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ORIGINAL ARTICLE

Effects of a portable, cable-based concentric-only resistance machine on muscular strength in untrained young adults

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ABSTRACT

The purpose of this study was to investigate the effects of concentric-only resistance training in comparison to traditional concentric-eccentric resistance training on upper and lower body strength using a portable cable-based concentric-only resistance machine. Thirty-two participants (10 females, 22 males; mean age of 23.4 ± 2.0) with minimal resistance training experience exercised thrice weekly to complete a 12-week training program. Participants were blinded and randomly allocated 1:1 to an intervention group (n = 16, wherein the resistance training used the concentric-only machine (CRT)) or a control group (n = 16, wherein the resistance training was completed using traditional concentric-eccentric with a conventional cable-based machine (CON)). While both groups improved in 1-RM chest press and squat press performance, there was no significant difference between groups. These findings suggest that the use of a portable CRT machine may confer similar strength benefits in comparison to traditional concentric-eccentric training. It is possible that the lack of the eccentric component with the CRT machine enables for a higher training volume to be completed, which consequently results in strength benefits.
Keywords: Performance analysis, Strength, Concentric, Training volume.

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INTRODUCTION

Americans have begun to prioritize at-home workouts as a means of preserving their health and fitness in light of the COVID-19 pandemic and stay-at-home directives, both of which resulted in the nationwide closure of most publicly accessible gyms. Although social distancing and limiting exposure in public spaces were commonly used strategies to slow coronavirus propagation, they have also led to greater inactivity amongst the general population (Füzéki et al., 2020). Fast forward to today, where, as a result of increased workloads and economic stresses caused by the pandemic, the time and inconvenience associated with attending a traditional commercial gym may be an even greater barrier to exercise for a large portion of the general population (Borodulin et al., 2015; Hoare et al., 2017). This increase in inactivity has far-reaching health implications, with many bodies of research supporting the link between physical inactivity and chronic disease progression (Lobelo et al., 2018). Due to the long-term repercussions of the COVID-19 pandemic, the demand for an effective, at-home exercise alternative is at an all-time high.

To accommodate this need, technological advances in the home-based fitness landscape have expanded through the use of new devices and services. These modalities aim to improve the user's health and fitness within the comfort of their own home. Recently, a portable cable-based resistance machine was developed that employs the use of a multi-plate clutch system allowing for concentric-only resistance training (CRT). According to the manufacturer, the device's 'out-of-gym' portable convenience unlocks a world of untapped exercise potential.

Muscle contraction involves two distinct processes: concentric and eccentric movement (Padulo et al., 2013). Concentric muscle loading involves applying resistance force to reduce the sarcomere length, whereas eccentric muscle loading pertains to the tension applied to lengthen the sarcomere (Colliander and Tesch, 1990; Padulo et al., 2013). Previous research has found that conventional, concentric-eccentric resistance training is superior for muscle strength acquisition compared to CRT (Blazevich et al., 2007; Franchi et al., 2014; Gabriel et al., 2006), and to a lesser extent eccentric-only training (Harris-Love et al., 2021; Hather et al., 1991; Norrbrand et al., 2008; Seger et al., 1998). Notwithstanding, eccentric movements tend to induce muscle damage and elevated inflammation, which typically results in heightened muscle soreness (i.e., delayed onset muscle soreness (DOMS)) (Choi et al., 2012; Higbie et al., 1996). This pattern is especially common in untrained individuals (Proske and Morgan, 2001). It has been proposed that concentrically-biased resistance training will still effectively improve muscle strength without the persisting symptoms of DOMS discomfort. However, there is a dearth of research on the benefits of portable CRT devices on muscular strength, specifically how they perform against conventional resistance training modalities.

Therefore, using a single-blind, randomized controlled study design, we investigated the effects of a portable CRT device on upper and lower body muscular strength during a 12-week workout protocol in comparison to conventional resistance training. While both conditions should improve strength, we hypothesize that conventional concentric-eccentric resistance training will produce significantly greater improvements in strength after 12 weeks of training.

