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A comparison of low volume 'high-intensity-training' and high volume traditional resistance training methods on muscular performance, body composition, and subjective assessments of training

AUTHORS: Giessing J[1], Eichmann B[1], Steele J[2], Fisher J[2]

[1] Institut für Sportwissenschaft, University of Koblenz-Landau, Germany
[2] Centre for Health, Exercise and Sport Science, Southampton Solent University, UK

Corresponding author:
James Steele
Centre for Health, Exercise and Sport Science,
Southampton Solent University,
East Park Terrace,
Southampton,
Hampshire,
United Kingdom
SO14 0YN
E-mail: james.steele@solent.ac.uk

ABSTRACT: Most studies of resistance training (RT) examine methods that do not resemble typical training practices of persons participating in RT. Ecologically valid RT programs more representative of such practices are seldom compared. This study compared two such approaches to RT. Thirty participants (males, n=13; females, n=17) were randomised to either a group performing low volume 'High Intensity Training' (HIT; n=16) or high volume 'Body-building' (3ST; n=14) RT methods 2x/week for 10 weeks. Outcomes included muscular performance, body composition, and participant's subjective assessments. Both HIT and 3ST groups improved muscular performance significantly (as indicated by 95% confidence intervals) with large effect sizes (ES; 0.97 to 1.73 and 0.88 to 1.77 respectively). HIT had significantly greater muscular performance gains for 3 of 9 tested exercises compared with 3ST ($p < 0.05$) and larger effect sizes for 8 of 9 exercises. Body composition did not significantly change in either group. However, effect sizes for whole body muscle mass changes were slightly more favourable in the HIT group compared with the 3ST group (0.27 and -0.34 respectively) in addition to whole body fat mass (0.03 and 0.43 respectively) and whole body fat percentage (-0.10 and -0.44 respectively). Significant muscular performance gains can be produced using either HIT or 3ST. However, muscular performance gains may be greater when using HIT. Future research should look to identify which components of ecologically valid RT programs are primarily responsible for these differences in outcome.

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INTRODUCTION

Resistance training (RT) is widely recognised as a mode of exercise that offers considerable value for optimising health and longevity. Participation in such exercise and the increased strength and muscle mass it produces has been evidenced to reduce the risk of numerous morbidities [1,2] in addition to all-cause mortality [3-8]. Thus, understanding which RT approaches are most efficacious is of considerable interest. A frequently debated topic in RT is volume, with number of sets of repetitions (sets x repetitions e.g. 1 x 12, 3 x 12 etc.) commonly being considered. Numerous reviews and meta-analyses have examined this area with contrasting findings [9-22] and further empirical work continues to offer contrasting results; some studies support multiple set approaches [23-25] and some studies report no differences between single and multiple set routines [25-32].

Research has examined set volume experimentally by controlling all other RT variables and only varying the set number. Though this allows examination of this variable in isolation, it does not necessarily represent ecologically valid programmes employed by people outside of an exercise laboratory gym. Examination of studies considering low and high set volumes [33] suggests intensity of effort [34] applied often differs. Surveys of strength and conditioning practices [35-40] highlight single set routines are most commonly performed to momentary muscular failure (MMF [a]) and multiple set routines often do not specify but tend to be performed to fixed repetition numbers/ranges or a repetition maximum (RM [b]).

Advocates of low volume RT typically suggest an approach colloquially called 'High Intensity Training' [41-46] which involves performance of a single set per exercise to MMF using a relatively moderate to long repetition duration and often utilises advanced techniques to allow the trainee to exercise 'beyond' MMF (i.e. drop sets, forced repetitions, rest-pause etc.). Advocates of multiple set RT, however, often suggest performance of >3 sets of between 8-12 repetitions using a relatively shorter repetition duration [47,48]. Whether sets are performed to RM or to MMF is often unspecified as the two concepts have not been clearly differentiated [33,49,50]. In fact some authors propose avoiding training to MMF as it is argued repeated training to MMF may lead to overtraining [51]. Willardson [50] highlights there is insufficient evidence to suggest multiple set RT should be performed to MMF. A recent survey of male bodybuilders training practices did not distinguish between RM and MMF, but indicated respondents generally performed ~3-6 sets of 7-12RM with 61-120 seconds rest between sets [52]. Its unclear but, based upon the above recommendations [50-51], such multiple set 'Body-building' routines likely employ training to a self-determined RM.

