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Exercise intensity influences body composition: a 6-month comparison of high-intensity interval, moderate- and low-intensity training among healthy older adults

Grace Rose, Emily Hume, Daniel Blackmore, Jules Mitchell, Samuel Belford, Tina Skinner, Maryam Ziaei, Stephan Riek, Perry Bartlett, Mia Schaumberg



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Highlights

- Only high-intensity interval training reduced fat mass while maintaining lean mass.
- Moderate-intensity training reduced fat mass but also caused declines in lean mass.
- Both moderate- and high-intensity training improved visceral adipose tissue.

Title: Exercise intensity influences body composition: a 6-month comparison of high-intensity interval, moderate- and low-intensity training among healthy older adults

Authors: Grace Rose^{a,b}, Emily Hume^{c,d}, Daniel Blackmore^d, Jules Mitchell^{b,e}, Samuel Belford^b, Tina Skinner^{b,f}, Maryam Ziaei^{g,h}, Stephan Riek^{b,i}, Perry Bartlett^d, Mia Schaumberg^{a,b}

^a School of Health, University of the Sunshine Coast, PO Box 5280, Sunshine Coast Mail Centre QLD 4560, Australia

^b School of Human Movement and Nutrition Sciences, The University of Queensland, Human Movement Studies Building, St Lucia QLD 4067, Australia

^c School of Health and Medical Sciences, University of Southern Queensland, 487-535 West St, Darling Heights QLD 4350, Australia

^d Queensland Brain Institute, The University of Queensland, Building 79, University of Queensland, St Lucia QLD 4067, Australia

^e Thompson Institute, University of Sunshine Coast, 12 Innovation Pkwy, Birtinya QLD 4575, Australia

^f School of Health Sciences, University of New South Wales, Wallace Wurth Building UNSW SYDNEY NSW 2052, Australia

^g Centre for Advanced Imaging, The University of Queensland, Building 57 University of Queensland, St Lucia QLD 4067, Australia

^h Kavli Institute for Systems Neuroscience, Norwegian University of Science and Technology, The Fred Kavli Building, Olav Kyrres gate 9, 7030 Trondheim, Norway

ⁱ Graduate Research School, James Cook University, Building 4, 1 James Cook Drive, Douglas, Qld, 4814 Australia

Author email addresses:

grose1@usc.edu.au

emily.hume@unisq.edu.au

d.blackmore@uq.edu.au

jules.mitchell@research.usc.edu.au

s.belford@hotmail.com

tina.skinner@unsw.edu.au

maryam.ziaei@ntnu.no

stephan.riek@jcu.edu.au

p.bartlett1@uq.edu.au

mschaum1@usc.edu.au

Correspondence:

Dr Grace Rose

School of Health, University of the Sunshine Coast

90 Sippy Downs Drive, Sippy Downs, QLD, Australia, 4556

E: grose1@usc.edu.au

Ph: +617 5409 8679

Abstract

Objective: To determine whether exercise of higher intensity can elicit greater improvements in body composition among older adults, given that body composition is implicated in the progression of chronic disease.

Study design: Sub-study of a randomised controlled trial (ACTRN12618000700235).

Main outcome measures: Healthy older adults (n=123, average age 72.0 years, body mass index 25.8 kg/m²) completed three 45-minute supervised exercise sessions per week for 6 months. Participants were randomised to treadmill-based moderate-intensity training (n=45), or high-intensity interval training (n=41) or a low-intensity active control condition (n=37), with individualised heart-rate prescription. Dual-energy x-ray absorptiometry was used to quantify body composition at baseline, and at 3 and 6 months.

Results: For fat mass, both high- (p=0.001) and moderate-intensity groups (p=0.016) demonstrated similar reductions that were both larger than control, post-intervention. Only moderate-intensity training was associated with reductions in fat-free mass (FFM) at 0–3

($p=0.005$) and 0–6 months ($p=0.050$), potentially exacerbating age-related reductions in muscle and other lean tissues. Overall, high-intensity training had greater between-group raw difference in lean mass than moderate-intensity training at 6 months ($p=0.042$) and this group was the only one with a net improvement in body fat percentage ($p=0.017$). Moderate-intensity ($p=0.009$) and high-intensity training ($p=0.023$) demonstrated comparable improvements in visceral adipose tissue over 0–6 months.

Conclusions: High-intensity training reduced fat and maintained lean mass in apparently healthy older adults, though changes were small and not clinically meaningful compared with exercise of lower intensity and considering measurement error. Where appropriate and feasible, higher-intensity exercise training may be considered to support improvements in health-related body composition in older adults.

Protocol registration: ACTRN12618000700235

Keywords:

Body composition; muscle; ageing; adiposity; exercise

1 Introduction

Ageing leads to detrimental change in body composition, including increases in fat mass (FM) and declines in muscle and fat free mass (FFM) [1]. Such changes are implicated in development of several globally prevalent preventable age-associated diseases, including cardiometabolic diseases [2] and cancer [3]. Preventative strategies are essential to mitigate age-associated body composition changes, and consequent morbidity and mortality.

