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Abstract

It is unclear how high-intensity, interval-type nontraditional exercise training programs can be feasible and effective options for inactive obese individuals. This randomized controlled trial investigated the hypothesis that a 10-month high-intensity, group interval-type neuromuscular training program (DoIT) with adjunct portable modalities, performed in a small-group setting, induces improvements in psychological well-being, subjective vitality and exercise behavioral regulations in obese women. Associations between adherence, psychological and physiological indicators were also investigated. Forty-nine previously inactive obese females (36.4±4.4 yrs) were randomly assigned to three groups (control; N=21, 10-month training; N=14, or 5-month training plus 5 month-detraining; N=14). DoIT was a supervised, progressive, and time-efficient (<30 min) program that used 10-12 functional/neuromotor exercises and prescribed work and rest time intervals (20-40 sec) in a circuit fashion (1-3 rounds) for 10 months. Questionnaires were used to measure psychological distress, subjective vitality, and behavioral regulations in exercise at pre-, mid-, and post-intervention. The 10-month training reduced psychological distress (72%, p=0.001), external regulation (75%, p=0.011) and increased vitality (53%, p=0.001), introjected regulation (63%, p=0.001), intrinsic regulation (33%, p=0.004), and identified regulation (88%, p=0.001). A moderate to strong positive relationship was found between adherence rate and identified regulation scores (r=0.59, p=0.001) and between VO₂peak and identified regulation scores (r=0.59, p=0.001). A mild dissociation between exercise intensity and perceived exertion was also observed. Our novel findings suggest that a 10-month implementation of a high-intensity interval neuromuscular training program promotes positive psychological adaptations provoking exercise behavioral regulation and adherence while inducing weight loss in previously inactive obese women.
**Keywords:** obesity, body composition, high-intensity interval training, psychological distress, vitality, self-determination theory.

**Introduction**

Obesity is a major risk factor for development of several chronic non-communicable diseases such as the metabolic syndrome, cardiovascular disease, and cancer with >50% of adult global population being overweight or obese (American College of Sports Medicine [ACSM], 2017). The worldwide prevalence of inactivity is a major public health issue because almost one in three adults fails to meet the current global recommendations on physical activity (PA) (Guthold, Stevens, Riley, & Bull, 2018). Current PA guidelines for adults require daily ≥150 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity aerobic activity. Adults should also participate in resistance exercise (RT) at least two days/week while 300 minutes of moderate-intensity aerobic activity are recommended for sustainable weight loss (ACSM, 2017). However, exercise is avoided by overweight/obese individuals due to weight stigma, which is associated with lower self-efficacy, motivation and exercise perceived competence (Schvey et al., 2017).

Systematic exercise is crucial for promoting physical and psychological health that increases longevity and improves quality of life (QoL) (ACSM, 2017). High-intensity interval training (HIIT), bodyweight training and functional training have emerged as some of the most attractive options for exercise programming (Thompson, 2018). HIIT-type programs are effectively and safely used in different populations including individuals at risk for chronic diseases (Gibala, Little, MacDonald, & Hawley, 2012). Recent reviews reported that inactive obese adults could perform HIIT-type protocols adjusted to their psychological and physiological profiles (Türk et al., 2017). Traditional exercise modalities based on moderate-intensity continuous training (MICT), RT, or combined training have been shown to be applied time-consuming and they are characterized by high attrition and low adherence rates when applied in the obese (Burgess, Hassmén, Welvaert, & Pumpa, 2017).

Previous studies suggest that subjective vitality is related to maintenance of weight loss and psychological well-being whereas behavior change skills are the best predictors of beneficial weight control and adherence to PA (Ryan, & Frederick, 1997; Teixeira et al., 2015). The intrinsic motivation is pivotal for exercise adherence (Ryan et al. 1997), but the role of longitudinal supervised HIIT-type programs in compliance rate and the relationship between various psychological and physiological markers has not
been thoroughly investigated. Additionally, others argued that intrinsic motivation, autonomous regulation, enjoyment, and competence, are related to exercise involvement (Thogersen-Ntoumani & Ntoumanis, 2006). However, long-term experimental evidence in sedentary obese adults is limited.

