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The effects of breakdown set resistance training on muscular performance and body composition in young males a006Ed females.

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Abstract

Breakdown (BD) training has been advocated by multiple commercial and academic publications and authors, seemingly as a result of the acute hormonal and muscle activation responses it produces. However, there is a relative dearth of research which has empirically considered this advanced method of resistance training (RT) over a chronic intervention whilst appropriately controlling other RT variables. The present study considered thirty-six male and female participants divided in to three groups; breakdown (BD, *n*=11), heavy-load breakdown (HLBD, *n*=14) and traditional (CON, *n*=11), performing full-body resistance training programmes 2 x / week for 12 weeks. No significant between group differences were identified for change in absolute muscular endurance for chest press, leg press, or pull down exercises, or for body composition changes. Effect sizes for absolute muscular endurance changes were large for all groups and exercises (0.86 – 2.74). The present study supports previous research that the use of advanced training techniques stimulates no greater muscular adaptations when compared to performing more simplified resistance training protocols to momentary muscular failure.

Key words: Drop-sets, advanced techniques, muscle, lean mass, body fat

INTRODUCTION

Resistance training (RT) leading to momentary muscular failure (MMF) has been evidenced as producing significantly greater muscular strength and hypertrophic adaptations when compared to RT not performed to MMF (14,15,18). It is thought that the sequential recruitment of motor units (MUs) and muscle fibres which occurs during RT performed to MMF through Henneman's size principle (3,23) amongst other potential mechanisms of adaptations (28) might stimulate the greatest increases in muscular strength and hypertrophy (14,15). A recent meta-analysis further supports that, when controlled for effort by training to MMF, significant strength and hypertrophy occur with both light and heavy loads (30).

Though training to MMF appears to be important for optimising adaptations, the use of advanced RT techniques that allow a trainee to potentially train *beyond* MMF should be considered. Recent work has examined advanced RT techniques such as rest-pause (18) and pre-exhaustion (13), finding they offer no further benefit over training simply to MMF. Another commonly discussed technique is that of breakdown sets (also known as drop sets and descending sets; 25,29). Breakdown (BD) sets require the performance of a set to MMF with a given load before immediately reducing the load and continuing repetitions to subsequent MMF. As such this technique can allow MMF to be achieved in addition to potentially inducing greater fatigue related stimuli. It is thought this might maximise recruitment of both type II and type I MUs through use of both heavier and lighter loads thus allowing the combination of high muscular tension as well as inducing greater MU fatigue, metabolic stress, and ischemia due to extended time under tension (29).

We might also consider fatigue in context of the reduction to muscular force made as a product of the exercise. For example a person will reach MMF with a load of 80% 1RM when their maximal force production <80% 1RM. This occurs as a product of inability to continue recruiting muscle fibres and/or a reduction in rate of discharge (rate coding; 10). As a result we might hypothesise that many lower threshold MUs and thus muscle fibres have not reached a state of complete fatigue despite their recruitment. However if the load is reduced (e.g. to 50% 1RM) then recruitment and/or rate of discharge is likely sufficient to produce enough force to continue to exercise. In this example our participant will reach MMF with a load of 50% 1RM when maximal force production <50% 1RM. This represents a pertinent example of BD training and as such we should consider whether this greater reduction to acute force results in chronic muscular adaptations in size and strength.

To date, there are few empirical research studies which have considered the use of BD training. Keogh et al. (24) and Goto et al. (20) considered the acute effects of BD training on muscle activation and hormonal response, respectively. However, neither study provides evidence towards chronic adaptations. Goto et al. (20) reported greater increases in growth hormone (GH) following the BD training protocol (sets of knee extension at 90% 1RM followed by a set at 50% 1RM) compared to a traditional resistance training protocol (sets of knee extension at 90% 1RM). Whilst this increased GH might suggest greater potential gains in hypertrophy (e.g. 28) authors have critiqued the hormone hypothesis suggesting that increases in GH are not proxy markers for strength or hypertrophy (4,32). In addition Keogh et al. (24) used a variation of BD training whereby participants only performed a single repetition at a near maximal load (95% 1RM) before reducing the load for each of 5 consecutive repetitions. A similar method was considered by Berger and Hardage (2) who compared a set of 10 maximal repetitions, starting at 1RM and decreasing in load for each subsequent repetition. The authors reported greater increases in strength compared to performing a single set of repetitions to 10RM. However, this protocol limits application by the use of a series of single near-maximal repetitions rather than multiple consecutive repetitions for a set to MMF before decreasing the load.