These two ecologically valid approaches to low and high volume RT have seldom been empirically examined within the literature and, where they have, often with inclusion of load periodization for multiple set groups [53-56]. Two studies directly compared low volume RT to MMF and higher volume RT not to MMF. Kramer et al. [53] examined three groups; a single set to MMF (SS), 3 sets of 10 repetitions (MS), and a 3 set periodized loading group (MSV). They reported significantly greater improvements in 1RM squat from both week 0-5 and 0-14 for the MS and MSV groups compared with the SS group. McGee et al. [54] also compared a single set to MMF (N), 3 sets of 10 repetitions (H), and a 3 set periodized loading group (P) upon cycling time to exhaustion and muscular performance using a squat endurance test reporting for both outcomes that H>P>N. The reasons for these results are uncertain considering the unclear data regarding set volume as a key RT variable [9-32] in addition to evidence suggesting superiority of training to MMF [21,22] and that training to MMF significantly improves cardiovascular fitness and endurance [57].

Since the present body of research regarding ecologically valid RT approaches is equivocal and studies have also not included use of advanced training techniques often employed in single-set training; the aims of the present study were to compare the use of 'High Intensity Training' and 'Body-building' style RT upon both muscular performance and body composition in addition to participant subjective assessments of training.

MATERIALS AND METHODS

Study Design

A randomised trial was conducted with two experimental groups examining ecologically valid low and high volume RT interventions upon muscular performance and body composition. The study design was ethically approved by the author's institution. All procedures were performed in accordance with the ethical standards of the Helsinki Declaration. Written informed consent was obtained from all participants.

Participants

Participants were healthy university sports students engaged in recreational sports. Power analysis of low and high volume RT research in participants without prior RT experience [26] was conducted to determine participant numbers (n) using an effect size (ES), calculated using Cohen's d [58] of ~1.1-1.3 for improvements in muscular performance. Participant numbers were calculated using equations from Whitley and Ball [59] revealing each group required between 9 and 13 participants to meet required power of 0.8 at an alpha value of $p<.0.05$. Thirty participants were initially identified and recruited. No initial dropouts were recorded after eligibility assessment so 30 participants were randomised to one of two groups using an online randomisation programme (Research Randomizer vs 3.0); a group performing a single set of each exercise to MMF plus drop-sets (HIT; n=16), or a group performing three sets of each exercise to a self-determined RM (3ST; n=14).

Equipment

Muscular performance measurement and training were performed using chest press, heel raise, rear deltoid, elbow flexion, seated row, knee extension, and knee flexion resistance machines (Nautilus Inc., USA). Body composition including body mass, whole body muscle and fat mass and percentage, visceral fat rating (total abdominal fat – see below), bone mass, muscle and fat mass and percentage for individual body segments (Left and right upper and lower limbs and trunk), total body water, and both extra- and intra-cellular water was estimated using bioelectrical impedance (Tanita MC 180, Tanita Europe B.V., Amsterdam). This device is reported as valid compared with dual energy X-ray absorptiometry for estimating total and segmental body composition in healthy adults [60], however, 'visceral fat rating' has been reported better representative of total abdominal fat compared with magnetic resonance imaging [61] and is referred to as such herein.