Numerous exercise regimens with various training configurations have been proposed to promote long-term adherence in weight management programs aiming to inspire a healthy behavior modification (Middleton, Anton, & Perri, 2013). It is currently unclear if HIIT-type programs are effective in promoting long-term motivation, behavioral modification, vitality, enjoyment and adherence to exercise participation in inactive overweight/obese adults within a real-world environment (Shepherd et al., 2015). Adherence is associated with affective responses to exercise intensity since enjoyment declines with increasing intensity and this may contribute to the alarmingly high rates of inactivity (Ekkekakis, Parfitt, & Petruzzello, 2011). The feasibility of traditional high-intensity exercise protocols in untrained, overweight/obese middle-aged women has been questioned due to their inherent intense nature demonstrating different affective responses compared to normal-weight individuals (Ekkekakis, Lind, & Vazou, 2010). Feelings of pleasure in HIIT protocols are better promoted by low exercise volumes and are reduced in individuals with poor conditioning (Frazão et al., 2016). The DoIT protocol, on the other hand, is a small group-based, supervised, progressive neuromuscular exercise training protocol with HIIT-like characteristics that uses bodyweight exercises that develop fundamental movement patterns (Batrakoulis et al., 2018). DoIT incorporates alternative modes and nontraditional implements aiming to create a hybrid regimen that combines the physiological adaptations of HIIT and RT in a time-efficient manner. DoIT uses short work intervals that better promote enjoyment compared to traditional protocols (Martinez, Kilpatrick, Salomon, Jung, & Little, 2015). Previous research indicated that DoIT reduces body mass and fat and induces considerable cardiorespiratory, neuromuscular and metabolic adaptations in inactive obese women requiring only ~100 minutes/week (Batrakoulis et al., 2018). Hence, it was hypothesized that this 10-month program may improve psychological health, well-being, and adherence in previously inactive obese Caucasian women. Thus, the primary aims of this study were to determine the effects of the DoIT protocol on (i) psychological distress, (ii) subjective vitality, and (iii) behavioral regulations in exercise in a cohort of obese women. Additionally, the secondary aims were to examine (i) associations between psychological and performance
outcomes, and (ii) associations between psychological outcomes and adherence rate. Both performance and adherence date were described elsewhere (Batrakoulis et al., 2018).

Materials and methods

Ethics statement
The methods, procedures, and ethics of this study were examined and approved by the Institutional Ethics Committee (ref. number 1025/15-7-2015). Procedures were in agreement with the 1975 Declaration of Helsinki as revised in 2013. This study was registered on the ClinicalTrials.gov website under the registry number NCT03134781.

Study design
This investigation is a part of a long-term study whose purpose, methodology and inclusion/exclusion criteria have been described in detail elsewhere (Batrakoulis et al., 2018). In this study, data on psychological well-being, vitality, behavioral regulation, and adherence rate are presented as well as correlations between these psychological markers and performance measures reported elsewhere (Batrakoulis et. al, 2018). The Consolidated Standards of Reporting Trial (CONSORT) diagram is illustrated in Figure S1. The study was based on a controlled, randomized, three-group, repeated-measures design. Following a preliminary power analysis that has been described elsewhere (Batrakoulis et al., 2018), 96 participants were initially approached. After an initial interview, 60 women met the required inclusion criteria and were then randomly assigned to three groups (49 completed the trial) (S1 Figure): (i) control group (C, N=21); (ii) 10-month training group (TR, N=14), or (iii) 5-month training plus 5-month detraining group (TRD, N=14). Initially, a 4-week adaptive and familiarization period was implemented during which participants were asked to follow an isocaloric diet and were familiarized with exercises techniques and session structure of DoIT (Batrakoulis et al., 2018). The dietician instructed participants on how to adapt to a weight maintenance diet (55-60% carbohydrate, 15-20% protein, 20%-25% fat). The diet plan was re-adjusted at 20 weeks. All groups were followed over a period of 10 months. During the first 5 months, TR and TRD performed the DoIT exercise protocol. In months 6-10, TR continued the exercise protocol whereas TRD abstained from training (detraining). C participated in measurements session but not in training. Psychological assessments were performed at baseline, at mid-training (5 months), and at post-training (10 months). At mid- and post-
training, the questionnaires GHQ-12, SVS, and BREQ-2 for psychological assessments were administrated five days after the last training bout each time to avoid the last training bout effect, i.e. to record the long-term effect of the training intervention. The experimental flowchart is illustrated in Figure S2.

