HIIT is not superior to MICT in altering blood lipids: a systematic review and meta-analysis

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ABSTRACT

Objective To compare the effects of moderate intensity continuous training (MICT) and high intensity interval training (HIIT) on adult lipid profiles; to identify training or participant characteristics that may determine exercise-induced change in total cholesterol (TC), triglycerides (TRG), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C).

Design Systematic review and meta-analysis.

Data sources English language searches of several databases were conducted from inception until September 2019.

Eligibility criteria for excluding studies Inclusion: (1) published randomised controlled human trials with group population n≥5; (2) intervention duration ≥4 weeks; (3) comparing HIIT with MICT; and (4) reporting pre–post intervention lipid measurements. Exclusion: subjects with chronic disease, <18 years, pregnant/lactating, elite athletic training; and studies with a dietary or pharmaceutical intervention component.

Results Twenty-nine data sets (mmol/L) of 823 participants were pooled and analysed. Neither HIIT nor MICT was better in decreasing TC (0.10 (−0.06 to 0.19), p=0.12, I²=0%), TRG (−0.05 (−0.11 to 0.01), p=0.10, I²=0%), LDL-C (0.05 (−0.06 to 0.17), p=0.37, I²=0%), or TC/HDL-C (−0.03 (−0.36 to 0.29), p=0.85, I²=0%). HIIT significantly raised HDL-C (0.07 (0.04 to 0.11), p<0.0001, I²=0%) compared with MICT.

Conclusion Neither HIIT nor MICT is superior for altering TC, TRG, or LDL-C, or TC/HDL-C ratio. Compared with MICT, HIIT appeared to significantly improve HDL-C. Clinicians may prescribe either protocol to encourage participation in exercise and reduce cardiovascular risk. To raise HDL-C, HIIT may result in a larger effect size compared with MICT.

PROSPERO registration number CRD42019136722.

INTRODUCTION

An abnormally elevated or lowered blood lipid profile, known as dyslipidaemia, is a significant risk factor of cardiovascular disease (CVD)1 2; ischaemic stroke3; non-alcoholic fatty liver disease (NAFLD)4; and chronic pancreatitis.5 6 Dyslipidaemia frequently coexists with other Metabolic Syndrome (MetS) factors such as obesity (Ob)7 and type 2 diabetes (T2D)8 9; and MetS is implicated in CVD risk.10 Moderate-intensity and vigorous-intensity aerobic physical activity positively impacts MetS factors, thus lowering CVD risk.11 12 Studies13 14 and systematic reviews15 16 have shown aerobic exercise reduces elevated total cholesterol (TC), triglycerides (TRG) and low-density lipoprotein cholesterol (LDL-C) and increases high-density lipoprotein cholesterol (HDL-C) in subclinical and clinical populations.

Much published work has examined and confirmed the beneficial physiological effects...
of aerobic physical activity or moderate intensity (55%–
70% of maximal heart rate (MHR), rate of perceived
effort (RPE) of 11–13 on the Borg scale)17 continuous
training, known as MICT. The WHO recommends a
minimum of 150 min per week of aerobic physical activity
at moderate continuous intensity, or 75 min at higher
intensity, to maintain or achieve health. However, WHO
reports insufficient aerobic physical activity levels among
adults>18 years.18 Poor adherence to such recommended
aerobic activity or MICT protocols results from lack of
time,19 and lack of support.20 Although enjoyment of
aerobic activity or MICT protocols results from lack of
exercise is positively associated with incidence of phys-
ical activity in adults, absence of enjoyment has not been
significant in explaining lack of exercise, and attitudes
towards exercise lack positive association with inci-
dence of aerobic physical activity.21 Such findings have
prompted searches for alternatives to MICT in order to
address continuing insufficient aerobic physical activity
levels.

High intensity interval training (HIIT) is a protocol
of short work intervals<60 s–8 min22 of vigorous (70%–
90% MHR or RPE Borg scale 14–16)17 to high intensity
(≥90% MHR or ≥2RPE Borg scale 17)17 interspersed with
active (40%–70% MHR or RPE Borg scale 8–13)17 or passive
(cessation of movement) recovery periods of 1–5 min.22
HIIT has been employed since the mid-20th century to
improve athletic exercise performance.22 Contemporary
protocols developed for non-athletes are intended
to reduce session time and provide a greater stimulus for
physiological and psychological adaptation compared with
MICT.