Participant Testing

Pre and post muscular performance testing was performed in the following order with 2-3 minutes rest between exercises; chest press, heel raise, rear deltoid, elbow flexion, seated row, knee extension, knee flexion, abdominal flexion, push-ups. A 10RM was determined for all exercises with the exception of push-ups following National Strength and Conditioning Association guidelines for RM testing [62]. To avoid any specific learning effect in post testing from training at a particular relative load, 50% of the absolute load for each participants 10RM was used for testing. For the push-up exercises no additional load was used. Participants performed repetitions to MMF at a repetition duration of 2 seconds concentric, 2 seconds eccentric. Pre and post testing utilised the same absolute load allowing comparison of repetitions performed due to the direct relationship between muscular strength and the number of repetitions possible at an absolute submaximal load [63]. This removed the need for 1RM testing and provides greater ecological validity as most persons rarely test or use their maximal strength but rather test muscular performance using repeated repetitions. Body composition was measured on a separate day from muscular performance testing both before and after the intervention following the manufacturer's guidelines. Participants also completed a questionnaire to determine their resistance training experience prior to the study (either 'total beginner', 'some experience', or 'advanced' rated 1 to 3 respectively), time spent on other exercise/sport activities each week (minutes), severity of delayed onset muscular soreness (DOMS) from training sessions (0-10, low to high respectively), duration of DOMS after training sessions (hours), satisfaction with muscular performance changes from the training intervention (0-10, low to high respectively), satisfaction with body composition changes from the training intervention (0-10, low to high respectively), and motivations to continue with the training they completed (0-10, low to high respectively).

Participant Training

Training was supervised and conducted 2x/week (at least 48 hours between sessions) for 10 weeks. Both groups performed a general warm-up on a stationary cycle ergometer for 5-10 minutes followed by a single set of low load chest press, seated row and bodyweight squats prior to each training session. Each group performed the following exercises in this order in circuit fashion; chest press, heel raise, rear deltoid, elbow flexion, seated row, knee extension, knee flexion, abdominal flexion, push-ups. The HIT group completed the circuit once performing a single set of each exercise with additional drop sets performed immediately upon reaching MMF. The 3ST group completed the circuit three times performing a single set of each exercise each time (3 sets per exercise in total). Rest between each exercise lasted as long as required for participants to move from one exercise to the next and normalise breathing for both groups. The 3ST group rested a further 2-3 minutes between each circuit. Both groups began the intervention using a 10RM load, but used bodyweight for the push-ups exercise. The HIT group used a repetition duration of 2 seconds concentric, 1 second isometric contraction at the top of the range of motion, and 4 seconds eccentric (2-1-4 seconds). The 3ST group trained using a repetition duration of 2 seconds concentric and 2 seconds eccentric (2-2 seconds). Both groups used a full range of motion. The HIT group performed repetitions to the point of MMF and then performed drop-sets, immediately reducing the load by 10-15% and continuing repetitions to MMF again (~2-3 further repetitions). Two drop-sets were performed (i.e. 10-15% drop from initial load followed by a further drop of 10-15% from the reduced load). Drop-sets for the push-ups exercise were as follows; first push-ups with feet elevated, followed by push-ups with feet on the floor, followed by push-ups from the knees. The 3ST group performed repetitions to a self-determined RM. Load was progressed for each group by 5% once participants could achieve greater than 15 repetitions before reaching MMF or RM for the HIT and 3ST groups respectively.

Data Analysis

No drop outs were recorded at any stage of the study thus data were available for 30 participants. Muscular performance and body composition outcomes met assumptions of normality using a Kolmogorov-Smirnov test thus parametric analysis was utilised for these outcomes. Questionnaire data did not meet assumptions of normality so non-parametric analysis was utilised. Baseline demographic, muscular performance, and body composition data in addition to absolute changes in strength and body composition were compared between groups using an independent T-test. Questionnaire data was compared between groups using a Mann-Whitney U test. Statistical analysis was performed using SPSS statistics computer package (vs.20) and p<.05 set as the limit for statistical significance. Further, 95% confidence intervals (CI) were calculated in addition to within participant ES using Cohen's d [58] for muscular performance and body composition outcomes to compare 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.

RESULTS

Participants Demographics. Participant demographics are shown in Table 1. Comparison between groups revealed a significant between groups difference for stature (t(28)=2.140, p=0.031) and BMI (t(28)=-3.988, p < 0.001).

Muscular performance

Table 2 shows pre and post, mean changes, ES and 95%CIs for muscular performance for each training group and exercise. Comparison between HIT and 3ST groups at baseline revealed a significant difference for the heel raise exercise (t(28)=2.316, p=0.031) but not for any other exercise. Comparison between groups for changes in muscular performance revealed differences between HIT and 3ST for heel raise (t(28)=2.812, p=0.009), elbow flexion (t(28)=2.503, p=0.018), and knee flexion (t(28)=2.325, p=0.028). 95%CIs indicated that both HIT and 3ST groups improved significantly in all exercises with the exception of the push-up. ESs for significant muscular performance changes in the HIT and 3ST groups were all considered large (0.97 to 1.73 and 0.88 to 1.77 respectively).