**Participants**

Participants were informed about all risks, discomforts and benefits involved in the study and signed a consent form before the commencement of the study. Participants were physically inactive (sedentary for ≥6 months before the study, had a VO$_2$ max ≤30 ml·kg$^{-1}$·min$^{-1}$, daily step count <7,000, and <30 min/day of moderate-to-vigorous PA), premenopausal women aged 30-45 years, overweight or obese (BMI of 25.1-34.9 and body fat ≥32%), healthy and medically cleared for strenuous exercise, nonsmokers and they were not dieting nor using nutritional supplements or medications and had not lost weight greater >10% of body mass before (≤6 months) the study. Participants were excluded from the study if they participated in ≤80% of total exercise sessions and adhered to a nutritional intervention or modified their daily PA levels during the study. Participants’ baseline characteristics are shown in Table 1.

**Exercise intervention**

The exercise protocol has been previously described thoroughly (Batrakoulis et al., 2018). Briefly, DoIT was a supervised protocol characterized by a hybrid format including a mix of endurance training (ET), core strengthening and RT elements, performed in a circuit fashion using prescribed time (20-40 sec) of effort and recovery intervals. The exercise protocol was performed three times/week (with a 48-hour recovery between sessions) for 10 consecutive months in a small-group (5-10 women) gym setting. The training intervention included initially three phases (phase 1: weeks 1-7; phase 2: weeks 8-14; phase 3: weeks 15-20) characterized by a progressive rise in exercise volume and intensity and a fourth one (weeks 20-40) that maintained the overload pattern of phase three with the work-to-rest ratio varying biweekly (Batrakoulis et al., 2018). All sessions used an asynchronous music in the background and were led by an experienced instructor. Exercises incorporated fundamental movement patterns using either the bodyweight or adjunct portable modalities as resistance (Batrakoulis et al., 2018). A 10-min warm-up preceded and a 5-min cool-down followed each session. At each station, participants performed, at moderate and controlled speed, as many repetitions as possible using proper
technique. Each session included alternate stations (8-12). During each session, heart rate (Polar Team Solution, Polar Electro-Oy, Kempele, Finland) and rates of perceived exertion (RPE) were monitored (Batrakoulis et al., 2018). Exercise intensity was calculated as mean heart rate (percentage of maximal heart rate obtained during VO\textsubscript{2max} testing) and mean RPE. A record of attendance was maintained throughout the study.

Measurements

The results and methods of measurement of somatometric variables, body composition, performance indices and physical activity have been reported elsewhere (Batrakoulis et al., 2018). However, we used these outcome variables in this work to explore their association with the psychological results since there is evidence that improvement of somatometric, body composition and performance outcomes during a lifestyle intervention, such as exercise, in the obese leads to higher adherence and attendance rates which in turn promotes further weight and fat loss and health gains (Carels, Cacciapaglia, Douglass, Rydin & O’Brien, 2003). In brief, height and body mass were measured to the nearest 0.1 cm and 0.1 kg, respectively, using a beam scale (Beam Balance-Stadiometer, SECA 220, Vogel & Halke, Hamburg, Germany) and body mass index (BMI) was calculated. The fat mass (FM) and fat-free mass (FFM) were assessed utilizing a dual energy X-ray absorptiometry (DXA) scanner (Lunar Prodigy Advance, GE Lunar Healthcare Corp., Madison, WI, USA) as previously described (Batrakoulis et al., 2019). Accelerometry (GT3X+, ActiGraph, Pensacola, FL, USA) was used to measure habitual PA level at pre-, mid-, and post-training over a 7-day period as described (Batrakoulis et al., 2018). Cardiovascular endurance (VO\textsubscript{2peak}) maximal strength assessment have described elsewhere (Batrakoulis et al., 2018). During each session, participants were asked to rate their exertion on Borg scale during exercise, taking into consideration their feeling of physical stress and fatigue as previously described (Batrakoulis et al., 2018).

