Can high intensity interval training improve mental health outcomes in the general population and those with physical illnesses? A systematic review and meta-analysis of 53 randomized controlled trials

Running heading: High Intensity Interval Training for Mental Health

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ABSTRACT

Objective- High-intensity interval training (HIIT) is a safe, feasible and time-efficient form of exercise. The aim of this systematic review was to investigate the mental health effects of HIIT, in healthy populations and those with physical illnesses, and to compare the mental health effects to both non-active controls and other forms of exercise.

Design- Random effects meta-analyses were undertaken for randomized controlled trials (RCTs) comparing HIIT with non-active (non-exercise) and/or active (exercise) control conditions for the following co-primary outcomes: mental wellbeing, depression, anxiety and psychological stress, calculating the standardized mean difference (SMD) and 95% confidence interval (CI). Positive and negative affect, distress and sleep outcomes were summarised narratively.

Data Sources- Medline, PsycINFO and Embase were searched from inception to 07.07.2020.

Eligibility criteria for selecting studies- RCTs that investigated HIIT in healthy populations and/or those with physical illnesses and reported change in mental wellbeing, depression, anxiety, psychological stress, positive and negative affect, distress and/or sleep quality.

Results- Fifty-three RCTs were retrieved. HIIT led to moderate improvements in mental wellbeing (SMD=0.427, 95%CI=0.124; 0.730), depression severity (SMD= –0.496, 95%CI= -0.973;-0.020) and perceived stress (SMD= -0.474, 95%CI= -0.796;-0.152) compared to non-active controls, and small improvements in mental wellbeing compared to active controls (SMD=0.272, 95%CI=0.088;0.456). There was a suggestion that HIIT may improve sleep and psychological distress compared to non-active controls, however these findings were based on a small number of RCTs.

Conclusion- These findings support the use of HIIT for mental health in the general population and those with physical illnesses.

Registration: Prospero (CRD42020182643)

Key words: High intensity interval training; meta-analysis; mental health; mental wellbeing; depression; anxiety

What is already known?

High intensity interval training (HIIT) is a potential safe, feasible and time-efficient form of exercise.

Preliminary research suggests that HIIT can improve mental health in people with mental health disorders.

The mental health benefits associated with HIIT, in healthy populations and those with physical illnesses, are unclear.

No meta-analysis has been performed thus far on research examining potential effects of HIIT on mental health in healthy populations and those with physical illnesses.

What are the new findings?

HIIT leads to moderate improvements in mental wellbeing, depression severity and perceived stress compared to no exercise.

In healthy populations and those with physical illnesses, HIIT leads to small improvements in mental wellbeing compared to other forms of exercise.

HIIT appears to be a useful intervention to target mental health.

INTRODUCTION

Physical activity, and its structured form exercise, have been shown to improve mental wellbeing and reduce the symptoms of depression and anxiety, across epidemiological studies and interventions, across a wide range of populations,[1–4]. These benefits have been observed in healthy men and women,[5], older adults,[6], adolescents,[7], people with neurological disorders,[8] and patients with chronic illnesses (e.g., cardiometabolic diseases, chronic pain, cancer and chronic obstructive pulmonary disease (COPD)),[9–11]. Moreover, preliminary research suggests a role of exercise in reducing perceived psychological distress,[12–15], and improving sleep quality,[16–18]. Additionally, a single bout of exercise may improve psychological well-being in the short-term,[19,20].

The majority of high-quality reviews have assessed the effects of traditional forms of exercise such as moderate intensity continuous training (MICT), walking and functional exercises. High-intensity interval training (HIIT) is gaining recognition as a safe and feasible form of exercise that may elicit gains in physical health in less time than traditional forms of exercise, in the general population and those with chronic conditions,[21]. HIIT involves alternating short bursts (commonly 30 seconds to 4 minutes) of high intensity exercise, that typically reaches ≥85% peak heart rate (HRpeak), followed by similar length recovery periods of rest/ light exercise typically carried out at ≤70% HRpeak,[22]. Two recent meta-analyses found encouraging evidence for the benefit of HIIT in improving mental health outcomes in people with mental disorders,[23,24]. Multiple trials in other people, such as healthy populations and those with physical illnesses, have investigated the effect of HIIT on mental health outcomes including mental wellbeing,[25,26], depressive and anxiety symptoms,[27,28], and sleep quality,[29] and have inconsistent findings. The lack of consistency in the literature is hampered by small sample sizes, and differences in HIIT protocols and participant characteristics.

The aim of this systematic review and meta-analysis was to investigate the mental health effects of HIIT in healthy populations and those with physical illnesses drawing evidence from randomised controlled trials (RCTs) of any type of HIIT exercise investigating mental wellbeing, depression, anxiety, stress and/or sleep disturbance, and to compare the mental health effects to both non-active controls and other forms of exercise. The secondary aim of this systematic review was to report the safety, adherence and design of the included HIIT interventions to aid translation into clinical practice.

METHODS

The systematic review and meta-analysis were performed in accordance with the PRISMA guidelines following a pre-determined published protocol (Prospero CRD42020182643). (PRISMA checklist= Appendix 1).

Definition of high intensity interval training

HIIT was defined as alternating short bursts of high intensity exercise, that reached ≥85% HRpeak/ ≥80% peak VO_2, or equivalent measure, interspersed with recovery periods of ≤5minutes in duration whereby a reduction in intensity was described,[22]. We included any form of exercise (treadmill, cycling, boxing, body-weight exercises).

Searches and study selection

Medline, PsycINFO and Embase were searched from inception to 07.07.2020 for RCTs investigating HIIT among healthy individuals and people with any physical health diagnosis (cardiometabolic diseases, COPD, cancer). To avoid repetition of published work,[23,24] RCTs investigating HIIT in populations with a structured mental health diagnosis were excluded.

The search terms used are found in Appendix 2. The reference lists of included articles were hand-searched.

Eligibility criteria

Three authors (RM, BS, NK) independently assessed articles based on the following eligibility criteria: 1) RCTs investigating HIIT, in any setting and age. We considered any form of control group including no treatment, therapeutic and lifestyle interventions, other exercise interventions except HIIT; 2) HIIT interventions of any duration and frequency, including follow-up studies; 3) a study population which included any human population including those with physical illnesses and excluding those with a structured mental health diagnosis (severe mental illnesses, substance and alcohol disorders, anxiety and stress disorders, eating disorders). Non-English language articles, conference abstracts and dissertation theses were excluded.

Outcomes

Primary outcomes

Changes in mental health parameters including: 1) mental wellbeing; 2) depressive symptoms; 3) anxiety; 4) psychological stress; 5) positive and negative affect; 6) distress; 7) insomnia and/or sleep quality.

Secondary outcomes

Adverse events (AEs) and completion rates.

Search results and data extraction

The title and abstract of all studies identified were reviewed, and relevant full-texts reviewed to determine eligibility. Eligibility was determined by three independent researchers (RM, BS, NK).

Data was extracted, from the papers selected for inclusion in the review, by one researcher (RM) and verified by a second researcher (BS). For each study, we reported: study design, sample size, participant demographics, intervention descriptions (including control interventions), effect sizes (ES); adherence; and any AEs.

Where an RCT was retrieved that measured mental health outcomes but did not provide the relevant statistics the authors were emailed to request the relevant data. Mental health outcomes measured as part of a disease-specific quality of life scale (e.g., Depression measured as part of the Parkinson's Disease Questionnaire-39) were excluded. Measures of sport related anxiety and stress were excluded.

Quality Assessment

The quality of the included RCTs were assessed using the Physiotherapy Evidence Base Database (PEDro) scale [30]. Scores were taken from the PEDro database (http://www.PEDro.org.au) where available. When a score was not already determined on the database for a study, it was generated by two independent researchers (RM and NK) (Appendix 3). High, fair and poor-quality studies achieved ratings of 8-10; 4-7 and 1-3 respectively.

Additionally, for each RCT, data regarding the intervention description was reported using the Consensus on Exercise Reporting Template (CERT),[31] to ensure complete reporting. This information was tabulated and is provided in Appendix 4.

Data synthesis

Between group meta-analyses were conducted when at least three RCTs were retrieved for each outcome. We conducted between group meta-analyses for RCTs comparing HIIT with non-active (non-exercise) and/or active (exercise) control conditions for the following outcomes: mental wellbeing, depression, anxiety and psychological stress (as measured via the Perceived Stress Scale,[32]). Separate meta-analyses were conducted comparing HIIT versus non-active and active controls on mental wellbeing using data retrieved from the SF-36,[33]. For this analysis, we included studies that provided a norm-based MCS score. When a raw data MCS score was provided the individual subdomains of the SF-36 were sought and a norm-based MCS score was calculated using z-score transformations and the relevant population means,[34]. In these instances, the standard deviation (SD) was imputed as 10; based on population data in the original SF-36 user manual,[34]. Due to variation in HIIT protocols and participant characteristics, we used a random-effects model calculating the standardised mean difference (SMD) and 95% confidence intervals (95% CI) using the difference between the two groups' pre-post change scores. Cohen's criteria were used as a benchmark for interpreting effect size (0.2 small, 0.5 medium, 0.8 large),[35]. Heterogeneity was assessed using the I^2 statistic. Publication bias was assessed with the Begg-Mazumdar Kendall's tau,[36] and Egger bias test,[37]. In addition, we conducted a trim and fill adjusted analysis,[38] to remove the most extreme small studies from the positive side of the funnel plot, and recalculated the ES at each iteration, until the funnel plot was symmetric about the (new) ES.

When an RCT was encountered that had two arms conducting HIIT (of different intensities/modalities) only one HIIT arm was included in the main meta-analysis to prevent replication of control conditions. In these instances, the HIIT regime that was most similar to other included RCTs was included in the main meta-analysis- a full explanation is in Appendix 5. For each of the primary outcomes, subgroup analysis for HIIT modality, HIIT intervention duration and frequency, and population characteristics were conducted were sufficient RCTs were available (Table 4). A sensitivity analysis was not conducted as all included studies received a PEDro rating of ≥4.

Positive and negative affect, psychological distress (measures of emotional disturbances) and sleep outcomes were summarised narratively due to variability in outcome measurement tools and paucity of retrieved RCTs.

Similarly, studies investigating the acute mental health effects of a single bout of HIIT were not included in the meta-analysis and were summarised narratively due to variability in mental health outcomes measured and paucity of retrieved RCTs. Follow-up data was also analysed in a narrative synthesis with effect size and/or significance level reported.

RESULTS

Search results and included studies

Search results are in Figure 1. Overall, 53 RCTs (n=2,901) were included (including three follow-up analyses,[39–41]) encompassing HIIT in adults with no medical comorbidities (N=10, n=577),[28,29,42–49], healthy older adults (N=3, n=142,[50–52], adolescents (N=2, n=133),[26,53], patients with cardiometabolic disorders (including obesity, hypertension, diabetes, metabolic syndrome (MetS), heart failure, coronary artery disease (CAD)) (N=29, n=1599),[25,27,59–68,39,69–77,40,41,54–58], COPD (N=3, n=193),[78–80], cancer-patients (N=2, n=78,)[81,82], patients with Lacunar stroke (N=1, n=71),[83], Crohn's disease (N=1, n=36),[84], cutaneous systemic sclerosis (SSc) (N=1, n=34),[85] and patients undergoing liver resection (N=1, n=38),[86] (see Fig 1). Mean age of participants ranged from 15.5-74.9 years.

Figure One- PRISMA flow-chart

[insert figure here]

The duration of the HIIT programme ranged from a single session to 10 months and 64% of programmes were conducted for 8-12 weeks. HIIT was conducted 1-5 times per week and session length ranged from 10-71 minutes. Fifty-five percent of RCTs prescribed cycling HIIT, 15% prescribed running HIIT, and other modalities included boxing, suspension training, resistance training and mixed-modality sports. Twenty-one RCTs compared HIIT to an active (exercise) control,[25,39,60,62,66,67,70,72,73,77–79,40,80,47,48,51,54–56,59], 22 RCTs compared HIIT to a non-active control,[26,27,63–65,68,69,71,75,81–83,28,85,86,41,43,44,49,52,53,61], 9 RCTs compared HIIT to both active and non-active conditions,[29,42,45,46,50,58,74,76,84], and one RCT compared HIIT to a low-energy diet,[57]. Where an active control group was prescribed, continuous cycling or jogging was provided on twenty-five occasions (83%). Four studies measured the acute effects of HIIT before and after individual sessions,[45,47,55,78], one study measured both acute and chronic mental health effects,[48] and the remaining studies measured the chronic mental health effects of HIIT.

Tables 1 and 2 respectively compile information on intervention details, and mental health findings. Full meta-analysis results are displayed in Tables 3-4.

Quality of included studies and exercise reporting

PEDRO scores are summarised in Appendix 3.

Total score ranged from 4,[28,41,42,51,55,61,63,71,74] to 8,[52,70,77,80,84], the mean score was 5.7. Allocation was concealed in 64.2% of RCTs, all RCTs ensured groups were similar at baseline and 39.6% blinded assessors. All studies provided measures of variability of key outcomes, 62.3% provided measures of key outcome for ≥85% of subjects initially recruited and 30.2% analysed results on an intention-to-treat (ITT) basis.

50/53 (94%) of RCTs reported the materials used in sufficient detail to allow accurate replication, three RCTs (8%) did not,[40,54,62] (these trials did not divulge into detail regarding exercise modality). Supervision was provided in 51 RCTs (96%), one RCT conducted non-supervised home-based HIIT,[83] and one did not provide supervision details,[62]. Additionally, in five RCTs participants were asked to conduct extra non-supervised HIIT sessions/supplementary home-based components,[27,53,65,67,70]. HIIT was mostly supervised by a researcher, physiotherapist or personal trainer, although background of the supervisor was not reported in 16 RCTs (30%). Twelve (23%) RCTs conducted HIIT in group settings, eight RCTs (15%) conducted 1:1 sessions, one RCT (2%) gave participants the choice of a group or individual session and 31 RCTs (58%) did not report delivery method of their supervised sessions. All RCTs HIIT intensity to each individual's HRpeak/VO2max/VO2peak/maximal capacity. Where reported, motivational strategies included positive encouragement,[40,54,55,74], motivational talks and fitness advice,[60,61,83], monetary compensation/gift vouchers,[26,42,63], free gym memberships,[42], Fitbits,[42], and certificates,[26]. It is also important to note that actual intensity reached during HIIT sessions was reported in 31 RCTs (58%), of which 26 (49%) stated that, on average, the desired heart rate (≥85% HRpeak/equivalent) was reached during high intensity bursts as per protocol,[26,28,64,66–72,74,77,39,79–82,84,85,41,44,46,49,52,53,62], and five RCTs (9%) reported that either a lower intensity was averaged/a proportion of participants did not meet the desired intensity,[40,45,54,75,78], whereas 22 RCTs (42%) offered no discussion as to whether the HIIT protocol was adhered to,[25,27,56–61,63,65,73,76,29,83,86,42,43,47,48,50,51,55].

Mental wellbeing

HIIT resulted in a moderate increase in MCS scores compared to non-active control (SMD= 0.427, 95%CI=0.124; 0.730, p=0.006, Q= 25.683, I^2=61.064%, N=11), and no evidence of publication bias,[50,52,81,58,61,63–65,74–76]. In subgroup analysis, HIIT regimes of duration ≥7 weeks significantly increased MCS scores compared to non-active control (SMD=0.580, 95%CI=0.330; 0.830), whereas those of duration <7 weeks did not (SMD= -0.264, 95%CI= -0.745; 0.217).

HIIT resulted in a small increase in MCS scores compared to active control (SMD= 0.272, 95%CI= 0.088; 0.456, I^2=0%, N=10), and no evidence of publication bias,[50,54,58,67,72–74,76,77,79]. Subgroup analyses revealed no effects of HIIT regime and population characteristics on change in MCS score compared to active control.

Figure Two- Meta-analysis of changes in MCS score for HIIT versus non-active controls

[insert figure here]

Depression

HIIT resulted in a moderate reduction in depression severity compared to non-active control, with high heterogeneity (SMD= –0.496, 95%CI= -0.973; -0.020, I^2=82.138%, N=10),[27,28,42,43,61,63,81–84]. There was no evidence of publication bias and subgroup analyses revealed no significant effects of HIIT regime and population characteristics.

Following HIIT, no reduction in depression severity compared to active control was found (SMD= –0.110, 95%CI= -0.310; 0.091, I^2=0%, N=9),[42,54,56,60,62,70,79,80,84].

Anxiety

Following HIIT, no reduction in anxiety severity compared to both non-active and active controls was found (SMD= -0.289, 95%CI= -0.700; 0.121, I^2=71.922%, N=8,[54,56,60,62,79,80]; SMD= -0.302, 95%CI= -0.732; 0.128, I^2=71.922%, N=8,[28,43,44,61,63,81,82,84], respectively).

Psychological Stress

HIIT resulted in a moderate decrease in perceived stress compared to non-active control (SMD= -0.474, 95%CI= -0.796; -0.152, I^2=20.432%, N=4), no evidence of publication bias was found,[42,44,53,81]. In subgroup analysis, HIIT regimes of frequency ≥twice weekly significantly reduced perceived stress compared to non-active control (SMD= -0.574, 95%CI= -0.877; -0.252), whereas those of frequency <twice weekly did not (SMD= -0.554, 95%CI= -0.896; 0.344). HIIT regimes significantly reduced perceived stress, in healthy populations, compared to non-active control (SMD= -0.474, 95%CI= -0.696; -0.256), whereas those in people with physical illnesses did not (SMD=-0.371, 95%CI= -0.654; 0.199).

One RCT compared HIIT to an active control condition,[42]. Following 12-weeks of HIIT there was no change in perceived stress compared to continuous aerobic exercise (CA),[42].

Positive and Negative Affect

Two RCTs,[48,69] observed no change in positive and negative affect following HIIT regimes of duration 10-12 weeks, compared to MICT, although significant within-group improvements in positive and negative affect were found in one RCT,[48]. In another RCT,[42], 12-weeks of CA significantly increased positive affect compared to HIIT and non-active control, although neither intervention improved negative affect.

Distress

Two RCTs,[53,71] observed a significant decrease in psychological distress following HIIT regimes of duration 3-10 months, compared to non-active control. In another RCT,[26], 8 weeks of HIIT did not improve psychological distress, compared to non-active control. Moreover, a further RCT,[59] observed a reduction in psychological distress following 12-weeks of HIIT or MICT, and no between-group differences.

Sleep Outcomes

One RCT observed an improvement in self-reported sleepiness following 12-weeks of HIIT compared to non-active control,[68]. Two RCTs,[29,81] observed no significant between-group differences in sleep quality following 12-weeks of HIIT and non-active control, although one RCT observed a significant within-group improvement in sleep quality in the HIIT group,[29].

There was no improvement in either insomnia,[62] nor sleep time,[51] following HIIT regimes of duration 10-12 weeks, compared to MICT.

Acute Mental Health Changes

Five RCTs evaluated the mental health effects of HIIT and continuous exercise before and after a single training session. Four RCTs,[45,48,55,78] observed no significant between-group differences in multiple mental health measures between HIIT and continuous exercise groups, although one of these RCTs,[78] observed within-group gains in positive, negative and global affect following HIIT, and another observed a significant improvement in acute measures of anxiety compared to non-active control,[45]. In another RCT,[47], HIIT acutely increased stress and negative affect, and decreased positive affect compared to MICT.

Long-term Mental Health Changes

Nine RCTs assessed the long-term effects of HIIT on mental health symptoms including depression,[40,41,69,81,84], anxiety,[40,41,69,81,84], combined anxiety/depression scales,[84,85], MCS scores,[39–41,75,81], stress,[81], positive and negative affect,[48,69], and sleep quality,[81] in follow-ups ranging from 3-months to 5-years post HIIT intervention. Compared to both active and non-active controls, there were no significant differences in any of these measures at follow-up except in one RCT where a greater decrease in anxiety was observed in the HIIT group from baseline to 5-year follow-up compared to a non-active control (HIIT mean change= −0.7 [95%CI:−1.5; 0.1]; control mean change= 1.2 [95%CI:−0.0; 2.5]), although when the cut-off values of anxiety were applied the frequency of anxiety showed no significant between-group differences,[41].