A further study by Goto et al. (19) compared traditional training to BD training reporting favourable strength increases for the BD training protocol. All participants performed 6 weeks of an identical resistance exercise protocol and were then divided in to either BD or traditional training groups. The traditional training group performed 5 sets of knee extension and leg press exercise 2 x / week at 90% 1RM with 3 minutes rest between exercise sets. The BD training group performed the same protocol with an additional set performed 30 seconds after the fifth sets using 50% 1RM, where all sets in both groups were continued to a point of MMF. The authors reported significantly greater results for leg press 1RM, as well as maximal isokinetic torque (300deg/s) and muscular endurance (repetitions to MMF at 30% of MVC) for the knee extension for the BD protocol compared to the traditional protocol. In addition the authors reported that the BD group showed greater increases in muscle CSA of the thigh compared to the traditional group; however this did not reach significance ($p< 0.08$). Whilst this appears to support the efficacy of BD training, there was a disparate training volume between the BD and traditional training groups, and BD training has customarily been described by the *immediate* performance of subsequent repetitions at the lighter load, not following a 30 second rest interval.

The most recent study considering BD training compared multiple and single set training protocols in males and females training 2 x / week for 10 weeks (17). The single set training group performed nine exercises(chest press, heel raise, rear deltoid fly, elbow flexion, seated row, knee extension, knee flexion, abdominal flexion, push-ups) and upon reaching MMF immediately reduced the load by 10-15% and continued for as many repetitions (~2-3) as possible. When they reached MMF a second time they repeated the breakdown set; reducing the load by a further 10-15% and performed further repetitions to MMF (~2-3). The multiple set group performed the same exercises to their self-determined 10RM (i.e. they stopped when they perceived themselves to be one repetition away from MMF; 18) for a single set in a circuit format, performing 3 circuits (e.g. 3 sets of each exercise). Data revealed significantly greater improvements in strength for heel raise, elbow flexion and knee flexion for the BD training group compared to the multiple set group. However, when data was analysed by gender females showed a greater strength increase for chest press, seated row, heel raise and push-up for the BD training protocol compared to the multiple set training protocol, whereas there were no significant between group differences for changes in strength for males. Whilst this represents an ecologically valid approach to resistance training the study does not control for volume of training and intensity of effort between groups.

It is surprising that a method as commonly advocated as BD training, in both commercial (e.g. 7,16,26,31) and academic literature (e.g. 1,29)is lacking evidence to support its efficacy. With this in mind, the aim of the present study was to determine the effects of 12-weeks resistance training with and without BD protocols on muscular performance and body composition.

METHODS

Experimental Approach to the Problem

A randomised controlled trial design was adopted, with three experimental groups included. The effects of three RT interventions were examined in trained participants upon muscular performance and body composition. The study design was approved by the relevant ethics committee at the first author's institution.

Participants

Participants were required to have had at least 6 months' RT experience (single set training to MMF for multiple exercises including most major muscle groups, ~ 2 x / week)and no medical condition for which RT is contraindicated to participate. Potential participants were considered from the present membership pool in a USA fitness facility (*Discover Strength*, Chanhassen, Minnesota). Forty one (males n=13, females n=28) persons attended an initial briefing and eligibility assessment regarding the research following advertisement and were subsequently recruited. Figure 1 shows a CONSORT diagram highlighting the participant numbers for enrolment, allocation, follow-up and analysis stages for the study. Written informed consent was obtained from all participants prior to any participation. Participants were randomised using a computer randomisation program to one of three groups; breakdown training (BD; n=11), heavy load breakdown training (HLBD; n=14) and a control group (CON; n=11). Participants were asked to refrain from any exercise away from the supervised sessions.