The Greek version of General Health Questionnaire (GHQ-12) was used to assess participants’ minor psychosocial distress (Garyfallos et al., 1991). GHQ-12 is a valid and reliable self-reported questionnaire on general levels of happiness, anxiety, depression, stress, and sleep disturbance. This questionnaire consists of 12 questions using a 4-point response Likert-type scale ranging from 0 (not at all) to 3 (very often) with a total score ranging from 0 to 36. Lower overall scores identify individuals with a better
psychological health. Cronbach alpha values greater than 0.70 have been reported in past research (Garyfallos et al., 1991).

Subjective vitality, an indicator of eudemonic well-being, was assessed using the Greek version of the subjective vitality scale (SVS) (Vlachopoulos & Karavani, 2009), a valid and reliable 7-item scale using a 7-point response Likert-type scale ranging from 1 (not at all true) to 7 (very true). This scale assesses feelings of aliveness and energy in general while determining the situational levels of subjective vitality, which is negatively associated with physical pain and positively associated with the amount of autonomy support in a particular situation. The total score ranges from 7 to 49 with a higher score indicating a better condition. This scale has been shown to possess Cronbach alpha values exceeding 0.80 (Nix, Ryan, Manly, & Deci, 1999).

Behavioral regulations in exercise were assessed using the Greek version of the Behavioral Regulation in Exercise Questionnaire–2 (BREQ-2) (Moustaka, Vlachopoulos, Vazou, Kaperoni, & Markland, 2010). BREQ-2 is a valid and reliable 19-item questionnaire that evaluates five types of regulations in exercise using five subscales (e.g., amotivation; 4 items, external regulation; 4 items, introjected regulation; 3 items, identified regulation; 4 items, and intrinsic motivation; 4 items). This questionnaire uses a 5-point response Likert-type scale ranging from 0 (definitely no) to 4 (definitely yes). The individual score per type of regulation was the summed score of all items per subscale. Previous research has shown the Greek BREQ-2 subscales to possess Cronbach alpha values of 0.77 to 0.88 (e.g., 0.87 for amotivation, 0.84 for external regulation, 0.77 for introjected regulation, 0.82 for identified regulation, and 0.88 for intrinsic motivation) (Moustaka et al., 2010).

Statistical analyses
Data normality was verified using the Shapiro-Wilk test (N=49). A non-parametric test was applied because our data sets in the majority of our variables did not follow a normal distribution in at least one or two time-points. To determine the time-effect in the study, the Friedman analysis of variance by ranks test was used, accompanied by the Wilcoxon signed-rank test to perform pairwise comparisons. Differences within groups for all dependent variables were examined using the Kruskal-Wallis analysis of variance (z values) and pairwise comparisons were performed using the Mann-Whitney U test to examine differences between groups (U values) as required when data do not follow a normal distribution. Pearson's correlation coefficient was used to examine the relationship
a) between adherence rate and psychological responses and b) between performance measures and psychological responses at post-training in TR and at mid-training in TRD. Correlational analyses included adherence and performance measures from TR and TRD using them as one group (N=28) and all data were expressed as Δ%. The level of statistical significance was set at p<0.05. The IBM SPSS Statistics for Windows, version 23 was used for analyses (IBM Corp., Armonk, N.Y., USA). Results are expressed as means ± standard deviation (SD)

Results
No significant differences were detected between groups at baseline. Exercise adherence rates for TR and TRD were recorded for the training protocol during implementation. In TR, no statistically significant differences were found in attendance rate in time (weeks 1-20: 93.0±2.5; weeks 21-40: 94.0±2.2; weeks 1-40: 93.5±2.0). A lower attendance rate, due to uncontrollable reasons, was noted in TRD (82.6 ± 2.7) than TR in weeks 1-20 (95% CI: 8.33–12.39; p<0.001). Results of mean training heart rate (HR) and rate of perceived exertion (RPE) have been described elsewhere (Batrakoulis et al., 2018). In summary, no differences were found in the mean HR between TR and TRD throughout training. HR increased progressively from phase 1 through phase 3 and stabilized thereafter in TR while RPE increased progressively from phase 1 to 4 (Figure 1).