Body Composition

Table 3 shows pre and post, mean changes and ES for body composition data for each group. Comparison between HIT and 3ST groups at baseline revealed a significant difference for the whole body fat mass (t(28)=-5.439, p < 0.001) and percentage (t(28)=-5.294, p < 0.001) in addition to trunk fat mass (t(28)=2.711, p=0.011) and percentage (t(28)=2.880, p=0.008). Comparisons between groups for changes in body composition data revealed no significant between group effects. 95%CIs indicated that there were no signifi-

TABLE 1. Participant's demographic characteristics.

	HIT (n=16)	3ST (n=14)
Age (years)	23±3	22±2
Stature (cm)*	175.50±8.16	169.21±7.91
Body Mass (kg)	68.58±9.04	73.30±11.65
BMI ($kg \cdot m^{-2}$)*	22.22±1.97	25.49±2.51
Gender Ratio (Males:Females)	9:7	4:10

Note: Results are mean ±SD; *denotes significant difference between groups.

TABLE 2. Pre, post, mean change and effect sizes for muscular performance data.

Group	Pre	Post	Change	95% CI	ES	p
Chest Press						
HIT	32.06±15.04	57.69±18.81	25.63±16.09	17.05 to 34.20	1.59†	0.073
3ST	31.07±13.85	46.93±19.26	15.86±12.02	8.92 to 22.80	1.32†	
Heel Raise						
HIT	32.81±12.53	60.63±22.44	27.81±16.04	19.26 to 36.36	1.73†	0.009*
3ST	24.79±5.55	37.86±14.13	13.07±12.04	6.12 to 20.02	1.09†	
Rear Deltoid						
HIT	30.50±11.51	64.25±32.94	33.75±27.16	19.28 to 48.22	1.24†	0.056
3ST	40.93±25.36	57.79±25.19	16.86±17.38	6.82 to26.89	0.97†	
Elbow Flexion						
HIT	27.38±6.82	48.69±11.69	21.31±12.41	14.70 to 27.92	1.72†	0.018*
3ST	23.86±8.38	35.50±9.88	11.64±7.90	7.08 to 16.20	1.47†	
Seated Row						
HIT	36.00±13.82	76.31±32.25	40.31±27.37	25.73 to 54.90	1.47†	0.062
3ST	31.07±13.85	66.21±20.05	23.64±17.93	13.29 to 34.00	1.32†	
Knee Extension						
HIT	35.69±13.08	53.25±19.70	17.56±18.13	7.90 to 27.22	0.97†	0.975
3ST	36.00±17.55	53.79±25.19	17.79±20.25	6.10 to 29.48	0.88†	
Knee Flexion						
HIT	37.5±20.48	65.19±35.80	27.69±19.09	17.52 to 37.86	1.45†	0.028*
3ST	44.5±18.68	58.43±17.25	13.93±11.95	7.03 to 20.83	1.17†	
Abdominal Flexion						
HIT	19.75±10.44	35.44±12.54	15.69±11.15	9.75 to 21.63	1.41†	0.898
3ST	21.43±9.89	36.64±11.32	15.21±8.58	10.26 to 20.17	1.77†	
Push-up						
HIT	21.81±13.15	41.00±41.04	19.19±40.21	-2.24 to 40.61	0.47	0.196
3ST	21.14±13.98	27.54±11.38	4.43±11.40	-2.15 to 11.01	0.39	

Note: Results are mean ±SD; 95% CI for changes; ES=Cohen's d; p values for between group comparisons of change in strength analysed using an independent T-test; *denotes significant difference between groups; †denotes significant difference from pre to post

cant changes for any body composition outcome for any of the groups with the exception of left leg fat mass and fat percentage. This change would seem likely a type I error.