INSERT FIGURE 1 ABOUT HERE

Procedures

Testing

Pre and post muscular performance testing was performed in the following order with 120 seconds rest between exercises using chest press, leg press, and pull down (MedX, Ocala, FL, USA) resistance machines. As participants were existing members of the facility where testing and training took place, all participants used their pre-existing training load for testing. It was estimated this load would allow performance of 8 to 12 repetitions at the 2 second concentric, 4 second eccentric (2:4) repetition duration used for testing and training. Pre and post testing utilised the same absolute load allowing total volume (e.g. load x repetitions) to be calculated as has been completed in previous research (8,13). This method allows comparison of absolute muscular endurance and is considered a representative method of muscular performance. This testing method provides strong ecological validity to realistic training conditions as most persons infrequently test or use their maximal strength. In addition it likely has greater application for BD training which might provide greater stimulus for lower threshold MUs as opposed to maximal strength testing which will recruit higher threshold MUs. The test was ceased when the participant failed during the concentric phase of a repetition or could not maintain the required repetition duration. Post testing was performed at least 48 hours following the final training session as per previous research (13). The instructor performing the pre and post testing was blinded to group assignment.

Body composition was estimated using air displacement plethysmography (Bod Pod GS, Cosmed, USA).Details of the test procedures for estimation of body composition have been previously described in detail elsewhere (9). Briefly, whilst wearing minimal clothing (swimsuit or tight fitting underwear) and a swim cap, participants were weighed using a calibrated digital scale. The participant is then seated in the Bod Pod for body volume measurement. From the body mass and body volume measurements, and predicted thoracic lung volumes, body density is estimated by the Bod Pod software and lean and fat mass estimations calculated using the Siri equation.

Training Intervention (BD, HLBD, CON)

Training was performed 2x/week (with at least 48 hours between sessions) for 12 weeks. Each exercise was performed for one set per training session at a 2:4 repetition duration until MMF (i.e. when they reached a point of concentric failure during a repetition) to control for intensity of effort between groups (31).All participants performed 2 exercise sessions per week. The first of these, workout 'A', consisted of chest press, leg press, pull down (MedX, Ocala, FL, USA) overhead press, adductor, abductor (Nautilus Evo, Vancouver, WA, USA), abdominal flexion (MedX Core Ab Isolator, USA), and lumbar extension (Roman chair using bodyweight or manual resistance; Hammer Strength, Rosemount, Ill, USA). The second session, workout 'B', consisted of pec-fly, pull-over (Nautilus Evo, Vancouver, WA, USA), leg extension (MedX, USA), dip, biceps curl (Nautilus Evo, Vancouver, WA, USA), seated calf raise (Hammer Strength, Rosemont, Ill, USA), leg curl, and core torso rotation (MedX, Ocala, FL, USA) resistance machines.

All groups performed a single set of each exercise for both workout A and B with the exception of the breakdown method which was used for the chest press, leg press and pull-down exercises in workout A only (e.g. the exercises which were tested). All other exercises were performed to MMF with a load permitting 8-12 repetitions. Once participants were able to perform more than 12 repetitions before achieving MMF, load was increased by ~5%. This is in accordance with previous recommendations and research (e.g. 12,26, respectively). For the chest press, leg press and pull down exercises the BD group performed a single set of 8-12 repetitions to MMF and immediately reduced the load by ~30% and then continued performing repetitions to MMF. Using the same 3 exercises the HLBD group used a heavier load permitting only ~4 repetitions, upon reaching MMF they decreased the load by ~20% and continued performing repetitions to MMF, and then repeated the breakdown reducing the load by a further 20% and performing repetitions to MMF. The CON group performed all exercises for a single set of 8-12 repetitions to MMF with no breakdown. The group protocols were chosen to allow parity between training load (the BD and CON groups both used the same relative load to begin; permitting 8-12 repetitions) and repetition volume (the HLBD and CON group both performed a total of ~8-12 repetitions).

Statistical Analysis

Power analysis of research using low volume RT in trained participants (13) was conducted to determine participant numbers (n) using an effect size (ES), calculated using Cohen's *d* (5) of 1.25 for improvements in strength. Participant numbers were calculated using equations from Whitley and Ball (34) revealing each group required 9 participants to meet required β power of 0.8 at an α value of $p \leq .0.05$.