Changes in GHQ-12 scores are shown in Figure 2. In C, GHQ-12 remained unaltered throughout the study. In TR, GHQ-12 score decreased from baseline to mid-(−65%, z=3.31, p=0.001) and post-training (−72%, z=3.31, p=0.001). In TRD, GHQ-12 score decreased from baseline to mid-training (−71%, z=3.30, p=0.001) and remained above pre-training levels following detraining (−33%, z=3.31, p=0.001). At mid-training, GHQ-12 score demonstrated similar values in TR and TRD and they were both lower than C (TR vs. C: −61%, U=7.500, p=0.000; TRD vs. C: −68%, U=8.000, p=0.000). At post-training, TR demonstrated lower GHQ-12 score than C and TRD (TR vs. C: −68%, U=0.000, p=0.000; TR vs. TRD: −57%, U=15.000, p=0.000) while TRD presented lower GHQ scores than C (−25%, U=81.000, p=0.026).

Changes in SVS scores are presented in Figure 2. No changes were noted in C. In TR, SVS score increased from baseline to mid- (+50%, z=3.44, p=0.001) and post-training (+53%, z=3.30, p=0.001). In TRD, SVS score increased from baseline to mid-training (+44%, z=3.36, p=0.001) and remained above pre-training levels following
detraining (+18%, \( z=3.31, p=0.001 \)). At post-training, TR demonstrated higher SVS score than TRD (+31%, \( U=16.000, p=0.000 \)).

Changes in self-regulation of exercise behavior are shown in Figure 3. There were neither significant differences in amotivation within any group as a function of time nor among groups at specific time points. In TR, external regulation decreased from baseline to mid- (-50%, \( z=2.45, p=0.014 \)) and post-training (-75%, \( z=2.53, p=0.011 \)). At post-training, TR demonstrated lower score in external regulation than C (-78%, \( U=87.000, p=0.044 \)). In TR, introjected regulation increased from baseline (1.9 ± 0.8) to mid- (+37%, \( z=2.46, p=0.014 \)) and post-training (+63%, \( z=3.36, p=0.001 \)). In TR, intrinsic regulation increased from baseline (2.7 ± 0.6) to mid- (+26%, \( z=3.00, p=0.003 \)) and post-training (+33%, \( z=2.92, p=0.004 \)). TR exhibited higher score in intrinsic regulation than C at mid- (+31%, \( U=84.500, p=0.034 \)) and post-training (+38%, \( U=55.500, p=0.001 \)). TRD demonstrated higher score in intrinsic regulation than C at mid-training (+27%, \( U=91.000, p=0.047 \)) and lower score than TR at post-training (-14%, \( U=46.500, p=0.016 \)). In TR, identified regulation increased from pre- to mid- (+53%, \( z=3.36, p=0.001 \)) and to post-training (+88%, \( z=3.33, p=0.001 \)). TR had a higher score in identified regulation than C at mid- (+73%, \( U=6.000, p=0.000 \)) and post-training (+133%, \( U=0.000, p=0.000 \)). Additionally, TR demonstrated a rise of identified regulation score from mid- to post-training (+23%, \( z=2.70, p=0.007 \)). In TRD, identified regulation increased from pre- to mid-training (+50%, \( z=2.83, p=0.005 \)). Identified regulation remained unchanged in C.

Results of body mass, body composition and performance have been described elsewhere (Batrakoulis et al., 2018). In brief, the 10-month exercise training decreased body mass by 6% (\( p<0.001 \)) and body fat by ~5.5% (\( p<0.001 \)) and improved lean body mass by 3.4% (\( p<0.05 \)), strength and endurance by 27% (\( p<0.001 \)). Gains induced by exercise training were attenuated but not lost due to a 5-month cessation of training in TRD.

Correlational analyses revealed a moderate to strong positive relationship between adherence rate and the identified regulation (\( r=0.59, p=0.001 \)). Lower body maximal strength demonstrated a moderate negative relationship with external regulation (\( r=-0.40, p=0.034 \)), a moderate positive relationship with introjected regulation (\( r=0.38, p=0.047 \)) and a moderate positive relationship with identified regulation (\( r=0.45, p=0.016 \)). VO\(_2\)peak demonstrated a moderate to strong positive correlation with identified regulation (\( r=0.59, p=0.001 \)).
Discussion

This study revealed that a long-term, small group, high-intensity, neuromuscular training, program implemented in overweight/obese pre-menopausal women resulted in (i) high adherence rate, (ii) reduced psychological distress, (iii) increased vitality and exercise behavior levels, and (iv) these training-induced adaptations were reduced but not lost after a 5-month detraining period. Obese middle-aged women exhibit reduced levels of vitality, psychological well-being, distress and anxiety compared to lean women (Swencionis et al., 2013).