Adverse Events

The occurrence of AEs was measured in 40 RCTs (75.5%), although it was sometimes unclear if events were exercise-related. Twenty-five RCTs observed no exercise-related AE in HIIT and control conditions,[25,27,52–54,57,60,61,63,67,71,76,29,81–83,85,86,39–41,46,49–51]. Two RCTs observed AEs (back pain,[42], cardiac instances,[66] following active control but none following HIIT

Nine RCTs observed non-serious AE following HIIT yet no events following control (across these 9 RCTs 15 exercise-related AEs were observed out of 223 HIIT participants). Events included migraine,[55]), vomiting, dehydration and dizziness,[84], muscle strains,[72], ankle injury,[62], osteoarthritis,[70], cardiac events and dizziness,[69], short-lived angina,[75], bursitis,[65] and back pain,[68].

Three RCTs observed AEs following both HIIT and active control (across these three RCTs 14.6% of HIIT participants experienced an AE compared to 11.9% and 5.9% of continuous exercise and walking participants respectively). Events included musculoskeletal injuries and sprains,[77]), syncope/panic-attack,[73]), COPD exacerbations, musculoskeletal pain, chest pain and newly diagnosed cancer,[80]. Another RCT observed 24 exacerbations in COPD patients, but did not specify if these were exercise-related nor if they occurred following HIIT or MICT,[79].

No RCTs reported AEs in healthy populations (0/8) whereas 40.6% of RCTs in people with physical health conditions (13/32) reported AEs following HIIT. BMI was reported in 38/40 RCTs that assessed AEs, of which 26.7% with mean BMI <30 (8/30) observed AEs following HIIT compared to 50% (4/8) with mean

BMI ≥30. Of those RCTs offering non-supervised home based HIIT, 4/6 (66.7%) observed no AEs,[27,53,65,67,83].

Adherence

Attendance to HIIT sessions was ≥90% in 23 RCTs,[25,28,59,60,62,63,66,67,69,71,79,81,29,82,85,86,46,47,49,52,55,56,58], ≥80-89% in eight RCTs,[48,50,54,64,68,73,76,80], ≥70-79% in five RCTs,[57,70,72,75,78], ≥60-69% in two RCTs,[44,84] and ≥50-59% in four RCTs,[42,53,65,77], although in some instances adherences figures only included programme completers. Adherence rates did not significantly differ between HIIT and active control conditions except for three RCTs of which two RCTs,[48,72] observed greater adherence to HIIT than control (walking and MICT) and one RCT,[77] observed greater adherence to control (walking). One RCT reported adherence to unsupervised home-based HIIT and observed 76.2% adherence,[70].

Table One- Basic Characteristics of included RCTs, including population characteristics and details of HIIT and control interventions

[insert table here]

Table Two- Mental health findings, adherence and adverse events

[insert table here]

Table Three- Random effects meta-analyses for RCTs comparing HIIT with active and non-active control conditions, and measures of heterogeneity

[insert table here]

Table Four- Subgroup analysis based on HIIT modality, HIIT intervention duration and length, and population character

[insert table here]

DISCUSSION

To the best of our knowledge, the current systematic review and meta-analysis is the first to compile and appraise an overview of the mental health benefits of HIIT among the general population and those with physical illnesses to date. Depression, anxiety, stress and fluctuating mental wellbeing are highly prevalent in the general population and go easily undetected,[87]. Our paper highlights multiple potential mental health benefits, across a range of ages and physical health statuses, thus suggesting that HIIT is an effective way of improving mental health and may be an alternative to traditional treatments such as medications and therapy, which can carry stigma,[88–90].

In our meta-analysis, HIIT led to moderate improvements in mental wellbeing, depression severity and perceived stress compared to non-active controls, and small improvements in mental wellbeing compared to active controls. Following HIIT, there was no improvement in anxiety severity compared to either active or non-active controls. In our narrative synthesis, there was inconsistency regarding the role of HIIT for psychological distress and sleep outcomes compared to non-active controls, whereas HIIT did not appear to effect positive and negative affect. These narrative findings were hampered by differences in operationalization of mental health concepts/variability of outcome measurement tools, differences in exercise regimes and population characteristics, and small sample size. Taken together, our findings suggest HIIT to be a viable intervention to improve some aspects of mental health and may convey greater benefits that some other forms of exercise for mental wellbeing, although more research is needed to establish the full range of benefits associated with HIIT.

Our subgroup analysis demonstrated greater improvements in mental wellbeing when HIIT was conducted for 7 or more weeks, compared to shorter regimes, and greater improvements in perceived stress when HIIT was conducted at least twice weekly, compared to a lower frequency. These findings are consistent with past work in people with physical illnesses whereby lengthier HIIT regimes, conducted on a frequent basis, were associated with greater health-related gains,[21]. We found no effect of HIIT modality on the significance of mental health gains. Equally, there did not appear to be differences in the magnitude of gain in those with, and those without, physical illness except for perceived stress whereby gains were seen in healthy populations but not those with physical illnesses. However, this finding was based on only four RCTs and should be interpreted with caution. Overall, these results may suggest that HIIT is equally effective for mental health regardless of the exercise modality and physical health status of the individual, or it may be that a larger sample is needed before reliable differences in effectiveness can be observed.

Additionally, we summarised acute and long-term mental health effects of HIIT. One RCT observed a significant improvement in acute measures of anxiety compared to non-active control and another observed acute within-group gains in some mental health measures, but no difference compared to active control, whereas a further RCT observed an acute worsening of mental health following HIIT. More work is needed to establish acute effects. In terms of the long-term benefits of HIIT, it appears that benefits in mental health are not sustained once the HIIT intervention is terminated. Thus, it appears that continuous participation in HIIT regimes is needed to maintain the mental health benefit. This said, there is encouraging evidence from a small number of trials regarding adherence and safety from unsupervised home-based HIIT and future research should focus on the sustainability and outcomes of home-based HIIT once formal supervised interventions end.

HIIT appeared to be safe amongst healthy individuals and those with various physical health conditions. This confirms findings regarding the safety of HIIT in previous research investigating the impact of HIIT in both people with physical health conditions and those with mental disorders,[22–24]. Sixty-eight percent of RCTs that measured AEs observed no AEs following HIIT and a further 22.5% reported only non-serious events. The remaining RCTs did not divulge into the severity of the observed events, but reported musculoskeletal injuries, COPD exacerbations, and syncope, although it was sometimes unclear if HIIT was directly responsible for causing the event, which highlights the importance of studies employing a serious AEs protocol when investigating HIIT,[22]. The rate of AEs did not seem to differ from the rate of AEs reported in active controls (73.9% (17/23) of active controls experienced no AEs). Interestingly, all RCTs that observed AEs recruited patients with either physical health conditions, or those who were overweight, and 83.3% of these RCTs reported a mean BMI ≥25.0 kg/m^2. This implies that clinicians must familiarise themselves with a patient's prior physical health before recommending enrolment in a HIIT regime, and carefully monitor those categorised as overweight/obese, although if a patient is deemed physically fit the risk of injury may be minimal. Of those RCTs that observed AEs, a variety of modalities were employed including cycling, jogging/running and boxing. Thus, it does not appear that certain modalities are more injury prone than others.

To add, 37 RCTs (70%) gave data regarding attendance, with 62% reporting ≥90% attendance to HIIT sessions and only 10.8% reporting attendance to be as low as 52-59%,[42,53,65,77]. Attendance did not appear to differ from active control conditions. Of those RCTs that reported ≥90% attendance to HIIT, all except one,[60] conducted HIIT on a more than weekly basis, and 70% (16/23 RCTs) conducted HIIT 3-5 times weekly. It may be that conducting HIIT on a more than weekly basis is beneficial to maintain motivation for ongoing attendance. High attendance was seen in RCTs conducted in a range of HIIT modalities, settings, intervention lengths and population characteristics suggesting that differing HIIT regimes can be acceptable to participants, and both healthy subjects and those with physical illnesses may be keen to participate, which is in contrast to the longstanding argument that HIIT may be too difficult or unpleasant for people to engage in,[91,92]. It may be that other factors, such as the expertise of the instructor, are more influential for attendance although few RCTs reported low attendance thus no patterns could be observed.

Greater mental health symptom severity at baseline was associated with greater mental health gains, although only one RCT compared changes in mental health parameters and baseline mental health symptom severity,[63]. This RCT observed no differences in mental wellbeing, depression severity and mood in their total sample of women at-risk for MetS following HIIT, but in participants with low baseline scores (more than 1 standard deviation from the normative value), clinically significant gains were seen in these measures,[63].

Participants with a broad range of physical health conditions were included in our systematic review and meta-analysis including cardiometabolic disorders, COPD, cancer, Crohn's disease and SSc, however there were not sufficient studies in each condition and each mental health outcome to allow for a subgroup analysis based on individual diagnosis. This said, a range of benefits were seen in a range of participant groups across individual studies. Thus, it seems likely that HIIT has mental health benefits across numerous physical health conditions. This is important because co-morbid depression, anxiety and stress are 2-3 times more likely in people with chronic physical illnesses, which can worsen physical outcomes and lead to increased disability,[93–95], and thus, need targeting.

Future research could consider individual preference and explore satisfaction with HIIT compared to other forms of exercise and evaluate whether HIIT may protect against the emergence of mental health problems. Moreover, it is important to note that 75.5% of included RCTs (40/53 RCTs) measured mental health as a secondary outcome. This is important because randomization procedures and number of participants needed in analysis may have been calculated with the primary outcome in mind, thus future research with mental health as the primary outcome is required.

Overall, the description of interventions tended to be reported in sufficient detail to allow accurate replication. A majority of studies reported equipment used, intervention procedure and supervision status in detail. That said, only 45% of studies reported mode of delivery (group/individual setting), 36% reported motivational strategies and 0% reported modifications. It could be that few reported motivational strategies and modifications because no motivational strategies or modifications were used, although this should be explicitly stated along with mode of delivery in future trials.

Despite our encouraging findings, it is important to note several limitations with the systematic review. Firstly, the quality of the intervention studies included was mixed (PEDro scores ranged from 4-8), namely only 30.2% analyzed results on an ITT basis and only 39.6% blinded assessors. Thus, caution is required when interpreting the findings. Future, high-quality RCTs are required. Secondly, sleep outcomes, psychological distress, and positive and negative affect were summarised narratively owing to the small number of trials assessing these parameters. Thirdly, there were minimal RCTs focussing on younger people and older adults and future research is warranted in these populations to clarify the mental health benefits. Additionally, no subgroup analysis was conducted accounting for baseline mental health symptom severity. It may be that HIIT has greater clinical efficacy in terms of mental health outcomes in people with more severe symptoms at baseline than our meta-analysis would suggest and may have been masked by those with reduced mental health symptom severity. This said, there was not enough variety in baseline mental health symptomology to conduct a separate subgroup analysis. For example, of the 17 studies assessing depression, 13 had a mean baseline depression rating below clinical threshold,[27,42,82–84,54,60–63,70,79,81], four had a mean depression rating demonstrating borderline levels for subthreshold depression,[28,43,56,80] yet none met severity for clinical depression. Similarly, 10/14 studies assessing anxiety had a mean baseline anxiety rating below clinical threshold,[28,43,44,54,61–63,81,82,84], 4/14 demonstrated borderline levels for subthreshold anxiety,[56,60,79,80] and none met severity for clinical anxiety. More research into the effect of baseline mental health symptom severity and magnitude of mental health gains is needed.

CONCLUSION

HIIT appears to lead to moderate improvements in mental wellbeing, depression severity, and perceived stress compared to non-active controls, and small improvements in mental wellbeing compared to active controls. Additionally, HIIT may improve sleep outcomes and psychological distress compared to non-active controls and appears to have good attendance and safety among a broad range of populations. Taken together, these findings offer support to the use of HIIT for mental health.

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LIST OF ABBREVIATIONS

coronary artery disease: CAD

Consensus on Exercise Reporting Template: CERT

confidence interval: CI

chronic obstructive pulmonary disease: COPD

continuous training at high intensity: CTHI

continuous training at ventilatory threshold: CTVT

cutaneous systemic sclerosis: SSc

Physiotherapy Evidence Base Database: PEDro

effect sizes: ES

High intensity interval training: HIIT

HIIT adding whole-body electromyostimulation training: HIITEMS

heart rate peak: HRpeak

intention-to-treat: ITT

mental component score: MCS

metabolic syndrome: MetS

Myocardial Infarction: MI

moderate intensity continuous training: MICT

Short-Form 36 Health Survey: SF-36

sprint interval training: SIT

standardized mean difference: SMD

randomised controlled trials: RCTs

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Figure One- Prisma flow chart

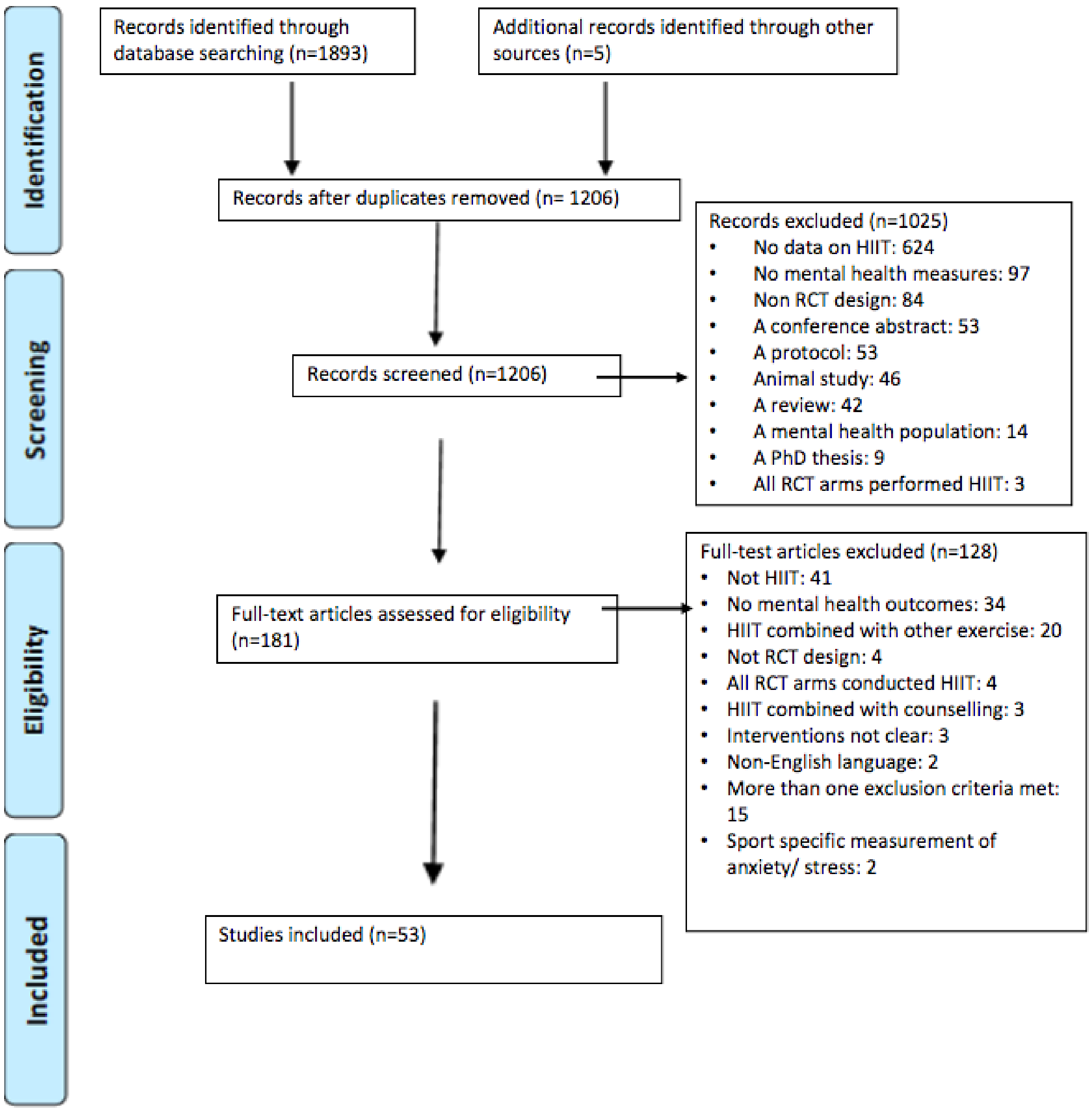

Figure Two- Forest plot showing changes in MCS score for HIIT versus non-active controls

Study name	Std diff in means	Standard error	Lower limit	Upper limit	P-value
	Statistics for each study				
Adams et al., 2018	0.762	0.265	0.242	1.282	0.004
Fu et al., 2013	0.735	0.377	-0.005	1.474	0.051
Christensen et al., 2012	0.629	0.395	-0.144	1.402	0.111
Freese et al., 2014	0.021	0.292	-0.551	0.593	0.943
Chou et al., 2019	1.553	0.391	0.786	2.319	0.000
Hurst et al., 2019	0.479	0.338	-0.183	1.142	0.156
Malmo et al., 2016	0.139	0.280	-0.410	0.689	0.620
Jimenez-Garcia et al., 2019	0.504	0.291	-0.066	1.074	0.083
Svensson et al., 2017	0.308	0.258	-0.197	0.814	0.232
Tew et al., 2017	-0.533	0.280	-1.081	0.015	0.057
Stensvold et al., 2010	0.513	0.467	-0.402	1.428	0.272
		0.155	0.124	0.730	0.006

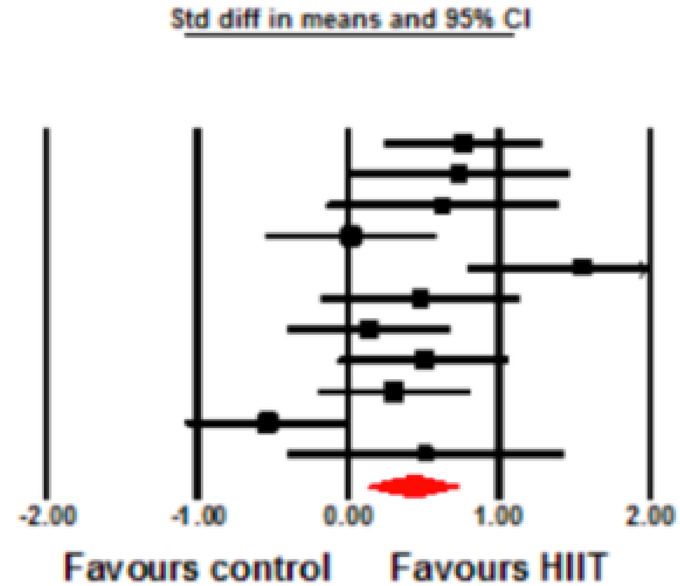

Table One- Basic Characteristics of included RCTs, including population characteristics and details of HIIT and control interventions