METHODS

Participants

Recruitment of thirty-two participants at the University of California, Los Angeles (UCLA) and the surrounding community met the following inclusion criteria: *(i)* apparently healthy men and women, *(ii)* 18-30 years of age, and *(iii)* history of resistance training <4 workouts/monthly the past 6-months. Exclusion criteria included: *(i)* significant medical diagnoses, including cardiovascular, pulmonary, musculoskeletal, or metabolic disorders that may limit the ability to exercise or increase the cardiovascular risk of exercising, and (ii) use of any drug or supplement known to enhance anabolic responses. All volunteers completed a pre-participation physical activity readiness questionnaire (PAR-Q) (Warburton et al., 2011) and an exercise history questionnaire. The UCLA Institutional Review Board reviewed and approved the study, and all participants gave their written informed consent. This study was conducted according to international standards for sport and exercise science research.

Study design

This was a 12-week, prospective, single-blinded, randomized control trial. Using a parallel research design, healthy, college-aged men and women volunteers (n = 32) with minimal resistance training experience were randomly allocated 1:1 (16 per group) into one of two groups: the intervention, portable CRT device ("CRT") or the control, conventional resistance training ("CON"), by an investigator independent of the recruitment of participants using an online-generated random number program. Allocation was concealed with the use of consecutively numbered envelopes. The participants worked out thrice weekly (i.e., for a total of 36 sessions), between 45-60 minutes with the primary objective of increasing muscle strength. A 12-week trial was selected to ensure a training adaptation from both research arms. To prevent confounding, participants were asked to refrain from additional resistance-type or high-intensity anaerobic training for the duration of the study. All assessments and training were administered by trained research personnel under the direction of the lab director in the UC Fit Digital Health – Exercise Physiology Research Laboratory on UCLA's campus. Dietary intake and macronutrient portions were not controlled apart from the requirement of not starting a dietary supplement or weight loss/gain diet that might affect total and fat-free body mass.

Training intervention

The resistance training consisted of eight exercises per session with each targeting all major muscle groups of the body. The exercises performed were: back squat, Romanian deadlift, levered hip thrust, bench press, standing shoulder press, lateral pulldown, biceps curl and triceps pushdown. These exercises were selected based on their common inclusion in strength-type resistance training programs. Training sessions were thrice weekly performed on non-consecutive days for 12 weeks. Sets consisted of 8 to 12 repetitions carried out to the point of momentary concentric failure – that is, the inability to perform another repetition while maintaining proper form. The participants were tasked with a cadence of repetitions, in a controlled fashion, with a concentric action of approximately one second and a deliberate eccentric action of approximately two seconds. Ninety second rest periods between sets were encouraged with approximately two minutes between exercises to accommodate setting up equipment used in subsequent resistance exercise. During successive sets, the load was adjusted for each exercise as needed to ensure the participant achieved momentary failure in the target repetition range. If less than eight repetitions were accomplished, the load was decreased based on what would be required to reach momentary failure in the desired loading range; if a participant completed more than 12 repetitions to momentary failure in a given set, the load was similarly increased. Each week attempts were made to progressively increase the loads to ensure the participants were training with as much resistance as possible within the confines of maintaining the 8 to 12 target repetition range. Prior to training, participants underwent 10 repetition maximum testing to determine individual initial training loads for each exercise.

Study group: Portable CRT device (CRT)

The cable-based resistance machine ((MaxPro®, MaxPro Fitness; Farmington, Michigan) employing concentric-only resistance is compact, portable and folds easily, weighing under 10 lbs. The manufacturer describes a multi-plate friction-based system using a 'power clutch' resistance dial on opposing ends of the cable inserts that easily turn to adjust with 25 resistance settings ranging from 5 to 300 lbs. of concentric resistance. Depending on the exercise choice, the user selects their grips (the unit comes with a 3-part barbell, 2 handles, and two ankle/wrist straps) and adjusts the resistance dials to the appropriate level. The user may then use the CRT alone or choose to attach it to a bench or high-strength extruded aluminium rails that mount directly into the wall. A simple one-button up/down operation allows a smooth and quick transition from one exercise to the next (Figure 1). The CRT also connects to a smartphone via Bluetooth where workouts are tracked and monitored for progress. For those randomized to CRT, this feature was used to record and log total exercise volume and total workout time.

Figure 1a. *Left panel*: A portable cable-based resistance machine (MaxPro®) employing concentric-only resistance training (CRT). Additional accessories including 3-part barbell bar, handles, ankle/wrist straps, and optional slimline wall track (background) to perform pulldown/pushdown exercises and foldable bench for presses. Figure 1b. *Right panel*: Demonstration of biceps exercise using the portable CRT device.

