort. Pavone and Moffat [13] also compared ISO strength following 6 weeks of either CONC or ECC training, reporting no significant differences between training groups. However, once again training load varied between CONC and ECC groups

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according to respective CONC and ECC 10RM tests. Finally, Smith and Rutherford [14] compared unilateral CONC and ECC training in untrained males (n = 5) and females (n = 5), reporting significantly greater strength increases for CONC compared with ECC training. This is in spite of accentuating the ECC actions by increasing the load by 35% compared with the CONC training load. This appears to be a volume-matched study and, as such, we cannot equate intensity of effort between conditions. It might be possible that intensity of effort was greater in the CONC group despite the heavier load used for the ECC condition.

A further study compared multiple training conditions including load and volume matched CONC and ECC training [15]. The authors reported no significant differences in strength increases between CONC and ECC groups. However, we cannot be certain that both conditions trained at the same intensity of effort. Groups matched for load and volume likely allowed persons performing ECC-only actions to exercise at a lower intensity of effort. Perhaps the most appropriate example considered isokinetic training; Moore et al. [16] compared nine young males performing unilateral CONC and ECC training matched for both intensity of effort (maximal contractions) and total external work. They reported no significant difference in strength increases between conditions. However, this study considered the use of isokinetic training which, as discussed, is limited in practicality.

The present body of literature is equivocal with regard to the efficacy of CONC and ECC training and no research to date was found which compared isoinertial CONC and ECC training with load-matched groups, where repetitions are manipulated to equate intensity of effort. With this in mind the present study aimed to compare the effects of 8 weeks of unilateral CONC or ECC knee extension exercise with equated loads performed to repetition maximum (RM).

Material and methods

The present study aimed to compare the effects of an 8-week unilateral CONC or ECC knee extensor RT programme performed at identical training loads. To avoid bias as a result of individual responses to training, we used a within-subject research design, where participants trained one leg CONC and ECC with the contralateral leg at an identical load. As such, the study could not be biased by differing inter-person responses to training as a result of genetics or other factors. This methodological approach is well represented in previous research [14, 17–18].

Following approval from the relevant ethics committee, 11 recreationally trained female participants were recruited and completed written informed consent (see Table 1 for participant characteristics). All participants were currently active but performed no structured resistance exercise programme. Power analysis of previous research was conducted to determine participant numbers (n) using an effect size calculated using Cohen's d [19] of 1.4 [20]. Participant numbers were calculated using equations from Whitley and Ball [21], revealing a required 8 participants to meet a power of 0.8 at an alpha value of $p \leq 0.05$ for detecting strength changes.

Table 1. Participant Characteristics

Characteristic	(Mean ± SD)
Age (years)	22.5 ± 4.1
Height (cm)	165.7 ± 5.4
Body mass (kg)	58.8 ± 6.7
BMI	21.5 ± 2.8

Maximum isometric knee extension torque was measured unilaterally using a MedX (USA) knee extension/flexion ergometer pre- and post-intervention, not less than 48 h following the final training session. The methods used have been described in a previous publication [22]. However, succinctly, following a dynamic bilateral warm-up at ~28kg using a 2-s CONC, 1-s ISO, and 4-s ECC repetition duration, participants performed three practice unilateral isometric tests at an estimated 50% of maximal effort. Each participant then performed maximal unilateral isometric tests at seven joint angles throughout the range of motion (96°, 78°, 60°, 42°, 24°, 6° of knee flexion). For each maximal isometric contraction participants were requested to build up to maximal force over 2–3 s and were provided with ~10 s rest between test angles. The torque produced was measured by a load cell attached to the movement arm. Following testing participants were asked to identify their dominant and non-dominant leg for assignment in to CONC and ECC training groups, respectively.