Study	Study Design and Sample Included	Sample Size	Sample Characteristics	Exercise Intervention	Control Group
Lucibello et al., 2020	Two-armed RCT. Young adults (age 18-30) were randomized to either 9 weeks of HIIT or a non-active control. Effects of exercise on depressive and anxiety symptoms were measured.	HIIT= 28; Non-active Control= 32	Low active young adults, 63% female (HIIT: age 20.4±2.6; BMI 23.7±4.5; Con: age 19.4± 1.6; BMI 21.8±3.4). All were full-time university students.	Three HIIT sessions per week for nine weeks. HIIT consisted of 20 min of intervals on a stationary cycle ergometer, alternating between a 1-min sprint at ~90–95% of their HRmax and 80% of Wmax, and 1 min of active rest cycling at 30% of Wmax, and a 3-min warm up and 2-min cool down at 50W.	The control group remained inactive for the nine-week intervention period.
Nytroen et al., 2019	Two-armed multi-centre RCT. De novo heart transplant (HTx) recipients were randomized to either 9 months of either HIIT or MICT. Effects of exercise on mental wellbeing, depressive and anxiety symptoms were measured.	HIIT= 39; MICT=42	Clinically stable HTx recipients >18 years of age (HIIT: age 50±12, BMI 24.8±3.4; MICT: age 48±14, BMI 25.6± 3.9), and receiving immunosuppressive therapy, 73% male. Baseline testing was performed after inclusion at a mean of 11 weeks after HTx surgery (range, 7–16 weeks).	HIIT consisted of 25 minutes comprising 2- to 4-min intervals at 85-95% of peak effort interspersed with 3-min rest periods performed at 60-70% HRpeak (modality not stated), and a 10min warm-up and 5-min cool-down conducted at 60-70% HRpeak. The 9-month intervention was divided into 3 periods. The first period (3–6 months after HTx) consisted of 1 HIIT session, 1 RT session (core musculature and large muscle groups), and 1 combined session per week. The second period (6–9	The control group performed the same amount of supervised physical activity. MICT consisting of 25 mins continuous exercise at 60-80% of peak effort, regular core strengthening exercises, and exercises for large muscle groups. Each session included a 10min warm-up and a 5-min cool-down conducted at 60-70% HRpeak.

				months after HTx) consisted of 2 HIIT sessions and 1 RT session per week. The last 2-3 months of the intervention consisted of 3 HIIT sessions per week.	
Rolid et al., 2020 (3-year follow-up of Nytroen et al., 2019)	Follow-up of a two-armed RCT. De novo HTx recipients were randomized to either nine months of either HIIT or MICT. Effects of exercise on mental wellbeing, depressive and anxiety symptoms were measured at 3-year follow-up.	HIIT=30; MICT= 35	Clinically stable HTx recipients >18 years of age. Mean age was 53± 11 and 51± 14 in HIIT and MICT groups respectively, 75% and 77% were male in each group respectively, donor age was 36±14 years and 37± 14 years in each group and BMI 24.6± 2.9 and 25.4±4.	HIIT consisted of 2- to 4-minute intervals at 85-95% of peak effort interspersed with 3-minute rest periods performed at 60-70% HRpeak 2-3 times each week. The 9-month intervention was divided into 3 periods, and the HIIT protocol became progressively more difficult.	MICT consisting of 25 minutes continuous exercise at 60-80% of peak effort, regular core strengthening exercises, and exercises for large muscle groups 2-3 times each week.
Allen et al., 2018	Three-armed pilot RCT. Young adult smokers were randomized to 12 weeks of HIIT, CA or a non-active control. Effects of exercise on depression, stress, positive and negative affect were measured.	HIIT=12; CA=9; Non-active Control=11	Adults ages of 18 and 40 (HIIT: age 30.4±1.5 years, BMI 25.1±1.6; CA age 29.2±1.8, BMI 27.3±2.2; Con: age 31±2.2, BMI 29.1±2), 63% female. Eligible participants currently smoked (≥ 5 cigarettes/day for ≥ last 6 months), and were minimally active and in stable physical/mental health.	HIIT consisted of a single 20-min session per week, on a stationary bike. Each session consisted of 4-bouts of 30 sec at 80-90RPM. During these bouts participants were encouraged to reach 75-80% of their HRR during weeks 1-2, 80-90% HRR during weeks 3-5, >90% HRR during weeks 6-12. Bouts were interspersed with a two-min at approximately 40-50 RPM and 35-45% of HRR. Sessions began with a 5-min warm-up and ended with a 3-min cool down.	The CA group completed three 30-minute sessions per week starting with mostly walking and gradually increases to mostly jogging. The control condition participants were instructed to maintain their current activity level until the end of the study.
May et al., 2019	Three-armed RCT. College students were randomised to 4 weeks of HIIT, heart rate variability coherence biofeedback (HRVCB) training or a non-active control. Effects of exercise on depression and anxiety was measured.	HIIT=30; HRVCB=30; Non-active Control=30	College students (mean ± SD age: 18.55 ± 0.99 years, 82% Female, 71% Caucasian). Participants were excluded if they exercised regularly (>120 min/week), were taking antidepressants or had chronic diseases.	Three cycling sessions per week for 4 weeks for 25 min. Each session comprised 10 × 60-s cycling bouts at 90% HRmax interspersed with 60-s recovery at a resistance of 50 W and included a 3-min warm-up and a 2-min cool-down at 50 W.	HRVCB training combines stress reduction strategies and biofeedback technologies. Interactive sessions lasted for 20 minutes and were conducted 3 times a week for 4 weeks. Non-active control participants were asked to report their normal daily activities
Krawcyk et al., 2019	Two-armed RCT. Patients with Lacunar stroke were randomised to 12 weeks of HIIT or usual care. Effects of exercise on depressive symptoms was measured.	HIIT=35, Usual care=36	Patients ≥18 year with a first-time lacunar stroke or a recurrent event of lacunar stroke. In the HIIT group mean age (± SD) was 63.7 years ± 8.9, 74% were male and BMI was 27.5±4.5. In the usual care group mean age was 63.7 ± 9.2 years, 81% were male and BMI was 25.6±3.6.	Home-based HIIT five times a week for 12 weeks. Each session consisted of three 3-min bouts of high intensity exercise carried out at 77-93% maxHR and interspersed with 2-min active recovery periods. Patients were provided with a stationary bicycle for use at home to ensure an easily accessible exercise modality.	The usual care group received secondary preventive medication and advice on self-managed lifestyle changes and were asked to maintain their habitual level of physical activity and to track their physical activity in an exercise diary.

Adams et al., 2018	Two-armed RCT. Testicular cancer survivors were randomised to 12 weeks of HIIT or usual care. Effects of exercise on depression, anxiety, stress and mental wellbeing were measured at end of intervention and 3-month follow-up.	HIIT=35; Usual care=28	Men aged 18-80 years (HIIT: mean age 44 ±11.6, Con 43.7±10.8) with a confirmed history of stage I-IV testicular cancer and who were post-surgery/treatment. 92.1% had a single orchidectomy, 36.5% received chemotherapy, 90.5% were Caucasian.	Three HIIT sessions per week, consisting of uphill treadmill walking or running for 12 weeks. HIIT consisted of four, 4-minute, high-intensity intervals. The intensity gradually increased from 75% to 95% of VO2peak over the intervention. Each interval was separated by a 3-minute active recovery period performed 5-10% below ventilatory threshold. Session were 35 min in length, including a 5-minute warm-up and a 5-minute cool-down.	Usual care participants were asked to maintain their baseline exercise levels.
Egegaard et al., 2019	Two-armed pilot RCT. Patients with non-small cell lung cancer (NSCLC) were randomised to 7 weeks of HIIT or a non-active control. Effects of exercise on depression and anxiety were measured.	HIIT=8; Non-active control=7	Patients who were referred for concomitant chemoradiotherapy with locally advanced NSCLC and aged >18 years. Mean age was 64 ± 5.8 years in the HIIT group and 65 ± 4.7 in the control group respectively. 62.5% and 71.4% were female in each group respectively, and most had IIIb NSCLC (50.0% and 57.1% in each group respectively). Mean BMI was 24.1±4.4 and 24.2±1.9 in each group.	Five 20-min cycling HIIT sessions per week for 7 weeks. HIIT comprised a 5-min warm-up followed by three 5-min exercise phases. Each session had four phases: The first and the third exercise phase comprised of interval training consisting of 5 × 30-s intervals at 80–95% of iPPO, with each interval separated by a 30-s pause. The second exercise phase consisted of continuous cycling at 80% PPO. Over the 7 weeks, the intensities were increased from 50%, 80%, 70% and 80% of PPO to 60%, 95%, 80% and 95% of PPO according to the four phases.	Control patients received no exercise training. They wore a HR activity tracker every day to track activity levels.
Eather et al., 2019	Two-armed feasibilty RCT. University students were randomised to 8 weeks of HIIT or wait list control. Effects of exercise on anxiety and stress were measured.	HIIT=27; Waist list Control=26	Male and female university students aged 18-25 years (HIIT: mean age 20.23±1.72 years, BMI 24.17±4.06; Con: age 20.48±2.01, BMI 22.96±4.2), with no existing medical conditions. 34% were male, 88.70% Australian, 32.08% overweight or obese.	Three HIIT sessions per week for 8 weeks lasting 8-minutes (weeks 1-4), 10-minutes (weeks 5-6), and 12-minutes (weeks 7-8) in duration, and a work to rest ratio of 30secs:30secs. HIIT involved combinations of aerobic (e.g., shuttles, skips, bear walks) and core resistance (e.g., push-ups, squats, sit ups) exercises using either body weight or basic equipment (e.g., sports balls) and a target HR of 85% HRmax or above was promoted.	Participants randomized to the control conditions were asked to continue with their usual physical activity routines during the intervention period.
Abdelhalem et al., 2018	Two-armed RCT. Ischemic Egyptian patients with mild left ventricular dysfunction were randomised to 12 weeks of MICT or HIIT. Effects of exercise on emotional wellbeing were measured.	HIIT=20; MICT=20	Egyptian patients with CAD, age >18 years old with LV ejection fraction. Mean age was 51.95 ± 8.07 years (range 38 –67 years) and 54.65 ± 7.63 (range 35–65) in MICT and HIIT groups respectively. 80% and 90% of participants were male in MICT and HIIT groups respectively. Mean BMI was 29.3 and 30.2 in each group.	HIIT was performed twice weekly for 12 weeks and consisted of 5 min of warm-up exercises followed by 30–35 min of treadmill exercise comprising higher intensity bouts (2-5 minutes at 85-95% HRR) interspersed with 2-5 minutes of moderate-intensity workloads, and a 5 min cool down.	MICT was performed twice weekly for 12 weeks. Exercise consisted of 5 min of warm-up exercises followed by 30–35 min of continuous treadmill exercise at 40–60% of HRR, and a 5 min cool down.

Mason et al., 2018	Three-armed RCT. Healthy adults were randomised to a single session of MICT, SIT or a non-active control. Effects of exercise on anxiety and distress were measured immediately after the exercise session and at 3 and 7 day follow-ups.	SIT=22; MICT=21; Control=21	Undergraduate students and community members, aged 18- 65 years, who completed less than 150 min of moderate intensity exercise each week. Mean age was 23.34 ±8.23, 27.75 ±12.91, and 22.81 ±5.99 in control, MICT and SIT groups respectively, 75%, 80% and 87% were female in each group and mean BMI was 26.55±5.62, 24.83±4.56 , and 24.57±4.22 respectively.	Participants completed a single 10-minute session of SIT. SIT included a 2-min warm-up, followed by three 20-s cycle sprints against an applied resistance at an intensity at or above 18 RPE and 85% of HRmax, and separated by an active recovery consisting of 2 min of low intensity cycling. SIT was followed by a 3-min cool-down.	MICT participants completed a single 50-minute session. MICT started with a 2-min warm followed by 45 min of MICT at 70% HRmax and RPE 13-15 on a stationary spin cycle, then a 3-min cool down. The non-active controll did not engage in any form of exercise training.
Saanijoki et al., 2017	Two-armed RCT. Insulin-resistant adults were randomised to 2 weeks of SIT or MICT. Effects of exercise on positive and negative affect and perceived stress were measured.	SIT= 13; MICT=13	Participants aged 40 -55 years, with a BMI 18.5-35 kg·m−2, blood pressure of ≤160/100 mm Hg, sedentary lifestyle, and impaired glucose tolerance and HbA1c less than 7.5 mmol·L−1 (age, 49 ±4 yr; BMI, 30.5 ±2.7]kg·m−2, 38% female).	Participants completed 6 HIIT sessions in 2 weeks. SIT comprised a warm-up and 4 to 6 × 30 s all out cycling efforts at maximal cadence with 4 min recovery between bouts. The number of bouts was increased from four to five, and further to six after every other training session.	MICT participants performed 6 MICT sessions in 2 weeks comprising continuous aerobic cycling for 40-60 min at 60% of peak workload. Training duration was increased from 40 to 50 min and further to 60 min after every other session.
Connolly et al., 2017	Three-armed RCT. Inactive women were randomised to 12 weeks of HIIT, continuous training (CT), or a non-active control. Effects of exercise on mental wellbeing were measured.	HIIT=15; CT =15; Non-active Control=15	Currently inactive premenopausal women without known metabolic or cardiovascular diseases. Women were assigned to HIIT (age, 44 ± 7 years; BMI 25.3±4.9), CT (age, 43±7 years; BMI 26.9 ±6.3), or a control group (CON: age,45±7 years; BMI 28.4±6.9 kg).	Participants completed 3 25-min HIIT sessions each week for 12 weeks on a stationary bike. Each participant completed repeated 1 min self-paced exercise bouts comprising 30 slow-intensity (~30% of maximum effort), 20 s moderateintensity (~50–60% of maximum effort) and 10 s high-intensity (>90% maximum effort) cycling. This 1-min cycle was repeated for 5 min with each 5 min block separated by 2 min passive recovery. During the first week participants performed 3–4×5 min bouts and in subsequent weeks participants completed 5×5 min bouts interspersed with 2 min recovery. Sessions included a 5 min warm up and a 5 min cool down.	Participants completed 3 CT sessions each week for 12 weeks on a stationary bike. CT consisted of cycling continuously at a self-paced intensity for 50 min. Sessions included a 5 min warm up and a 5 min cool down. Non-active controls continued their normal daily lives.
Sosner et al., 2019	Three-armed RCT. Hypertensive adults were randomised to 2 weeks of MICT on dry land, HIIT on dry land or HIIT in a swimming pool. Effects of exercise on mood profiles were measured.	HIIT dry land= 14; HIIT immersed=14 ; MICT dry land=14	Forty-two participants (22 men, 20 women; age 43–80 years). All had SBP ≥ 130 mmHg and/or DBP ≥ 85 mmHg and SBP ≥ 180 mmHg and/or DBP ≥ 110 mmHg. 55% participants had an antihypertensive treatment, 45% had a statin for dyslipidaemia, 19% had diabetes mellitus. (HIIT dryland: age 65±8, BMI 30.7±4.7; HIITimmersed: age 63±9, BMI 28.8± 3.9; MICT: age 65±6, BMI 29.7± 4.5).	Participants completed 6 exercise sessions on a stationary cycle (3 times a week for 2 weeks) of either HIITdryland or HIITimmersed. The HIITdryland consisted of a 5-min warm-up, followed by two 10-minute sets of exercise, composed of repeated phases of 15 s of cycling at 100% of PPO, interspersed by 15 s of passive recovery and 4 min of passive recovery between the sets, and a 5-min cool-down. HIITimmersed was performed on a mechanically braked cycle ergometer in an indoor swimming pool using the same protocol.	Participants completed 6 MICT sessions on a stationary cycle (3 times a week for 2 weeks). Each session was preceded by a 5-min warm-up, followed by a 24-min at 50% of PPO, then a 5-min cool-down.

Costigan et al., 2016	Three-armed RCT. Adolescents were randomised to 8 weeks of HIIT, HIIT-RT or control. Effects of exercise on psychological well-being and distress were measured.	HIIT=21; HIIT-RT=22; Control=22	Participants were students aged 14-16 years attending study school (45 males, 20 females). Mean BMI was 22.29± 3.53 kg-m2; 21.72 ±2.10 kg-m2; 22.08± 3.56 kg-m2 in control, HIIT and HIIT-RT groups respectively, and mean age was 15.6±0.6, 15.7±0.7 and 15.5±0.6 respectively.	HIIT and HIIT-RT participants completed three HIIT sessions per week for 8 weeks. HIIT sessions (inclusive of a short warm-up including stretching, 8–10 min of HIIT (weeks 1–3: 8 min; weeks 4–6: 9 min; weeks 7–8: 10 min) and cooldown). HIIT comprised a work to rest ratio of 30:30 s and target intensity was ≥85% of HRmax. Activities included shuttle runs, jumping jacks, and skipping. Participants randomised to HIIT-RT sessions carried out a combination of cardiorespiratory and body weight RT exercises (e.g., shuttle runs, jumping jacks, skipping, combined with body weight squats, and push-ups) in the same 30:30s format.	Control participants continued with their programmed PE and usual lunchtime activities for the 8-wk intervention period.
Dunne et al., 2016	Two-armed RCT. Patients undergoing elective liver resection for colorectal liver metastases (CRLM) were randomised to 4 weeks of HIIT or standard care. Effects of exercise on mental wellbeing were measured.	HIIT=20; Standard Care=18	Patients with resectable CRLM, aged over 18 years (mean age 62 (range 54–69) years, 70% male, BMI 29.5 kg/m2 ±4.1). Resectability was defined as metastases deemed surgically treatable with curative intent (either 1- or 2-stage resection).	Twelve bicycle based HIIT sessions over a 4-week period. The interval sessions included a warm-up and cool-down, and 30 min of interval training alternating between light exercise (60% VO2 peak) and vigorous (>90% V02 peak) intensity.	Participants received standard care.
Rizk et al., 2015	Three-armed RCT. Patients with COPD were randomised to 12 weeks of continuous training at high intensity (CTHI), continuous training at ventilatory threshold (CTVT) or HIIT. Effects of exercise on positive, negative and global affect were measured before and after a single exercise session.	CTHI=13; CTVT=12; HIIT=10	Patients with a COPD diagnosis; aged ≥40 years, with a smoking history ≥10 American pack-years. Mean age was 66±7, 69±9 and 67±11 in CTHI, CTVT and HIIT groups respectively, mean BMI was 28.3±4.9 kg/m2, 27.1 ±5.4 kg/m2, 28.3 ±5.4 kg/m2 respectively, and 31%, 50% and 40% were male in each of the three groups.	Three bicycle based HIIT sessions each week for 12 weeks. IT consisted of 30-second intervals at 100% Wpeak interspersed with 30-second intervals of unloaded pedalling. Training included a 10-min warm-up and 5-min cool-down. Session duration was adjusted for each subject using metabolic equations to equal total amount of work performed to 25 min of CTHI.	Three bicycle based sessions each week for 12 weeks. CTHI consisted of 25 min of pedalling at 80% of Wpeak. For CTVT, participants pedalled continuously at the HR reached at the ventilatory threshold. Session duration for CTVT was adjusted for each subject using metabolic equations to equal total amount of work performed to 25 min of CTHI. Training included a 10-min warm-up and 5-min cool-down.
Pedersen et al., 2015	Two-armed RCT. Non-diabetic participants with CAD were randomised to 12 weeks of HIIT or a low energy diet (LED). Effects of exercise on depression and anxiety were measured.	HIIT=35; LED=35	Patients with CAD diagnosed more than 6 months prior to inclusion, BMI 28–40 m/kg2, age 45–75 years and no diabetes, 78% were men (HIIT: age 62.3±5.7, BMI 31.6, LED: age 63.6±6.8, BMI 31.1).	Three bicycle based HIIT sessions each week for 12 weeks. HIIIT consisted of intervals of 1–4 min, with a total of 16 min at 85–90% of VO2peak, Borg scale 17–18, separated by active pauses of 1–3 min. The total duration of each training session was 38 min. Each session started with a 10 min warm-up on a staircase (total of 73 steps) or on an exercise bike.	Participants maintain a low energy diet (800–1000 kcal/day) for 8–10 weeks followed by 2–4 weeks' transition to a weight maintenance diet characterised by a high protein/low glycemic index diet.