After drop-outs data were available from 36 participants (BD, n = 11; HLBD, n = 14; CON, n = 11). Data met assumptions of normality of distribution when examined using a Kolomogorov-Smirnov test. Baseline data were compared between groups using a one-way analysis of variance (ANOVA) to determine whether randomisation had succeeded. Between groups comparisons for absolute changes in muscular performance and body composition outcomes were performed using one-way ANOVA. Where assumptions of homogeneity of variance were violated the Welch's F test statistic was used. Any significant between-group effects were examined further with post-hoc Tukey testing to determine the location of significant differences. Statistical analysis was performed using IBM SPSS Statistics for Windows (version 20; IBM Corp., Portsmouth, Hampshire, UK) and $p \leq .05$ set as the limit for statistical significance. Further, 95% confidence intervals (CI) were calculated in addition to ES using Cohen's *d*(5) for each outcome to compare the magnitude of effects between groups where an ES of 0.20-0.49 was considered as small, 0.50-0.79 as moderate and ≥0.80 as large. Due to the discrepancy in gender ratio between the CON group and both BD and

HLBD the above analyses were also conducted with males excluded and it is noted in the results section where these finding differed from the combined gender results. The researcher who performed the data analyses was blinded to group assignment.

RESULTS

Participants

Participant baseline demographics are shown in Table 1. Demographic variables did not differ between groups at baseline.

INSERT TABLE 1 ABOUT HERE

Absolute Muscular Endurance

ANOVA did not reveal any significant between group effects for baseline muscular endurance data for any exercise. Figure 2 shows the mean changes in absolute muscular endurance with 95%CIs for each group and exercise with 95%CIs indicating that significant changes in muscular performance within each group occurred for every exercise. ANOVA did not reveal any significant between group effects for change in absolute muscular endurance for chest press ($F_{2,\ 18.089}$ = 3.531, p = 0.051), leg press, ($F_{2,33}$= 0.349, p = 0.708), and pull down ($F_{2,33}$ = 0.286, p = 0.753). Results did not differ when females were examined separately and no significant differences were identified though it is noted that observed β for female only comparisons ranged 0.11 – 0.45 and so this may have resulted in a type II error. ESs for muscular performance changes were all considered large and for BD, HLBD, and CON groups respectively were: 1.22, 2.74, and 1.46 for chest press; 1.29, 1.19, and 0.86 for leg press; and 1.32, 2.48, and 2.27 for pull down.

INSERT TABLE 2 AROUND HERE

INSERT FIGURE 2 AROUND HERE

Body composition

ANOVA did not reveal any significant between group effects for baseline body composition data. Table 2 shows mean changes, 95%CIs and ESs for body composition changes. ANOVA did not reveal any significant between group effects for change in either body mass ($F_{2,33}$ = 0.394, p = 0.677), body fat percentage ($F_{2,33}$ = 0.532, p = 0.592), or lean mass ($F_{2,33}$ = 0.509, p = 0.606). Results did not differ when females were examined separately and no significant differences were identified though it is noted that observed β for female only comparisons ranged 0.178 – 0.267 and so this may have resulted in a type II error.

DISCUSSION

The present study examined the effects of BD training using both heavy- and traditional-load protocols, compared to a control group training to MMF, in trained participants. Results indicated that neither BD (+61.5%) nor HLBD (+54.7%) groups attained significantly greater gains in absolute muscular endurance than CON group (+51.3%). The use of 3 training protocols accommodated parity between groups in both repetition volume (HLBD and CON groups both performed ~12 repetitions per exercise) and training load (BD and CON groups both used an initial load allowing 8-12 repetitions). The advanced technique of immediately reducing the load when reaching MMF and performing subsequent repetitions both with a heavy- (HLBD) and moderate-load (BD) resulted in no greater gains in muscular performance improvement beyond that of performing a single set protocol of 8-12 repetitions to MMF. The magnitude of improvement in muscular performance for all groups and all exercises were considered large and significant from examination of ESs and 95%CIs.