Participant Subjective Assessments

Table 4 shows the questionnaire data for each group. No significant differences between groups were found for any of the questions.

DISCUSSION

This study compared two ecologically valid RT approaches upon muscular performance improvements and body composition changes. Results suggested that both HIT and 3ST produced significant improvements in muscular performance, however, HIT produced significantly greater muscular performance gains than 3ST for 3 of the tested exercises and had larger ESs for eight of the tested exercises. No significant changes in any body composition measures occurred for either group; however, ESs indicated small effects favouring the HIT group. Reasons for the greater muscular performance gains in the HIT group are not wholly clear as, due to examining ecologically valid RT methods, a number of variables differed between the two training groups (i.e. set volume, intensity of effort, the use of drop-sets, and repetition duration).

As noted, it is unclear whether set volume indeed impacts strength gains [9-32]. It may be that the lower volume HIT group (performing a total of ~14-16 repetitions [sets x repetitions; 1 x ~10 + 2 x ~2-3]) avoided overtraining compared with the higher volume 3ST group (performing a total of ~30 repetitions [sets x repetitions; 3 x ~10]) allowing greater improvement. However, no other data suggests superiority for single set RT nor has this been claimed by other authors elsewhere [19]. It is unlikely the difference in set volume affected results through this mechanism. The HIT group also employed drop-sets on every exercise which might actually contribute to overtraining if employed too regularly [64]. Whether use of techniques, such as drop-sets, common in HIT style RT are necessary in addition to training to MMF for enhancing adaptations is uncertain. Goto et al. [65] compared training to MMF with and without use of

TABLE 3. Pre, post, mean change and effect sizes for body composition data.