Saanijoki et al., 2015	Two-armed RCT. Healthy middle-aged men were randomly assigned to 2 weeks of HIIT or MICT. Effects of exercise on perceived stress and positive and negative affect were measured.	HIIT=14; MICT=14	Healthy sedentary men (HIIT: age 48±5, BMI 25.6±2.7, MICT: age 48±5, BMI 26.1±2). All were aged 40–55 yr, had a BMI of 18.5–30 kg·m−2, normal fasting blood glucose concentration, and a sedentary life.	Six bicycle based HIIT sessions withing a 2-week time period. The HIIT group subjects performed progressive HIIT exercises consisting of 4–6 × 30-s maximal sprints against a resistance equivalent to 7.5% of whole body weight, with 4 min of recovery between the sprints. The number of sprints, starting from 4, increased by one in every second training session.	Six bicycle based MICT sessions within a 2-week time period. The MICT group performed 40- to 60-min continuous aerobic cycling exercises at 60% peak workload. Training duration increased by 10 min in every second training session starting from 40 min in the first session.
Chrysohoou et al., 2014	Two-armed RCT. Patients with chronic heart failure (CHF) were randomised to 12 weeks of HIIT or a non-active control. Effects of exercise on depressive symptoms was measured.	HIIT=50; Non-active control=50	Patients with CHF due to left ventricular systolic dysfunction (NYHA classes II–IV, ejection fraction ≤ 50%). Mean age was 63 ±9 in the HIIT group, 88% were male, years of known CHF was 4.2 ±4.6 and mean BMI was 28.85 ±4.2 kg/m2. Mean age was 56 ±11 years in the control group, 72% were male, years of known CFH was 3.9 ±4.8 and mean BMI was 31.3 ±7 kg/m2.	Patients exercised at an intensity equivalent to 80% WRpeak and progressively to 100% of WRpeak for 30 s alternated with 30 s of rest for an accumulative period of 45 min/day, 3 days/week for 12 consecutive weeks. A cycling based HIIT protocol was issued.	Patients in the usual care group were managed as usual by the admitting physician in the Heart Failure Unit, and no advice for any specific exercise protocol was given.
Fu et al., 2013	Three-armed RCT. Patients with heart failure (HF) were randomised to 12 weeks of HIIT, MICT or a non-active control. Effects of exercise on mental wellbeing was measured.	HIIT=15; MICT=15; Non-active control=15	Patients with HF (left ventricular ejection fraction (LVEF) ≤40% or LVEF >40% with episodes of acute pulmonary edema). Mean age was 67.5±1.8 years, 66.3±2.1 years and 67.8±2.5 years in HIIT, MICT and control groups respectively, 67%, 64% and 67% were male in each group respectively, HF duration was 4.2±1.8 years, 4.5±2.0 years and 4.3±1.6 years respectively and mean BMI was 24.5, 24.4 and 24.5.	HIIT was conducted on a bicycle ergometer thrice weekly for 12 weeks. HIIT included a 3-min warm up, five 3-minute intervals at 80% of VO2peak separated by 3-minute exercise at 40% of VO2peak, a 3-min cool-down at 30% of VO2peak.	MICT was conducted on a bicycle ergometer thrice weekly for 12 weeks. MICT included a 3-min a warm-up followed by continuous 60% of VO2peak for 30 min, then a 3-min cool-down at 30% of VO2peak. The non-active control subjects followed advice from their rehabilitation physicians with regard to home-based physical activity.
Terada et al., 2013	Two-armed feasibility RCT. Patients with Type 2 Diabetes (T2D) were randomised to 12 weeks of HIIT or MICT. Effects of exercise on psychological wellbeing and distress were measured.	HIIT=7; MICT=8	Men and women aged between 55 and 75 years, diagnosed with T2D were eligible. Fifteen participants (8 males and 7 females). Mean age was 62 ±3 years and 63±5 years in HIIT and MICT groups respectively, and T2D duration was 6±4 years and 8±4 years respectively and mean BMI was 28.4± 4.1 and 33.1± 4.5.	HIIT was conducted 5 days per week for 12 weeks. HIIT involved alternating between 1-min intervals at 100% average relative intensity (VO2R) followed by 3-min recovery intervals at 20% VO2R except for one day each week, when they performed MICT protocol. Participants were progressed from 30 min per session for weeks 1–4 to 45 min per session for weeks 5–8, and then to 60 min per session for weeks 9–12. Stationary cycling and treadmill walking were performed alternately for exercise variety.	MICT was conducted 5 days per week for 12 weeks. The MICT group performed continuous exercise at 40% VO2R. Session duration was matched to the HIIT group, and sessions were conducted using stationary cycling and treadmill walking.

Freyssin et al., 2012	Two-armed RCT. Patients with chronic HF were randomised to 8 weeks of HIIT or continuous training (CT). Effects of exercise on symptoms of anxiety and depression were measured.	HIIT=12; CT=14	Twenty-six patients with stable chronic HF and a left ventricular ejection fraction less than 40%. Participants were receiving a beta-blocker, diuretic therapy. Mean age was 55±12 and 54±9 years in CT and HIIT groups respectively and 50% were male in each group and mean BMI was 24.1± 5.4 and 24.8±4.	The physical activity program included 13 hours of exercise per week (2–3h/d, 5d/wks comprising HIIT or CT, 4 hours of gymnastics , 3 hours of balneotherapy and therapeutic educational sessions on risk factors and physical practice. HIIT included 6 sessions of 71 minutes of exercise including a 10-min warm-up, 12 repetitions of 30 sec of cycling exercise (at 50% max power during the first 4 weeks and 80% max power during the last 4 weeks), followed by 60 sec of complete rest. Each training session consisted of 3 series (12 repetitions of 30s of exercise), separated by 5 min of rest.	The CT completed the same physical activity program but with HIIT substituted for 6 sessions of 61 min of CT. Half of the CT was performed on a treadmill and half on a cycle ergometer. CT was composed of a 10-min warm-up followed by 45 min of aerobic exercise corresponding to the heart rate at the first ventilator threshold (VT1) and a final 5 min of active recovery.
Christensen et al., 2012	Sub-study of a two-armed RCT. Heart transplant recipients were randomised to 8 weeks of HIIT or a non-active control. Effects of exercise on symptoms of anxiety and depression and mental wellbeing were measured.	HIIT=14; Non-active control=13	Patients were above 18 years of age, and were at least 12 months after transplantation, none had significant rejection in the previous 3 months. Patients were approximately 7 years posttransplant. Patients were all treated with a calcineurin inhibitor and an antiproliferative agent. Mean age was 53 ±11 and 47 ±18 years in HIIT and control groups respectively, 86% and 77% were male and mean BMI was 26.3±3.3 and 26.1±6.	Thrice weekly sessions for 8 weeks using bicycles and staircase running. Each exercise started with a warm-up period above 50% of VO2 peak and was followed by 42 min of HIIT with interval blocks of 4 min/2 min/30 s according to 80%, 85% and 90% of VO2 peak and recovery periods of 1/2 min. It was followed by 10 min of staircase running at 80% of peak VO2 and recovery walking at 50% peak VO2. Patient were given education about the benefits of exercise before and after training sessions.	The control group did not receive any training.
Arnardottir et al., 2007	Two-armed RCT. Patients with COPD were randomised to 16 weeks of HIIT or MICT. Effects of exercise on symptoms of anxiety and depression and mental wellbeing were measured.	HIIT=28; MICT=32	Patients with moderate or severe COPD, all were smokers or ex-smokers. All had a forced expiratory volume in 1 s (FEV1) <60% of predicted value and FEV1/VC (vital capacity) <0.7 after bronchodilatation. The age range was 43–80 years (mean age 65±7 and 64±8 in HIIT and MICT groups respectively, and mean BMI was 24.1±5 and 23.5± 4.4.	Bicycle based HIIT sessions twice weekly for 16 weeks. All sessions started with ergometer cycling. The target training intensity was ⩾80% of the baseline W peak in the "uphill" intervals (5 intervals, 3 min each) and 30%–40% of the baseline W peak in the "downhill" intervals (4 intervals, 3 min each). Total cycle time was 39 min including 6-min warm-up and cool-down at 30-40% W peak. Both groups took part in identical callisthenic, relaxation and resistance training.	Bicycle based MICT sessions twice weekly for 16 weeks. The target training intensity was ⩾65% of baseline W peak. otal cycle time was 39 min including 6-min warm-up and cool-down at 30-40% W peak.

Tew et al., 2019	Three-armed pilot RCT. Patients with Crohn's disease were randomised to 12 weeks of HIIT, MICT or usual care. Effects of exercise on anxiety and depression were measured at end of intervention and 6-month follow-up.	HIIT=13; MICT=12; Usual care=11	Male and female patients, aged 16-65 years of age (HIIT: 37±11.1, MICT 38.5±13, Con 35±10) with a clinical diagnosis of Crohn's disease. Patients had a stool calprotectin of < 250 μg/g, stable medication (> 4 weeks), and quiescent or mildly-active disease. A higher proportion of participants were male in the HIIT (54%) and control (64%) groups than the MICT group (25%). The mean time since diagnosis was 13.7 years (range from 4 months to 38.2 years).	Three exercise sessions per week for 12 consecutive weeks on a cycle ergometer, with each session comprising a 5-min warm-up at 15% of Wpeak, ten 1-min bouts at 90% Wpeak, interspersed with 1-min bouts at 15% Wpeak, and then a 3-min cool-down at 15% Wpeak. After the initial 12-week supervised training period, participants were encouraged to continue a similar exercise regime on their own.	MICT participants received three exercise sessions per week for 12 consecutive weeks on a cycle ergometer, with each session comprising a 5-min warm-up at 15% of Wpeak, 30 min at 35% Wpeak, and then a 3-min cool-down at 15% Wpeak. Participants allocated to usual care did not receive any supervised exercise or exercise advice.
Choi et al., 2018	Two-armed RCT. Patients with Myocardial Infarction (MI) were randomised to 18 sessions of HIIT or MICT. Effects of exercise on symptoms of anxiety and depression were measured.	HIIT=24; MICT=22	Patients with first time ST-segment elevation myocardial infarction (STEMI) treated by primary percutaneous coronary intervention (PCI) with 'low or moderate' risk. (HIIT: mean age 57.31± 12.62, BMI 24.65± 3.36; MICT: age 57.31± 12.62, BMI 26.3± 2.47).	Eighteen sessions were offered and patients completed 1-2 sessions per week for 9-10 weeks. HIIT consisted of 4×4 min exercise periods at 85–100% of HRmax interspersed with 3 min of recovery between bouts at 50–60% of HRmax. Training sessions started with a 10 min warm-up and finished with a cool-down at 40–50% of HRmax.	Eighteen sessions were offered and patients completed 1-2 sessions per week for 9-10 weeks. Patients worked continuously at 60–70% of HRmax. Exercise was continued for the same time-period as the HIIT group.
Shepherd et al., 2015	Two-armed RCT. Inactive adults were randomly assigned to 10 weeks of HIIT or MICT. Effects of exercise on positive and negative affect and acute moods were measured post intervention and at 3 month follow-up.	HIIT=46; MICT=44	Inactive individuals, aged 18–60 years were recruited. All subjects entering the study were free of any known metabolic or cardiovascular disease and did not meet current physical activity guidelines. Mean age was 42±11 and 43±11 years in HIIT and MICT groups respectively, mean BMI was 27.7±5.0 and 27.7±4.6 kg/m2 respectively and 33% and 34% of each group were male.	Three bicycle based HIIT sessions per week for 10 weeks. HIIT included, a 5 min warm up of low intensity cycling, repeated high intensity sprints of between 15 -60 sec at >90% HRmax, interspersed with active recovery periods of 45-120 sec, and a 5 min cool down. Each HIT lasted 18–25 min.	Three bicycle based MICT sessions per week for 10 weeks. MICT included a short warm up, continuous cycling for 30 min (week 1) progressing to 45 min (week 10) at ~70% HRmax, and a short cool down. Subjects were also asked to perform 2 unsupervised moderate-intensity sessions (brisk walking, jogging, cycling, or elliptical cross training) each week.
Puhan et al., 2006	Two-armed RCT. Patients with COPD were randomised to 3 weeks of HIIT or high intensity continuous exercise (HICT). Effects of exercise on symptoms of anxiety and depression were measured at 5 week follow-up.	HIIT=48, HICT=50	Patients with COPD as defined by FEV1–FVC ratio <70% of predicted, FEV1 < 50% of predicted after bronchodilation (HIIT: mean age 69±9.2, BMI 25.4± 6.9; HICT: age 68.9± 9.2, BMI 24± 5.8).	Patients completed 12-15 bicycle based HIIT sessions over 3 weeks. Each session included a 2-min warm-up, 20-min alternating between high-intensity intervals for 20 sec at 50% of short-term maximum exercise capacity (corresponding to 90-100% of normal maximal capacity) and low-intensity intervals for 40 sec at 10% of short-term maximum exercise capacity, and a 2 min cool-down.	Patients completed 12-15 bicycle based HICT sessions over 3 weeks. Each session began with a 2-min warm-up at 20% of maximum exercise capacity, continuous exercise for 20 minutes at 70% or more of maximum exercise capacity, and a 2-min cool down (gradual decrease from 70% to 0%).

Freese et al., 2014	Two-armed RCT. Women at risk for MetS were randomised to 6 weeks of SIT or a non-active control.	SIT=23; Non-active control=24	Women (30-65 years of age) who were at risk for developing MetS, defined as having abdominal obesity (waist circumference >88cm) and at least one of the following - TG >150mg/dL, HDL-cholesterol <50 mg/dL, BP >130/>85 mmHg, or fasting glucose >100 mg/dL or on medication for any of these risk factors. Mean age was 51.7±10.4 and 52.5±7.7 years in SIT and control groups respectively and mean BMI was 31.5±7.1 and 31.5±6.1 kg/m2 respectively.	Three bicycle based SIT sessions per week for 6 weeks. SIT consisted of a 5-min warm-up followed by repeated 30-s all-out cycling sprints against a resistance of 0.09kg per kg of fat-free mass interspersed with 4 min active recovery periods with no resistance applied. Participants completed 4 sprints during the first 2 weeks, and the number of sprints was then increased by one sprint every week until participants completed 8 sprints during week 8.	Participants were instructed to maintain their pre-study physical activity.
Jurado-Fasoli et al., 2020	Four-armed RCT. Middle-aged sedentary adults were randomised to a control group, physical activity recommendation from the World Health Organization (PAR), 12 weeks of HIIT or HIIT adding whole-body electromyostimulation training (HIITEMS).	Con=20; PAR=20; HIIT=20; HITEMS=20	Middle-aged adults (40 women, 40 men), aged 45-65 years. All engaged in <20 minutes of moderate-intensity physical activity on 3 d/wk over the last 3 months and were free of disease. (HIIT: age 53.1±5.6, BMI 26.4±3.1; PAR: age 54.9±4.5, BMI 25.4±2.9; Con: 51.7±4.1, BMI 26.7±3.9; HITEMS: age 53.4±5.4, BMI 28.1±4.7).	Two HIIT sessions/week for 12 weeks performing two different complementary protocols each week: (a) treadmill HIIT with long intervals (type A session) and (b) weight-bearing exercises in circuit form HIIT with short intervals (type B session). The training volume was 40-65 min/wk at >95% of the maximum oxygen uptake in type A session, and >120% of the maximum oxygen uptake in type B session. HIITEMS performed HIIT with the addition of electrical impulses.	The PAR group performed a concurrent training 3 d/wk for 12 weeks comprising 150 min/wk at 60%-65% of the HRR for the endurance training and ~60 min/wk, at a 40%-50% of one-repetition maximum for the RT. The endurance training section used treadmill, cycle ergometer and elliptical ergometer. Weight-bearing and guided pneumatic machines were used in RT section. The control group were provided with general advice and were instructed to maintain their lifestyle.
Bruseghini et al., 2020	Two-armed RCT. Older male adults were randomised to 12 weeks of HIIT or MICT. Effects of exercise on sleep time were measured.	HIIT=12; MICT=12	Healthy, elderly male volunteers aged 65-75 years. Mean age was 69.4±4.3 and 69.67±4.1 years in HIIT and MICT groups respectively and mean BMI was 26.5±2.8 and 26.8±2.9 kg/m2 in each group respectively.	Three bicycle based HIIT sessions per week for 8 weeks. HIIT consisted of 7 × 2 min bouts at 85–95% of VO2max interspersed by 2 min of recovery at 40% of VO2max. Each session begun with a 10-min warm-up. The training session lasted from 45-60 min.	Three bicycle based MICT sessions per week for 8 weeks. MICT consisted of aerobic training on a stationary bike or treadmill (20–30 min at 46–64% of VO2max). Each session begun with a 10-min warm-up. The entire training session lasted from 45-60 min.

Chou et al., 2019	Two-armed RCT. Patients with HF were randomised to 12 weeks of HIIT or non-active control. Effects of exercise on mental wellbeing were measured.	HIIT=17; Non-active control=17	Patients diagnosed with HF (left-ventricular ejection fraction (LVEF) ≦40% or HF with preserved EF, i.e., LVEF >40% with episodes of acute pulmonary edema). Mean age was 60.9±0.5 and 59.7±5.3 years in HIIT and control groups respectively and mean BMI was 26.1 and 25.1 respectively.	HIIT was conducted on a bicycle ergometer thrice weekly for 12 weeks. HIIT included a 3 min warm-up, five 3-min intervals at 80% of VO2peak separated by 3-min exercise at 40% of VO2peak, and a 3-min cool-down.	GHC patients only engaged in general home-based health care, as instructed by their rehabilitation physicians.
Hurst et al., 2019	Two-armed RCT. Older adults were randomised to 12 weeks of HIIT or a non-active control. Effects of exercise on mental wellbeing was measured.	HIIT=18, Non-active control=18	Adults aged over 50 years without pre-existing, neuromuscular or skeletal conditions or systemic disease who did not engage in structured exercise more than twice per week. Mean age was 61.9 (50–81) and 62.8 (50–74) years in HIIT and control group respectively, 61% and 56% in each group were male respectively and mean BMI was 28.1 ± 4.4 and 27.4 ± 5.3 kg/m2 in each group.	Two HIIT sessions per week for 12 weeks. Each session included a 6 min warm-up, four sets of high-intensity exercise at > 90% HRmax (upper- (bent over row, shoulder press), lower- (squat, split squat) and full-body (power clean and press, step and press, pulldown to squat, high pull) exercises) and a 4-min cool-down. In week 1, repetition duration was 45-s. Each set was followed by 3 min of passive rest. Repetition duration increased by 10 s at the end of every third week, with duration being 75-s by week 10. Total exercise duration increasing from 12 to 20 min.	Participants maintained habitual physical activity.
Mitropoulos et al., 2018	Three-armed RCT. Patients with cutaneous systemic sclerosis (SSc) were randomised to 12 weeks of HIIT cycle ergometer (HIIT-CE), HIIT arm cranking ergometer (HIIT-ACE) or a non-active control. Effects of exercise on symptoms of anxiety and depression were measured.	HIIT-CE=11; HIIT-ACE=11; Non-active control=12	Patients with limited cutaneous scleroderma (31 women, 3 men), with disease duration between 1-10 years. Mean age was 69.1 ± 9.7; 65.1 ± 10 and 62.2 ± 14.3 years in HIIT-ACE, HIIT-CE and control groups respectively, mean BMI was 25.6 ± 4.8, 24.5 ± 3.6 and 27.3 ± 4.0 kg/m2 respectively and mean illness duration 7.8 ± 2.3, 7.7 ± 2.1 and 6.3 ± 2.0 in the three groups respectively.	Twice weekly HIIT sessions each week for 12 weeks. Each session included a 5 min warm-up on an arm crank or cycle ergometer depending on the group, followed by HIIT for 30 s at 100% of PPO interspersed by 30 s passive recovery for a total of 30 min and then a 5 min cool-down.	The control group did not perform any type of physical activity.
Malmo et al., 2016	Two-armed RCT. Patients with non-permanent atrial fibrallation (AF) were randomised to 12 weeks of HIIT or a non-active control. Effects of exercise on mental wellbeing was measured.	HIIT=26; Non-active control=25	Patients with symptomatic, ECG-documented, nonpermanent AF. Mean age was 62±9 and 56±8 years in control and HIIT groups respectively, 88% and 77% in each group were male and mean BMI was 28.2±4.3 and 28.2±4.8 in each group respectively.	HIIT three times weekly for 12 weeks consisting of treadmill running/ walking. HIIT consisted of a 10-min warm-up, four 4-min intervals at 85-95% of HRpeak with 3 min of active recovery at 60-70% of HRpeak between intervals, and a 5-minute cooldown period. Patients were allowed to perform 1 exercise per week at home, where exercise intensity was documented with a heart rate monitor.	The control group continued their previous exercise habits.