HIIT has been shown to increase peak oxygen
consumption (VO\textsubscript{2MAX} or VO\textsubscript{2PEAK}) compared with MICT
in cardiovascular disease (CVD) populations,23 despite
VO\textsubscript{2MAX} being only one component of positive changes to
cardiorespiratory fitness.24 Studies indicate that a positive
impact on biomedical health indices is protocol depend-
ent in clinical25 and healthy26 populations.

To encourage individuals to undertake aerobic physical
activity, both HIIT27 and MICT28 are promoted as enjoy-
able and effective, although no consensus exists as to
which aerobic exercise protocol is more so. Studies have
shown a minimum volume of weekly aerobic exercise for a
minimum duration29 and a weekly aerobic exercise energy
expenditure (EEE) threshold of 1200–2200 kcal30 is neces-
sary to induce positive changes to lipids. Systematic reviews
and meta-analyses of the effect of aerobic physical activity
on lipid levels have established that longer intervention
and session duration results in greater effects.31 32

A systematic review comparing HIIT against MICT
found no difference on blood lipids in healthy and clinical
populations, but no meta-analysis was conducted.33

A pooled analysis comprising only three studies and
consisting of CVD, MetS and overweight populations
unsurprisingly showed equivocal effects on serum lipids.34
Other systematic reviews35 36 37 38 and meta-analyses35 37–40
have investigated the effect of exercise on lipids, but have
not compared HIIT against MICT. Thus no previously
published meta-analysis exists that has examined the
effects of HIIT versus MICT on lipids in subclinical popu-
lations.

The aim of this study was therefore to conduct a system-
atic review and meta-analysis comparing the effects of HIIT
and MICT on TC, TRG, HDL-C, LDL-C and TC/HDL-C
in subclinical populations and to examine whether one
protocol surpassed the other.

METHODS
This systematic review and meta-analysis was registered
in the International Prospective Register of Systematic
Reviews.41 Its results are presented according to the Prefered
Reporting Items for Systematic Reviews and Meta-Analyses
statement.42

Search strategy
GW and NS conducted systematic English-language
searches of PubMed, all EBSCO health and medical data-
bases including SPORTDiscus, MEDLINE and CINAHL,
as well as Web of Science and EMBASE from inception to
September 2019.

Searches included a mix of MeSH and free text terms
relevant to the concepts of: exercise training intensity for
e.g., (high OR HIIT OR sprint OR SIT OR vigorous
AND moderate continuous OR MICT OR moderate intensity
continuous exercise (MICE) OR continuous moderate exercise (CME));
interval training for example, (intermittent OR interval OR reps AND training OR exercise);
intervention duration for example, (weeks NOT single bout); exercise-induced lipid metabolism; metabolic
syndrome for example, (metabolic syndrome OR MetS
OR T2D OR diabetes OR hypertension OR overweight OR
obese); and blood lipids for example, (lipids OR cholesterol
OR lipoprotein OR triglycerides). Searches excluded for
pregnancy, lactation, elite athletes, juveniles, CVD, stroke,
cancer and NAFLD. Systematic reviews and reference lists
of papers were hand searched for additional studies.

Participants and interventions inclusion/exclusion criteria
Subclinical (healthy or overweight or MetS or MetS
factors such as hypertensive), and clinical (Ob and T2D)
participants taking usual medications, and with a sample
size population of n≥5 in HIIT and MICT groups were
included.

Two distinct exercise protocols differentiated by effort as
per established guidelines17 and described as either steady
state (MICT) or higher effort plus active or passive recovery
intervals (HIIT), separate to warm up and cool-down, were
required. No restrictions were placed on exercise session
time, number and time length of work and recovery inter-
vales or exercise type. Levels and measurement of effort such
as percentage of VO\textsubscript{2MAX} or VO\textsubscript{2PEAK}, percentage of peak
heart rate (HR\textsubscript{PEAK}) or MHR or heart rate reserve or indi-
vidual anaerobic threshold heart rate (HR\textsubscript{LAT}), Borg scale,
metabolic equivalent (MET), or percentage of workload or
watts (W\textsubscript{MAX} or W\textsubscript{PEAK}) were required. Resistance-training
or combined-training interventions without separate HIIT and MICT interventions as comparators were excluded.