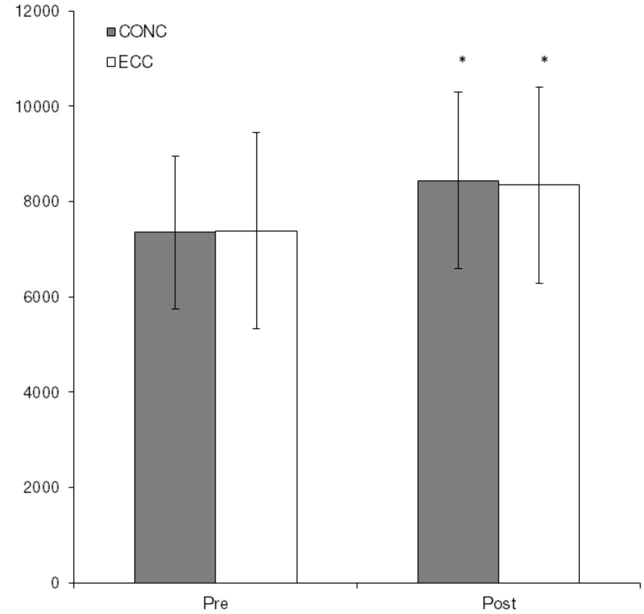
Unilateral knee extension training was performed on the same MedX device used in testing. All participants performed a single set of unilateral CONC and ECC knee extension exercise at 80% of their maximum tested functional torque (TFT) once a week for 8 weeks. Whilst this might appear a low volume/frequency of exercise, previous research has reported significant strength increases in isolated movements from this volume/frequency [23]. The CONC limb was trained first, performing only the CONC phase of each repetition at a 3 s duration with a research assistant performing the ECC phase of each repetition. Participants were asked to perform the repetitions until they could no longer maintain the required cadence (e.g. RM). After 3–5 min rest, participants then performed ECC repetitions only with their contralateral limb, once again at a 3 s duration, with the research assistant performing the CONC phase of each repetition. As previously, participants were asked to perform repetitions until they could not lower the load at the required cadence (RM). Once the participant could perform more than 12 CONC repetitions the load was increased by 5% for the next exercise session for both CONC and ECC exercise to maintain parity in the load between CONC and ECC training conditions. Verbal commentary during any testing/training was restricted to coaching guidance of technique rather than encouragement of performance.

Isometric force data was considered as SI provided by MedX clinical equipment. This has been reported previously [23], where SI represents the area under a force curve created in each isometric test and accommodates potential increases or decreases throughout the entire strength curve for all seven test positions. This negates biasing data by seeking an average increase or decrease or only considering specific joint angles. All pre- and post-test data were analysed using SPSS ver. 20 (IBM, USA) and checked for normal distribution using a Kolmogorov–Smirnov (K–S) test. A two-way repeated measures analysis of variance (ANOVA) was used to examine the effects of the two independent variables condition (CONC and ECC) and time (Pre and Post) upon the dependent variable of isometric strength expressed as SI. Finally, since evidence has shown that persons are 20–60% stronger during ECC actions compared with CONC actions, a paired samples *t*-test was also performed to compare mean total training volume (load × repetitions; TTV) for the duration of the intervention between CONC and ECC conditions. The level of significance was set to $p < 0.05$ in all cases. Effect sizes were calculated based on Cohen's *d* [19].

Results

A K–S test confirmed normal distribution of data for the pre- and post-intervention tests and absolute change for the isometric torque SI values ($p > 0.05$). The two-way repeated measure ANOVA revealed a significant within subject effect for time only ($F(1,10) = 21.235$, $p = 0.001$). Figure 1 shows pre- and post- values for SI for both CONC (pre-$\bar{x}$ = 7353, ± 1598 to post-$\bar{x}$ = 8442, ± 1805; 14.8%) and ECC (pre-$\bar{x}$ = 7386, ± 1848 to post-$\bar{x}$ = 8349 ± 2059; 13.0%) conditions. Both within subject effects for condition and interaction of condition x time were not significant (respectively, $F(1,10) = 0.037$, $p = 0.851$ and $F(1,10) = 0.441$, $p = 0.522$). Effect sizes for CONC (0.60) and ECC (0.53) training were calculated, revealing moderate effect sizes [19]. A Pearson product-moment correlation coefficient was also computed to assess the relationship between CONC and ECC SI values pre- and post-intervention for all participants. There was a positive correlation between both CONC and ECC conditions ($r = 0.70$, $p = 0.017$).