Conraads et al., 2015	Two-armed RCT. Patients with CAD were randomised to 12 weeks of HIIT or aerobic continuous training (ACT). Effects of exercise on mental wellbeing was measured.	HIIT=100; ACT=100	Patients with stable CAD (90% men). All participants had angiographically documented CAD or previous acute myocardial infarction; left ventricular ejection fraction >40%; and were stable with regard to symptoms and medication for at least 4 weeks. (HIIT: age 58.4±9.1, BMI 28±4.4; ACT: age 59.9±9.2, BMI 28.5±4.3).	Bicycle based HIIT training three times weekly for 12 weeks. HIIT consisted of four 4-min intervals at 85–95% of peak HR interspered with four 3 min intervals of active rest at 50–70% of peak. Each session begun with a 10 min warm-up at 60–70% of HRpeak and each session was 38 minutes long in total.	Bicycle based ACT training three times weekly for 12 weeks. ACT consisted of a 5 min warm-up at 60–70% peak HR, 37 min of at least 70–75% of peak HR and 5 min cooldown at 60–70% of peak HR. Total exercise time was 47 mins.
Pattyn et al., 2016 (1 year follow-up of Conraads et al., 2015)	Follow-up of a two-armed RCT. Patients with CAD were randomised to 12 weeks of HIIT or aerobic continuous training (ACT). Effects of exercise on mental wellbeing was measured at 1-year follow-up.	HIIT=80; ACT=83	Patients with stable CAD patients were recruited. (HIIT: age 57.4±8.7, BMI 27.8±4; ACT: age 59.9±9.2, BMI 28.4±4.2).	Bicycle based HIIT training three times weekly for 12 weeks. HIIT consisted of four 4-min intervals at 85–95% of peak HR interspered with four 3 min intervals of active rest at 50–70% of peak. Each session begun with a 10 min warm-up at 60–70% of HRpeak and each session was 38 minutes long in total.	Bicycle based ACT training three times weekly for 12 weeks. ACT consisted of a 5 min warm-up at 60–70% peak HR, 37 min of at least 70–75% of peak HR and 5 min cooldown at 60–70% of peak HR. Total exercise time was 47 mins.
Jaureguizar et al., 2016	Two-armed RCT. Patients with CAD were randomised to 8 weeks of HIIT or MICT. Effects of exercise on mental wellbeing was measured.	HIIT=36; MICT=36	Patients who were diagnosed with stable New York Heart Association functional class I or II CAD with angina pectoris or myocardial infarction and no heart failure. Mean age was 58± 11 years in both groups, 78% and 92% were male in HIIT and MICT groups respectively, mean BMI was 29.6± 4.4 and 29.5± 4.1 kg/m2 in both groups respectively.	Bicycle based HIIT three times weekly for 8 weeks. HIIT consisted of 20-sec repetitions at 50% of the maximum load followed by 40-sec recovery periods at 10%. Each session included a warm and cool-down, session duration was 40 min. The exercise workload applied at the peak intervals was 104.5% +/- 22.2% (first month) and 134.5% +/- 29.7% (second month) of the maximum load.	Bicycle based MICT three times weekly for 8 weeks. Patients cycled continuously at a HR below the HR at VT1 during the first month and at VT1 plus 10% in the second month. Session duration was 40 min. The intensity of exercise in the first month was 64.2% +/- 8.5% of O2peak and 69.5% +/- 8.7% in the second month.
Karlsen et al., 2017	Two-armed RCT. Obese subjects with moderate-to-severe obstructive sleep apnoea (OSA) were randomised to 12 weeks of HIIT or a non-active control. Effects of exercise on sleep quality were measured.	HIIT=15; Non-active control=15	Participants with moderate-to-severe OSA, a BM ≥30 kg/m2, and an apnoea–hypopnea index score ≥15. Mean age was 52.5±7.4 and 49.9±9.7 years in HIIT and control groups respectively, 31% and 20% were female in each group respectively and mean BMI was 38.5±7.0 and 37.7±4.8 kg/m2 respectively.	Two HIIT sessions per week for 12 weeks. HIIT consisted of 4×4 min of treadmill walking or running at 90%–95% of HRmax interspersed with 3 min rest periods at ∼70% of HRmax. Each training session started with 10 min warm-up at ∼70% of HRmax.	The control group was encouraged to continue their normal lifestyle.

Ellingsen et al., 2017	Three-armed RCT. Patients with HF with reduced ejection fraction were randomised to 12 weeks of HIIT, MICT or recommendation of regular exercise (RRE). Effects of exercise on anxiety, depression, positive and negative affect was measured after the intervention and at 52-week follow-up.	HIIT=82; MICT=73; RRE=76	Eligible patients with symptomatic, stable, pharmacologically optimally treated chronic heart failure. Median age was 60 years (IQR 53–70 yrs); 19% were women. Median left ventricular ejection fraction at baseline was 29% (IQR, 24%–34%). Mean BMI was 27.6, 27.5 and 27.7 in HIIT, MICT and RRE groups.	Three HIIT sessions each week for 12 weeks on a treadmill or bicycle. HIIT consisted of four 4-min intervals at 90-95% of HRmax separated by 3-min active recovery periods of moderate intensity. HIIT sessions lasted 38 min including warm-up and cool-down at moderate intensity.	Three MICT sessions each week for 12 weeks on a treadmill or bicycle. MCT was conducted at 60-70% of HRmax for 47 mins. Patients randomized to RRE were advised to exercise at home and attended a session of moderate-intensity training at 50-70% of HRmax every 3 weeks.
Lee et al., 2019	Two-armed RCT. Women with CAD were randomised to 24 weeks of HIIT or MICT. Effects of exercise on depressive symptoms was measured.	HIIT=17, MICT=14	Thirty-one postmenopausal female CAD patients (≥50 years of age). All had documented CAD, left ventricular ejection fraction >35%. Mean age was 69.6± 5.9 and 69.3± 9.9 years in MICT and HIIT groups respectively and mean BMI was 28.0± 5.7 and 26.6± 4.2 kg/m2 respectively.	One, supervised HIIT session per week and four additional unsupervised home-exercise sessions per week. HIIT began with 6 weeks, 'run-in' period where patients performed usual care which was identical to the MICT group. In the seventh week of the study, patients began performing HIIT 3 days per week and two usual care MICT sessions per week. HIIT consisted of a 5-10min warm-up, four 4-min intervals of walking/jogging at 90%–95% of Peak HR, interspersed with 3 min of active recovery performed at ~50%–70% of Peak HR; and a 5min cool-down.	One supervised MICT session per week and four additional unsupervised home-exercise sessions per week. MICT consisted of usual care sessions of either walking or jogging on the track or treadmill for approximately 30–40 min, performed at 60–80% of V̇O2peak, in addition to a warm-up and cool down period.
Batrakoulis e t al., 2019	Three armed RCT. Inactive obese women were randomised to 10 months of HIIT, 5 months of HIIT and 5 months of detraining or a non-active control. Effects of exercise on psychosocial distress was measured.	10 months HIIT=14; 5 months HIIT + 5 months detraining=1 4; Non-active control=21	Premenopausal women aged 30-45 years who were physically inactive (sedentary for ≥6 months before the study, daily step count <7,000, and <30 min/day of moderate-to-vigorous PA), overweight or obese (BMI of 25.1–34.9 and body fat ≥32%). (HIIT: age 36.4±5, BMI 28.2±2.8, Con: age 36±4.2, BMI 29.6±3).	HIIT performed three times/week consisted of a hybrid format including a mix of endurance training (ET), core strengthening and RT elements, performed in a circuit fashion using 20–40 sec of effort and recovery interval and a 10-min warm-up and 5-min cool-down. There was a rise in intensity. Mean HR as % of HRmax reached 72.5% in weeks 1-7, 79.7%, in weeks 8-14, 87.0% in weeks 15-20, 87.5% in week 21. During the first 5 months, both HIIT groups performed HIIT. In months 6–10, one group continued the exercise protocol whereas the other abstained from training.	Control participants did not participate in training.
Yardley et al., 2017	Follow-up of a two armed RCT. Heart transplant (HTx) recipients were randomized to a one-year HIIT program or usual care. Effects of exercise on symptoms of anxiety and	HIIT=26; Non-active control=26	Patients with clinically stable HTx and aged >18 years; 1–8 years after HTx and receiving optimal medical treatment. Mean age was 48 ±17 and 53 ±14 years in HIIT and control groups respectively, 67% and 71% were male in each group and time	HIIT was performed on a treadmill. HIIT was divided into three 8-week periods of exercise with three sessions every week. Additionally, the patients were encouraged to continue any physical activity on their own. The HIIT-sessions consisted of a 10 min warm-up, followed by four 4 min exercise bouts at 85–95% of HRmax, interposed by 3 min active recovery periods corresponding to ∼11–13 on the Borg.	The control group received basic, general care given to all HTx patients.

	depression were measured at 5-year follow-up.		after HTx was 4.3 ± 2.4 and 3.8 ± 2.1 in each group respectively and mean BMI was 27.73± 5.73 and 28.9± 6.74.		
Leahy et al., 2018	Two armed feasibility RCT. Adolescents were randomised to 14 weeks of HIIT or a wait-list control. Effects of exercise on psychological distress and subjective stress were measured.	HIIT=38; Waist-list control=30	Sixty-eight participants (37 males, 31 females) from Grade 11 from two consenting secondary schools. Mean age was 16.2±0.4 in each group and mean BMI was 21.7±3.1 and 22.8± 2.8 in HIIT and control groups.	Three HIIT sessions per week for 14 weeks. HIIT sessions comprised of a 2-min warm-up, followed by 8-16 min of HIIT, and a 2-min cool-down. HIIT workouts included a combination of aerobic- (e.g., shuttle runs) and resistance- (e.g., push-ups) exercises. Participants were able to select from the following workouts: Gym HIIT, Sport HIIT, Class HIIT, Dance HIIT, Combat HIIT and Brain HIIT. HIIT consists of 30 second bouts at >85% HRmax interspersed with 30 seconds of rest.	The wait-list control group participated in usual school activities and received the intervention following the posttest assessment period.
Stavrinou et al., 2018	Three armed RCT. Healthy inactive adults were randomised to HIIT twice weekly for 8 weeks, HIIT thrice weekly for 8 weeks or a non-active control. Effects of exercise on mental wellbeing was measured.	HIIT-2=14; HIIT=3= 13; Non-active control=8	Inactive healthy adults, none were smokers and none had any diagnosed metabolic or cardiovascular diseases. (HIIT-3: age 31.9±2.4, BMI 21.7±3.1; HIIT-2: age 31.5±3.5, BMI 23.6±4.6; Con: age 31.7±0.8, BMI 23.4±3.1).	Participants in both HIIT groups undertook a 3-week familiarization period consisting of three moderate-to-high intensity interval training sessions. Afterwards, the HIIT-2 and HIIT-3 intervention groups trained two and three times per week respectively, on a cycle ergomteres, for 8 weeks. Each HIIT session consisted of a 3-min warm-up, 10 x 60-s cycling intervals at ~83 % of Wpeak interspersed with 60 s of low intensity exercise at~30 % Wpeak at 50 rpm, and 2-min cool-down.	Participants in the control group continued their usual daily activities.
Jimenez-Garcia et al., 2019	Three armed RCT. Older adults were randomised to 12 weeks of HIIT, moderate intensity interval training (MIIT) or a non-active control. Effects of exercise on mental wellbeing was measured.	HIIT=28; MIIT=27; Non-active control= 27	Community-dwelling older adults aged over 60 years, none had psychiatric, neurological or systemic diseases. (HIIT: age 68.23±2.97, BMI 29.82±3.17; MIIT: age 68.75±5.98, BMI 30.33±3.07; Con: age 68.52±6.33, BMI 32.13±2.3).	Suspension training (TRX) HIIT twice a week for 12 weeks. Before the intervention, participants of the HIIT and MIIT groups performed a 4-week familiarization period consisting of 2 session/week with video demonstrations and 6 repetition practice trial. Afterwards, HIIT consisted of a 10-min warm-up, main squat activity with suspension system divided into four 4-min intervals at an intensity of 90–95% of HRmax interspersed with 3-min active rest intervals at 50–70% (25min), and a 10-min cool-down.	The MIIT group received 2 sessions per week of TRX for 12 weeks after the familiarization period. MIIT participants followed the same protocol that HIIT group, but intensities were lower: 70% and 50% of HRmax for the main squat activity and the active rest intervals respectively. The non-active control group maintained their daily lifestyle and received a series of guidelines to encourage physical activity.

Cheema et al., 2015	Two armed pilot RCT. Adults with abdominal obesity were randomised to 12 weeks of boxing HIIT or MICT. Effects of exercise on mental wellbeing was measured.	HIIT=6; MICT=6	All participants were aged >18 years; had a BMI >25 kg/m2; had waist circumference >94 cm in men and >80 cm in women. The cohort ranged in age from 19 to 72 years (mean age 43± 19 and 36± 15 years in HIIT and MICT groups respectively, BMI ranged from 26.4 to 40.3 kg/m2 (HIIT mean: 32±5.9, MICT 30.8±2.6).	HIIT boxing four times per week for 12 weeks. Each session lasted for 50 min and included a 5 min warm-up followed by three 2-min intervals (at 86-89% HRmax) of each of the following five exercises: (1) heavy bag, (2) focus mitts, (3) circular body bag, (4) footwork drills, and (4) skipping interspersed with 1 min of rest between intervals.	Four, 50-min sessions of brisk walking per week for 12 weeks. Participants were instructed to begin each session with a 5-min gradual warm-up and walk as quickly as possible for the remainder of the session. Mean HR ranged from 64-77% of HRmax.
Koufaki et al., 2014	Two armed feasibility RCT. Patients With Chronic HF were randomised to 24 weeks of MICT or HIIT. Effects of exercise on mental wellbeing was measured.	HIIT=8; MICT=9	Adults over 18 years of age (3 women) with documented signs and symptoms of Chronic HF with an ejection fraction (EF) < 45% and in sinus rhythm. None had pacemakers, major surgery or myocardial infarction within the previous 8 weeks. (HIIT: age 59.8±7.4, BMI 28.9±4.7; MICT: age 59.7± 10.8, BMI 29.5±4.7).	Three bicycle based HIIT sessions per week for 24 weeks. HIIT consisted of 2 × 15 min bouts of cycling, comprising low intensity cycling phases of 1 min at 25–40 watts (equivalent to 20–30% of PPO) followed by high intensity cycling for 30s at 50% of the maximum workload (equivalent to ~100% of PPO).	Three bicycle based MICT sessions per week for 24 weeks. Patients cycled at 90% of their predetermined VT (corresponding to 40–60% of VO2peak). Exercise stimulus progressed from 3 separate bouts of cycling of 7–10 min in duration, to a single 40 min of continuous cycling bout by 5–6 months.
Svensson et al., 2017	Three armed RCT. People classified as obese were randomised to 16 weeks of HIIT, moderate intensity training (MIT) or a non-active control. Effects of exercise on mental wellbeing was measured.	HIIT=49; MIT=39; Non-active control=22	Healthy, inactive individuals with a BMI >35 kg/m2 and one or more risk factors for ailments such as type II diabetes, hypertonia and/or hyperlipidaemia. Mean age was 43.6± 8.3, 47± 10.3 and 47.4± 9.1 in HIIT, MIT and control groups respectively and mean BMI was 41.6± 5.2, 43.1± 7.6 and 44.7± 7.1 respectively.	Three one-hour HIIT sessions per week for 16 weeks. HIIT was carried out at 85-95% of HRmax. The training in both HIIT and MIT groups was performed with an interval length of 6 min for aerobic exercise using cycle ergometers, syncro machines, rowing machines or treadmills, and 2 min for strength-endurance exercise using arm, leg, and trunk machines. There was a 30-s pause in-between each bout.	The MIT group were supervised for 30 min, 3 times/week, and were also recommended to exercise an additional 3 times a week on their own, with a recommended intensity of 40–55% of HRmax, following the same regime as the HIIT group. The actual exercised intensities in the MIT supervised training session were 76–85% of HRmax. The non-active control group received no intervention.
Tew et al., 2017	Two armed feasibility RCT. Patients awaiting elective abdominal aortic aneurysm (AAA) repair were randomised to 4 weeks of HIIT or usual care. Effects of exercise on mental wellbeing was measured at end of intervention and 12 weeks post discharge.	HIIT=27; Usual care=26	Patients aged at least 18 years who had been listed for an open or endovascular repair of an infrarenal AAA with a diameter of 5·5–7·0 cm. Mean age was 74·6± 5·5 and 74·9± 6·4 in HIIT and control groups respectively, BMI was 26·5± 4·1 and 26·8± 3·4 respectively and AAA diameter was 6·0± 0·4 and 5·8± 0·4 respectively.	Three bicycle based HIIT sessions each week for 4 weeks. Each of the first three sessions comprised a 10-min warm-up, eight 2-min intervals of high-intensity cycling (performed at the power output corresponding to anaerobic threshold on a baseline cardiopulmonary exercise test) interspersed with 2-min rest periods of unloaded cycling, and a 5-min cool-down. In subsequent sessions, participants had the choice of performing eight 2-min or four 4-min high intensity intervals (power output guided by participants' ratings of perceived exertion (RPE) (RPE-L or RPE-C of 5 and 7 respectively).	Usual care comprised evidence-based medical optimization.

Stensvold et al., 2010	Four-armed RCT. People with MetS were randomised to 12 weeks of HIIT, strength training (ST), HIIT + ST or a non-active control. Effects of exercise on mental wellbeing was measured.	HIIT=11; ST=11; HIIT + ST=10; Non-active control=11	Forty-three patients (26 men and 17 women) with MetS (central obesity, elevated SBP and DBP, high plasma glucose and TG levels, and low levels of HDL-C). None had unstable angina pectoris or uncompensated heart failure. (HIIT: age 49.9±10.1, BMI 31.3±4.3; ST: age 50.9±10.4, BMI 32.2±4.2, Con: age 47.3±10.2, BMI 31.9±4.1; HIIT+ ST: age 52.9±10.4, BMI 30.3±3.5).	Three treadmill based HIIT sessions each week for 12 weeks. HIIT included a 10-min warm-up at 70% of HRpeak, four intervals of 4 min at 90 –95% of HRpeak interspersed with 3-mins of active recovery at 70% of HRpeak, a 5-min cooldown period. Total exercise time was 43 min.	ST was performed three times per week for 12 weeks for 40-50min. During the first week of training, the resistance was set at 60% of each individual's 1-RM. After the first week, the resistance training program consisted of three sets at 80% of 1-RM. ST included low row, bench press, hack lift, lateral raise exercise, triceps pulldown, biceps curl, and low-row and core exercises. The HIIT + ST group performed HIIT twice a week and ST once a week. The non-active control group was instructed not to change their dietary patterns or physical activity levels during the study period.
Lunt et al., 2014	Three-armed feasibility RCT. Overweight inactive adults were randomised to 12 weeks of aerobic interval training (AIT), maximal volitional interval training (MVIT) or an active control group undertaking walking-based exercise (WALK). Effects of exercise on mental wellbeing was measured.	AIT=16; MVIT=16; WALK=17	Adults aged 35–60 years, with a BMI 28–40 kg/m2, and partaking in less than 2x30 minutes of moderate intensity physical activity each week, with no major health problems. (AIT: age 48.2±5.6, BMI 32.1±3.1; MVIT: age 50.3±8, BMI 32.4±2.9; WALK: age 46.3±5.4, BMI 32.7±3.4).	Three sessions of AIT or MVIT per week for 12 weeks. AIT involved 4 min bouts (85–95% HRmax) of fast walking or jogging, interspersed by 3 min walking bouts. MVIT involved 30 sec repetitions of volitional maximal 'all-out' walking or jogging up a slope, interspersed with recovery periods of 4 min walking. Initially participants undertook 3 repetitions but aimed for up to 6 repetitions of 45 seconds of maximal volitional activity. Session length was 40min for AIT and 24.5- 40min for MVIT including a 10min warm-up and 5min cool down.	Three sessions of WALK per week for 12 weeks. WALK was a walking-based prescription of a 33 min walk which aimed to achieve a HR of 65–75% HRmax. Total session length was 48 min including a 10min warm-up and 5min cool down.