Exercise adherence remained high (>90% in TR and >80% in TRD) throughout the intervention. These observations are the first recorded over a long-term period of implementation of a supervised HIIT-type training protocol in obese adults. Similarly, a shorter (10 weeks) HIIT-type program performed in a real-world gym setting demonstrated higher adherence and lower dropout rates compared to MICT in normo- and over-weight adults (Shepherd et al., 2015). Therefore, this study corroborates previous findings of shorter HIIT-like interventions that such protocols promote adherence and attendance among the obese.

Psychological distress progressively improved throughout training and attenuated, but not lost, following detraining (-33% vs. baseline). This finding is aligned with outcomes of previous studies suggesting that women’s involvement in systematic PA is associated with lower levels of distress which is strongly related to obesity (Carroll, Blanck, Serdula, & Brown, 2010). Thus, it may be concluded that exercise and particularly HIIT-type training protocols should be systematically implemented in obese women.

The reported levels of subjective vitality at post-training exceeded the baseline levels by more than 50% in those who trained for 10 months and it was maintained high even after prolonged detraining. These results are in line with previous findings reported by interventions using short-term interventions with traditional exercise modes under free-living conditions (Edmunds, Ntoumanis, & Duda, 2007). It is notable that vitality, in this study, was found to be the best predictor of weight loss and was associated with positive changes in psychological well-being. The increased vitality may be attributed to an increased feeling of self-control for autonomous reasons that in turn lead to enhanced feelings of subjective vitality that may then restore lost self-confidence (Muraven, Gagne, & Rosman, 2008). Although a sense of competence may be crucial for promotion of
vitality in response to exercise, social relatedness may be equally important due to the social interaction in a group exercise setting especially for those with limited perception of autonomy support and vice versa (Edmunds et al., 2007). Increased vitality may promote motivation to make behavioral modifications that could aid weight loss due to increased subjective levels of autonomy, which is crucial for weight loss and weight maintenance in the context of a positive feedback loop (Williams, Grow, Freedman, Ryan, & Deci, 1996). Autonomy appears to be more important towards the completion of a neuromuscular training program when a stagnation of an earlier progress is present (Solberg et al., 2012). Promotion of subjective vitality due to weight loss may be related with the increased adherence rate seen here probably due to increased barrier efficacy (Edmunds et al., 2007).

All types of behavioral regulation in exercise, except amotivation, were improved by exercise even after detraining. These results provide evidence that performance improvements may enhance some aspects of behavioral regulation in exercise among obese women who lose weight (Batrakoulis et al., 2018). Since identified regulation indicates the degree to which participants appreciate the benefits associated with exercise (Edmunds et al., 2007), it is important that participants understand the value of systematic exercise training as it is also evidenced by the moderate to strong correlation obtained between identified regulation and adherence rate. It appears that improvement of the anthropometric profile and performance outcomes during a lifestyle intervention such as exercise promotes adherence and attendance among the obese population (Carels, Cacciapaglia, Douglass, Rydin & O’Brien, 2003). This further supported by (i) the moderate correlation of maximal strength changes with external \( (r = -0.40) \), introjected \( (r = 0.38) \) and identified regulation \( (r = 0.45) \) to exercise and (ii) the moderate to strong correlation of VO\( \text{2peak} \) with identified regulation \( (r = 0.59) \).

Previous studies on self-determination theory (SDT) suggested that autonomy support and intrinsic motivation are positively associated with the psychological need for satisfaction, well-being and self-determined regulation of exercise behavior (Edmunds et al., 2007). These results suggest that the increased commitment of obese women to exercise seen here, may be attributed to the perceived enhanced competence, need satisfaction and facilitation of the internalization process by the instructor in this small-group setting that promoted a more self-determined form of behavior regulation (Edmunds et al., 2007). These results support not only the SDT but also the basic needs
theory which states that psychological well-being, if satisfied, may positively affect health outcomes (Ryan & Deci, 2000).