Moderate-to-vigorous physical activity (MVPA) is associated with lower fat mass (FM) and higher fat free mass (FFM) [4] and aerobic exercise training can likewise improve these outcomes [5][6]. Higher exercise intensity may evoke a greater potential to improve body composition, via several mechanisms, including a greater energy requirement and post-exercise energy expenditure [7], more muscle contractions and protein synthesis rate [8]. Conversely, moderate intensity exercise could be more effective due to favouring of fat as a metabolic substrate [9].

Despite known mechanisms, the evidence for which intensity is best to improve body composition among older adults is sparse [10]. Most evidence is derived from younger

populations, which may not represent the different metabolic and hormonal profiles of older adults [11]. Additionally, intensity comparison studies that include older adults predominantly include individuals who live with a chronic disease or obesity [10]. This study addresses limitations through recruitment of an “apparently healthy” older adult population to investigate the influence of exercise intensity on body composition in the absence of possible inhibitory effects of disease.

Therefore, the aims of this study were to: 1) investigate the effect of six months of high-intensity interval training compared to moderate-intensity continuous training and a low-intensity training control on health-related body composition, measured via FM, FFM, body fat percentage (BF%), and visceral adipose tissue (VAT) among healthy older adults, and 2) determine whether body composition changes were clinically meaningful.

2 Materials and methods

2.1 Overview

This is a sub-study of a published randomised controlled clinical trial (University of Queensland, Australia), for which the primary objective was to assess the influence of exercise intensity on cognitive function in healthy older adults [13]. The study was powered for cognitive outcomes accordingly. This sub-study comprised a 6-month, three-arm, randomised, controlled exercise intervention and assessed body composition (tertiary outcome). Following baseline assessment, participants were stratified for sex, and randomised (1:1:1) to one of three intensity groups (full randomisation details within [13]). Participants attended three supervised exercise sessions per week for 6-months according to their allocated group: low (LIT), moderate (MICT) or high-intensity interval training (HIIT), with reassessment of all outcome measures at 3- and 6-months (*Supplementary Figure 1*). The LIT group served as an active control to minimise confounding from participation, incidental physical activity and lifestyle changes. All study procedures were approved by a human medical research ethical review committee (Bellberry®; 2016-01-038-A-2) and the protocol was registered (ACTRN12618000700235). Study data can be made available at the discretion of author P.B., upon request.

2.2 Participants and presentation

Full participant inclusion criteria and recruitment details are reported elsewhere [13]. In short, apparently healthy men and women aged 65-85 years at the time of study inclusion were

recruited via multiple strategies (03/2016-08/2018). Participants had no pre-existing medical conditions that would make strenuous exercise unsafe (e.g., cardiac conditions, mental illness, cognitive impairment). Participants were asked to present in a well-hydrated state, avoid planned exercise for 24 hours and caffeine, alcohol and heavy meals for 4 hours preceding assessment, and take normal daily medications throughout the study period.

2.3 Body composition and anthropometry outcome measures

Body mass (Mercury Load Cell Digitiser; A&D, Melbourne AUS) and standing height (Stable stadiometer, Seca, Hamburg DE) were measured before body composition assessment. Body composition analysis (FM, FFM, BF% and VAT) was completed using DXA (Dual-energy X-ray Absorptiometry; Discovery QDR 4500W and/or Horizon A, Hologic®, Massachusetts USA) under standardised conditions [14]. Scans were completed and analysed by a trained operator using manufacturer-supplied software (APEX® version 3.3 and/or 5.6.0.5) and according to the manufacturer instructions. Calibration was completed in accordance with the manufacturer recommendations (technical CV FM=0.78% and FFM=0.52%).

2.4 Control parameters

2.4.1 Exercise volume/ energy expenditure

Session heart rate was averaged and calculated as percentage of individual heart rate peak. Assuming a linear relationship between $\dot{V}O_2$ and HR, an estimation of average metabolic equivalents (METs) per session was calculated as:

$$\text{Average session METs} = \text{Peak METs during graded exercise test} \times \text{average \%HR}_{\text{peak}}$$

Total EE was then calculated using the following equation [15]:

$$\text{total kcal} = ((0.0175 \times \text{body mass (kg)} \times \text{calculated METs}) \times \text{session time}) \\ \times \text{total number of exercise sessions}$$

2.4.2 Physical activity and dietary intake

Participants were encouraged to maintain usual physical activity throughout the study. At baseline, habitual physical activity was objectively measured for seven consecutive days using tri-axial accelerometry (Actigraph®, Pensacola, FL, USA) with 60-second epochs analysed using established MVPA intensity cut-points [16]. Dietary intake was assessed using a 3-day food diary at baseline and analysed for total energy intake (kcal) and macronutrient intake (kcal) by a dietitian dietary analysis software (Foodworks, Xyris®, AUS).