Key terms: BMI= Body mass index; Con = control; HIIT= high intensity interval training, HRmax= maximum heart rate; HRpeak= heart rate peak; HTx= heart transplant recipients; MICT= moderate intensity continuous training; SIT= sprint interval training; RCT= randomised controlled trial; QoL= quality of life; Wpeak= peak workload

Table Two- Mental health findings, adherence and adverse events

Study	Outcome Measurement Tool	Is Mental health a primary or secondary analysis?	Outcomes	Adverse Events	Attendance	Conclusions
Lucibello et al., 2020	21-item Beck Anxiety Inventory (BAI); 21-item Beck Depression	Primary outcome.	Anxiety and depressive symptoms decreased over the course of the intervention for both HIIT and control groups [main effect of time: anxiety: $p < .001$, $\eta p2 = 0.51$; depression: $p < .001$, $\eta p2 = 0.41$]. There was no group by time interaction ($p > .05$).	Adverse events not reported.	Forty-six participants completed the study (HIIT=25; control=21). HIIT adherence was 99.7%, with 23 of 25 participants attending all 27 sessions.	Nine weeks of HIIT may not alter indicators of anxiety and depression in young adults.

	Inventory-II (BDI-II)					
Nytroen et al., 2019	Hospital Anxiety and Depression Scale (HADS); Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Anxiety and Depression scores were low in both groups at both time points. There was no significant difference in anxiety and depression scores nor mental wellbeing between the groups and no group by time interaction (Anxiety: MD -0.4 [95%CI -1.8; 0.9], p=0.529; Depression: MD -0.2 [95%CI -1.4; 1.0], p=0.741; MCS: MD 3 [95%CI -2; 9], p=0.170).	No serious exercise-related adverse event occurred in either group. The intervention could not be completed at 100% every week by all participants because some inactive periods occurred as a result of lung infections, cardiac events, musculoskeletal problems, hospitalizations related to outstanding conditions.	Eighty-one participants were tested at baseline, and 3 dropped out during the intervention (78 patients completed the 1-year follow-up: 37 in the HIIT group and 41 in the MICT group). Of the initially planned sessions, 81% were accomplished in both groups.	Nine months of HIIT may not alter indicators of anxiety, depression and mental wellbeing in HTx recipients.
Rolid et al., 2020 (3-year follow-up of Nytroen et al., 2019)	Hospital Anxiety and Depression Scale (HADS); Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Mental health scores remained high and stable during the 3-year follow-up (HIIT baseline: median [IQR] 59 (13), 3-year: 56 (10); MICT baseline: 56 (10), 3-year: 57 (12). The between-group differences from baseline to the 3-year follow-up for both HADS-A and HADS-D were not significant (HADS-A: HIIT baseline: median [IQR] 2.0 (4.0), 3-year 4.0 (4.0); MICT baseline: 3.0 (3.0), 3-year 3.0 (5.0); HADS-D: HIIT baseline: 2.0 (4.0), 3-year 2.0 (5.0), MICT baseline: 1.0 (1.3), 3-year 1.0 (3.0)).	No serious exercise-related adverse event occurred in either group.	Twenty-eight HIIT participants and 34 MICT participants completed the 3 year-follow-up.	Nine months of HIIT may not alter indicators of anxiety, depression and mental wellbeing in Hxz recipients at 3-year follow-up.
Allen et al., 2018	Centers for Epidemiologic Study – Depression Scale (CESD); Positive and Negative Affect Scale (PANAS); Perceived Stress Scale (PSS)	Secondary outcome.	There was no change in depression, perceived stress or negative affect over the course of the intervention and no between-group differences (depression: HIIT mean change +0.50 ± 1.09; CA +4.00 ± 3.05; Con +1.50 ± 0.93, p-value2=0.6307; Negative Affect: HIIT mean change +0.63 ± 1.08; CA +1.60 ± 1.78, Con −0.10 ± 1.68, p-value2=0.7160; Stress: HIIT mean change +2.75 ± 1.16; CA +1.60 ± 2.94; Con +2.90 ± 2.10 p-value2=0.5889). There were significant differences regarding change in positive affect between groups (HIIT mean change +2.88 ± 1.39; CA: +4.40 ± 2.06; Con −2.70 ± 1.56; p-value2=0.0197).	A total of 20 adverse events were reported of which 19 were unrelated to the study (cold/flu), with one deemed possibly related (low back pain in a CA participant).	Seven participants completed the HIIT intervention, 5 completed the CA intervention and 10 remained in the control group at 12-weeks. Approximately half of the personal trainer sessions were attended in both the HIIT (52±9%) and CA (49±13%) groups.	Twelve weeks of exercise may improve positive affect in adult smokers, although greater effects were seen following CA compared to HIIT. No changes in depression, stress or negative affect were observed.

May et al., 2019	enter for Epidemiologic Studies Depression Scale (CES-D); State-Trait Anxiety Inventory (STAI)	Secondary outcome.	There was no pre-post intervention by experimental condition interactions for depressive or anxiety scores (Depression: HIIT pre 16.94 ± 1.02, post 15.38 ± 0.91; HRVCB pre 14.46 ± 1.01, post 13.00 ± 1.13; Con pre 16.01 ± 1.07, post 16.45 ± 1.01; Anxiety: HIIT pre 17.38 ± 1.33, post 16.63 ± 1.03, HRVCB pre 17.39 ± 1.48, post 16.54 ± 1.14; Con pre 17.22 ± 1.34, 16.02 ± 1.11).	Adverse events not reported.	Attendance not reported.	Four weeks of HIIT may not elicit changes in depression and anxiety in college students.
Krawcyk et al., 2019	Major Depression Inventory (MDI); World Health Organization-Five Well-being Index (WHO-5) questionnaire (mental wellbeing)	Secondary outcome.	No change was detected between groups for depression nor mental well-being (WB: MD −0.6 [95%CI: −7.7; 6.5, p=0.86; depression HIIT median [IQR] pre: 5 [1;10], post 6 [3;13]; Con pre: 9 [4;12], post 7 [4;15], p=0.086).	No adverse events related to the intervention were recorded.	Thirty-one participants completed the HIIT intervention and 32 completed usual care follow-up.	Twelve weeks of HIIT may not elicit changes in depression and mental wellbeing in patients with Lacunar stroke.
Adams et al., 2018	Center for Epidemiologic Studies Depression Scale 10-item inventory; Spielberger State Anxiety Scale 10-item inventory; Pittsburgh Sleep Quality Index; Perceived Stress Scale 14-item inventory; Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Compared to usual care, HIIT did not lead to any significant improvements in depression, anxiety, stress, or sleep quality (depression: SMD−0.2 [95%CI:−1.6;1.3], p=0.81; anxiety: SMD −1.6 [95%CI:−3.9; 0.8], p=0.19, stress: SMD −1.7 [95%CI:−4.4; 1.0], p=0.22, sleep: −0.6 [95%CI:−1.4; 0.2], p=0.15). Compared to UC, HIIT significantly improved MCS (SMD: 3.9 [95%CI: 0.3; 7.5], p = 0.034). Compared to usual care, HIIT did not lead to any significant improvements at 3-month follow-up (depression: SMD-1.2 [95%CI:-2.9; 0.5), p=0.17; anxiety: SMD: -1.3 [95%CI:-3.5; 0.9], p=0.25; stress -2.4 [95%CI:-5.4; 0.7], p=0.12; sleep: SMD-0.7 [95%CI: -1.8; 0.4], p=0.19; MCS: SMD: 1.3 [95%CI:-2.5; 5.0], p=0.51).	No exercise-related serious adverse events were reported or observed.	100% of participants randomised to HIIT and 93% randomised to usual care completed the intervention, 83% and 82% completed the 3-month follow-up respectively. Exercise attendance was 99%.	Twelve weeks of HIIT may led to significant improvements in mental wellbeing, but not depression, anxiety, stress or sleep quality in testicular cancer survivors.
Egegaard et al., 2019	Hospital Anxiety and Depression Scale (HADS)	Secondary outcome.	Results from the HADS Scale showed no significant within or between group differences from baseline to post intervention (anxiety: MD 0.33 [95%CI:−2.99; 3.64], p=0.829; depression: MD 0.64 [95%CI:−2.62; 3.91], p=0.667).	Two patients were hospitalized due to chemotherapy adverse events. No adverse events or any	There were no dropouts. The overall attendance rate to exercise was 90.0% (range: 53.8–100.0%).	Seven weeks of HIIT did not led to changes in depression nor anxiety in a pilot study

				unexpected reactions were observed during exercise sessions.		with lung cancer patients.
Eather et al., 2019	Perceived Stress Scale (PSS); Spielberger State-Trait Anxiety Inventory (STAI)	Secondary outcome.	No significant within or between group differences from baseline to post intervention were observed for perceived stress nor anxiety (stress: MD -1.1 [95%CI: -4.2;-2.0], p=0.476, d=0.20; anxiety: MD -0.2 [95%CI:-1.5;-1.1], p=0.709, d=0.02).	Adverse events not reported.	Retention was 75.5% and average attendance for HIIT sessions was 66.7% (54.5% of participants attended 2+ sessions/week).	Eight weeks of HIIT did not led to improvements in anxiety or perceived stress in university students.
Abdelhalem et al., 2018	RAND 36-Item Health Survey mental (emotional) component	Secondary outcome.	The HIIT group showed better improvement in emotional wellbeing than the MICT group (MICT pre:273.00 ± 31.97, Post: 377.00 ± 31.30; HIIT pre: 283.00 ± 20.80, post: 398.00 ± 15.76, t=−2.680, p=0.011).	No serious adverse events occurred during the study.	All the patients were compliant to the program with no missing sessions or dropouts.	Both HIIT and MICT lead to improvements in emotional wellbeing in patients with CAD, although greater improvements are seen after HIIT.
Mason et al., 2018	Anxiety Sensitivity Index-3 (ASI-3); Distress Tolerance Scale (DTS)	Primary outcome.	Compared to control, both exercise groups reported significant reductions in total ASI-3 scores. Medium effects were found for changes in both SIT, d= −0.35 (95% CI [-0.70, −0.07]), and MICT, d= −0.45 (95% CI [-0.80, −0.16]), although changes in anxiety were not significantly different between SIT and MICT groups (d= −0.10 (95% CI [-0.44, 0.25]). Neither SIT nor MICT had significant effects on anxiety at 3 and 7 day follow-up compared to control. Neither exercise or control had a significant effect on distress scores. SIT was associated with a non-significant reduction in DTS scores (d= −0.15 (95% CI [-0.44, 0.11]), while MICT was associated with a non-significant reduction in DTS scores and a trivial effect, d= −0.04 (95% CI [-0.31, 0.22]).	Adverse events not reported.	82% of participants completed the first follow-up and 80% completed the second follow-up.	An acute bout of SIT and MICT may led to immediate reductions in anxiety compared to a non-active control.
Saanijoki et al., 2017	Perceived Stress Questionnaire (PSQ); Positive and Negative Affect Schedule (PANAS)	Primary outcome.	There was no group X time interaction for neither stress, positive nor negative affect (Stress: F=1.03, p=0.32, positive affect: F=2.64, p= 0.12, negative affect: F=0.09, p=0.77).	One participant experienced a migraine during the first SIT session, it is not clear if this was an exercise-related adverse event.	Two subjects from the SIT group dropped out during the trial, one because of claustrophobic feelings during baseline testing and one due to migraine during the first SIT session. Three subjects from the MICT group discontinued the trial due to personal reasons. 11 subjects in SIT and 10 subjects in MICT group finalized all their assigned training sessions.	Two weeks of HIIT did not led to improvements in stress nor affect in insulin resistant adults.

Connolly et al., 2017	14-item Warwick-Edinburgh Mental Well-being Scale (WEMWBS)	Secondary outcome.	WEMWBS scores increased following CT (pre: 49±9 , post: 52±7, P < 0.05) but not HIIT (pre:52±9, post: 54±7) or CON (pre: 42±8, post: 42±6). There was no difference in WEMWBS between training groups (p=0.198, Partial η2= 0.074).	No study related injuries were reported.	One participant from HIIT and CT withdrew from the study due to non-study related injuries and one participant from CON withdrew due a substantial increase in physical activity. Both HIIT and CT groups completed a total of 35±1 training sessions (2.9±0.1 sessions per week).	12 weeks of HIIT did not lead to improvements in mental wellbeing in inactive women.
Sosner et al., 2019	"Profile Of Mood States" (POMS) test	Secondary outcome.	Whereas MICT did not change any dimension of mood, HIITdryland moderately improved fatigue (−4.25 ± 6.36, g = −0.32; P = 0.04) and the energy index (+6.42 ± 8.11, g = 0.31; P = 0.02), while HIITimmersed resulted in a moderate decrease in anxiety (−3.18 ± 4.27, g = −0.56; P = 0.04) and confusion (−2.66 ± 2.17, g = −0.58; P = 0.004).	Adverse events not reported.	Eleven, twelve and ten participants completed MICT, HIITdryland or HIITimmersed conditions respectively.	Two weeks of HIIT may lead to improvements in mood states in hypertensive adults.
Costigan et al., 2016	Psychological well-being: 8-item Flourishing Scale; Kessler Psychological Distress Scale (K10)	Primary outcome.	Small intervention effects for well-being were found for both HIIT conditions (HIIT: 2.81, 95% CI = −2.06 to 7.68; d = 0.34, 95% CI = −3.84 to 3.32; HIIT-RT: 2.96, 95% CI = −1.82 to 7.75; d = 0.36, 95% CI = −3.86 to 3.13), although these changes were not significantly different from the control group (SMD: 2.96 [95%CI: -1.82; 7.75], p=0.219). There were no intervention effects for psychological distress for either HIIT groups, compared to control (SMD:-0.19 [95%CI: -2.97; 2.59}, p=0.891].	Adverse events not reported.	Attendance not reported.	While results were not significant, HIIT may improve mental health markers in adolescents.
Dunne et al., 2016	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Compared to standard care, HIIT was associated with improvements in overall SF-36 mental health (HIIT: pre: 66(22), post: 77(19), change: +11 [95%CI: 5, 18), Con: pre:72(19), post:72(23), change: 0 [95%CI:−9, 9], P =0.037) scores.	There were no reported adverse outcomes of the exercise intervention.	Nineteen patients completed HIIT and 15 patients completed standard care follow-up. One HIIT patient was lost after developing an unrelated malignancy. Of HIIT patients, 18 of 19 completed 100% of the exercise sessions, with one patient missing two sessions due to primary tumour care.	Four weeks of HIIT may lead to improvements in menatl wellbeing in patients undergoing CRLM.
Rizk et al., 2015	Positive and Negative Affect Schedule (PANAS); global vigour and affect (GVA) instrument (global affect)	Primary outcome.	PANAS results revealed a significant time effect from rest to post-exercise for positive (F = 9.74, p < 0.001) and negative (F = 6.43, p = 0.005) affect scores, but no time by intervention group interaction. GVA results indicated a significant time effect from rest to post-exercise for both global affect (F = 8.47, p < 0.001) and vigour (F = 9.79, p < 0.001) but time by intervention group interaction observed a significant increase in vigour following CTHI and CTVT, but not following HIIT (p < 0.05).	Adverse events not reported.	Mean attendance was not significantly different between groups (CTHI: 70.1 ± 32.9% (range: 49.3–91.0); CTVT: 81.9 ± 17.2% (range: 71.0–92.9); IT: 73.3 ± 28.6% (range: 52.9–93.8), F = 0.61, p = 0.55).	An acute bout of HIIT may lead to improvements in positive and negative affect in patients with COPD, although improvements are not disimilar to those seen following an acute

						bout of CTHI or CTVT.
Pedersen et al., 2015	Hospital Anxiety and Depression Scale (HADS)	Secondary outcome.	A decrease was obtained in the HADS-A score in both groups with no between group differences (HIIT change: -1.0 [95%CI:-1.9; -0.04]; LED change: -0.6 [-1.2; -0.05]) while HADS-D remained unchanged (HIIT change: -0.4 [95%CI: -1.1; 0.3]; LED change: -0.2 [95%CI: -1.1; 0.7]).	No serious adverse events were seen related to either intervention. Side effects to LED were mild (dizziness (n = 10), headaches (n = 9), obstipation (n = 9) and fatigue (n = 7)).	Twenty-six (74%) HIIT and 29 (83%) LED participants completed intervention per protocol.	12 weeks of HIIT may be associated with a reduction in anxiety and no change in depressive symptoms in patients with CAD, although improvements seen are similar when compared to LED.
Saanijoki et al., 2015	Perceived Stress Questionnaire (PSQ), The Positive and Negative Affect Schedule (PANAS)	Primary outcome.	HIIT versus MIT exercise acutely increased perceived stress (group X time interaction F=8.69, p=0.007) and decreased positive affect (F=4.33, p=0.049). Participants in the HIT group experienced more negative affect than the MICT group (F=5.84, p=0.024).	Adverse events not reported.	During the intervention, one subject from both groups dropped out; thus, 26 subjects completed the study. All six exercise sessions were performed by all participants except one MIT participant who performed only four exercise sessions.	HIT increases experience of negative emotions in sedentary adults.
Chrysohoou et al., 2014	Zung Depression Rating Scale (ZDRS)	Secondary outcome.	No between group differences were observed regarding depression status of patients; however, ZDRS scores was significantly lower after intervention in the exercise group (P = 0.005), while they remained similar in the control group (P = 0.19) (HIIT: pre=37 ± 8, post=30 ± 6; Con: pre=37 ± 8, post=41 ± 10, p=0.54).	No serious adverse events related to exercise were observed.	Thirty-three participants from the HIIT group completed the intervention and were analysed, 39 participants remained in the non-active control for analysis.	Twelve weeks of HIIT may possibly improve depressive symptoms in patients with CHF, although more research is needed.
Fu et al., 2013	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	HIIT significantly increased the subclass scores of the mental (43.3 to 51.3) dimension in SF-36. However, MICT and non-active control scores remained unchanged for SF-36 mental components.	Adverse events not reported.	The rates of compliance with the HIIT, MICT, and control subjects were 93.3%, 86.7%, and 86.7%, respectively.	Twelve weeks of HIIT may improve mental wellbeing more that MICT and non-active controls in patients with HF.

