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Comparison of time-matched aerobic, resistance or combined exercise training in women living with obesity: The EXOFFIT study

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Abstract

Background: Improvements in cardiorespiratory fitness (CRF) have been shown to largely attenuate the negative health risks associated with obesity. To date, literature on women with obesity has focused upon the evaluation of aerobic-based exercise interventions. Hence, there is a need to evaluate resistance and combined interventions with this cohort.

Objective: This study aimed to evaluate the feasibility and efficacy of three exercise modalities in women with obesity for improving CRF, strength, body composition and other health outcomes.

Methods: Sixty-seven women with obesity were randomly assigned to the control (CON) or one of three exercise groups (aerobic [AE], resistance [RE], COM). Exercise groups were trained x3 times/week for 12 weeks (up to 150-min/week). Feasibility outcomes included adherence, attendance, recruitment and retention rates and adverse events. Secondary outcomes were CRF (predicted VO2 max), body composition (body weight [BW], waist circumference [WC], body fat percentage [%BF], fat mass [FM] and lean mass) and strength (5RM bench press, leg dynamometry, grip strength) and self-reported measures of physical activity, mood, sleep, pain and quality of life.

Results: Findings support the feasibility of all three exercise modalities in terms of adherence, attendance, and retention. Interventions with a resistance component (COM and RE) were associated with the greatest improvements across the broad range of health outcomes measured. Combined was the most promising for body composition outcomes including body mass index (Effect size [ES] = 0.79, $p = 0.04$), BW (ES = 0.75, $p = 0.05$), %BF (ES = 0.77, $p = 0.04$), FM (ES = 0.83, $p = 0.03$) and WC (ES = 0.90, $p = 0.02$), physical activity (i.e., moderate physical activity [ES = 0.69, $p = 0.07$), mood (ES = 0.83, $p = 0.03$) and sleep (ES = 0.78, $p = 0.04$). Resistance was most promising for CRF (ES = 1.47, $p = 0.002$), strength (i.e., bench press [ES = 2.88, p=<0.001]) and pain (i.e., pain severity [ES = 0.40, $p = 0.31$]).

Conclusions: For health outcomes, these results indicate the importance of including a resistance component when prescribing exercise for women with obesity to achieve meaningful improvements.

CLINICAL TRIAL REGISTRATION: ISRCTN13517067

KEYWORDS
exercise, feasibility, fitness, obesity, women

1 | INTRODUCTION

Increasing cardiorespiratory fitness (CRF) through exercise, even in the absence of weight loss, has been shown to largely attenuate obesity-related health risks.[1] While a recent metanalysis supports the prescription of combined exercise (COM = aerobic [AE] and resistance [RE]) for improving CRF and body composition in adults with obesity, most of the included studies were conducted in men[2] As it is unclear how the physiological differences between the sexes (i.e., lower CRF in women)[3] translates into sex-specific responses, the recommended prescription may not prove equally effective for both sexes.

Exercise research in women with obesity is sparse and primarily focused on AE to improve body composition.[4] A recent systematic review[4] identified the paucity of studies investigating CRF and RE. Thus, this lack of data does not allow for accurate RE prescription for improving CRF. This review also highlighted the lack of research investigating the effectiveness of exercise for improving other health outcomes including quality of life (QoL) in women with obesity. Yet these measures are recommended for inclusion in intervention studies by current core outcome sets for better understanding individualized heterogenous responses to exercise and differences in risk of developing adiposity.[5,6] Factors such as poor sleep, low mood and low QoL have been shown to contribute to a negative cycle of lower physical activity (PA) levels, decreased fitness and increased obesity severity, which further impact these health factors.[7,8]

Though exercise has been shown to be positively correlated with an improvement in broad health outcomes in women with obesity,[9,10] the most effective and feasible exercise mode to achieve optimal benefits remains unclear. To understand the true efficacy of different interventions, it is paramount that the impact of exercise volume (product of frequency, intensity, time) on efficacy, potentially associated with concurrent training, is controlled for (i.e., through time-matched interventions). Though some studies have investigated time- or calorie-matched exercise interventions in similar cohorts,[11,12] to date, no research studies have used a direct time-matched comparison between the different exercise modalities (AE, RE, COM) specifically in a cohort of only women with obesity.

The primary purpose of this study was to evaluate the feasibility of three time-matched exercise programs (AE, RE, COM), which were targeting changes in CRF in women with obesity, and to inform whether a future randomized controlled trial (RCT) could or should be undertaken. This study primarily aimed to assess the following measures of feasibility:

(i) recruitment challenges,
(ii) retention,
(iii) attendance rates
(iv) adherence rates,
(v) incidence of adverse events.

The secondary aim was to determine the mean difference between groups (three exercise groups and a non-exercise control [CON]) at 12 weeks in:

(i) CRF (predicted VO2 max)
(ii) Body composition (body mass index [BMI], body weight [BW], percentage body fat [%BF], lean mass, fat mass [FM], waist-hip ratio [WHR] and waist circumference [WC])
(iii) strength (five repetitions maximum [5RM] bench press, leg dynamometry, grip strength)
(iv) self-reported QoL, PA, sedentary time, sleep, mood, and pain

2 | METHODS

2.1 | Trial design

A 12-week feasibility pilot RCT of three time-matched interventions (AE, RE, COM) was performed between September 2021 and December 2022. All experimental procedures were approved by University College Dublin (UCD) Research Ethics Committee ((LS-21-49-Davis-ODonoghue). The trial is reported per the Consolidated Standards of Reporting Trials guidelines extension for randomized pilot and feasibility trials[13] and the Standard Protocol Items: Recommendations for Interventional Trials[14]). The study was registered with ISRCTN (ISRCTN13517067).