Study group: Conventional Resistance training (CON)

A conventional cable/pulley-based crossover machine using dual-selectorized weight stacks was utilized by the CON group. Aside from the different training resistance between groups (i.e., concentric-eccentric vs concentric-only), the two machines mimicked near-identical movement patterns for the seven resistance exercises making this an ideal control. An iPhone app (UC Fit Research, Los Angeles, CA) tracked all sessions, including total training volume (i.e., load multiplied by sets multiplied by reps) and time.

Baseline and Post-Measures

Body mass was measured in duplicate on a calibrated medical scale (accuracy ± 0.1kg), and height was determined using a precision stadiometer (Seca, Hanover, MD, USA; accuracy ± 0.01 m). For mass, participants removed unnecessary clothing and accessories. For height, participants were instructed to stand as straight as possible with unshod feet flat on the floor. Body fat percentage was measured using a validated octipolar, multi-frequency, multi-segmental bioelectrical impedance analyser (BIA R20; InBody Co., Seoul, Korea) (Dolezal et al., 2013).

To ensure accuracy, participants adhered to standard pre-measurement BIA guidelines recommended by the American Society of Exercise Physiologists. The measure was performed after at least three hours of fasting and voiding, with participants instructed to remain hydrated and not exercise 2 hours before testing.

Lower and upper body muscular strength was assessed by the 1-repetition maximum (1-RM) method using squat and bench press exercises, respectfully. Testing comported with recognized guidelines established by the National Strength and Conditioning Association. The 1-RM is the highest weight lifted through a full range of motion at the correct speed only once. The squat 1-RM testing was conducted before the bench press with a 15-min rest period in-between. Participants were required to reach parallel in the squat for the attempt to be considered successful. Successful bench press was achieved if the participant displayed a five-point body contact position (i.e., head, upper back, and buttocks firmly on the bench with both feet flat on the floor) and executed full-elbow extension but not 'locked out'. Participants first warmed up on either a treadmill or cycle ergometer and did light stretching. Examiners allowed participants to practice the movement with no load before gradually adding weight and having them perform the first set with 6 to 8 repetitions. After one minute of rest, the load is increased, and the participant performed 3 to 4 repetitions. After one min rest, the participant performed 1 to 2 repetitions at a load estimated to be near a maximal effort. A final two-minute rest is given, the participant then attempts their 1-RM. For each 1-RM trial, participants attempted two repetitions (Baechle and Earle, 2008). The repeatability of strength tests was assessed on two non-consecutive days in a pilot study of five untrained men. The ICC for the bench press 1-RM and squat 1-RM was 0.97 and 0.95; SEM for these was 2.0 and 2.2 kg, respectfully.

Statistical analysis

Based on pilot testing and allowing for 15% missing data, a sample size of 32 participants (i.e., 16 per research arm) was determined to be sufficient to assess changes in strength outcomes based on $\alpha = 0.05$ and $\beta = 0.20$. All data were exported to IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, N.Y., USA) for analysis with an a-priori α level of = 0.05, and all tests were two-tailed. Descriptive statistics are presented as mean (SD). Grubbs' test was employed to detect potential outliers, and none were found. Before comparisons, all variables were assessed for normality via Shapiro-Wilk tests. Within-group (CRT vs. CON) comparisons at baseline and after 12 weeks were made by paired t-tests and Wilcoxon signed-rank tests for normally and non-normally distributed variables, respectively. Changes between groups were analysed by Welch's independent t-tests (normal) or Mann-Whitney U tests (non-normal). Given that this is one of the first randomized trials testing a portable CRT machine, we did not employ strict type 1 error control; however, we limited the number of main outcome measures and based our interpretation on the pattern of results seen for each domain rather than on individual statistical tests.

RESULTS

Thirty-two study participants (10 females) had an average age of 23.4 ± 2.0, ranging from 18 to 27 years old, completed the 12-week training program without injuries or serious adverse events, although two participants required an additional one week to complete the program due to minor illness or vacation. Training compliance for three sessions weekly for a total of 36 sessions was 100% for both groups. Although the average training time per session between groups did not differ (CON; 53 ± 4 vs. CRT; 49 ± 5 min, $p = .897$), the average training volume for each session (i.e., exercises x sets x volume x weight) between groups was almost 10% greater for the CRT vs. CON (18,908 ± 1310 kg vs. 17,045 ± 1687 kg, $p < .05$), respectfully. Anthropometric and muscular strength measures are described in Table 1. Both groups improved upper and lower body muscular strength from baseline to week 12. No differences existed between groups in age, height, body mass, body fat %, 1-RM chest press and 1-RM squat press at baseline and post-training.