Terada et al., 2013	Subjective exercise experiences scale (SEES), a 12-item, 7-point Likert scale to assess positive and negative feeling states: positive well-being, psychological distress, and fatigue	Secondary outcome.	Changes in positive well being, psychological distress and fatigue were not significant. There were no differences between HIIT and MICT (HIIT: psychological wellbeing pre: 5.5±1.0, post: 5.6±1.0; psychological distress pre: 1.9±0.9, post: 1.2±0.2; fatigue pre: 2.5±0.9, post: 2.6±1.6; MICT: psychological wellbeing pre: 5.4±1.2, post: 6.5±0.5; psychological distress pre: 2.1±1.3, post: 1.1±0.2; fatigue pre: 3.2±1.7, post:1.9±1.0).	Adverse events not reported.	No participants were lost to follow-up. Both HIIT and MICT groups had similar exercise adherence (97.2 ± 2.7 and 97.3 ± 3.7% of the eligible exercise sessions completed within HIIT and MICT conditions, respectively). Reasons for not attending sessions included: health issues, automobile troubles, and work.	HIIT did not significantly change well-being, although research with a larger sample size is warranted.
Freyssin et al., 2012	Hospital Anxiety and Depression Scale (HADS)	Secondary outcome.	The level of anxiety and depression was significantly improved by both HIIT and CT. This improvement was not significantly different between groups (HADS-D: HIIT= pre: 6.6±1.8, post:3.4±2.5, CT= pre: 7.3±2.3, post: 3.1±1.3, interaction effect p=0.501; HADS-A: HIIT= pre: 8.8±3.5, post: 6.5±3.1, CT= pre: 9.4±4.8, post: 6.7±3.8, interaction effect p=0.792).	No cardiac event and no major decompensation were observed.	The adherence to the training was 100% with no dropouts.	Both HIIT and CT may improve symptoms of anxiety and depression in patients with HF with no between group differences.
Christensen et al., 2012	Hospital Anxiety and Depression Scale (HADS); Mental Component Summary (MCS) of the Short Form-36 QoL scale	Primary outcome of this sub-study which is a secondary analysis of the main RCT.	A significant reduction in anxiety and depression was seen in the HIIT group but not the control group (HADS-A: HIIT pre: 4.7±1.8, post: 1.8±1.2, Control pre: 3.2±1.6, post: 3.7±2.3, p=0.001; HADS-D: HIIT pre: 1.9±1.8, post: 0.7±0.8, Control pre: 1.8±1.1, post: 1.3±0.9, p=0.034). A significant effect on mental health was found (HIIT pre: 81.7±15.1, post: 90.0±8.1, Control pre: 86.3±7.9, post: 81.9±8.9, p=0.03).	No serious adverse events were observed. In one subject in the HIIT group, antihypertensive medication had to be reduced due to symptomatic hypotension.	All patients completed the intervention.	Eight weeks of HIIT may lead to greater improvements in anxiety and depressive symptoms in heart transplant recipients when compared to usual care.
Arnardottir et al., 2007	Hospital Anxiety and Depression Scale (HADS); Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Anxiety, depression and the mental health SF-36 subdomain were significantly improved by training in both groups (HADS-A: HIIT pre= 7.2 ±4.5, post= 5.2 ±4.3; MICT pre=6.9 ±3.5, post=4.8 ±3.9; HADS-D: HIIT pre=5.8 ±3.6), post= 4.3 ±3.6; MICT pre=5.4 ±3.2, post= 4.0 ±3.0; Mental health: HIIT pre=65.1 ±25.0, post=75.8 ±17.3; MICT pre: 69.1 ±9.5, post: 75.7 ±16.9). There was, however, no significant between-groups difference.	Twenty-four patients dropped out due to exacerbations, it is not clear if these were exercise-related.	One hundred patients were included, and 60 patients completed the programme. The reason for drop-out were exacerbations (n=24), lack of motivation or transport problems (n=10), other diseases (n=5) and family problems (n=1). The patients who completed the programme had a mean attendance rate of 29±3 of 32 possible sessions (no difference in attendance rate between the two training groups).	Sixteen weeks of both HIIT and MICT may improve mental health markers in patients with COPD.

Tew et al., 2019	Hospital Anxiety and Depression Scale (HADS); EQ 5D-5L anxiety/depression subscale	Secondary outcome.	No between group differences were observed regarding depression and anxiety (HADS-A: HIIT pre: 5.5 ±3.9, 3 month: 5.2 ±2.5, 6 month: 3.8 ±3.5; MICT pre:6.8 ±5.2, 3 month: 5.5 ±3.6, 6 month: 5.3 ±4.3; Con pre:7.7 ±4.3, 3 month: 6.2 ±4.2, 6 month: 5.5 ±3.6; HADS-D: HIIT pre:3.6 ±3.1, 3 month: 2.7 ±1.7, 6 month: 2.7 ±1.5; MICT pre:3.8 ±2.9, 3 month: 2.7 ±3.3, 6 month: 3.1 ±3.1; Con pre: 5.2 ±2.9, 3 month: 2.6 ±2.5, 6 month: 4.4 ±4.0). No between group differences were observed on the ED 5D-5L anxiety/depression subscale (HIIT pre: 1.54 ±0.78, 3 month: 1.42± 0.52, 6 month: 1.30± 0.48, MICT pre: 1.83± 0.72, 3 month: 1.58± 0.79, 6 month: 1.64± 0.51, Con pre: 1.82± 1.25, 3 month: 1.73± 0.79, 6 month: 2.0± 0.89).	There were three non-serious exercise-related adverse events, all related to HIIT. These included vomiting, dehydration and dizziness.	No participants formally withdrew, but one HIIT participant was lost to the 6-month follow-up. 62% and 75% of sessions were attended in HIIT and MICT groups respectively.	Twelve weeks of HIIT did not lead to superior improvements in anxiety and depression when compared to MICT and usual care in patients with Crohn's disease.
Choi et al., 2018	Hospital Anxiety and Depression Scale (HADS); PHQ-9 (Patient Health Questionnaire-9) (depression); Insomnia Severity Index (ISI)	Primary outcome.	Depression severity significantly decreased in the HIIT group compared to MICT (HADS-D: HIIT pre: 6.57± 2.24, post: 4.68± 2.81, MICT pre: 5.41± 3.29, post: 5.88± 3.67, p=0.025, PHQ-9: HIIT pre: 5.50± 3.95, post: 2.00± 2.00, MICT pre: 4.69± 4.32, post: 3.77± 3.70). Scores for anxiety and ISI for insomnia were not significantly different between the two groups (HADS-A: HIIT pre: 5.63± 3.04, post: 3.94± 2.85, MICT pre: 7.05±3.13, post: 4.76± 3.13, p=0.449; ISI: HIIT pre: 7.31± 5.77, post: 4.88± 5.59, MICT pre: 5.77± 3.78, post: 5.62± 3.68, p=0.150).	Two patients (one patient in each group) could not finish all 18 sessions because of ankle injury and occupational reasons. The remaining 44 patients completed 18 sessions of exercise without any adverse events.	23 patients in the HIIT group and 21 patients in the control group were analyzed in this study, they completed all 18 sessions.	18 sessions of HIIT may reduce depressive symptoms in patients with PI compared to MICT, although no effects on insomnia or anxiety were found.
Shepherd et al., 2015	Positive and Negative Affect Schedule (PANAS); 12 item Exercise-Induced Feeling Inventory (acute moods)	Secondary outcome.	There was a significant increase in positive affect as a result of the training ($p<0.01$; $\eta_p^2=.14$) and a significant decrease in negative affect in both groups ($p=0.05$; $\eta_p^2=.04$), there were no between-group differences and these gains were not sustained at 3-month follow-up. The effects of single exercise sessions on acute moods were assessed immediately after the training sessions in weeks 4 and 8 in both groups. There were no significant differences between the groups in either week 4 ($p>0.05$; $\eta_p^2=.08$) or week 8 ($p>0.05$; $\eta_p^2=.08$).	Adverse events not reported.	Adherence to the training intervention was significantly greater in the HIT group (83±14% prescribed sessions attended; n = 42) compared to the MICT group (61±15% of prescribed sessions attended; $t_{67.74} = 4.51$; $p<0.001$; n = 36). Overall, 4 and 8 people in the HIIT and MICT groups, respectively, were lost to follow-up at 10 weeks.	Ten weeks of HIIT and MICT may improve positive and negative affect within no differences between the two training regimes.

Puhan et al., 2006	Hospital Anxiety and Depression Scale (HADS)	Secondary outcome.	Improvements in depression and anxiety symptoms were similar across groups (HADS-D: HIIT mean difference from baseline (MD) 2.05 ±2.90, HICT MD 2.93 ±2.80, adjusted difference -0.58 [95%CI:-1.65; 0.49]; HASD-A: HIIT MD 1.95 ±2.22, HICT MD 2.25 ±3.09, adjusted difference -0.22 [-95% CI:-1.24; 0.80]).	Eleven patients did not complete the rehabilitation because of COPD exacerbations (3 HIIT, 2 HICT); musculoskeletal pain (2 HIIT, 1 HICT); and, in the HICT group only, chest pain, an accident, and lung cancer. It is not clear if any of these event were exercise related.	One patient in each group withdrew informed consent for unspecified reasons. Forty-three (89.6%) and 44 (88.0%) patients completed the inpatient rehabilitation in the HIIT and HICT groups, respectively.	Improvements in anxiety and depression are similar following both HIIT and HICT regimes of duration 3 weeks in patients with COPD.
Freese et al., 2014	30-item Profile of Mood States-Brief Questionnaire (POMS-B); Mental Component Summary (MCS) of the Short Form-36 QoL scale	Primary outcome.	In the full sample there were no differences in mental wellbeing between SIT and control groups (SIT: pre 71.7± 20.8, post 76.3± 16.8, Con: pre 74.8± 14.1, post 81.5± 9.6, ES-0.15). In participants with low baseline scores, participants in the SIT group experienced increases in mental wellbeing compared to control (SIT: pre 45.7± 17.7, post 65,7± 21.7, Con: pre 68.9± 19.8, post 76.7± 11.7, ES=0.77). For POMS-B data, there were no improvements for depression (ES=-0.27), anger (ES=-0.49), vigor (ES:-0.23), fatigue (ES:-0.27), confusion (ES=-0.43) and overall mood (ES=-0.40). However, in those that reported low mood at baseline (more than 1 SD from the normative value), SIT participants experienced greater improvements in tension (ES=-0.82), depression (ES=-1.7), anger (ES=-1.04), vigor (ES=0.87), fatigue (ES=-0.87), confusion (ES=-1.00) and overall mood (ES=-1.92), compared with control.	One patient experienced an injury that was non related to SIT.	14 withdrew or were excluded (for non compliance) during the intervention (8= control, 6=SIT). The remaining participants completed all 18 sessions.	Six weeks of SIT may led to positive improvements in mental wellbeing and mood, in women at risk for MetS, compared to non-active control, but only in those with below average scores at baseline.
Jurado-Fasoli et al., 2020	Pittsburgh Sleep Quality Index (PSQI); sleep time	Primary outcome.	All intervention groups showed a lower PSQI global score at follow-up compared to baseline (4.81 ± 3.85 vs 3.06 ± 2.57, P = .013; 5.47 ± 3.74 vs 3.53 ± 2.53, P = .003; 5.56 ± 2.73 vs 3.44 ± 2.58, P = .022; for PAR, HIIT and HIIT-EMS, respectively), while no differences were observed in the control group. There were no pairwise differences among groups in PSQI global score, total sleep time, sleep efficiency and wake after sleep onset (all P > .05).	No adverse events occurred during the exercise sessions.	Eleven participants were lost at follow-up (control group: 5; PAR: 3; HIIT: 2; HIIT-EMS: 1). Participants attended 98.7% of their exercise sessions.	Twelve weeks of PAR, HIIT and HIIT-EMS induced an improvement in subjective sleep quality in sedentary middle aged adults.
Bruseghini et al., 2020	sleep time	Secondary outcome.	Sleep time remained constant during the intervention and no between group interaction was found.	No injuries or health disorders occurred.	No dropouts were recorded during the study period.	Tweleve weeks of HIIT had no effect on sleep time in older adults.

Chou et al., 2019	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	HIIT significantly increased mental dimensions in SF-36, however mental health scores remained unchanged in the control group (HIIT 44.5 ± 4.5 to 52.1 ± 4.4, Con 46.3 ± 6.3 to 45.1 ± 6.7, P< 0.05).	Adverse events not reported.	The compliance rates with HIIT and GHC patients were 88.2% and 88.2%, respectively.	Twelve weeks of HIIT may improve mental wellbeing in patients with HF compared to general healthcare.
Hurst et al., 2019	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	There were possibly small beneficial effects for the SF-36 mental health domain in the HIT group compared with control (HIIT adjusted mean change 2.9 [90%CI: 0.7; 5.0), Con adjusted mean change 0.1 [90%CI:− 2.3; 2.1], between-group difference 2.9 [90%CI:− 0.1; 6.0]. MCS score increased in the HIIT group and decreased in the control group (HIIT: pre 55.12± 4.37, post 56.39± 3.50; MICT: pre 54.65± 4.82, post 53.17± 7.32).	No adverse events were reported during any of the exercise testing or training sessions.	No participants were lost to follow-up. All 18 participants completed the HIT intervention with an overall attendance of 99% (429 out of a possible 432 sessions).	Twelve weeks of HIIT may possibly improve mental health in older adults compared to a non-active control.
Mitropoulos et al., 2018	Anxiety and depression subcomponent of the EQ-5D-5 L QoL scale	Secondary outcome.	There were no significant differences between the groups neither at baseline nor after the completion of the exercise intervention in anxiety/ depression scores (HIIT-ACE pre:1.7 ± 0.8, post: 1.5 ± 0.7 . HIIT-CE pre: 1.6 ± 0.7, post: 1.2 ± 0.4, Con pre: 1.6 ± 0.7, post: 1.9 ± 1.4).	No exercise-related complications were reported.	Compliance to the 12-week exercise programme twice weekly was 92% and 88% for the HIIT-ACE and HIIT-CE group respectively, with one drop-out for each exercise group.	Twelve weeks of HIIT did not lead to superior improvements in anxiety and depression when compared to a non-active control in patients with SSc.
Malmo et al., 2016	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	HIIT participants experienced a significant improvement in mental health scores whereas the control group did not, however no between-groups difference was observed (HIIT pre: 50.6±8.4, change to follow-up: 3.6±6.5, Con pre: 50.5±10.8, change to follow-up: 1.4±7.2).	There were no major adverse events, but 2 patients experienced episodes of bursitis that required them to substitute bicycle exercise for treadmill exercise for a short period of time.	All patients completed the study period. As a result of intercurrent infections and musculoskeletal symptoms, 6 patients completed <80% (56%–78%) of the planned number of exercises.	Twelve weeks of HIIT lead to improvements in mental health in patients with AF whereas a non-active control did not.
Conraads et al., 2015	Mental Component Summary (MCS) of the Short Form-12 QoL scale	Secondary outcome.	Mental wellbeing improved significantly following both HIIT and ACT, with no group differences (HIIT pre: 36.1 ± 7.8, post 38.6 ± 7.7, ACT pre: 35.8 ± 7.5, post: 38.8 ± 5.7).	No adverse events were reported during the training sessions. One patient (ACT) had an acute myocardial infarction, >24 h after his last training session. Two other patients (both ACT) had a significant ST-depression during the exercise test at 6 weeks.	Twenty-six participants dropped-out of the intervention (HIIT=15, ACT=11). Compliance for the HIIT group was 35.7 ± 1.1 training sessions and for the ACT group 35.6 ± 1.5 training sessions.	Similar improvements in mental wellbeing were seen following 12 weeks of HIIT and 12 weeks of ACT in patients with CAD.

Pattyn et al., 2016 (1 year follow-up of Conraads et al., 2015)	Mental Component Summary (MCS) of the Short Form-12 QoL scale	Secondary outcome.	Mental wellbeing did not significantly change from end of intervention to 1-year follow-up (HIIT 12 weeks: 38.6± 7.6, 52 weeks: 39.4± 7.2, ACT 12 weeks: 38.7± 5.5, 52 weeks: 39.4± 5.8).	No adverse events were reported during the training sessions. Nine patients had a CAD related adverse event during the follow-up period (6 AIT, 3 ACT).	Twenty-six participants dropped-out of the intervention (HIIT=15, ACT=11) and a further 11 were lost to 1-year follow-up (HIIT=5, ACT=6).	Mental wellbeing remained stable from end of HIIT to 1 year follow-up in patients with CAD.
Jaureguizar et al., 2016	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Significant increases in mental health were observed in the HIIT group (HIIT pre: 41.0± 12.4, post: 49± 11, change 7.8± 14.0, p< 0.01, MICT pre: 48±12, post: 50±14).	No incidents or complications were recorded.	Adherence to the treatment sessions was 87.5% in the MCT group and 92% in the HIIT group.	A greater improvement in mental wellbeing was seen following 8 weeks of HIIT compared to MICT in patients with CAD.
Karlsen et al., 2017	Epworth sleepiness questionnaire (ESQ)	Primary outcome.	The Epworth self-reported sleepiness scale was significantly improved in the HIIT group compared with the control group (p≤0.05) at 12 weeks (HIIT pre: 10.0± 3.6, post: 7.3± 3.7; Con pre: 5.9± 4.3, post: 6.5± 5.0).	One participant in the HIIT group experienced back pain, it is not clear whether this was exercise-related.	Two patients in the HIIT group were lost to follow-up (1 due to back pain, 1 lack of time). Subjects in the HIIT group performed 21±3 supervised training sessions (88% compliance).	Twelve weeks of HIIT improved self-reported sleepiness in subjects with obese sleep apnoea compared to a non-active control.
Ellingsen et al., 2017	Hospital Anxiety and Depression Scale (HADS); Global Mood Scale (Positive and negative affect)	Secondary outcome.	There were no within-group or between-group differences in anxiety, depression or global mood at baseline, 12 weeks, or 52 weeks (HADS-A (median): HIIT: pre: 4.0 post: 4.0, 52 weeks 4.0, MICT: pre: 4.0, post: 4.0, 52 weeks: 4.0, RRE: pre: 5.0, post: 4.0, 52 weeks: 4.0; HADS-D (median): HIIT: pre: 4.0, post: 3.0, 52 weeks: 3.0; MICT: pre: 4.0, post: 3.0, 52 weeks: 4.0, RRE: pre: 3.0, post: 3.0, 52 weeks 4.0; positive affect (median): HIIT: pre: 21, post: 21, 52 weeks: 22; MICT: pre: 20, post: 23, 52 weeks: 21, RRE: pre: 21, post: 22, 52 weeks: 22; negative affect (median): HIIT: pre: 12, post: 9, 52 weeks: 12; MICT: pre: 12, post: 10, 52 weeks: 10, RRE: pre: 12, post: 9, 52 weeks: 12).	There were no significant differences between groups in number of SAEs (HIIT=9, MICT=6, RRE=5). Three events occurred within 3 hours of exercise in the HIIT group. One patient had ventricular arrhythmia with cardiac arrest and stopped the exercise program. Another patient had inappropriate implantable cardioverter-defibrillator discharge unrelated to arrhythmia during exercise. A third experienced dizziness.	Nine dropped out because of SAEs, and 7 withdrew or were lost to follow-up. Median adherence to supervised training was 35 (34–36) sessions of 36 possible in HIIT and MCT and 4 (3–4) of 4 in RRE.	Twelve weeks of HIIT had no effect on anxiety, depression, positive and negative affect in patients with HF.