2.2 | Participants

Recruitment was primarily through the Irish Coalition of People Living with Obesity (ICPO) and the UCD intranet, seeking women aged 18–50 years, with a BMI>30 $kg.m^{-2}$. Individuals expressed interest by email, phone or via the study website and were medically screened and vetted for eligibility (Table 1) by the trial coordinator (M.E.D). Eligible individuals were provided with information regarding the trial procedures and then proceeded to baseline

TABLE 1 Eligibility criteria for inclusion in trial as per protocol.[15]

Criterion	Characteristics of eligible participants
1	Female aged 18–50 years at time of consent
2	Have a body Mass index (BMI) ≥30 $kg.m^{-2}$ and/or a waist circumference >88 cm
3	Are currently physically inactive (exercising less than 150 min/week)
4	Have not undergone weight loss surgery in past 6 months or another surgery in the past 3 months
5	Not pregnant (or within 6 months post-pregnancy) or lactating
6	Do not have a significant mental illness or cognitive deficits
7	Are not participating in another trial (exercise-based or targeting weight-loss) at time of consent
8	Are not contraindicated or no clinician (i.e. GP) has advised them against exercising (i.e. chest pain during activity or at rest, severe hypertension, etc.)
9	Do not have an unstable cardiovascular, respiratory, renal or hepatic condition

Abbreviation: GP, general practitioner.

testing. Written informed consent was obtained before any procedures commenced. At baseline appointment, participants with a resting blood pressure (BP) above the cut-off of 160/100 or with other contraindications to testing were excluded.[16] The study was conducted at UCD's Institute for Sport and Health.

2.3 | Outcomes

The same battery of assessments including CRF, strength and body composition was performed pre- and post-intervention. Assessments and instruments used are described in detail elsewhere.[15] All components of pre- and post-assessments were conducted by the trial coordinator, a qualified physiotherapist (BSc MSc) with a post-graduate diploma in cardiac rehabilitation. Resting BP and heart rate (HR) were measured three times and averaged. Fitness was measured using a graded submaximal walking treadmill test as per the modified Balke-Ware protocol for females[17] and for obesity[18] until 85% of age-predicated HRmax was reached. VO_2max was estimated using the Fitness Registry and the Importance of Exercise National Database (FRIEND) equation.[19] Muscular strength was assessed using a 5-RM bench press and maximum grip and leg strength. Waist and hip circumferences were measured using standard methods.[20] Bioelectrical impedance (SECA mBCA 515, SECA GmbH & Co.) was used to measure BW, %BF, FM and lean mass. This device has been shown to have a high level of reliability when compared with the gold standard measurement device (Dual Energy X-ray Absorptiometry; Coefficient of Variation: 0.99; Lin's Concordance Correlation Coefficient: 0.92).[21]

TABLE 2 Self-reported outcomes.[15]

Outcomes	Measure(s)
Pain	Brief pain inventory (short form) [BPI-SF]
Health-related quality of life	EuroQol-5D-5 L (EQ-5D-5 L) questionnaire
Mood	Patient health questionnaire-9 (PHQ-9)
Physical activity & sedentary time	International physical activity questionnaire (short form) [IPAQ-SF]
Sleep	Pittsburgh sleep quality index (PSQI)

Participants also completed a battery of self-reported questionnaires (Table 2) and provided relevant sociodemographic information. Subjective measures were selected based upon the core outcome sets for weight management interventions[5,6] and self-reported pain was also measured due to strong associations between pain and obesity and its potential impact on exercise participation and adherence.[22]

2.4 | Feasibility

Data collected included: number of women that expressed interest in participating and were recruited, randomized, retained, and lost to follow-up; attendance rates, reason for missed exercise sessions, adherence to prescribed program (target %HRR [heart rate reserve], etc.); and incidence of adverse events as per protocol.[15]

2.5 | Randomization

Participants were block randomized (allocation ratio: 1:1:1:1) and allocated to a group using a computer-generated random allocation sequence (completed by GO'D). Given the nature of the intervention, participants were not blinded to their allocation. Though blinding of assessors and instructors was not possible, neither were involved in group allocation and were unaware of unique participant numbers until data analysis was completed. The trial statistician (C.B.) was also unaware of group allocation until data analysis was complete.

2.6 | Interventions

Participants were randomized to either the non-exercise control (CON) or one of three supervised progressive programs. All exercise sessions included a warm-up (low-intensity bike or cross-trainer, full body movements) and a cool-down (global stretches). Program progressions are outlined in Table S1. The AE program was completed on a stationary bike, cross-trainer, or combination of both. Heart rate was recorded incrementally throughout the session (Garmin; model: Forerunner 45) as well as equipment used, time spent and machine

resistance level and/or incline. The AE program progressed in intensity from weeks 1 to 12 from 40% to 50% HRR (weeks 1–2) to 75%–80% HRR (weeks 11–12). The RE program comprised of 18 exercises (6 per session) with 45-s of rest between sets of 12 reps (Table S2-S3). Participants' reps, sets and weights were recorded at each session. The RE program progressed in intensity and volume from week 1 to 12 from 2 × 12 reps at 40–50% 1RM (weeks 1–2) to 3-6 sets x12 reps at 75%–80% 1RM (week 12). The COM program comprised of a 50:50 split of the AE and RE programmes (i.e., 25-min of AE, three exercises from RE) and was similarly monitored for adherence. Participants in CON were instructed to maintain their physical activity (PA) levels until after post-intervention testing. They were then offered the opportunity to join their preferred exercise intervention.

2.7 | Data analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 27 (SPSS Inc., Chicago, IL). Feasibility outcomes (e.g., intervention fidelity) are reported as percentages. Secondary outcomes are reported as means with standard deviation (SD) or numbers and percentages. All self-reported outcomes were scored in line with guidelines and previous literature[23–32] (see Table 4 for additional detail).