Recent publications (13,14,18) have suggested that training to MMF appears sufficient stimulus to catalyse optimal muscular adaptations without the need for advanced training methods such as pre-exhaustion or rest-pause training. Schoenfeld (29) suggested that BD training might produce greater adaptations as a result of the high muscular tension associated with heavier loads, greater MU fatigue, and metabolic stress and ischemia as a result of the increased time under tension. Indeed, multiple commercial texts (7,16,26,33) and academic publications (1,29) have previously recommended the use of BD training. However, whilst this hypothesis seems logical, the present study has failed to support any chronic adaptations from BD training beyond that of more simple methods. In fact, the present study is concurrent with our understanding of the size principle; that there is a sequential recruitment of MUs, from the smallest to the largest, as a product of fatigue (3,23). As such the present study supports that this sequential recruitment sufficiently stimulates adaptation without the need for subsequent stimulation in the form of BD training or other advanced techniques. However, it would be imprudent not to discuss that analyses for the CP revealed p = 0.051, with ESs differing considerably between BD, HLBD and CON groups (1.22, 2.74, and 1.46, respectively). Whilst we cannot state that a p = 0.05 value *approaches* significance because we cannot be certain whether a greater sample size would have resulted in a higher or lower p value, we can ascertain from ESs that in the present study greater (although not significant) improvements in muscular performance were obtained for the CP when using a heavier load. Conversely, this trend was not consistent for LP or PD exercises. It should, however, also be noted that for the PD exercise the CON group attained an ES similarly high as did the HLBD group and thus this may just be reflection of the heterogeneity of responses within those groups for those exercises.

Body composition changes within the present study were minimal in all participants across all training groups, and were likely within the margin of error, as has been reported in previous research (13), for the method of measurement used (6,11). However, research has reported large increases in cross-sectional area (CSA) of the quadriceps in young and older females (ESs = 1.08 and 2.23, respectively) without significant change in body mass, body composition, and fat free mass (22). In addition, large increases in quadriceps CSA, following 9 weeks of lower body RT in young and older males (ESs = 1.61 and 4.64, respectively) were apparent with only small but significant increases in body mass (0.9kg and 0.8kg, respectively) with no change to body composition. Within the present study the pooled male data showed a statistically significant increase in body mass of 1.5kg (95%CIs 0.37kg to 2.7kg). Since there was no change in body composition, from a practical perspective these figures might represent a relatively meaningful increase in muscle mass over a 12-week period. This suggests that hypertrophic adaptations might have occurred within the present study but were unidentifiable by our anthropometric measurements. Considering this, future research should look to specifically investigate the effects of advanced techniques such as BD training upon more valid measures of hypertrophy such as magnetic resonance imaging, computed tomography, or ultrasound. In addition, since the present study measured absolute muscular endurance future research should consider maximal strength testing and/or peak torque testing using isokinetic and/or isometric dynamometry.

The present study has considered trained participants and as such adds to the limited research considering this population group. However, the training intervention only applied BD training to the 3 tested exercises. Since other exercises performed also recruited the major muscles that were used in the tested exercises (e.g. pec-fly, pullover, leg extension, and leg curl) we might consider that performing BD training for other exercises might have affected results. In addition whilst the present study attempted between group parity in training load (BD and CON) and repetitions (HLBD and CON), it could be argued that upon reaching failure performing another set, albeit with a decreased load, amounts to performing a higher training volume. Further that volume-load (reps x sets x load) was not equated between groups may have affected outcomes. As such future research should consider further manipulation and control of these variables in accordance with BD training.

We should also consider the large number of females within the present study, and indeed the disparate number of males and females between groups (Table 1). Whilst statistical analysis was performed for independent genders we should be cautious to consider these results wholly representative of either population specifically. Our research design may have been improved by use of a gender counterbalanced approach to randomisation. The female only comparisons resulted from considerably reduced power and thus may reflect a type II error. However, the combined gender groups were deemed sufficiently powered based upon *a priori* estimates and indeed muscular performances outcomes in this study were examined using absolute changes as opposed to relative changes the former of which has been shown to not differ between genders despite differences in relative changes (21). There was though slightly more favourable ESs in the BD group despite not achieving significance which may reflect sampling and randomisation inadequacy possibly affected these outcomes. Future research might consider a similar methodological approach with different population groups controlled for gender, and differing manipulation of variables discussed herein. In addition further research might investigate the perceived effort and muscular discomfort associated with training to, and beyond, MMF along with potential psychological effects such as motivation, enjoyment, etc. considering that recent research has also suggested that motivation to continue performing RT using advanced techniques such as BD sets may be lower than RT involving lower intensity of effort (17).