Long-term adherence to exercise is difficult to be achieved even in physically active individuals due to reasons such as time commitment, pleasure, intrinsic regulation, amotivation, inconvenience, musculoskeletal injuries and health issues (Thum, Parsons, Whittle, & Astorino, 2017). Accumulating evidence link HIIT to higher compliance rates (Jung et al., 2014) although the high intensity factor may be considered a barrier to exercise adherence and enjoyment in sedentary overweight women (Ekkekakis, Lind, & Vazou, 2010). Short-term, very intense interval-type training of relatively-sedentary young adults was associated with progressively declining levels of enjoyment (Foster et al., 2015). The affective and enjoyment responses to exercise are important attributes of the psychological perspective of any exercise regimen, and therefore, many recent studies have focused on the investigation of those adaptations in various populations including inactive obese adults. The exercise protocol in this study, based on previous findings, utilized a progressive workload and intensity scheme aiming to provide the selected cohort with a feasible, safe but also challenging high-intensity exercise stimulus. DoIT incorporated portable modalities (e.g., kettlebells, battling ropes, etc.) that are considered very popular non-traditional implements, which might enhance participants’ feeling of pleasure and exercise compliance through variety and functionality compared to traditional modalities (Thompson, 2018). Moreover, the instructor’ role may be a critical factor for enhancing psychological health in sedentary obese women (Edmunds et al., 2007).

Previous studies examining the effects of different exercise intensities on psychological responses in sedentary obese adults present conflicting results (Ekkekakis et al., 2011; Thum et al., 2017). Thus, it is unclear if intense DoIT-type protocols that induce marked elevations in blood lactate (Batrakoulis et al., 2018) are associated with lower or higher affect and enjoyment that demote or promote consistent behavioral regulation in exercise. HIIT offers multiple recovery breaks that not only provide a dissolution of less positive affective responses, but also prevents monotony and introduces a sense of accomplishment that overall increases self-confidence (Jung et al., 2014). From a public health perspective, it must be underlined that pleasant exercise may promote adherence (Jung et al., 2014; Shepherd et al., 2015, Stavrinou, Bogdanis, Giannaki, Terzis, & Hadjicharalambous, 2019). A mild dissociation was observed between exercise intensity and perceived exertion, i.e. participants reported that they felt
the intensity of their effort as moderate (RPE ~15) while at the same time the objectively measured exercise intensity approached maximal levels, i.e. ~90% of maximal heart rate (Batrakoulis et al., 2018). This finding indicates that even previously inactive individuals did not feel as tired and exhausted as they should under conditions of very intense exercise, a response that might have contributed to increased enjoyment and as such to the observed increased compliance seen in this long-term exercise training intervention. This observation is in line with findings suggesting that RPE and not HR or VO\textsubscript{2} better predict the affective responses during MICT and HIIT, i.e. affective responses are modulated not only by exercise intensity but mainly by how participants perceive intensity (Oliveira et al., 2015).

This study introduces certain strengths and limitations. The training protocol was longer than most of anti-obesity exercise protocols employed in the literature (usually <6 months) thereby allowing us to monitor its long-term effects on psychological responses. This study included a training-deterring training group which allowed us to observe the maintenance of this training intervention. The control group allowed the extraction of safer conclusions regarding the effectiveness of the intervention. The dietary control excludes a potential diet effect on the effects of the exercise intervention on the outcomes of the study and the strict inclusion criteria ensured the recruitment of a homogeneous sample at baseline. However, a number of limitations of this research are present. The sample size was relatively small and larger scale studies are needed in the future. Participants were females of a certain age which precludes the generalization of the results on other populations. Although a dietary control was applied, we cannot eliminate the possibility that some nonetheless changed their dietary habits. Although three points of measurements were used (baseline, mid-training, post-training), one cannot be certain about the changes in our dependent variables over time, i.e. when they peaked. Future studies could use more frequent assessments.

**Conclusion**

The present study provides extensive evidence on a long-term effectiveness of a high-intensity interval neuromuscular training on psychological adaptations and adherence in previously inactive obese women. Results indicate that such a program may support the concept of SDT, i.e. small group training provides positive psychological adaptations that may be related with increased autonomous motivation, self-regulation of exercise behavior, self-efficacy, vitality, enjoyment, and adherence that offer a feasible and
sustainable alternative for exercise-induced weight loss. Although detraining attenuated these responses, training-induced gains remained higher than those at baseline. These findings provide valuable insight into continuous efforts to design exercise interventions that maximize performance and health outcomes without compromising compliance and provide evidence that overweight/obese women can become accustomed to intense training protocols in the real world. Our novel study also suggests investigating the efficacy of this type of programs on engagement of the core affect (hedonic pleasure) and emotional experience that is associated with cognitive appraisal.