Given that the feasibility of the intervention and procedures is the study's main aim, statistical testing was performed as a supplementary evaluation. The mean (SD) difference pre-to post-intervention was calculated for all outcomes. Two-way (group × time) ANOVAs were performed to explore differences in response to training over time between groups (Table 4 and Table S4). For secondary outcomes, head-to-head comparison of training response between each pair of groups was explored with mean and 95% CI group differences along with pairwise effect sizes (Table S5). Statistical significance was set at $p < 0.05$.

3 | RESULTS

3.1 | Participant demographics

Participant flow through the study is illustrated in Figure 1. Sixty-seven participants were enrolled and randomized. Participants' baseline characteristics are presented in Table 3. Mean age was 36.3 (±9.1) years and BMI was 37.9 (±6.6) kg/m^2. Based on obesity classification using BMI,[33] participants were divided into classes I (37.3%), II (32.8%) and III (29.9%). Per obesity severity determined via the Edmonton Obesity Staging System (EOSS),[34] most participants were impacted by obesity-related complications (80.6%), with nearly half (47.8%) classified as Stage 2. Reported comorbidities and musculoskeletal pain areas are also provided in Table 3, with over 60 percent (61.2%; n = 41) of participants reporting the presence of musculoskeletal pain.

3.2 | Feasibility

3.2.1 | Recruitment and retention

During recruitment (July 2021-October 2022), 160 women expressed an interest in participation. Months where the study received most contact from interested women were July 2021 (n = 20), March 2022 (n = 27) and September 2022 (n = 28). Recruitment sources included the UCD internal network (staff and student Ezines, n = 75), ICPO advocacy group (n = 44), general practitioners (n = 13), friend/word of mouth (n = 12), flyer (n = 11), social media (n = 4) and through the flyer displayed in primary care (n = 1). The UCD internal network (46.9%) and ICPO advocacy group (27.5%) were the greatest contributors to recruitment. Most women expressed interest through the study website (n = 97; 60.6%) or via email (n = 51; 31.9%). Prior to screening, 40 (25%) withdrew interest or did not respond to contact. Of the 120 screened, almost half (n = 53, 44%) were deemed ineligible due to being above age cut-off (n = 18), below BMI cut-off (n = 22), above PA threshold (n = 3), having unstable health conditions (n = 8) and being unable to attend in-person sessions (n = 2).

All those eligible for study participation (n = 67) agreed to be tested and randomized. Fourteen (21%) participants were lost to follow-up (n = 11 dropouts; n = 3 did not complete post-intervention testing [dropout ratio, CON:AE:RE:COM = 1:2:8:3]). Of these, seven (10.5%) were lost due to ill health (AE = 2, RE = 4, COM = 1), three (RE = 2, COM = 1) did not commence the intervention after randomization, while four withdrew due to changes in personal circumstances (RE-1, COM = 1) or lack of time (CON = 1, RE = 1).

3.2.2 | Program attendance, adherence and adverse events

Mean number of sessions attended per participant was 28 over the 12-week period. The highest average attendance was in COM (AE: 71% [26/36], RE: 76% [27/36], COM: 85% [31/36]). Combined also had the highest average adherence (session length and prescribed intensity) of the three interventions at 84% (25/31 for AE and 27/31 for RE components of COM), with AE and RE groups 82% (21/26) and 79% (22/28), respectively. Most non-adherent sessions in the AE group were due to not meeting prescribed intensity, while in the RE group it was due to not meeting prescribed time for the session. These findings were similarly reflected for the COM group. There were no adverse events recorded for any intervention.

3.3 | Secondary outcomes

Table 4 provides an overview of mean difference data for all secondary outcomes (pre-post data is detailed in Table S4). At baseline, there were no significant differences between the groups in CRF, body composition and strength outcomes. Cardiorespiratory fitness