Group		Pre	Post	Change	95% CI	ES	P
Body Mass (kg)	HIT	68.58±9.04	69.04±9.35	0.46±2.27	-0.75 to 1.67	0.20	0.222
	3ST	73.30±11.65	74.04±11.07	0.75±2.35	-0.61 to 2.10	0.32	
Fat Free Mass (kg)	HIT	55.47±9.28	55.88±8.80	0.42±1.59	-0.43 to 1.26	0.26	0.117
	3ST	51.05±9.03	50.50±9.16	-0.55±1.66	-1.51 to 0.41	-0.33	
Whole body							
Muscle Mass (kg)	HIT	52.69±8.85	53.09±8.40	0.40±1.50	-0.40 to 1.20	0.27	0.108
	3ST	48.49±8.60	47.95±8.73	-0.54±1.61	-1.47 to 0.39	-0.34	
Fat Mass (kg)	HIT	13.12±4.13	13.16±4.53	0.05±1.74	-0.88 to 0.97	0.03	0.170
	3ST	22.25±5.07	23.54±4.77	1.29±3.02	-0.45 to 3.03	0.43	
Fat Percentage	HIT	19.31±6.07	19.11±5.98	-0.20±2.03	-1.28 to 0.88	-0.10	0.098
	3ST	30.34±5.23	31.92±5.21	1.58±3.55	-0.47 to 3.63	0.44	
Total Abdominal Fat (rated 1 to 59)	HIT	1.88±1.15	1.82±1.22	-0.06±0.57	-0.37 to 0.24	-0.11	0.259
	3ST	1.29±0.73	1.43±0.76	0.14±0.36	-0.07 to 0.35	0.39	
Bone Mass (kg)	HIT	2.79±0.44	2.81±0.41	0.02±0.09	-0.02 to 0.07	0.26	0.090
	3ST	2.58±0.43	2.55±0.44	-0.03±0.08	-0.08 to 0.02	-0.39	
Right Leg							
Muscle Mass (kg)	HIT	9.10±1.67	9.13±1.63	0.03±0.24	-0.09 to 0.16	0.14	0.064
	3ST	8.18±1.79	7.78±1.75	-0.40±0.86	-0.89 to 0.10	-0.46	
Fat Mass (kg)	HIT	2.40±1.13	2.44±1.21	0.04±0.23	-0.08 to 0.16	0.18	0.302
	3ST	2.57±0.89	3.84±3.92	1.27±4.27	-1.20 to 3.73	0.30	
Fat Percentage	HIT	20.23±9.83	20.34±9.98	0.12±1.43	-0.64 to 0.88	0.08	0.107
	3ST	23.51±8.78	26.44±8.13	2.93±6.59	-0.88 to 6.73	0.44	
Left Leg							
Muscle Mass (kg)	HIT	8.82±1.62	8.87±1.57	0.05±0.23	-0.07 to 0.17	0.22	0.151
	3ST	7.99±1.70	7.90±1.74	-0.09±0.30	-0.27 to 0.08	-0.31	
Fat Mass (kg)	HIT	2.41±1.09	2.45±1.15	0.04±0.24	-0.09 to 0.17	0.17	0.320
	3ST	2.50±0.82	2.62±0.78	0.12±0.16	0.02 to 0.21	0.72†	
Fat Percentage	HIT	20.79±9.65	20.84±9.71	0.04±1.54	-0.78 to 0.86	0.03	0.620
	3ST	23.31±8.06	24.48±8.22	1.17±1.64	0.23 to 2.12	0.72†	
Right Arm							
Muscle Mass (kg)	HIT	2.92±0.81	2.92±0.79	0.01±0.10	-0.05 to 0.06	0.06	0.379
	3ST	2.49±0.73	2.93±2.08	0.44±1.78	-0.59 to 1.47	0.25	
Fat Mass (kg)	HIT	0.66±0.22	0.68±0.26	0.01±0.10	-0.04 to 0.07	0.13	0.420
	3ST	0.58±0.15	0.65±0.26	0.07±0.27	-0.08 to 0.23	0.27	
Fat Percentage	HIT	18.54±7.33	18.64±7.42	0.10±2.14	-1.04 to 1.24	0.05	0.672
	3ST	18.61±4.70	19.14±4.92	0.53±3.29	-1.37 to 2.43	0.16	
Left Arm							
Muscle Mass (kg)	HIT	2.90±0.84	2.91±0.82	0.02±0.12	-0.05 to 0.08	0.13	0.411
	3ST	2.45±0.75	2.43±0.76	-0.02±0.12	-0.09 to 0.05	-0.17	
Fat Mass (kg)	HIT	0.69±0.24	0.71±0.27	0.02±0.09	-0.03 to 0.07	0.23	0.990
	3ST	0.61±0.16	0.64±0.16	0.02±0.10	-0.03 to 0.08	0.22	
Fat Percentage	HIT	19.52±7.89	19.43±7.78	-0.09±2.13	-1.22 to 1.05	-0.04	0.378
	3ST	19.65±4.99	20.42±5.43	0.77±3.09	-1.01 to 2.56	0.25	
Trunk							
Muscle Mass (kg)	HIT	28.96±4.09	29.26±3.82	0.29±0.91	-0.19 to 0.78	0.32	0.168
	3ST	27.38±3.77	25.23±7.32	-2.15±6.86	-6.12 to 1.81	-0.31	
Fat Mass (kg)	HIT	6.95±2.10	6.88±2.40	-0.07±1.16	-0.68 to 0.55	-0.06	0.996
	3ST	4.86±2.12	4.79±2.35	-0.07±1.90	-1.17 to 1.03	-0.04	
Fat Percentage	HIT	18.54±4.44	18.08±4.65	-0.46±2.60	-1.85 to 0.92	-0.18	0.290
	3ST	14.02±4.10	14.81±3.85	0.79±3.74	-1.37 to 2.95	0.21	
Total Body Water (kg)	HIT	40.02±6.59	40.27±6.21	0.27±1.26	-0.42 to 0.93	0.20	0.126
	3ST	36.85±6.53	36.40±6.55	-0.86±1.81	-1.15 to 0.24	-0.38	
Extra-cellular Water (kg)	HIT	16.03±2.24	16.12±2.15	0.09±0.40	-0.12 to 0.30	0.23	0.074
	3ST	14.66±2.37	14.49±2.40	-0.17±0.37	-0.39 to 0.04	-0.46	
Intra-cellular Water (kg)	HIT	23.97±4.39	24.17±4.13	0.19±0.86	-0.27 to 0.65	0.22	0.138
	3ST	22.20±4.16	21.90±4.16	-0.29±0.86	-0.79 to 0.21	-0.34	

Note: Results are mean ±SD; 95% CI for changes; ES=Cohen's d; p values for between group differences for change in body composition data analysed using Independent t-test; † denotes significant difference from pre to post

TABLE 4. Questionnaire data.