2.5 Exercise training intervention

All training sessions were supervised by qualified Exercise Scientists/Physiologists. Exercise intensity was recorded every one to five minutes using HR (T31 heart rate monitor, Polar[®], Melbourne AUS) and RPE (Borg, 6-20) according to individualised target HR (protocol reported in detail elsewhere) [13]. Attendance was calculated as the number of sessions attended divided by the total number of sessions available to attend. Adherence was calculated as the total minutes where the minimum target HR was met divided by the total exercise time, for the HIIT group the minimum HR applied to the final two minutes of the interval.

In the HIIT group, participants completed a 10-minute warm-up followed by four, 4-minute intervals at 85-95% of HR_{peak} interspersed by 3-minutes of active recovery at 60-70% HR_{peak} followed by a 5-minute cool-down, totalling 40-minutes of treadmill exercise [13] (*Supplementary Figure 2*). In the MICT group participants completed a 10-minute warm-up, a 30-minute continuous walking session at 60-70% of HR_{peak} , and a 5-minute cool down, totalling 45-minutes treadmill exercise. In the LIT group, participants attended an indoor 45-minute balance, stretching and toning class, with a 10-minute warm up, 30-minute class at 45-55% of HR_{peak} , and 5-minute cool down.

2.6 Statistical Analysis

Data were analysed per protocol; body composition outcomes included were determined prior to analysis. Following assessment of normality of response variables and residuals, one-way ANOVA (parametric) and Kruskal-Wallis comparison of ranks (non-parametric) tests were used to examine group differences at baseline. To examine the influence of exercise intensity on body composition changes, generalised linear mixed modelling (GLMM) was conducted with Bonferroni adjusted post-hoc comparisons. Prior to analysis, all predictors were assessed by correlation matrix and regression variance inflation factors (VIF); there was no evidence of collinearity among predictors (VIF range=1.0-2.4). Alongside group and time fixed factors, baseline measures were included as continuous, fixed co-variables, as were total energy consumption (kcal), baseline physical activity (MVPA), exercise energy expenditure (kcal), age (years) and sex. Baseline protein intake (g) was included as a covariate in FFM and BF% analyses. Individuals were treated as random effects. Change over time in covariates (physical activity, protein and energy intake) were assessed using repeated measures ANOVA, with post-hoc Bonferroni correction. To establish whether individuals met clinically meaningful thresholds, individual change data between 0-6 months was

compared to the minimally clinically important difference (MCID) combined with biological error (BE) to create a total threshold in waterfall plots. This was completed for BF% (MCID = 0.22%, BE = 0.65%, total threshold = 0.77%) [17], and VAT (MCID = 25 g, BE = 31 g, total threshold = 56 g) [18]. Body composition MCID values reflect countering of age-associated body composition change [17, 18]. Fisher's exact tests assessed whether the proportion of participants who met clinically meaningful thresholds for BF% and VAT significantly differed among groups.

3 Results

3.1 Participant completion and changes in covariates

Following screening, 159 participants completed baseline assessments and were randomised into low-, moderate- or high-intensity training groups for this sub-study. A total of 123 men and women (LIT n=37; MICT n=45; HIIT n=41; female %=51) completed the intervention. On average, participants were 72 years of age, of age-appropriate BMI [19] but overweight by BF% [20], generally physically active, and showed no baseline group differences, including energy and protein intake (*Table 1*). Although not statistically significant, the HIIT group averaged 45-60 minutes less physical activity than MICT and LIT. The consort diagram (*Figure 1*) denotes participant flow through this sub-study. Adherence was 96% (HIIT), 100% (MICT and LIT), with 99% overall attendance. The average HR_{peak} percentages for each group over the course of the intervention were 79% (± 8 ; HIIT), 74% (± 16 ; MICT) and 59% (± 8 ; LIT). Adverse events are reported elsewhere [13]. There were no differences among groups for change to accelerometry-measured physical activity levels ($p=0.826$), total energy ($p=0.613$) or protein intake ($p=0.890$) throughout the intervention.

3.2 Exercise intensity influence on body composition

Figure 2 represents intervention group and time effects on body composition (see *Supplementary Tables 1 and 2* for supporting data). At 3- and 6-months, the HIIT group had significantly lower FM than the LIT group (3-months [mean= -0.77 kg, 95%CI= -1.44, -0.99]; 6-months [mean= -1.10 kg, 95%CI= -1.77, -0.44]). At 6 months, the MICT group also showed significantly lower FM compared to LIT (mean= -0.86 kg, 95%CI= -1.55, -0.16). No significant differences in FM were observed between HIIT and MICT. Underpinning group-level differences, HIIT significantly reduced FM between 0-6 months (0.54 kg, $p=0.026$), and MICT between 3-6 months (0.50 kg, $p=0.035$).