The paired samples *t*-test revealed a significant difference in TTV between the CONC and ECC conditions ($t(10) = -9.170$, $p < 0.001$; ECC = 15903 ± 3316, CONC = 8091 ± 1292).



* Significant difference (p < 0.05) to pre-intervention values for relative training condition

Figure 1. Mean pre- and post-intervention SI values for CONC and ECC training; error bars represent *SD*

Discussion

The purpose of the present study was to consider isometric strength improvements as a result of load and intensity-of-effort matched CONC or ECC unilateral knee extension resistance training. The data revealed significant strength increases in both CONC and ECC training with no significant differences in absolute change between conditions. Previous reviews have suggested that training with heavier loads does not incur greater strength or hypertrophic increases than training with lighter loads when training to a high enough intensity of effort (e.g. RM, MMF, etc.) [3, 4]. With this in mind and since previous research has suggested that ECC muscle actions are 20–60% stronger compared with CONC actions [7, 8], the present study used load-matched groups where participants trained to RM. Data analysis revealed significantly greater mean total training volume for ECC compared with CONC conditions (15903 vs. 8091, respectively), supporting the idea of greater strength of a muscle when performing ECC actions.

Previous research considering isoinertial training with equated load and training volume has reported similar strength increases between CONC and ECC training [15], whilst other studies with a greater ECC (compared with CONC) load also reported statistically similar results [7, 13]. However, to date, the present study appears to be the only experiment which has considered load and intensity-of-effort matched isoinertial unilateral training to RM in recreational females. The results suggest that, even when the load is equated between ECC and CONC groups, the additional repetitions performed by the ECC group as a result of training to RM allowed intensity of effort to be matched between groups. As such, our results support previous research which has reported statistically similar results between CONC and ECC training groups performing isoinertial exercise [7, 13, 15]. However the data from Ben-Sira et al. [15] suggests a trend toward greater strength increases for CONC compared with ECC training (effect size = 0.99 and 0.80, respectively), likely as a result of load and volume but not intensity-of-effort matched training conditions. Indeed, the data from Jones and Rutherford [7] also showed a trend toward greater gains for CONC compared with ECC training conditions (effect size = 0.65 and 0.44, respectively) even with a greater load for ECC training. This might be a result of not equating intensity of effort between groups.

Since participants in the present study trained to condition-matched intensity of effort (RM), the present data supports previous reviews [3, 4] that load and volume are of less significance to muscular adaptation than intensity of effort, even when considered for differing muscle actions. In addition, since previous research has reported favourable gains for CONC compared with ECC training, even where ECC load was 35% greater than CONC [14], we can further consider the importance of training to a high intensity of effort rather than increased load, irrespective of muscle action. Further research might consider a methodological design to test this by comparing conventional (CONC + ECC), CONC and ECC repetitions with the caveat that all groups exercise to RM.

Conclusions

Practical applications from the present study suggest that eccentric-only repetitions are an efficacious method of improving strength when performed at a repetition duration that maintains muscular tension and to a high enough intensity of effort. This presents an alternative to conventional- or concentric-only training and might suit persons suffering from orthopaedic injury preventing concentric training.

Whilst the direct applications from the present study are not extensive, we should consider that the data presented support previous publications that have reported similar muscular/neural adaptations between groups training at different loads/repetitions ranges but matched for intensity of effort. Practically, we may consider the relative limitations of performing eccentric-only exercise where it might be necessary to perform significantly greater total training volume for equivocally the same results. However, the authors contest that, whilst potentially limited in application, the present study presents important conclusions with regard to intensity of effort, load, repetitions, muscular actions and chronic muscular adaptations.

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Paper received by the Editor: June 5, 2014
Paper accepted for publication: October 24, 2014

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