**Comparator**
HIIT protocols as the intervention were compared against MICT protocols as the control for differentiated impacts on blood lipids.

**Outcomes**
Pre–post intervention lipid measurements reported as mmol/L or mg/dL for any of TC, TRG, HDL-C, LDL-C or TC/HDL-C were required.

**Study selection**
GW and NS assessed the resulting titles and abstracts of randomised controlled trials (RCTs) lasting ≥4 weeks, which compared HIIT and MICT protocols, and reported pre–post intervention lipid measurements in humans ≥18 years. Subsequently, the full text of potentially eligible studies was reviewed according to participant, intervention and outcome inclusion and exclusion criteria. TvdT was consulted to resolve disputes. The flow of papers through the search and inclusion process is presented in figure 1.

**Data extraction**
GW and AM extracted the data to a pre-established extraction form and NS and TvdT confirmed the data extraction. For each study the following information was extracted: (1) author(s), year of publication and study design characteristics, (2) demographic and clinical characteristics, (3) HIIT intervention and MICT control protocols, (4) values before and after HIIT intervention and MICT control for any of TC, TRG, HDL-C, LDL-C or TC/HDL-C ratio and expressed as mean (M) or mean difference (MD), SD or converted to SD (SE using SD=square root (Sample Size) x SE), as well as main findings concerning lipids.

**Data synthesis**
Statistical analyses were performed using Revman V.5.3 (The Nordic Cochrane Centre, Copenhagen, Denmark)

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**Figure 1** PRISMA flow diagram adapted from Moher et al. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
for continuous data by using the MD and SD of the MD. Where the MD and SD of the MD were not reported, the MD was calculated by subtracting the preintervention M from the postintervention M. The SD of the MD was calculated as follows: SD=\text{square root} \left( (SD_{\text{pre-treatment}})^2 + (SD_{\text{post-treatment}})^2 - (2r \times SD_{\text{pre-treatment}} \times SD_{\text{post-treatment}}) \right), assuming a correlation coefficient (\(r\))=0.5, considered a conservative estimate. Revman V.5.3 also enabled calculations of the SD of the MD using group sample size and p values or 95% CIs when provided. Where data was not presented in text or tables and authors could not be reached, data presented in figures was extracted where possible.

Data were pooled for meta-analysis when two or more studies measured the same outcome and provided data in a format suitable for pooling. Where a study included multiple HIIT groups, data were entered separately for each group and the sample size of the MICT group was divided by the number of HIIT groups to eliminate inflation of the sample size. GW entered the data in Revman V.5.3; TvdT reviewed the data entry for accuracy. A random effects inverse variance model was used with Revman V.5.3; TvdT reviewed the data entry for accuracy.

Meta-analysis and subanalyses
For meta-analysis of the four cholesterol fractions and single ratio, all included studies were grouped under each fraction and data was pooled. Subanalyses were conducted according to: age; gender; presence or absence of MetS risk and/or factor(s) or T2D; and weight-bearing or non-weight-bearing exercise.

Sensitivity analysis
In order to evaluate the influence of each study on the overall effect size of pooled data, we conducted iterative leave-one-out sensitivity analyses. Where subanalyses gave rise to significance, iterative leave-one-out analysis (K−1, where K=the number of studies, and each study is excluded from the pool analysis one at a time) was also conducted.

Heterogeneity and publication bias
Heterogeneity was quantified using the I^2 test where heterogeneity values range from 0% (homogeneity) to 100% (complete heterogeneity). Visual inspection of funnel plots was used to assess risk of publication bias. If the 95% CIs of a study were outside the pooled 95% CIs, the study was removed as an outlier.

Study quality
Study quality was assessed by AM and GW and reviewed by NS and TvdT, using the validated Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) a 15-point scale specific to exercise training studies. A score ≥10 indicates a better study quality and reporting. In the case of discrepancies NS was consulted.

A study quality subanalysis of studies grouped according to TESTEX scores (≥10,<10) was also conducted.