The HIIT group had significantly greater FFM than MICT at 6-months (mean=0.69 kg,

95%CI= 0.02, 1.35). However, neither group differed from LIT, and no group-level differences were observed at 3-months. In exploring change over time, those in the MICT group had a significant decline in FFM at 0-3 months ($p=0.005$), which also approached significance at 0-6 months ($p=0.050$).

For BF%, HIIT was the only group to demonstrate a significant between-group difference at 3- (mean= -0.73%, 95%CI= -1.40, -0.06) and 6-months (mean= -1.10%, 95%CI= -1.77, -0.43), compared to LIT, and a significant effect of time between 0-6 months ($p=0.017$). However, there were no group-level differences between HIIT and MICT.

At 6-months, MICT had significantly lower VAT mass compared to LIT (mean= -41.21 g, 95%CI= -76.73, -5.69). The HIIT group similarly trended toward lower VAT mass compared to LIT at 3 months (mean = -34.20 g, 95% CI = -69.00 to 0.59) and 6 months (mean = -33.77 g, 95% CI = -68.35 to 0.81), though these differences were not statistically significant. There were no significant differences between HIIT and MICT for changes in VAT mass. Over time (0–6 months), both HIIT ($p = 0.023$) and MICT ($p = 0.009$) groups demonstrated significant reductions in VAT mass.

3.3 Influence of exercise intensity on clinically meaningful body composition change

Clinically meaningful change in body composition is shown in *Figure 3*. The HIIT group had the highest percentage of participants with a clinically meaningful decrease in BF% ($n=44\%$) compared to MICT ($n=27\%$) and LIT ($n=33\%$). The HIIT group also had the least participants with a clinically meaningful increase in BF%. Among groups, the percentage of participants that met the MCID for VAT was similar ($n=30-38\%$). However, the MICT group had the least participants that had a clinically meaningful increase in VAT ($n=7\%$) compared to both HIIT ($n=20\%$) and LIT ($n=19\%$). Statistically, the proportion of participants who achieved a clinically meaningful change in BF% or VAT did not differ significantly among groups (BF%: $p=0.197$; VAT: $p=0.198$).

4 Discussion

The present study directly compared exercise intensity influence on concurrent FM and FFM changes, using a technique subject to low rates of biological error [14] and an intervention with high attendance (99-100%), within a healthy older adult population. Overall, HIIT appeared to elicit favourable changes across several health-related body composition domains, including FM and FFM. Whilst MICT exercise appeared equally as effective in

reducing FM, the MICT group concurrently experienced a significant decline in FFM which was mitigated in the HIIT group. Higher-intensity training may have been more effective at maintaining FFM due to higher skeletal muscle loading and elevated muscle protein synthesis [8]. Combined, these factors could contribute to improved muscle maintenance. However, none of the training intensities resulted in clinically meaningful change on average (*Figure 3*). Though clinically meaningful improvements in BF% were seen among many individual HIIT participants (44%), and were greater in proportion than MCID changes seen within the MICT (27%) and LIT (35%) groups (*Figure 3*), clinically meaningful improvements were not seen across the majority (>50%) of participants. Clinically meaningful changes were also not statistically different among groups, indicating that no single intensity reliably produces clinically meaningful body composition change. These results highlight the need for more targeted approaches to exercise prescription in this population, perhaps involving diet [41].

Body composition changes throughout the intervention were generally lower or on par with expected change. In healthy older adults, moderate-to-vigorous aerobic exercise is known to reduce FM by 0.6-3.0 kg, with an average of 1.5 kg [21-28]. For BF%, a loss of 1.27% is average [22, 23, 25-27, 29]. Within the current study, changes in FM were approximately three-fold lower and changes in BF% two-fold lower than previously reported in studies of healthy older adults (*Supplementary table 2*). It is possible that lower baseline FM among our participants may have limited the reduction in FM throughout the intervention. Indeed, studies where participants has the most similar baseline FM to the current study had similar results (average -0.6 kg) [25, 27], except for one study which was of longer duration (-1.7 kg) [21]. Intensity effects also aligns with cumulative evidence from the most recent systematic review by Keating et. al [10], who showed that higher- and moderate-intensity exercise training have similar influences on body adiposity. For VAT, changes were lower than previous results in healthy older adults, and did not favour HIIT unlike previous studies of a similar or shorter duration [27, 33]. This may be due to participants tending to have lower than average levels of VAT (1500 g) [18], whereas previous research shows those with higher baseline VAT tend to experience greater reductions in VAT with higher-intensity exercise [34, 35] compared to studies where participants have lower baseline VAT [36, 37].