Table 1. Anthropometric, upper and lower body muscular strength measures at baseline and after 12-wk training for the CON and CRT groups.

	CON group (n = 16; 5 females)				***p*-between**
	Baseline	12 Weeks	Change	*p*-within	
Age (yr.)	23.4 (2.0)	-	-	-	.922
Height (cm)	171 (8.7)	-	-	-	.893
Body mass (kg)	68.8 (7.2)	69.3 (12.1)	0.5 (3.4)	.730	.718
Body fat (%)	17.3 (4.9)	17.2 (3.8)	-0.1 (1.9)	.433	.843
CP 1-RM (kg)	54.5 (13.5)	68.4 (14.5)	13.9 (3.8)	**<.001**	.867
SP 1-RM (kg)	65.7 (13.7)	90.8 (19.1)	25.1 (4.2)	**<.001**	.820
	CRT group (n = 16; 5 females)				
	Baseline	12 Weeks	Change	*p*-within	
Age (yr.)	23.1 (1.9)	-	-	-	
Height (cm)	170 (9.9)	-	-	-	
Body mass (kg)	70.3 (12.9)	69.5 (9.3)	0.8 (2.2)	.411	
Body fat (%)	18.1 (3.4)	17.8 (3.2)	-0.3 (1.2)	.667	
CP 1-RM (kg)	55.7 (14.8)	69.8 (15.1)	14.1 (3.1)	**<.001**	
SP 1-RM (kg)	64.1 (16.3)	90.1 (20.0)	26.0 (6.5)	**<.001**	

Note. Values are mean (SD). No significant differences were observed between groups at baseline and 12-wk training. CP = chest press; SP = squat press; 1-RM = 1-Repetition Maximum.

DISCUSSION

Contrary to our original hypothesis, gains in muscular strength were notably similar across groups, with 12-wk of concentric-only and concentric-eccentric resistance training showing no differential effects on upper and lower body strength. The results presented herein suggest that the portable cable-based resistance machine that provides concentric-only resistance may be as effective as traditional concentric-eccentric resistance training in increasing muscular strength. Given the scarcity of training studies comparing concentric-only versus concentric-eccentric resistance training, the present study contributes to our understanding of the efficacy of concentric-only resistance training.

Although both the CON and CRT groups produced significant within-group improvements in chest press and squat press 1-RM (13.9 ± 3.8 kg and 25.1 ± 4.2 kg versus 14.1 ± 3.1 kg and 26.0 ± 6.5 kg, $p < .001$, respectively), no significant differences were detected between both groups. Traditional concentric-eccentric resistance training has been shown to be superior to CRT for increasing muscle strength (Blazevich et al., 2007; Franchi et al., 2014; Gabriel et al., 2006). However, the current study's findings, combined with previous research, suggest that CRT may be able to elicit significant changes in upper and lower body strength. Similarly, a 12 week study comparing the effects of maximal concentric-eccentric training to maximal concentric-only resistance training found no differences in training-induced lower-body hypertrophy (Mallinson et al., 2020). Although both groups yielded notable increases in quadriceps muscle cross sectional area (CON 3.9 ± 2.3%, ECC + CON 4.0 ± 3.1%, both $p < .001$) and isometric strength (CON 44.8 ± 40.0%, $p < .001$; ECC + CON 36.9 ± 40.0%, $p < .01$), no between-group differences were observed. Likewise, another study that compared the effects of concentric versus eccentric exercise immediately preceding eccentric training found that concentric exercise was associated with a quicker spontaneous recovery of maximal isometric force generation and reduced muscle soreness (Nosaka and Clarkson, 2010).