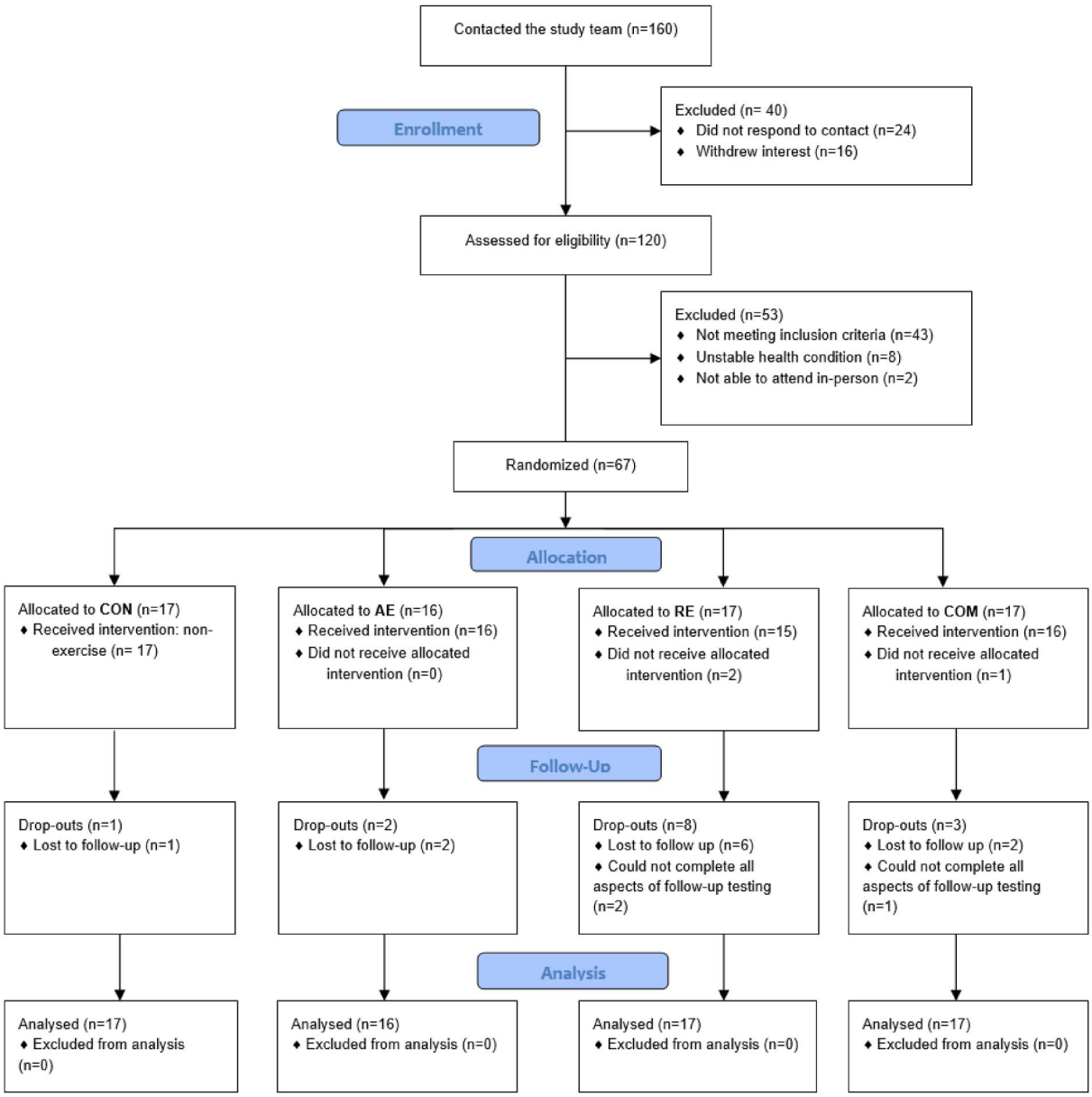

FIGURE 1 CONSORT participant flow diagram.

improved in all three exercise groups, while the control group remained the same. Resistance exercise was associated with the greatest improvement in CRF at +2.77 mL/kg/min (SD = 1.49), with the ES indicating a strong and significant improvement compared with control (ES = 1.47, $p = 0.002$; Table S5). Changes in CRF in COM and AE were +1.52 (SD = 2.20; ES = 0.71, $p = 0.064$) and +1.47 (SD = 1.65; ES = 0.64, $p = 0.093$) respectively.

For body composition, COM had the greatest decrease in BMI (−1.2 kg/m2 [SD = 2.05], ES = 0.79, $p = 0.04$), %BF (−1.6% [SD = 3.0], ES = 0.77, $p = 0.044$) and WC (−4.2 cm [SD = 4.0], ES = 0.9, $p = 0.021$) compared with control (Table S5). With respect to lean mass, RE was the only group to show improvement compared with control (+0.24 kg [SD = 0.6], ES = 0.31, $p = 0.465$). Strength outcomes improved for all exercise groups from baseline. For 5RM bench press and leg strength, RE had the greatest improvement of +10.0 kg (SD = 3.8; ES = 2.88, $p \leq 0.001$) and +6.9 kg (SD = 7.3; ES = 0.28, $p = 0.515$) compared with control. Change in grip strength was greatest in COM (+2.0 kg [SD = 3.6], ES = 0.63, $p = 0.096$).

As per the IPAQ-SF (Table 4 and Table S4), all three exercise groups increased their physical activity levels (PAL), with more COM participants (pre = 5.9%, post = 86.7%) reporting high PAL post-intervention than pre-intervention. Comparing sedentary time with control, COM also demonstrated the greatest decrease in average sitting time (min/weekday) of −98.0 (SD = 230.8; ES = 0.72, $p = 0.053$), more than double the decrease in RE (−38.2 [SD = 93.0], ES = 0.63, $p = 0.119$) and triple the decrease in AE (−23.6 [SD = 224.2], ES = 0.34, $p = 0.366$). For pain (BPI-SF), the number of participants with pain remained relatively unchanged in the COM (pre = 47.0% [n = 8]; post = 46.7% [n = 7]), while this number decreased in both the AE (pre = 62.5% [n = 10]; post = 35.7% [n = 5]) and RE (pre = 52.9% [n = 9];

TABLE 3 Baseline demographics of participants.