PRACTICAL APPLICATIONS

Results from the present study suggest that considerable increases in muscular performance can be attained by the use of brief, infrequent and uncomplicated resistance exercise, specifically in persons with previous resistance training experience. Furthermore, this study adds to the relative dearth of empirical research that advanced training techniques appear to produce no greater gains in muscular performance than traditional sets of RT performed to muscular failure. From a practical perspective the present study reinforces our understanding of the size principle that exercise to MMF recruits all available MUs irrespective of load and advanced techniques. For strength coaches and athletes with limited time resources and engaging in sport-specific skill training, the present study supports that a time efficient manner of uncomplicated training appears an efficacious approach to improving absolute muscular endurance.

ACKNOWLEDGEMENTS

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Figure 1. Consort Diagram

Figure 2. Mean muscular endurance changes and 95% confidence intervals for each group and exercise. BD = breakdown, HLBD = heavy load breakdown, CON = control.

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Table1. Participant baseline characteristics

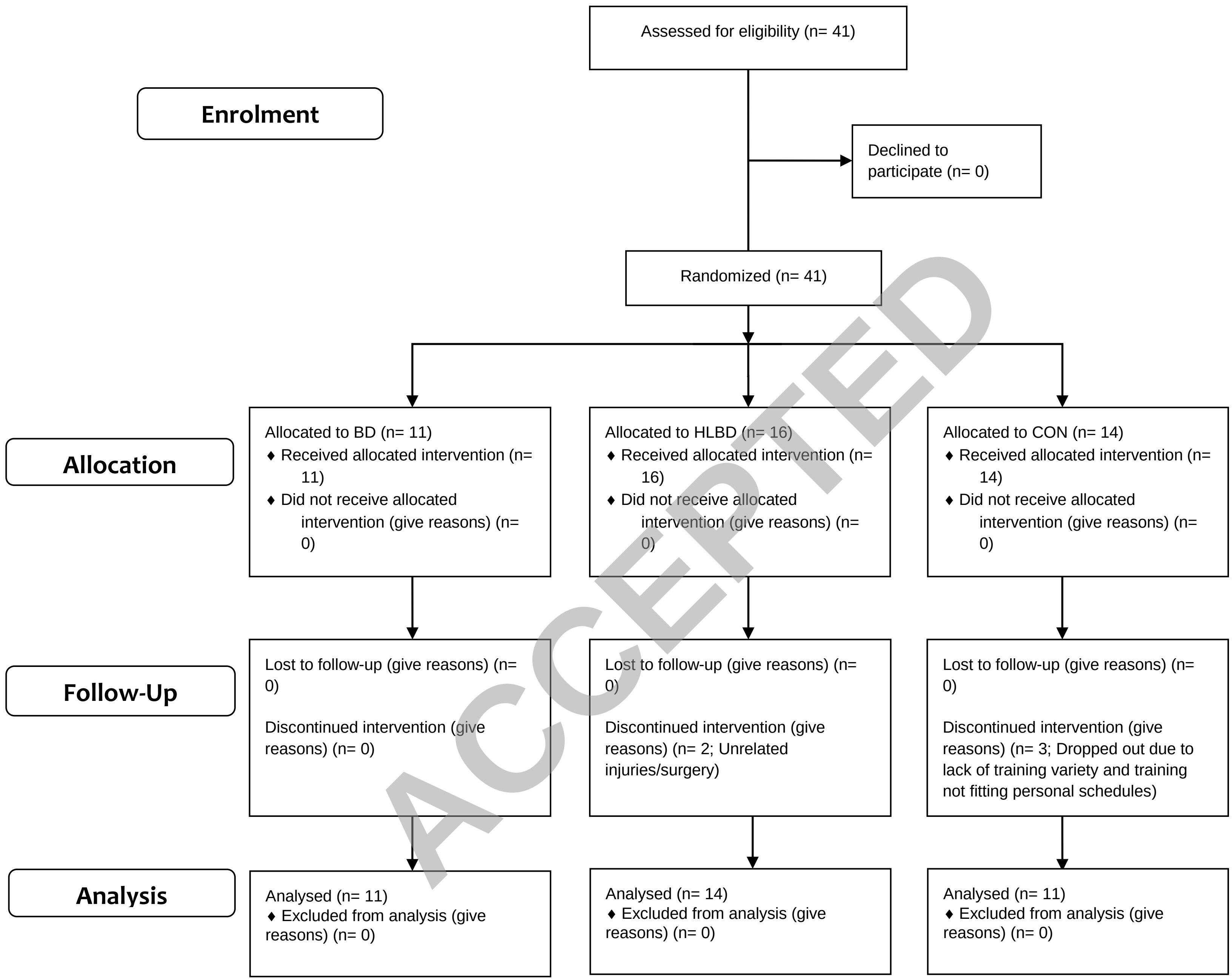
	BD	HLBD	CON	*p*
Age (y)	38±7	37±13	34±12	0.654
Stature (cm)	167.12±9.70	167.42±8.15	173.81±9.85	0.160
Body mass (kg)	68.81±10.15	69.16±13.36	75.77±15.96	0.387
BMI	24.63±2.91	24.50±3.14	24.86±3.32	0.961
Sex ratio (male: female)	3:8	2:12	6:5	N/A