The findings of the present study, we believe, may be attributed to the increase in training volume permitted by the reduced eccentric phase in the CRT group. The CRT group had a nearly 10% higher average training volume for each session (i.e., exercises x sets x volume x weight) than the CON group (18,908 ± 1310 kg versus 17,045 ± 1687 kg, $p < .05$, respectively). Participants were instructed to maintain a specific cadence for each repetition, with 1 second concentric and 2 seconds of eccentric action. CRT, on the other hand, was performed much faster during each repetition because it lacked resistance during the eccentric phase. As a result, while the CRT group may have spent less time under tension overall, the trade-off allowed for more training volume to be completed. Interestingly, despite the increase in training volume, the average training time of 51 minutes per session did not differ between groups.

The dynamics between training volume, strength, and hypertrophy have been extensively researched. Increased resistance training volume has been linked to heightened metabolic stress and mechanical tension, which subsequently stimulates anabolic pathways that lead to muscle hypertrophy (Schoenfeld, 2010). Such a trend has been demonstrated to be consistent with low-load, high volume resistance exercise compared to high-load, low volume training (Burd et al., 2010). To this end, regardless of repetition ranges within each set, overall training volume has been identified to be a primary contributor to strength and hypertrophy adaptations (Klemp et al., 2016). While specific repetition ranges may contribute less to strength and hypertrophy than training volume, the number of sets appears to be important. Increased upper-body strength and cross-sectional area have been shown to correlate with higher set counts within an exercise protocol (Sooneste et al., 2013). Consequently, a dose-response relationship between training volume and strength metrics may have contributed to the findings of the current study. Another way to quantify training volume is volume load (VL), which refers to the number of repetitions completed multiplied by the external load of the weight lifted (McBride et al., 2009). Increases in VL have been associated with increases in 1-RM dynamic bicep strength across both males and females (Peterson et al., 2011). Furthermore, in males with no prior weight training experience, a dose-response relationship between training volume has been observed (Radaelli et al., 2015). During a six-month study that included four different resistance training groups (1-set, 3-set, 5-set, and control), the 5-set group produced significantly higher elbow extensor muscle thickness and bench press 20-RM performance relative to the other groups that completed less training volume. These results are consistent with those of the present study, which found that individuals with no prior weight training experience gained strength in response to increases in training volume.

Our results with this CRT machine show that it is just as effective as traditional concentric-eccentric resistance training in terms of muscle gains while avoiding DOMS during rest and recovery. Concentric exercises require less muscle force than eccentric exercises and increase blood flow to the muscles and tendons, which promotes tissue healing (Radak, 2018). Concentric exercises have also shown to induce short-term analgesic effects that mitigate DOMS and enhance recovery from muscle damage (Zainuddin et al., 2006). As a result, for the general fitness enthusiast, athletes in prehabilitation training cycles, and those in physical therapy during post-rehabilitation, this CRT machine may be a viable tool for improving muscular strength. Future studies would be beneficial in evaluating reinjury and recovery rates in older populations and athletes.

While this study contributes to a preliminary understanding of the efficacy of concentrically-focused training using a portable cable-based resistance machine, it is not without limitations. First, the results from the present study would be more generalizable with a larger sample size. To that end, the participants in this study consisted of active, college-aged volunteers who were all highly motivated to adhere to the training protocol. The results from the present study may not reflect the potential effects of this intervention on other (i.e.. sedentary) populations. Furthermore, increasing the intervention period may allow for a better long-term assessment of changes in muscle strength and cardiovascular measures.

CONCLUSION

This study demonstrates the potential efficacy of concentrically focused resistance training platforms in improving participant fitness, with implications for both recreational and clinical use.

AUTHOR CONTRIBUTIONS

The study was conceived and designed by T.Y., A.K., S.M., B.P., M.S.M., and B.A.D. T.Y., A.K., S.M., T.H.N., D.M.B., T.L.N., A.E.B., and R.J.L. performed data collection. T.Y., A.K., S.M., B.P., T.H.N., D.M.B., A.E.B., R.J.L., M.S.M., E.V.N. and B.A.D. completed data analysis. T.Y., A.K., and S.M. interpreted data and composed the manuscript while M.S.M., E.V.N., and B.A.D. made crucial edits. All authors have read and agreed to the published version of the manuscript.

ETHICS COMMITTEE APPROVAL

This study was performed in accordance with the ethical standards of the Helsinki Declaration and was approved by the UCLA Institutional Review Board (#11-003190). All participants provided written informed consent.

SUPPORTING AGENCIES

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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