	Mean ± SD (range) or *N* (%)				
Participant baseline characteristics	**Total sample (*n* = 67)**	**CON (*n* = 17)**	**AE (*n* = 16)**	**RE (*n* = 17)**	**COM (*n* = 17)**
Age (Years)	36.3 ± 9.1 (19–50)	34.1 ± 9.0 (19–50)	38.6 ± 8.6 (22–50)	34.8 ± 9.5 (19–50)	37.7 ± 6.7 (22–48)
Baseline BMI (kg/m^2)	37.9 ± 6.6 (30.0–58.9)	36.7 ± 6.6 (30.4–48.2)	39.7 ± 6.0 (31.1–54.5)	37.0 ± 7.1 (30.3–57.2)	38.5 ± 6.7 (30.0–58.9)
Obesity severity (by EOSS)					
Stage 0	13 (19.4%)	6 (35.3%)	2 (12.5%)	3 (17.6%)	2 (11.8%)
Stage 1	22 (32.8%)	3 (17.6%)	6 (37.5%)	3 (17.6%)	10 (58.8%)
Stage 2	32 (47.8%)	8 (47.1%)	8 (50.0%)	11 (64.7%)	5 (29.4%)
Obesity class (by BMI)					
Class I	25 (37.3%)	9 (52.9%)	2 (12.5%)	9 (52.9%)	5 (29.4%)
Class II	22 (32.8%)	3 (17.6%)	8 (50.0%)	5 (29.4%)	6 (35.3%)
Class III	20 (29.9%)	5 (29.4%)	6 (37.5%)	3 (17.6%)	6 (35.3%)
Ethnicity					
White	61 (91.0%)	15 (88.2%)	14 (87.5%)	16 (94.1%)	16 (94.1%)
Asian	4 (6.0%)	2 (11.8%)	1 (6.3%)	1 (5.9%)	0
Black	2 (3.0%)	0	1 (6.3%)	0	1 (5.9%)
Nationality					
Irish	50 (74.6%)	12 (70.6%)	13 (81.3%)	11 (64.7%)	14 (82.4%)
Other European	6 (9.0%)	3 (16.6%)	0	3 (17.6%)	0
Other	11 (16.4%)	2 (11.8%)	3 (18.7%)	3 (17.6%)	3 (17.6%)
Education[a]	17 (25.4%)	5 (29.4%)	4 (25.0%)	6 (35.3%)	2 (11.8%)
Second level education or below third level education (level 6)	3 (4.5%)	0	1 (6.3%)	1 (5.9%)	1 (5.9%)
Third level education (level 8)	23 (34.3%)	6 (35.3)	4 (25.0%)	5 (29.4%)	8 (47.1%)
Third level education (level 9)	17 (25.4%)	5 (29.4)	6 (37.5%)	2 (11.8%)	4 (23.5%)
Third level education (level 10)	7 (10.4%)	1 (5.9%)	1 (6.3%)	3 (17.6%)	2 (11.8%)
Employment					
Full-time employment	44 (65.7%)	10 (58.8%)	12 (75.0%)	10 (58.8%)	12 (70.6%)
Part-time employment	4 (6.0%)	0	1 (6.3%)	2 (11.8%)	1 (5.9%)
Looking after home/family or career	4 (6.0%)	2 (11.8%)	1 (6.3%)	0	1 (5.9%)
Student	15 (22.4%)	5 (29.4%)	2 (12.5%)	5 (29.4%)	3 (17.6%)
Marital status					
Single	27 (40.3%)	9 (52.9%)	6 (37.5%)	7 (41.2%)	5 (29.4%)
Have a partner/married (without children)	13 (19.4%)	3 (17.6%)	4 (25%)	4 (23.5%)	2 (11.8%)
Have a partner/married (with children)	23 (34.3%)	3 (17.6%)	6 (37.5%)	5 (29.4%)	9 (52.9%)
Separated/Divorced (with children)	2 (3.0%)	1 (5.9%)	0	1 (5.9%)	0
Single parent	2 (3.0%)	1 (5.9%)	0	0	1 (5.9%)
Number of children					
None	39 (58.2%)	12 (70.6%)	9 (56.3%)	11 (64.7%)	7 (41.2%)
1–2	24 (35.8%)	4 (23.5%)	6 (37.5%)	5 (29.4)	9 (52.9%)
3 or more	4 (6.0%)	1 (5.9%)	1 (6.2%)	1 (5.9%)	1 (5.9%)

TABLE 3 (Continued)

Participant baseline characteristics	Mean ± SD (range) or N (%)				
	Total sample (*n* = 67)	CON (*n* = 17)	AE (*n* = 16)	RE (*n* = 17)	COM (*n* = 17)
Had bariatric surgery					
Yes	6 (9.0%)	2 (11.8%)	1 (6.3%)	0	3 (17.6%)
No	61 (91.0%)	15 (88.2%)	15 (93.8%)	17 (100%)	14 (82.4%)
Comorbidities					
Hypertension	31 (46.3%)	6 (35.3%)	11 (68.8%)	5 (29.4%)	9 (52.9%)
Depression/Anxiety	14 (20.1%)	3 (17.6%)	2 (12.5%)	7 (41.2%)	2 (11.8%)
Pre-diabetes and/or elevated fasting blood glucose levels	8 (11.9%)	3 (17.6%)	1 (6.3%)	3 (17.6%)	1 (5.9%)
Polycystic ovary syndrome (PCOS)	8 (11.9%)	5 (29.4%)	1 (6.3%)	3 (17.6%)	0
Hypercholesteremia	5 (7.5%)	0	4 (25.0%)	1 (5.9%)	0
Hypothyroidism	7 (10.4%)	1 (5.9%)	3 (18.8%)	1 (5.9%)	2 (11.8%)
Asthma	9 (13.4%)	1 (5.9%)	2 (12.5%)	1 (5.9%)	5 (29.4%)
Other	27 (40.3%)	3 (17.6%)	10 (62.5%)	8 (47.1%)	6 (35.3%)
History and/or presence of musculoskeletal pain					
Low back pain	20 (31.3%)	3 (17.6%)	5 (31.3%)	6 (35.3%)	8 (47.1%)
Hip/Knee pain	14 (20.9%)	5 (29.4%)	8 (50.0%)	3 (17.6%)	2 (11.8%)
Foot/Ankle pain	9 (13.4%)	3 (17.6%)	1 (5.1%)	4 (23.5%)	1 (5.9%)
Shoulder/Elbow/Wrist/Neck	7 (10.4%)	1 (5.9%)	3 (18.8%)	4 (23.5%)	1 (5.9%)

Abbreviations: AE, aerobic; BMI, body mass index; CON, control; EOSS, Edmonton obesity staging system; RE, resistance.
[a]Third Level Education: Level 6 (Diploma/Certificate, Level 8 (Honors Degree), Level 9 (Master's Degree), Level 10 (PhD).

post = 36.4% [n = 4]) groups and RE had the greatest decrease in number of pain sites (−1.9 [SD = 3.9], ES = 0.70, $p = 0.087$) with respect to control. For mood, depression scores improved in all exercise groups with the greatest improvement in COM (−3.1 [3.7], ES = 0.83, $p = 0.029$) when compared with control.