An interesting finding from the present analysis is that, despite similar change in FM and VAT between HIIT and MICT, only HIIT had a significant reduction in BF% from baseline to 6-months (*Figure 2, Supplementary Table 2*). This is likely due to the convergence of FM

and FFM changes. Whilst HIIT and MICT groups both experienced declines in FM, the MICT group had concurrent declines in FFM while the HIIT group maintained their FFM (*Figure 2*). Previous studies in older adults have only observed a small increase (+150g) in FFM on average following aerobic exercise interventions of varied intensities [21, 24-29]. A handful of studies have compared high- and moderate-intensity exercise training in healthy people, but these have focussed on young or middle-aged adults [27, 38] and included resistance training [27]. Only one recent study has examined high-intensity training alone in older adults. [39]. Compared to the present study (between 0-, 3- and 6-months) results from previous studies (12 weeks) that included longer duration high-intensity intervals (>10 seconds) report similar intensity differences, with losses or no change in FFM with MICT [38, 40] and no change or slight increases in FFM with HIIT [39, 40]. Notably, the study that showed an increase with FFM following HIIT included older adults (average 80 years) [39]. The results from this study suggest that HIIT may offer benefits beyond MICT as a form of aerobic training that might help to mitigate FFM loss. However, further research is needed to confirm these effects and establish clinical recommendations.

There are several limitations of the present study. Given that participants exceeded target heart rate ranges in the LIT and MICT groups, the recorded average %HR_{peak} for each group was closer than anticipated, especially between HIIT and MICT. Limited separation of the exercise intensity groups may have diminished the influence of exercise intensity on change in body composition and calls into question the internal validity of the exercise intervention. Given the recommended classifications for aerobic activities (50-70%, 70-85% and >85% HR_{peak/max} for moderate, vigorous and high intensities, respectively) [42], LIT would be more appropriately classed as moderate intensity and MICT and HIIT at overall vigorous intensities. In terms of body composition measurement, assessment was not conducted under fasted conditions due to completion of the exercise capacity test immediately following; as such, between-day error may have been greater than anticipated. Further, the use of MRI and 4-compartment body composition models are known to be more longitudinally reliable for measurement of FFM than DXA, which might have reduced the sensitivity of our results [14, 43]. Within analysis, an estimation of exercise volume was included as a covariate to adjust for the influence of the metabolic cost of exercise [15], though not by direct breath-by-breath analysis. This may have reduced the specificity of exercise intensity's influence on body composition. One further limitation of this study is the inability to explore sex-specific responses due to sample size constraints. Although the overall cohort was relatively large,

stratifying by sex across intervention groups and timepoints would have resulted in insufficient statistical power. Future studies with larger samples may be better positioned to investigate sex-specific effects in older adults.

The results of this study indicate that vigorous intensity exercise using HIIT appears most efficacious to improve health-related body composition to a small degree when compared to continuous exercise training of a moderate/vigorous intensity. However, body composition changes were not clinically meaningful on average. Other exercise modalities, particularly progressive resistance training, could be included alongside higher-intensity aerobic training for improvements in FFM. Further research combining hypertrophic resistance training with longer interval HIIT could provide insight into optimal exercise prescription for the maintenance of skeletal muscle mass during ageing. Overall, findings from this study suggest that where possible, healthy older adults should opt for high-intensity interval training over other aerobic intensities for body composition benefits.

Contributors

Grace Rose participated in conceptualisation, methodology, validation, investigation, formal analysis, and visualisation, and drafted the original paper.

Emily Hume participated in investigation (data acquisition), review and editing of the draft paper, and project administration.

Daniel Blackmore participated in conceptualisation, methodology, data curation, review and editing of the draft paper, project administration, and funding acquisition.

Jules Mitchell participated in investigation (data acquisition), data curation, review and editing of the draft paper, and project administration.

Samuel Belford participated in investigation (data acquisition), and review and editing of the draft paper.

Tina Skinner participated in conceptualisation, methodology, and review and editing of the draft paper.

Maryam Ziaei participated in conceptualisation, methodology, review and editing of the draft paper, and funding acquisition.

Stephan Riek participated in conceptualisation, methodology, review and editing of the draft paper, and funding acquisition.

Perry Bartlett participated in conceptualisation, methodology, review and editing of the draft paper, supervision, and funding acquisition.

Mia Schaumberg participated in conceptualisation, methodology, investigation, review and editing of the draft paper, supervision, project administration, and funding acquisition.

All authors saw and approved the final version and no other person made a substantial contribution to the paper.

Ethical approval

The work described has been carried out in accordance with the Declaration of Helsinki. All study procedures were approved by a human medical research ethical review committee (Bellberry®; 2016-01-038-A-2) and the protocol was registered (ACTRN12618000700235). Informed consent was obtained for experimentation with human subjects.

Provenance and peer review

This article was commissioned and was externally peer reviewed.

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Data sharing and collaboration

There are no linked research data sets for this paper. Data will be made available on request.