	HIT	3ST	p
Other Weekly Activity (minutes)	106±62.20	119.64±107.58	0.758
Training Experience (rated 1 to 3)	1.31±0.48	1.36±0.50	0.799
DOMS Severity (rated 1 to 10)	2.94±2.05	3.08±2.15	0.887
DOMS Duration (hours)	27.06±19.20	26.57±14.26	0.700
Satisfaction with Muscular Performance Outcomes (rated 1 to 10)	7.56±1.41	6.86±1.23	0.209
Satisfaction with Body Composition Outcomes (rated 1 to 10)	5.7±1.79	4.64±3.03	0.522
Motivation to Continue Training (rated 1 to 10)	6.5±2.99	7.88±1.17	0.279

Note: Results are mean +SD; p values for between group comparisons using a Mann-Whitney U test.

drop-sets upon hypertrophy. Their results suggested greater hypertrophy using a drop-set; however, this also provided additional volume. In the present study the HIT group, though employing drop-sets, still performed a lower total training volume (sets x repetitions) than the 3ST group yet still produced greater muscular performance gains suggesting additional volume from drop-sets may not be the influencing factor.

Different intensities of effort between the two groups, however, may have influenced the different muscular performance gains. The HIT group trained to MMF (and used drop-sets) whilst the 3ST group trained to a self-determined RM. As highlighted multiple set training is often not performed to MMF as it is suggested there is lack of evidence for its recommendation [50] and its potential to promote overtraining [51]. Evidence, however, suggests training to MMF does confer greater adaptations [21,22]. It has also been reported even experienced trainees under-predict the number of possible repetitions to MMF [66] suggesting that many persons including those initiating RT likely under-predict also. Thus, though the 3ST group trained with a greater volume, they perhaps did not train to a sufficiently high intensity of effort (i.e. ended sets more than 1 repetition away from MMF), questioning the use of 'intuitive' approaches to control RT effort. Indeed some have argued the success of low volume RT, such as HIT, is dependent upon achieving sufficient intensity of effort by training to MMF [33]. A recent study found, in advanced trainees, a single set RT intervention performed to a self-determined RM does not improve strength [67]. Our results indicate that, though multiple sets to RM produce muscular performance improvement, they may not fully recompense avoiding training to MMF. This does contrast with prior investigations of single sets to MMF compared with multiple sets not to MMF [53,54]. This might suggest that, though no evidence suggests single set training as superior to multiple set training when other factors are controlled, single set training may produce greater adaptations when training to MMF is combined with drop-sets perhaps owing to greater intensity of effort and fatigue related stimuli [68,69].

The lack of significant body composition changes reported in this study may be owing to the sample size used. It has been noted that, though studies of strength and muscular performance gains can be sufficiently powered with the sample size used here (which was calculated for strength outcomes), studies examining changes in body composition and particularly changes in muscle mass are highly prone to type II errors [18]. A recent study employing the same body composition testing with a larger sample size reported significant changes in muscle mass and fat percentages after a single set to MMF protocol in trained participants reinforcing the likelihood of a type II error in the present study [67]. Indeed, though they did not achieve significance, whole body muscle mass changes were slightly more favourable in the HIT group (0.40+1.50kg, 95%CIs -0.40 to 1.20, ES=0.27) compared with the 3ST group (-0.54+1.61kg, 95%CIs -1.47 to 0.39, ES=-0.34). With regards to whole body fat mass changes there was no change in the HIT group (0.05+1.74, 95%CIs -0.88 to 0.97, ES=0.03) and an increase in the 3ST group (1.29+3.02, 95%CIs -0.45 to 3.03, ES=0.43). These factors combined to result in the HIT group producing a slightly more favourable change in whole body fat percentage also (-0.20+2.03, 95%CIs -1.28 to 0.88, ES=-0.10) compared with the 3ST group (1.58+3.55, 95%CIs -0.47 to 3.63, ES=0.44). Our participants also subjectively reported some content with body composition outcomes yet with no differences between groups which might indicate aesthetic improvements not represented in objective measurement.