Across all domains of the EQ-5D-5 L at baseline and post-intervention, the presence of issues impacting QoL was minimal. For overall QoL, RE showed the greatest improvement in the EQ-5D index score (+0.05 [SD = 0.12], ES = 0.3, $p = 0.451$). On Euro-Qol Visual Analogue Scale, at follow-up, COM was associated with the greatest improvement in the score with a change of +10.9 (SD = 17.1, ES = 0.93, $p = 0.015$). With respect to sleep (Table 4 and Table S4), as per PSQI, COM showed the greatest improvement in global sleep score (−2.9 [SD = 3.3], ES = 0.78, $p = 0.038$). This was also reflected in a greater reduction in the percentage of participants categorized as poor sleepers in COM (−50%) versus AE (−6.3%) or RE (−25%).

4 | DISCUSSION

This is the first study to examine the feasibility of different exercise modalities in women with obesity using time-matched progressive training interventions. The main findings support the feasibility of all three exercise modalities in terms of adherence, attendance, and retention. For health outcomes, the results indicate the importance of including a resistance component when prescribing exercise for this cohort to achieve meaningful improvements (i.e., QoL [EQ-5D-5 L index] estimated minimally important difference between 0.03 and 0.05).[35]

Across the 15-month recruitment period, 160 women expressed interest in participating (average 10.67 participants/month). Ultimately, less than half of those interested (41.8%) were randomized. Based on the sample size calculation for a full-scale RCT (Table S5), monthly recruitment would need to be doubled to complete the RCT within the same timeframe. Similar to previous research,[36] the largest contributor to recruitment was university staff and students. As the study was hosted in a university, this is unsurprising. Location convenience allowed flexible attendance where otherwise time or transport may have been barriers as previously seen.[37, 38] However, this introduced recruitment bias, where most participants were in full time-employment (66%) and had a university degree or higher (70%), suggesting a moderately high socio-economic status, a factor positively correlated with exercise participation and adherence.[39] Utilization of active recruitment strategies (i.e., identifying eligible clients through healthcare organizations) and multisite rollout for a full-scale RCT might address this bias and improve recruitment through these sources.

TABLE 4 Estimated effect of interventions (mean difference) for all outcomes.

Outcome	Mean ± SD or *N* (%)				*p* value group × time interaction effect
	CON (*n* = 16)	AE (*n* = 14)	RE (*n* = 9)	COM (*n* = 14)	
Resting HR (bpm)	+2.8 ± 9.0	−4.6 ± 9.0	−5.2 ± 14.9	−6.7 ± 12.1	0.098
Systolic BP (mmHg)	+1.9 ± 9.1	−0.1 ± 11.6	−1.8 ± 8.6	−0.2 ± 10.1	0.842
Diastolic BP (mmHg)	+0.0 ± 9.0	−3.4 ± 8.5	−0.1 ± 7.6	−4.3 ± 7.3	0.418
Cardiorespiratory fitness					
VO_2 Max [estimated] (ml.kg.min^{-1})	+0.23 ± 1.83	+1.47 ± 1.65	+2.77 ± 1.49	+1.52 ± 2.20	0.016
Body composition					
BMI (kg/m^2)	+0.2 ± 1.6	−0.6 ± 0.9 (1.5% change)	−0.2 ± 0.8 (0.5% change)	−1.2 ± 2.1 (3.1% change)	0.075
Weight (kg)	+0.5 ± 4.4	−1.6 ± 2.6	−0.4 ± 2.1	−3.2 ± 5.4	0.097
Body fat percentage (%)	+0.2 ± 1.4	−0.2 ± 1.1	−1.2 ± 1.2	−1.6 ± 3.0	0.053
Fat mass (kg)	+0.5 ± 3.4	−1.0 ± 1.9	−1.2 ± 2.0	−3.1 ± 5.2	0.062
Visceral fat (L)	−0.0 ± 0.7	−0.2 ± 0.5	−0.2 ± 0.4	−0.5 ± 0.5	0.189
Fat free Mass (kg)	−0.1 ± 1.8	−0.6 ± 1.5	+0.8 ± 1.2	−0.1 ± 1.5	0.224
Lean mass (kg)	−0.1 ± 1.2	−0.5 ± 1.0	+0.2 ± 0.6 (0.9% change)	−0.2 ± 1.4	0.434
Waist circumference (cm)	−0.1 ± 5.0	−1.5 ± 3.4 (1.3% change)	−2.2 ± 3.4 (2.1% change)	−4.2 ± 4.0 (3.7% change)	0.068
Waist hip ratio	+0.0 ± 0.0	+0.0 ± 0.0	−0.0 ± 0.0	−0.0 ± 0.0	0.260
Strength					
5RM bench press (kg)	−0.8 ± 3.7	+1.6 ± 3.6 (5.7% change)	+10.0 ± 3.8 (39.4% change)	+8.9 ± 4.4 (36.9% change)	<0.001
Leg dynamometry (kg)	+4.1 ± 11.8	+2.9 ± 11.0 (3.7% change)	+6.9 ± 7.3 (9.8% change)	+4.8 ± 9.9 (6.2% change)	0.939
Grip strength (kg)	−0.0 ± 2.8	+1.7 ± 3.1 (5.3% change)	+0.4 ± 4.7 (1.3% change)	+2.0 ± 3.6 (6.3% change)	0.362