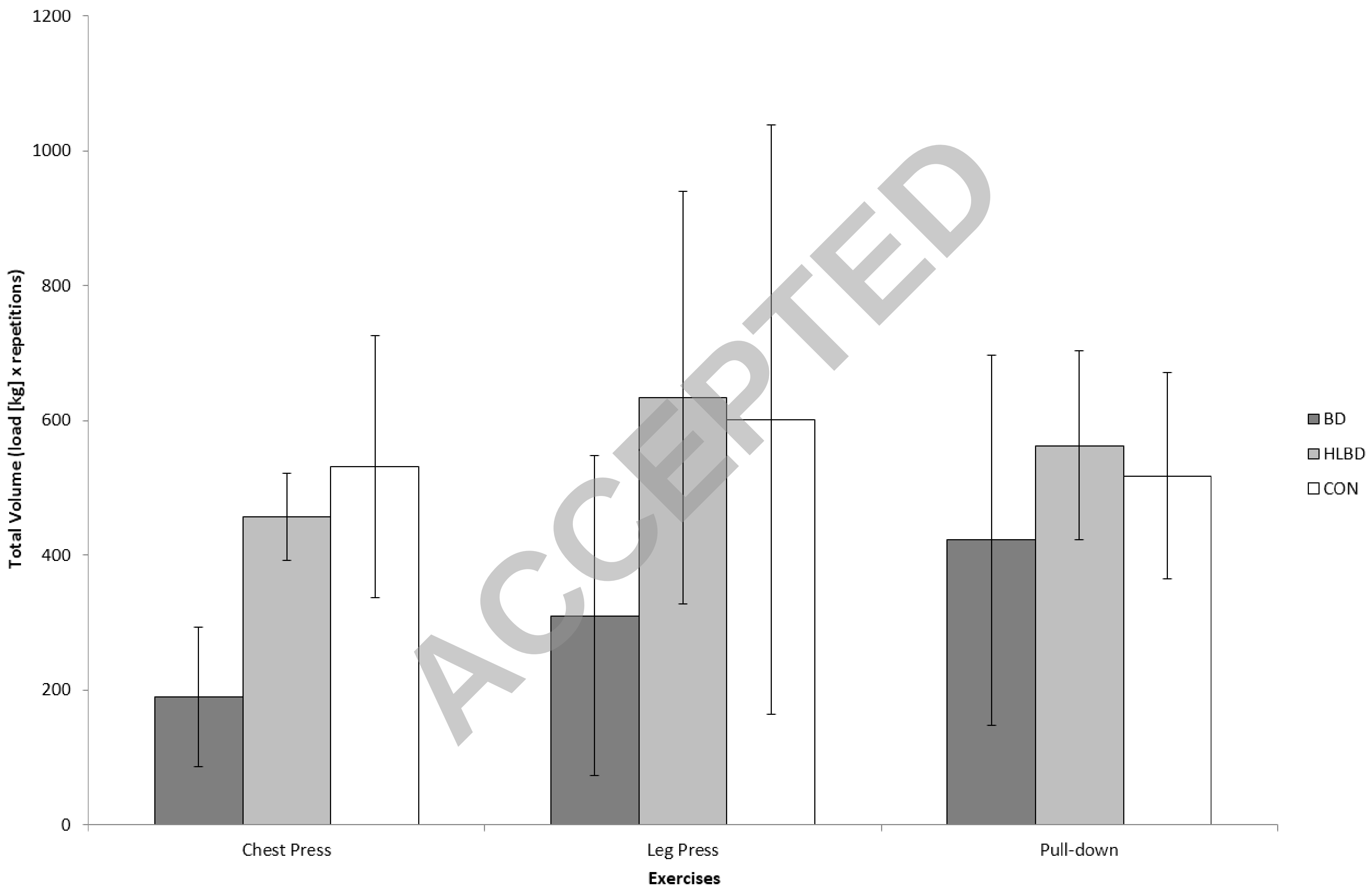
Note: Results are means ± SD; *p* values for between group effects using ANOVA; BMI = body mass index; BD = breakdown; HLBD = heavy load breakdown; CON = control; N/A = not applicable