Average duration of the workouts is worth considering in context of the results presented. Without considering between exercise rest durations and assuming ~10 repetitions per exercise at the repetitions durations used, per session the HIT group trained for ~10.5 minutes, whereas the 3ST group trained for between ~24 and ~27 minutes. The practical implications of these findings combined with the questionnaire data are also notable. Participant subjective assessments of training were similar for both groups. Thus it would seem reasonable to suggest that HIT is a more desirable approach as it has the potential to produce greater gains in muscular performance despite being perceived similarly in a number of subjective outcomes including severity and duration of DOMS from training sessions, satisfaction with muscular performance and body composition changes, and motivations to continue with the training they completed. It is notable that motivation to continue training was similar between groups. Hass et al. [70] previously reported that dropout rate was higher for a multiple set RT program compared with one employing single sets. Twenty five percent dropped out from the multiple set group (5 for lack of adherence and 2 for injuries) compared with none in the single set group. In their study the multiple set group took ~1 hour to complete their training compared with 25 minutes for the single set group and programs lasting >1 hour per session are known to have higher drop outs [71]. We did not have any drop outs in our study perhaps due to the fact that both interventions took <1 hour. Further, the drop outs from the study of Hass et al. may be due to the fact that both single and multiple set groups trained to MMF. This perhaps highlights that the fact our 3ST group did not train to MMF may be a reason for similar motivation to continue with higher volume training. In other exercise modalities (i.e. aerobic exercise modes) it has been shown that participants report greater enjoyment of both moderate effort continuous and shorter duration higher effort exercise as opposed to continuous duration high effort exercise [72,73].

Limitations of the present study should be noted. First the sample size used appeared insufficient to detect changes in the body composition measures taken and in addition participant's nutritional intakes were not assessed. As research comparing these two ecologically valid methods of RT has focused upon strength and muscular performance outcomes thus far [53,54] future work should examine body composition and muscular hypertrophy using larger sample sizes and controlling for nutritional factors. Also, due to not using a gender counterbalanced approach to randomisation, gender ratio differences between groups may have affected our outcomes. Our research design may have been improved by use of a gender counterbalanced approach to randomisation. However, 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 [74]. Further, though it could be considered a strength that this study examined ecologically valid RT approaches, as a number of variables differed between the groups (set volume, intensity of effort, the use of drop-sets, and repetition duration) conclusions can only be drawn as to the efficacy of the two approaches as a whole. Indeed it could be argued that 'Body-building' style training also utilises advanced techniques such as drop sets and so future work might compare the effects of set volume whilst controlling inclusion of advanced training techniques. Finally, recent studies considering the effects of set volume have included greater than 3 sets and suggested that both 5 [43] and 8 sets [42] may produce greater strength and hypertrophic adaptations. Whether low volume RT whilst utilising advanced techniques such as in 'High Intensity Training' produces similar adaptations to these even higher set volumes remains to be investigated.

CONCLUSIONS

To conclude, the results of this study suggest significant muscular performance gains can be produced using either a 'High Intensity Training' style (HIT) or 'Body-building' style (3ST) RT approach. However, muscular performance gains may be greater when using HIT, therefore we recommend HIT for maximising muscular performance gains over a 10 week period.

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Endnote:
(a) Momentary muscular failure (MMF) has been defined as "the inability to perform anymore concentric contractions without significant change to posture or repetition duration" [21], and occurs when a person cannot match the required force to continue moving a given load [50] thus representing a maximal intensity of effort [43].

(b) In contrast to MMF, Repetition maximum (RM) would best be described as the number of complete repetitions prior to MMF [33]. In practice, however, prescription of training to an RM necessitates prior load determination regularly for a true RM. Should the exercise be ended once the trainee determines they could not complete further repetitions if attempted (i.e. they predict MMF on the next repetition), this might be considered volitional fatigue or self-determined RM, not a true RM or MMF, thus it represents a somewhat ambiguous end-point to a set of exercise.

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