Self-reported outcomes	CON (*n* = 16)	AE (*n* = 14)	RE (*n* = 11)	COM (*n* = 15)	
IPAQ-SF[a]					
Total physical activity (MET-mins per week)	182.7 ± 1001.1	1693.1 ± 3695.9	887.7 ± 1679.9	1929.9 ± 1571.7	0.131
Total vigorous PA (MET-mins per week)	−7.5 ± 225.4	1497.1 ± 3351.3	672.7 ± 749.8	1184.0 ± 565.0	0.103
Total moderate PA (MET-mins per week)	143.8 ± 508.0	178.6 ± 348.3	320.0 ± 921.4	673.3 ± 980.3	0.184
Total walking (MET-mins per week)	46.4 ± 855.6	17.7 ± 1477.8	−105.0 ± 934.3	72.6 ± 826.2	0.977
Sitting time (min per weekday)	+37.5 ± 134.4	−23.6 ± 224.2	−38.2 ± 93.0	−98.0 ± 230.8	0.249
PHQ-9					
Overall score	−0.25 ± 3.1	−1.7 ± 5.3	−3.0 ± 5.6	−3.1 ± 3.7	0.275
BPI[b]					
Pain severity score (mean)	−0.5 ± 1.7	−0.9 ± 1.7	−1.3 ± 2.3	0.0 ± 1.3	0.296
Pain interference score	−0.34 ± 1.4	−0.7 ± 1.0	−0.8 ± 1.4	+0.1 ± 2.3	0.419
Activity interference	−0.5 ± 2.1	−0.6 ± 1.3	−0.9 ± 2.5	+0.4 ± 2.9	0.875
Affective interference	−0.3 ± 1.3	−0.6 ± 1.0	−0.5 ± 1.2	−0.5 ± 2.2	0.438
Number of pain sites	0.0 ± 1.5	−1.0 ± 1.6	−1.9 ± 3.9	−0.8 ± 2.7	0.279

TABLE 4 (Continued)

Self-reported outcomes	CON (n = 16)	AE (n = 14)	RE (n = 11)	COM (n = 15)	
EQ-5D-5 L[c]					
Overall index score	0.01 ± 0.14	−0.02 ± 0.20 (2.8% change)	0.05 ± 0.12 (5.8% change)	−0.04 ± 0.26 (4.8% change)	0.634
EQ VAS	−3.2 ± 13.1	+2.1 ± 26.7	7.9 ± 16.3	10.9 ± 17.1	0.193
PSQI					
Global score (average)	−0.3 ± 3.4	−0.7 ± 2.1	−1.5 ± 2.8	−2.9 ± 3.3	0.094

Abbreviations: AE, aerobic; BMI, body mass index; BP, blood pressure; BPI, brief pain inventory; CON, control; EQ-VAS, Euro-Qol Visual Analogue Scale; HR, heart rate; IPAQ-SF, international physical activity questionnaire (short form); PA, physical activity; PSQI, Pittsburgh sleep quality index; RE, resistance.

[a]Note that IPAQ data is truncated in line with IPAQ scoring guidelines.[26] Daily time spent in different activity categories, which exceeded 3 h was truncated using a scoring spreadsheet by Cheng.[28] Metabolic energy equivalent classification (MET-min/week) per physical activity category was calculated using the IPAQ automatic report.[27]

[b]Note: For BPI-SF, pain interference scores were categorized as either activity inference (based on average of walking, work and general activity interference items) or affective interference (mood, enjoyment of life, relation with others, and sleep items).[24] A cut-off was used to differentiate between high (≥7) and low (<7) interference levels.[24] Participants' musculoskeletal pain distribution was categorized into seven sites and the number of sites was grouped as no pain, single site pain, or multisite pain (≥2 sites).[25]

[c]For EQ-ED-EL, an index was derived using the value set for Ireland.[31]

Adherence and attendance rates to supervised exercise have ranged significantly in different obesity studies (i.e., 53%–93%),[40–42] with no universally clear cut-off for high versus low defined previously. With a cut-off of >70% generally used for intervention studies,[43] adherence and attendance were high for COM, RE and AE. Given that being female has been correlated with lower program adherence and PA engagement, the higher engagement in this study positively reflects on the feasibility of the exercise interventions.[44] Additionally, the higher education status and young age (48% aged >40 years) of participants potentially contributed to the promising engagement observed.[45]

Close supervision by health care professionals may have contributed to higher adherence. Fear of injury, pain and failure are known barriers to exercise engagement in women with obesity,[46,47] while professional support is a strong facilitator.[48] Training using a women-specific program with women similar to themselves and without men,[37,49] alongside exercising in a private space, an environment which potentially feels safe and non-judgmental are factors that are likely to have addressed some of the feelings and fear of stigmatization and judgment that are negatively correlated with exercise engagement with this cohort.[46,49]

Overall study attrition (21%) was comparable with dropout rates observed in previous obesity and sedentary adult exercise literature.[40,42,50,51] Similar to other research, the main reasons for dropouts were ill health, lack of time and changed mind.[51] While health issues were the most common reason for attrition, other factors, including low social support and exercise self-efficacy, may have contributed to recruitment and retention challenges.[49,52] With weight loss often cited as the primary motivator for women with obesity to engage in exercise,[52] the focus on health and wellbeing as opposed to weight loss during the intervention may have been a barrier and negatively impacted program adherence.[53,54] Similarly, participants' beliefs regarding exercise may have contributed to drop-out, particularly for RE where attrition was considerably higher than that observed in AE or COM. A quarter of those that dropped out of the RE group did so before commencing the intervention. Barriers observed in previous literature such as lack of experience with RE, fears regarding risk of injury and the viewpoint that RE is a masculine activity may have impacted uptake following randomization.[54] Addressing participants' beliefs about realistic weight loss associated with exercise and RE apprehensions warrants further consideration to successfully recruit for and maintain engagement.

This study found the greatest improvement in CRF with RE and COM. Previous meta-analyses found COM to be most promising for adults with obesity and more specifically, AE was found to be most promising for women with obesity.[2,4,55] The increase in CRF observed with RE may be dependent upon the fact that initial fitness levels were below 40 mL/kg/min,[56] and that the increased lean mass associated with RE is linked with improved CRF (i.e., 1 kg lean mass increase = 200 mL/min CRF increase).[56] Improved leg strength with RE, as observed in this study (+6.9 kg), is linked with enhanced tolerability to cardiopulmonary testing and thus higher CRF in sedentary females.[57] Indeed, on average, it took an additional 6.21 min for RE participants to achieve submaximal VO_2max criteria post intervention, nearly twice that observed in COM (+3.35) and AE (+3.71). It must also be noted that the high attrition from the RE resulted in unequal participant groups, which must be considered when interpreting findings.