Lee et al., 2019	Centre for Epidemiological Studies Depression Scale (CES-D)	Secondary outcome.	Both groups endorsed fewer depressive symptoms after the programme, with the HIIT group demonstrating a larger reduction in symptoms (HIIT: pre 11.5± 5.6, post 9.4± 5.1, MICT: pre 13.9 ±5.3, post 13.0 ±7.6), though there was not the power to detect statistical differences between groups.	The patients did not experience any serious adverse events following the exercise sessions. One woman had worsening osteoarthritis in her knee following HIIT which was a pre-existing condition.	59% of the women dropped out from the HIIT group, while 50% of the women dropped out from the MICT group. Patients completed 72.2%±15.2% of the five exercise sessions prescribed per week in the MICT group, and the HIIT group completed 76.2%±13.6% of their 5 weekly exercise sessions (p>0.05).	A 24 week HIIT regime may lead to greater improvements in depressive symptoms compared to usual care in women with CAD.
Batrakoulis et al., 2019	General Health Questionnaire (GHQ-12) (psychological distress); subjective vitality scale (SVS) (Eudemonic well-being)	Primary outcome.	In control subjects, GHQ-12 remained unaltered. In HIIT-10month, GHQ-12 score decreased from baseline to mid- (−65%, p = 0.001) and post-training (−72%, p = 0.001). In HIIT-5months + detraining, GHQ-12 score decreased from baseline to mid-training (−71%, p = 0.001) and remained above pre-training levels following detraining (−33%, p = 0.001). No changes were noted in SVS in control subjects. In HIIT-10 month, SVS score increased from baseline to mid- (+50%, p = 0.001) and post-training (+53%, p = 0.001). In HIIT-5months + detraining, SVS score increased from baseline to mid-training (+44%, p = 0.001) and remained above pre-training levels following detraining (+18%, p = 0.001). At post-training, HIIT-10month demonstrated higher SVS score than HIIT-5months + detraining (+31%, p = 0.000).	No injuries or other exercise-induced health problems were recorded.	Training had an 8% and 94% attrition and attendance rates, respectively.	Five to ten months of HIIT may improve psychosocial distress and subjective vitality in inactive obese women compared to a non-active control.
Yardley et al., 2017	Beck's Depression Inventory (BDI); The Hospital Anxiety and Depression Scale (HADS); Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	There was no difference in MCS score from baseline to 5-year follow-up (HIIT: pre: 53±11, 5-year: 51±14, (−1.9 [95%CI: −3.7-(−0.5)], Control: pre: 51±8, 5-year: 48±12 (−1.7 [95%CI: −6.0-2.6]). At the 5-year follow-up, there was no significant difference between the groups for depression. Anxiety decreased in the HIT group and increased in the control group with a significant difference at the 5-year follow-up (HIIT mean change:−0.7 [95%CI: −1.5-0.1], control mean change: 1.2 [95%CI:−0.0-2.5]. When the cut-off values of anxiety (>7) were applied, the frequency of anxiety between the two groups showed no significant differences, but there was a trend toward a higher percentage of patients with anxiety in the control group (28%) compared with the HIT group (21%).	There were no serious exercise related adverse events.	Forty-one patients were available at 5-year follow-up.	HIIT may reduce the burden of anxiety in HTx recipients.

Leahy et al., 2018	Strengths and Difficulties Questionnaire (SDQ) (psychological distress); Perceived Stress Scale	Secondary outcome.	There was a moderate group-by-time interaction for the total psychological difficulties score [-2.1 units (95% CI, -4.0 to -0.3), P=0.023, d=0.57]. Analysis revealed significant reductions in 'emotional problems' [-0.9 units (95% CI, -1.6 to -0.01), P=0.022, d=0.61] and 'peer problems' subscales [-0.7 units (95% CI, -1.3 to -0.1), P=0.017, d=0.60]. There were no group-by-time effects for perceived stress [-0.1 (95%CI,-0.3 to 0.09), P=0.253, d=0.26].	No exercise related adverse events were observed.	84% of the intervention participants and 97% of the control participants were retained at follow up. Participants averaged 1.7 (0.3) sessions/week over the study period.	14 weeks of HIIT may possibly psychological distress in adolescents, although it did not impact perceived stress.
Stavrinou et al., 2018	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Mental wellbeing was significantly elevated in both HIIT-2 (7.3, 90 %CI = -0.3 to 14.0, p = 0.003, Cohen's d = 0.54) and HIIT-3 (8.9, 90 %CI = 3.0 to 14.8, p = 0.001, Cohen's d = 0.69) compared with baseline. However, this improvement was significantly higher compared with the control group only for HIIT-3 (p = 0.045, Cohen's d = 0.64) but not for HIIT-2 (p = 0.17, Cohen's d = 0.38).	No adverse events or musculoskeletal injuries were reported.	No participants withdrew from the study and adherence was 97.8% in both HIIT groups.	8 weeks of HIIT, performed thrice weekly, may improve mental wellbeing in inactive adults compared to a non-active control.
Jimenez-Garcia et al., 2019	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	The analysis of MCS showed a significant main effect for the variable time, F(1, 69)=5.19, p=.026, η2=.07, but no significant effect was seen for the variable group x time (Con pre: 71.19±24.40, post: 69.91± 19.67; MIIT pre: 66.90± 21.76, post: 75.13± 15.11; HIIT: pre: 68.60± 22.97, post: 77.73± 18.44, p> .05).	The methodology highlights that injuries were reported but no injuries were noted with the trial results.	A total of 26 completed HIIT, 24 completed MIIT and 23 completed the control program. Subjects showed high adherence to the exercise training programs, participating in at least 83.33% of the sessions.	12 weeks of HIIT did not significantly improve mental wellbeing in older adults compared to MIIT and a non-active control, but significant pre-post improvements were seen.
Cheema et al., 2015	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	Mental wellbeing scores increased by 9.6% in the boxing group and decreased by 4.1% in the walking group (boxing pre: 45.01± 7.73, post 49.31± 11.40, % change: 9.64± 21.46; walking pre: 50.93± 8.71, post: 49.12± 11.34, % change -4.10± 12.80).	Two participants in the HIIT group experienced an adverse event which may have been due to the intervention. One participant experienced tennis elbow so substituted kicking and elbow striking in place of punching. One participant experienced a strain of the gastrocnemius muscle and substituted rowing for skipping.	Two female participants in the walking group withdrew: one due to a pre-existing knee injury requiring surgery (week 2) and one for personal reasons (week 5). Adherence to training was 79 ± 15% and 55 ± 43% in the boxing and walking groups, respectively.	Boxing HIIT may improve mental wellbeing in adults with abdominal obesity, a large trial is needed.
Koufaki et al., 2014	Mental Component Summary (MCS) of the Short	Secondary outcome.	No significant group × time interactions were observed for the mental health subscale score (MICT pre: 75.3 ± 18.9, 12 weeks: 76.5 ± 17.8, post: 68.5 ±	There was one episode of syncope during exercise (HIT) and one anxiety/panic attack	Originally 16 patients were allocated to HIIT and 17 to MICT, 8 HIIT patients and 9 MICT patients were included in the final analysis, the	24 weeks of HIIT did not improve mental wellbeing in patients with chronic HF.

	Form-36 QoL scale		24.3; HIIT pre: 67.3 ± 20.5, 12 weeks: 70.6 ± 18.4, post: 65.2 ± 12.9).	(CAT). Two patients (CAT) could not tolerate the exercise prescription due to severe orthopedic pain.	others were lost to follow-up due to medical reasons or loss of interest. Every patient had accumulated at least 85% of planned sessions.	
Svensson et al., 2017	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Primary outcome.	The MCS mean score increased significantly ($p < 0.01$) for the HIIT group but not for MIT nor control (HIIT pre: 49.7± 12.5, post: 53.4± 9.6, MIT pre: 53.1± 8.7, post: 52.7± 11.6, Control pre: 48.6± 9.6, post: 50.2± 13.9).	Adverse events not reported.	Dropout rates were 31% in the control group, 36% in the HIIT and 42% in the MIT groups. Reasons included medical reasons (n=18), work commitments (n=12), lack of time (n=12), personal reasons (n=12 participants) or no stated reason (n=12).	16 weeks of HIIT led to improvements in mental wellbeing in obese participants whereas MIT and control did not.
Tew et al., 2017	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	HIIT had no effect on the total MCS score (HIIT pre: 57± 6, post: 54.6, Con pre: 53± 10, post: 55.1 [difference –0·5, –3·3 to 2·3], 12 week follow-up HIIT: 55·6 , Con: 55.0 [difference 0·6, –2·4 to 3·6]).	One participant reported feeling unwell approximately 8 h after the exercise session; subsequent cardiology assessment showed no abnormality, but the subject withdrew from the study. One non-serious adverse event was reported following HIIT: short-lived angina.	The retention rate was 91%. Five of 53 participants formally left the study (3 HIIT, 2 control), 3 withdrew as they were no longer undergoing surgery and 1 had surgery expediated. One HIIT participant withdrew after completing just one exercise session and feeling unwell. Overall attendance rate was 76%.	4 weeks of HIIT had no effect on the mental wellbeing of patients awaiting AAA repair.
Stensvold et al., 2010	Mental Component Summary (MCS) of the Short Form-36 QoL scale	Secondary outcome.	There was a larger increase in MCS following HIIT and ST compared to non-active control (HIIT pre: 67.77, post 76.04; ST pre: 70.94, post: 83.72; Control pre: 82.28, post: 81.66).	No major complications or cardiac events occurred during the study period.	Participants were required to complete at least 80% of the exercise sessions. One person from the ST group and one person from the control group refused to complete the training.	12 weeks of HIIT or ST may improve mental wellbeing in people with MetS, more research is needed.
Lunt et al., 2014	Mental Health subdomain of the Short Form-36 QoL scale	Secondary outcome.	MCS score marginally increased following HIIT and MVIT but not following WALK (HIIT: pre 71.94± 14.73, post 76.73± 15.38; MVIT: pre 73.75± 11.02, post 77.25± 14.72; WALK: pre 75.65± 14.84 post 76.47± 11.32).	Eight exercise related adverse events were reported (WALK: 1 Shin splints; AIT: 2 Ankle sprain, 1 Calf strain; MVIT: 1 Iliotibial band syndrome, 1 Achilles tendonitis, 1 Bilateral flexor tendinitis, 1 Plantar fasciitis).	Attendance at sessions was 75%, 59% and 75% in WALK, AIT and MVIT groups respectively. 32 participants completed >70% of their exercise prescription (WALK n=14; AIT n=9; MVIT n=9).	Twelve weeks of interval training had no effect on mental wellbeing compared to an active control in a feasibility trial with overweight inactive adults.

Key terms: BMI= Body mass index; CA= continuous aerobic training; Con = control; HIIT= high intensity interval training, HTx= heart transplant recipients; MD= mean difference; MICT= moderate intensity continuous training; SIT= sprint interval training; QoL= quality of life; RCT= randomised controlled trial

Table Three- Random effects meta-analyses for RCTs comparing HIIT with active and non-active control conditions, and measures of heterogeneity

Analysis	Number of RCTs	Meta-analysis				Heterogeneity		Egger's Intercept			Begg and Mazumdar rank correlation		Duval and Tweedie trim and fill
		Point estimate of effect sizes (SMD)	95%CI lower boundary	95%CI upper boundary	P value (two-tailed)	I^2(%)	Q-value	Intercept	t-value	P value (two-tailed)	Tau	P value (two-tailed)	SMD [95%CI] (adjusted studies)
HIIT vs Active Controls : MCS	10	0.272	0.088	0.456	0.004	0	4.607	-0.838	1.098	0.304	-0.222	0.371	Unchanged
HIIT vs Non-Active Controls : MCS	11	0.427	0.124	0.730	0.006	61.064	25.683	3.962	1.540	0.158	0.218	0.350	Unchanged
HIIT vs Active Controls: Depression	9	-0.110	-0.310	0.091	0.284	0	7.175	-0.122	0.093	0.929	-0.139	0.602	0.165 [-0.359; 0.030] (2)
HIIT vs Non-Active Controls : Depression	10	-0.496	-0.973	-0.020	0.041	82.138	50.389	-0.034	0.010	0.993	-0.089	0.721	-0.675 [-1.132; -0.219] (2)
HIIT vs Active Controls : Anxiety	7	-0.289	-0.700	0.121	0.170	67.28	44.300	-0.201	1.020	0.401	-0.034	0.389	Unchanged
HIIT vs Non-Active Controls : Anxiety	8	-0.302	-0.732	0.128	0.169	71.922	24.930	-2.953	1.035	0.341	-0.250	0.386	-0.427 [-0.881; 0.027] (1)
HIIT vs Non-Active Controls : Stress	4	-0.474	-0.796	-0.152	0.004	20.432	3.770	4.051	1.407	0.295	0.500	0.308	Unchanged

Key terms: CI= confidence interval; HIIT= high intensity interval training; MCS- mental component summary score; RCT= randomized controlled trial; SMD= standardized mean difference

Table Four- Subgroup analysis based on HIIT modality, HIIT intervention duration and length, and population character

	Analysis	Number of RCTs	Meta-analysis				Heterogeneity		Between-Groups Effect
			Point estimate of effect sizes (SMD)	95%CI lower boundary	95%CI upper boundary	P value (two-tailed)	I^2(%)	Q-value	P value
HIIT versus Active Controls: MCS	**HIIT Modality**								
	Cycling	4	0.316	0.021	0.612	0.036	0	0.564	0.611
	Running	2	0.016	-0.524	0.556	0.954	0	0.572	
	Other	4	0.298	0.035	0.560	0.026	0	2.486	
	Duration								
	≥7 weeks	10	0.272	0.088	0.456	0.004	0	4.607	-
	Frequency								
	≥twice weekly	10	0.272	0.088	0.456	0.004	0	4.607	-
	Population								
	Healthy participants	1	-0.090	-0.645	0.465	0.751	0	0	0.175
	Participants with physical illnesses	9	0.317	0.121	0.512	0.001	0	2.770	
HIIT versus Non-Active Controls: MCS	**HIIT Modality**								
	Cycling	4	0.375	-0.209	0.959	0.208	85.836	21.181	0.986
	Cycling + staircase running	1	0.629	-0.609	1.867	0.319	0	2.501	
	Running	3	0.470	-0.204	1.143	0.172	23.409	2.611	
	Other	3	0.427	-0.224	1.077	0.198	0	0.300	
	Duration								
	≥7 weeks	**9**	**0.580**	**0.330**	**0.830**	**<0.001**	**24.288**	**10.566**	**0.002**
	<7 weeks	**2**	**-0.264**	**-0.745**	**0.217**	**0.282**	**46.822**	**1.880**	
	Frequency								
	≥twice weekly	11	0.427	0.124	0.730	0.006	61.064	25.683	
	Population								
	Healthy participants	2	0.492	-0.243	1.227	0.189	0	0.003	0.854
	Participants with physical illnesses	9	0.416	0.063	0.769	0.021	68.454	25.360	

HIIT versus Active Controls: Depression	**HIIT Modality**							
	Cycling	6	-0.015	-0.271	0.242	0.910	0	2.576	0.246
	Other	3	-0.258	-0.578	0.063	0.115	38.544	3.254	
	Duration								
	≥7 weeks	7	-0.106	-0.344	0.132	0.383	9.945	6.663	0.948
	<7 weeks	2	-0.121	-0.515	0.272	0.546	0	0.509	
	Frequency								
	≥twice weekly	6	-0.084	-0.311	0.144	0.471	0	0.713	0.640
	<twice weekly	3	-0.198	-0.619	0.223	0.357	67.967	6.244	
	Duration + Frequency								
	≥twice weekly and ≥7 weeks	4	-0.065	-0.347	0.217	0.653	0	0.154	0.658
	<twice weekly and/or <7 weeks	5	-0.155	-0.439	0.129	0.285	41.398	6.826	
	Population								
	Healthy participants	1	-0.005	-0.873	0.863	0.991	0	1.281	0.808
	Participants with physical illnesses	8	-0.116	-0.324	0.092	0.275	1.628	7.116	
HIIT versus Non-Active Controls: Depression	**HIIT Modality**								
	Cycling	8	-0.485	-1.086	0.117	0.114	85.720	49.018	0.904
	Cycling + staircase running	1	-0.824	-2.566	0.918	0.354	0	0	
	Treadmill walking or running	1	-0.284	-1.918	1.351	0.734	0	0	
	Duration								
	≥7 weeks	8	-0.319	-0.831	0.194	0.223	69.973	23.312	0.137
	<7 weeks	2	-1.169	-2.164	-0.173	0.021	94.140	17.065	
	Frequency								
	≥twice weekly	9	-0.545	-1.058	-0.033	0.037	83.657	48.951	0.536
	<twice weekly	1	-0.011	-1.622	1.599	0.989	0	0	
	Duration + Frequency								
	≥twice weekly and ≥7 weeks	7	-0.359	-0.933	0.215	0.221	73.543	22.678	0.391
	<twice weekly and/or <7 weeks	3	-0.817	-1.692	0.059	0.067	91.097	22.463	
	Population								
	Healthy participants	3	-0.673	-1.582	0.237	0.147	93.095	28.964	0.649
	Participants with physical illnesses	7	-0.420	-1.016	0.176	0.167	69.752	19.836	
HIIT versus Active Controls: Anxiety	**HIIT Modality**								
	Cycling	5	-0.289	-0.700	0.121	0.270	67.280	44.300	0.563
	Other	2	-0.212	-0.654	0.234	0.330	25.220	12.200	
	Duration								
	≥7 weeks	5	-0.389	-0.650	0.090	0.070	47.280	24.300	0.110
	<7 weeks	2	-0.212	-0.654	0.234	0.330	25.220	7.400	
	Frequency								
	≥twice weekly	5	-0.501	-0.891	0.221	0.200	57.820	16.300	0.340
	<twice weekly	2	-0.320	-0.608	0.334	0.390	56.880	9.400	
	Duration + Frequency								
	≥twice weekly and ≥7 weeks	3	-0.389	-0.812	0.321	0.380	55.440	12.300	0.890
	<twice weekly and/or <7 weeks	4	-0.112	-0.454	0.255	0.400	30.210	4.400	
	Population								
	Participants with physical illnesses	7	-0.289	-0.700	0.121	0.170	71.922	44.300	-
HIIT versus Non-Active Controls: Anxiety	**HIIT Modality**								
	Cycling	6	-0.250	-0.783	0.283	0.358	74.152	19.343	0.698
	Other	2	-0.449	-1.301	0.403	0.302	70.515	3.392	
	Duration								

	≥7 weeks	6	-0.475	-0.957	0.007	0.054	69.739	16.523	0.176
	<7 weeks	2	0.149	-0.616	0.914	0.702	50.707	2.029	
	Frequency								
	≥7 weeks	8	-0.302	-0.732	0.128	0.169	71.922	24.931	-
	Duration + Frequency								
	≥twice weekly and ≥7 weeks	6	-0.475	-0.957	0.007	0.054	69.739	16.523	0.176
	<twice weekly and/or <7 weeks	2	0.149	-0.616	0.914	0.702	50.707	2.029	
	Population								
	Healthy participants	3	0.087	-0.494	0.668	0.769	16.130	2.385	0.090
	Participants with physical illnesses	5	-0.579	-1.086	-0.072	0.025	71.513	14.041	
HIIT versus Non-Active Controls: Stress*	**Frequency**								
	≥twice weekly	**3**	**-0.574**	**-0.877**	**-0.252**	**0.040**	**22.21**	**7.770**	**0.039**
	<twice weekly	**1**	**-0.554**	**-0.896**	**0.344**	**0.400**	**8.432**	**1.770**	
	Duration								
	≥7 weeks	4	-0.474	-0.796	-0.152	0.004	20.432	3.770	-
	Population								
	Healthy participants	3	**-0.474**	**-0.696**	**-0.256**	**0.04**	**10.10**	**2.71**	**0.040**
	Participants with physical illnesses	1	**-0.371**	**-0.654**	**0.199**	**0.21**	**3.432**	**1.33**	

*No subgroup analysis was conducted for HIIT Modality because all four RCTs investigating the effects of HIIT on psychological stress, compared to non-active controls, employed different modalities, thus no meaningful split could be carried out.

Key terms: CI= confidence interval; HIIT= high intensity interval training; MCS- mental component summary score; RCT= randomized controlled trial; SMD= standardized mean difference