Table 2. Mean changes and effect sizes for body composition outcomes

Outcome	BD			HLBD			CON			*p*
	Change	95% CI	ES	Change	95% CI	ES	Change	95% CI	ES	
Body Mass (kg)	0.55±1.15	-0.22 to 1.32	0.48	-0.05±2.07	-1.25 to 1.14	-0.02	0.48±2.16	-0.98 to 1.93	-0.22	0.677
Body Fat (%)	0.00±1.57	-1.05 to 1.05	0	-0.01±3.33	-1.93 to 1.92	0	0.94±2.01	-0.41 to 2.29	0.46	0.592
Lean Mass (kg)	0.41±1.14	-0.35 to 1.32	0.36	-0.19±1.37	-0.98 to 1.14	-0.14	-0.32±1.58	-1.38 to1.93	-0.20	0.606

Note: Results are mean ±SD; ES = Cohen's *d*; *p* values for between group effects using ANOVA


Assessed for eligibility (n= 41)
Enrolment
Declined to participate (n= 0)
Randomized (n= 41)
Allocation
Allocated to BD (n= 11)
♦ Received allocated intervention (n= 11)
♦ Did not receive allocated intervention (give reasons) (n= 0)
Allocated to HLBD (n= 16)
♦ Received allocated intervention (n= 16)
♦ Did not receive allocated intervention (give reasons) (n= 0)
Allocated to CON (n= 14)
♦ Received allocated intervention (n= 14)
♦ Did not receive allocated intervention (give reasons) (n= 0)
Follow-Up
Lost to follow-up (give reasons) (n= 0)
Discontinued intervention (give reasons) (n= 0)
Lost to follow-up (give reasons) (n= 0)
Discontinued intervention (give reasons) (n= 2; Unrelated injuries/surgery)
Lost to follow-up (give reasons) (n= 0)
Discontinued intervention (give reasons) (n= 3; Dropped out due to lack of training variety and training not fitting personal schedules)
Analysis
Analysed (n= 11)
♦ Excluded from analysis (give reasons) (n= 0)
Analysed (n= 14)
♦ Excluded from analysis (give reasons) (n= 0)
Analysed (n= 11)
♦ Excluded from analysis (give reasons) (n= 0)


1200
1000
800
600
400
200
0
Total Volume (load [kg] x repetitions)
Chest Press
Leg Press
Pull-down
Exercises
BD
HLBD
CON
ACCEPTED