Declaration of competing interest

Emeritus Professor Perry Bartlett reports financial support was provided in full by Stafford Fox Medical Research Foundation. All other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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6 Figures

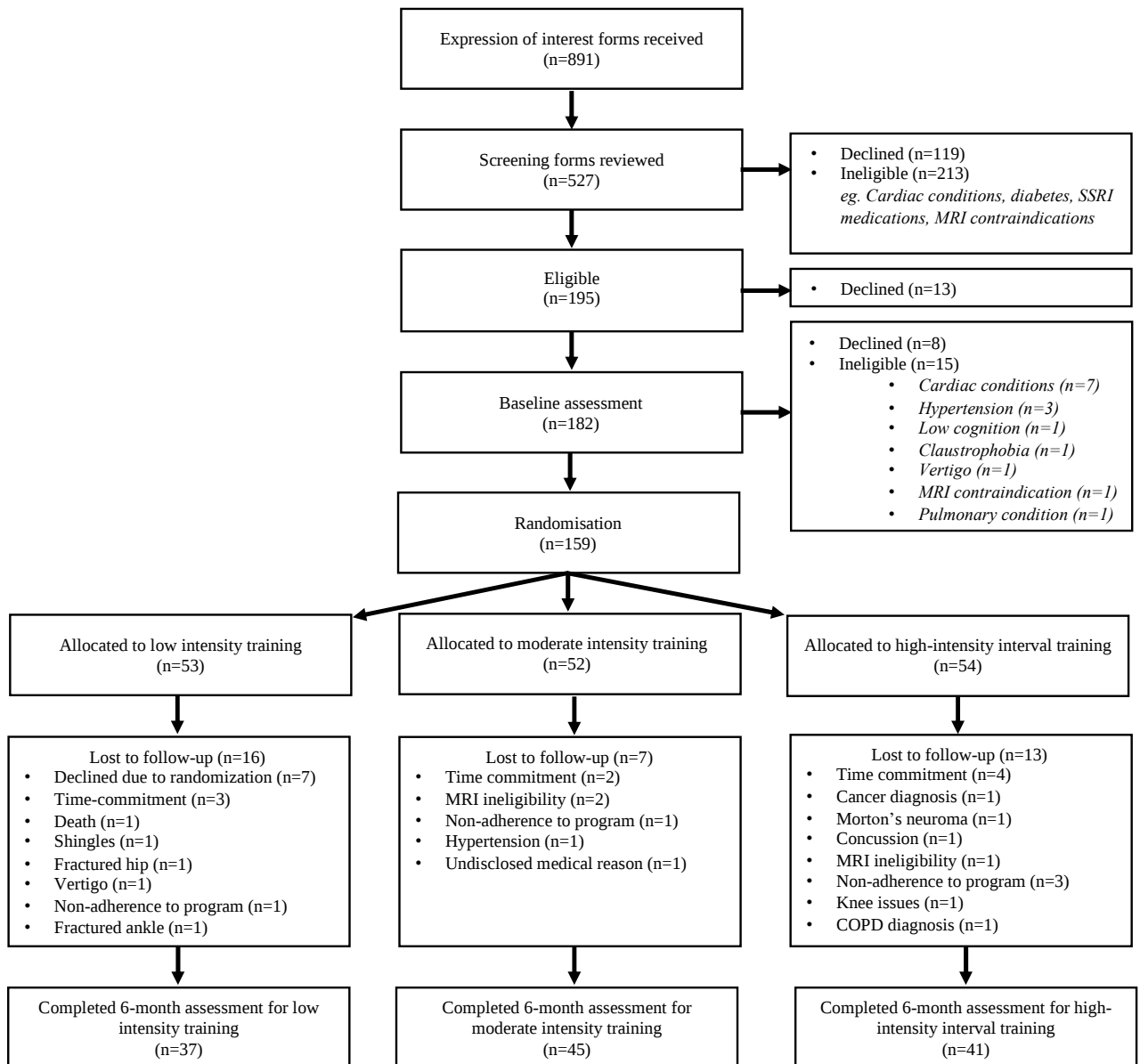


Figure 1. CONSORT diagram following participants through to intervention completion