Unsurprisingly, RE was associated with the greatest improvements in upper and lower limb strength The increase in strength in this study is significant when compared with other studies in female obesity where improvements were as low as 5%,[58–60] especially considering the BMI and %BF ranges of the participants (BMI: 30–59; %BF: 39–55) and the fact that excess adiposity is associated with an impaired response to strength-training.[61,62]

Consistent with previous research,[4,63–65] COM resulted in the greatest anthropometric improvements. These findings align with the current understanding of physiological benefits of both types of training. Where aerobic exercise is associated with improved insulin sensitivity, fat hydrolysis and reduced adipose accumulation,[4,65–68] resistance training has been shown to correlate with increased metabolic rate and lean mass.[68,69] Equally, as observed with the reduction in %BF in both COM and RE, the inclusion of a resistance component leverages the physiological capability of women for fat oxidation during endurance exercise.[70, 71] Thus, the combination of these modalities results in increased energy expenditure that ultimately correlates with decreased weight and improved body makeup (i.e., FFM:FM ratio).

While all three interventions improved PAL, only COM and RE demonstrated an improvement in sitting time which could translate into clinical significance with the reduction in COM greater than three times the minimally effective change (30-min) which has been correlated with a decrease of 2%–4% in cardiovascular risk and 2% in mortality risk.[72–74] Pain severity, interference and prevalence reported amongst the participants was lower than reported in previous studies in adults with obesity,[75,76] even compared with a similar BMI profile[77] and in an Irish context.[78] Though the participants were not without comorbidities, they were generally well, and this was reflected in both pain and QoL scores. However, despite milder pain scores and high QoL on average, the exercise interventions still demonstrated benefit, with RE associated with the greatest decrease in pain severity, number of pain sites and QoL scores. These findings are consistent with current evidence supporting the effectiveness of strength training for improving QoL and musculoskeletal pain 79–82. Indeed, recent research has highlighted the link between RE and the increased release of beta-endorphins, endocannabinoids and anti-inflammatory cytokines, which alter underlying pain pathways.[83]

Consistent with previous literature, the findings demonstrate that the exercise interventions with a resistance component (COM, RE) were more effective than AE in improving depression scores.[59] The physiological and psychosocial underpinnings which explain the higher efficacy of resistance training for improving depressive symptoms are still poorly understood. However, research suggests that the benefits of this form of training can be linked to the fact that participants can easily perceive the benefit (i.e., strength gains) of their efforts, which contributes to higher self-efficacy.[84,85] Biologically, resistance training reduces the pro-inflammatory factors associated with depression and increases serum brain-derived neurotropic factor (BNDF) levels, which improves depression.[84,86,87] As with previous research, the benefits of the resistance-based programmes also translated into improved sleep.[88,89] Improved sleep quality has important longer-term impact upon health in women with obesity, with poor sleep associated with decreased glucose tolerance, insulin sensitivity, altered levels of appetite regulating hormones and further weight gain.[7,90]

This study has several strengths. The first relates to the study design. While it is not the first study to compare all three exercise modalities in this cohort,[91] it is the first to evaluate the feasibility of these modalities in women with obesity. In line with this, close supervision of participants throughout exercise sessions and detailed recording of intensity measures denotes high levels of rigor of feasibility outcomes and intervention effectiveness for improving outcomes. Secondly, a broad range of outcomes were included to better explore the impact of these modalities on both physical and self-reported health outcomes. Finally, this study time-matched and progressed the intensity of the three exercise interventions synchronously to help control for differences between the session lengths that could contribute to a combined intervention being more effective, an issue that has previously impacted the results of other studies.[65] Conversely, the main study limitation is attrition from RE resulting in an uneven comparison between exercise groups, something which must be considered when interpreting overall results. In addition, with respect to measuring improvements in PA, future studies should perhaps aim to recruit participants who are only sedentary (i.e., energy expenditure <1.5 METs).[92] Indeed, while all participants recruited were physically inactive (i.e., not meeting PA guidelines) as per inclusion criteria, the use of this as a cut-off introduced some variability in terms of average PAL at baseline between participants (i.e., 0 min of PA vs. 140 min of PA).

5 | CONCLUSION

Findings indicate that exercise prescription for women with obesity should prioritize the inclusion of a resistance training component. This study found that all three exercise interventions were feasible with high adherence and attendance rates and no adverse events. Ill health was the largest contributor to attrition, though overall retention rates were comparable to current literature in this area. Participant demographics were influenced by the predominant recruitment source and for a full RCT, active recruitment strategies may be necessary to address this bias. For physical outcomes, COM or RE were found to be more efficacious than AE in improving fitness, strength, and body composition in this cohort. A full-scale RCT should be conducted to further explore the impact of exercise dosage (i.e., impact of >150 min/week) and the most effective intensity range for a progressive program in women with obesity (i.e., commence at 60% HRR, not 40% HRR).

AUTHOR CONTRIBUTIONS

All coauthors have fulfilled each of the following criteria: have made a substantial contribution to research design or the acquisition, analysis, or interpretation of data; have drafted the paper or revised it critically; and have approved the submitted and final versions. MED participated in the conception and design of the work, contributed to the data collection, analysis and interpretation of the data and drafting the work and revising it critically for important intellectual content. CB participated in the analysis of data and interpretation of the results and revising the work. GO'D participated in the conception and design of the work, contributed to the data collection, analysis and interpretation of the data and drafting the work and

revising it critically for important intellectual content. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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