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Disclosure statement
No potential conflict of interest was reported by the authors.

References


Table 1. Psychometrics scores at pre-, mid-, and post-training in each group.

<table>
<thead>
<tr>
<th>Variables (score)</th>
<th>Pre</th>
<th>Mid</th>
<th>Post</th>
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</thead>
<tbody>
<tr>
<td>Psychological distress</td>
<td></td>
<td></td>
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<tr>
<td>TR</td>
<td>4.99 ± 0.86</td>
<td>4.08 ± 0.61</td>
<td>5.12 ± 1.19</td>
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<tr>
<td>TRD</td>
<td>15.00 ± 7.07</td>
<td>25.29 ± 6.45</td>
<td>25.14 ± 3.7 ±</td>
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<tr>
<td>Subjective vitality</td>
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<tr>
<td>TR</td>
<td>5.12 ± 0.86</td>
<td>4.08 ± 0.61</td>
<td>6.45 ± 1.19</td>
</tr>
<tr>
<td>TRD</td>
<td>25.29 ± 7.07</td>
<td>25.29 ± 6.45</td>
<td>24.14 ± 3.7 ±</td>
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<tr>
<td>Amotivation</td>
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<tr>
<td>C</td>
<td>0.62 ± 0.70</td>
<td>0.64 ± 0.61</td>
<td>0.79 ± 1.19</td>
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<tr>
<td>TR</td>
<td>0.86 ± 0.86</td>
<td>0.70 ± 0.61</td>
<td>0.71 ± 1.19</td>
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<tr>
<td>TRD</td>
<td>0.70 ± 0.70</td>
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<td>0.61 ± 1.19</td>
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<tr>
<td>External regulation</td>
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<tr>
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<td>1.93 ± 0.83</td>
<td>2.62 ± 1.04</td>
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<tr>
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<tr>
<td>Introjected regulation</td>
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<tr>
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<tr>
<td>TR</td>
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<td>1.02 ± 0.50</td>
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<td>Intrinsic regulation</td>
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<td>1.64 ± 0.79</td>
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<tr>
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<td>0.47 ± 0.79</td>
<td>0.50 ± 0.50</td>
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<tr>
<td>TRD</td>
<td>1.45 ± 1.02</td>
<td>1.45 ± 0.61</td>
<td>1.45 ± 0.63</td>
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</tbody>
</table>

C, control group; TR, 10-month trained group; TRD, 5-month trained and 5-month detrained group; * significant difference with Pre ($p < 0.01$); † significant difference with Mid ($p < 0.01$); ‡ significant difference with C ($p < 0.01$); †† significant difference with TR ($p < 0.01$).
Figure 1. The exercise intensity and perceived exertion throughout training. RPE, rate of perceived exertion; HRmax, maximal heart rate; * significant difference with Phase 1 \((p < 0.05)\); # significant difference with Phase 1 \((p < 0.05)\); ‡ significant difference with Phase 2 \((p < 0.05)\); † significant difference with Phase 2 \((p < 0.05)\); § significant difference with Phase 1 \((p < 0.05)\).
Figure 2. Psychological distress and subjective vitality changes during the experimental period. *significant difference with Pre ($p < 0.01$); # significant difference with Mid ($p < 0.01$); ‡ significant difference with Control ($p < 0.01$); † significant difference with Training ($p < 0.01$).
Figure 3. Behavioral regulation in exercise changes during the experimental period. * significant difference with Pre ($p < 0.01$); # significant difference with Mid ($p < 0.01$); ‡ significant difference with Control ($p < 0.01$); † significant difference with Training ($p < 0.01$).
Supplemental material

S1 Figure. CONSORT diagram of the study.

[Image of the CONSORT diagram]
**S2 Figure.** Experimental flowchart. C, control group; TR, training group (5 months); TRD, training (5 months) - detraining (5 months) group; DoIT, exercise protocol; ¹ for all groups (4-week adaptive period); ² only for TR and TRD; ³ for all groups.