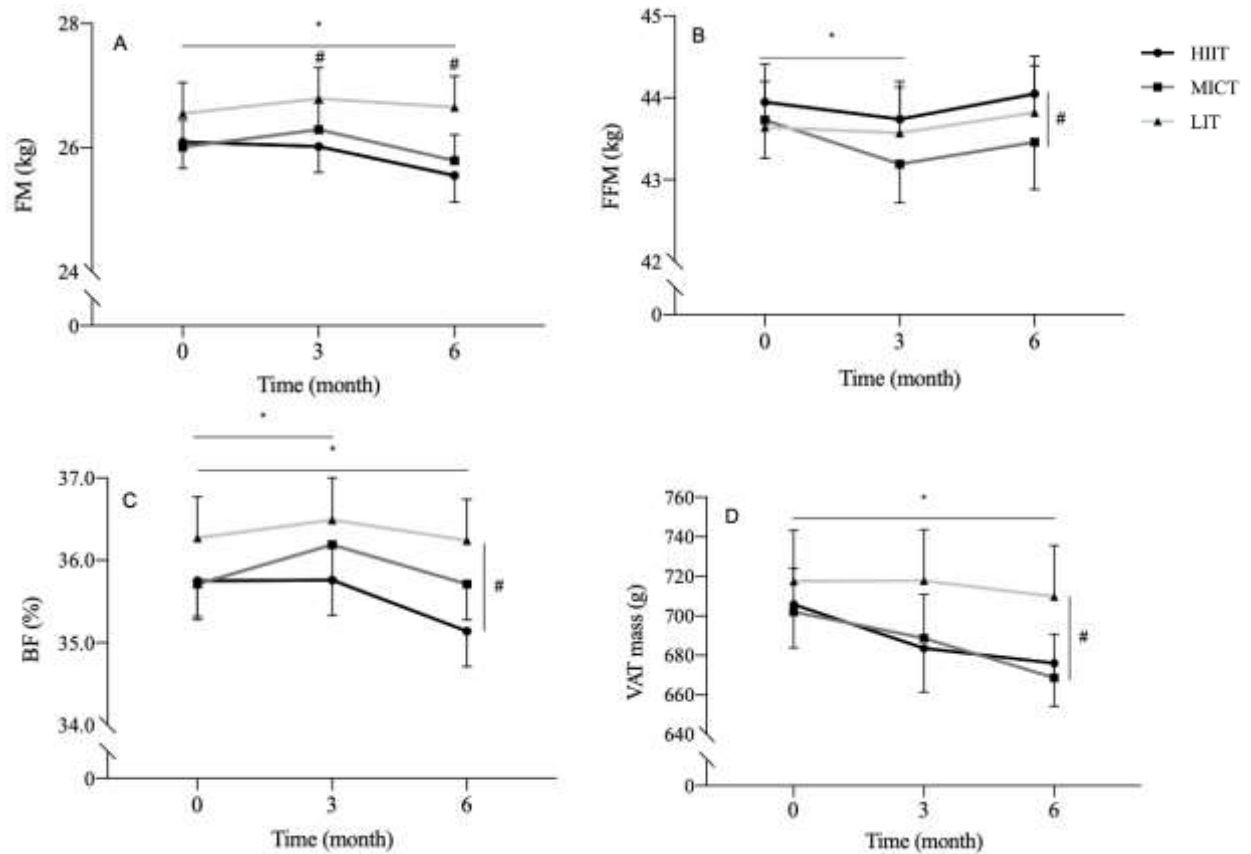


Figure 2. Change in body composition across the six-month intervention including FM (A), FFM (B), BF% (C), VAT (D)

Generalised linear mixed modelling analysis ($n=123$). Fixed factors: group, time, *group* $\times$ *time*, Fixed covariates: baseline concentration of relevant body composition parameter, participant age, sex, baseline physical activity, average energy intake and total exercise volume (six-month energy expenditure). For FFM and BF% protein intake also included. Data presented as mean and 95% confidence intervals.

* Significant within-group difference at $p \leq 0.05$

Significant between-group difference $p \leq 0.05$

BF%: body fat percentage, FFM: fat-free mass, FM: fat mass, HIIT: high-intensity interval training, LIT: low-intensity training, MICT: moderate-intensity continuous training

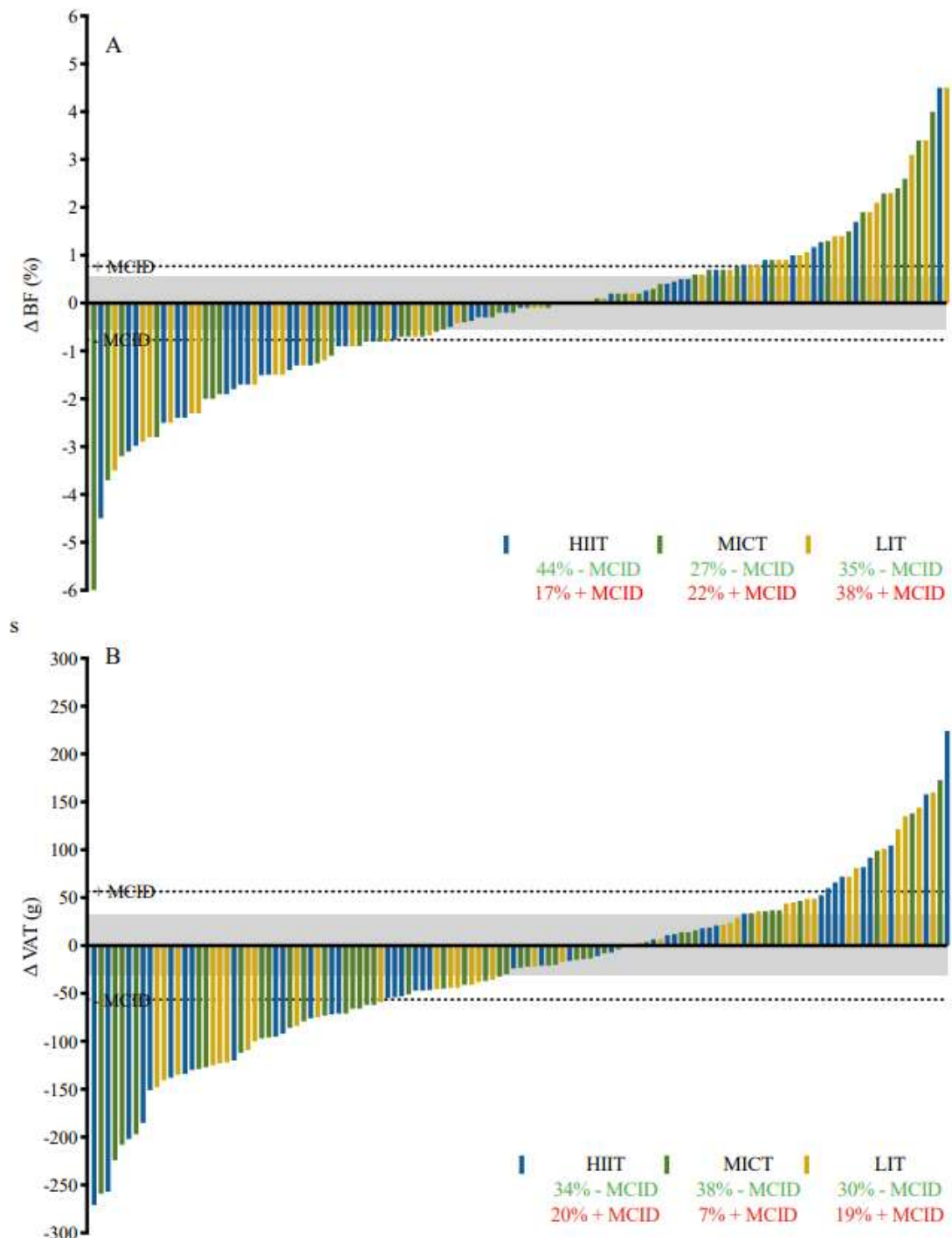


Figure 3. Individual delta changes (0-6-months) in BF% (A), VAT (B), in reference to clinically meaningful change

Shaded region represents longitudinal (between-day error) of BF% ($\pm 0.65\%$) and VAT mass (± 31.43 g); dotted line represents minimal clinically important difference (MCID) added to longitudinal error for BF% ($\pm 0.77\%$) [17] and VAT (± 56.43 g) [18]. All people who fall outside of the MCID limits are reported as a percentage of the group sample, where ‘-MCID’ represents those who have lost a clinically meaningful amount of BF%/VAT (i.e., improvement), and ‘+MCID’ represents those who have gained a clinically meaningful amount of BF%/VAT (i.e., detrimental).

BF%: body fat percentage, HIIT: high-intensity interval training, LIT: low-intensity training, MICT: moderate-intensity continuous training, VAT: visceral adipose tissue,

7 Tables

Table 1. Participant baseline characteristics

	LIT	MICT	HIIT	p
n	37	45	41	
Female (%)	54	56	44	-
Age (years) ¹	71.0 ± 4.2	72.0 ± 3.9	72.0 ± 4.3	0.278
BMI (kg.m ⁻²) ¹	25.5 ± 3.5	25.8 ± 3.8	26.2 ± 3.6	0.710
FM (kg) ¹	26.1 ± 6.6	25.4 ± 5.7	26.4 ± 7.3	0.785
FFM (kg) ¹	43.5 ± 9.4	43.9 ± 10.2	46.8 ± 9.4	0.239
BF (%) ¹	36.5 ± 7.7	35.8 ± 6.3	34.8 ± 6.6	0.561
Physical activity (MVPA/wk) ²	258 ± 427	252 ± 415	172 ± 207	0.142
Total energy intake (kcal) ¹	1849 ± 473	1951 ± 561	1887 ± 787	0.769
Protein intake (g) ¹	83 ± 22	86 ± 22	82 ± 34	0.747

¹ Descriptive data presented as mean ± standard deviation, comparison among groups using One-way ANOVA. Significance p<0.05

² Descriptive data presented as median ± interquartile range, comparison among groups using Kruskal Wallis test. Significance p<0.05

BF%: Body fat percentage, BMI: body mass index, FFM: fat-free mass, FM: fat mass, HIIT: high-intensity interval training, LIT: low intensity training; MICT: moderate intensity continuous training, MVPA: moderate-vigorous physical activity, wk: week