RESULTS
Combined searches generated a total of 126 articles. After removal of duplicates and exclusion of articles based on abstract and title, 37 full-text articles remained for screening. One study using a non-HIIT protocol, two studies using dietary intervention, two studies of increasing intensity not high-intensity intervals, one study with no MICT group, one study reporting only preintervention values, one study combining outcome measures of both protocols, and a feasibility study were excluded. One study tested two HIIT protocols, one of which was excluded. Two further excluded studies were non-RCTs. Three studies tested two HIIT protocols against the same group of MICT participants, hence after screening, a total of 29 data sets from 26 studies met the stated inclusion criteria.

Study, participant, and intervention characteristics
Summarised descriptions of studies, participants and interventions included in trials are provided in Table 1 below and detailed descriptions in online supplementary file 1.

Comparative outcome measures
Total cholesterol
Twenty-one studies of 24 data sets with a total of 653 (352 HIIT, 301 MICT) subjects reported on TC MD (0.10 mmol/L (−0.03 to 0.22), \(p=0.12, I^2=0\%\)), shown in figure 2. No significance was found. Sensitivity analysis (K−1) did not change results.

Subanalyses did not change significance, see online supplementary files table 2.

Triglycerides
Twenty-three studies of 25 data sets with a total of 736 (392 HIIT, 344 MICT) subjects reported on TRG MD (−0.05 mmol/L (−0.11 to 0.00), \(p=0.10, I^2=0\%\)), shown in figure 3. No significance was found. Sensitivity analysis (K−1) did not alter significance.

Subanalyses changed significance in favour of HIIT for (1) age grouping 35–55 years (−0.10 mmol/L (−0.19 to −0.01), \(p=0.03, I^2=0\%\)); (2) Mets or MetS factors/risk (−0.10 mmol/L (−0.18 to −0.02), \(p=0.01, I^2=0\%\)); and (3) weight-bearing protocols (−0.11 mmol/L (−0.21 to 0.00), \(p=0.04, I^2=0\%\)). Sensitivity analysis (K−1) of these these subanalyses resulted in no significance with the removal of one study, see online supplementary files table 2.

High-density lipoprotein cholesterol
Twenty-six studies comprising 28 data sets with a total of 739 (384 HIIT, 355 MICT) subjects reported on HDL-C MD (0.07 (0.04 to 0.11), \(p<0.0001, I^2=0\%\)), as shown in figure 4, and favoured HIIT. Removal of one outlier did not alter significance. Sensitivity analysis (K−1) resulted in insignificance with the removal of one study.
<table>
<thead>
<tr>
<th>Study (A–Z)</th>
<th>Participants N, status, gender</th>
<th>Exercise type, HIT work interval intensity, MICT intensity</th>
<th>Sessions week</th>
<th>Weeks</th>
<th>Outcomes</th>
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<tbody>
<tr>
<td>Ciolac et al</td>
<td>22 healthy ♀</td>
<td>Treadmill walking or running HIIT: 80%–90% VO₂&lt;sub&gt;MAX&lt;/sub&gt;, MICT: 60%–70% VO₂&lt;sub&gt;MAX&lt;/sub&gt;</td>
<td>3</td>
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<td>TC, TRG, HDL-C, LDL-C</td>
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<td>Connolly et al</td>
<td>30 healthy ♀</td>
<td>Ergocycle HIIT: 30–&lt;100% sprint, MICT: 70%–85% HR&lt;sub&gt;PEAK&lt;/sub&gt;</td>
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<td>TC, TRG, HDL-C, LDL-C, TC/HDL-C</td>
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<td>Cuddy et al</td>
<td>27 Ov–Ob ♀♂</td>
<td>Ergocycle HIIT: 100% sprint; MICT: 40%–65% HRR</td>
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<td>Fisher et al</td>
<td>23 Ov–Ob ♀♂</td>
<td>Ergocycle HIIT: 85% sprint, MICT: 55%–65% VO₂&lt;sub&gt;PEAK&lt;/sub&gt;</td>
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<td>TC, TRG, HDL-C, LDL-C</td>
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<td>Hwang et al</td>
<td>29 Ov ♀♂</td>
<td>All-extremity ergometer HIIT: 90% HR&lt;sub&gt;PEAK&lt;/sub&gt;, MICT: 70% HR&lt;sub&gt;PEAK&lt;/sub&gt;</td>
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<td>8</td>
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<td>Keating et al</td>
<td>22 Ov ♀♂</td>
<td>Ergocycle HIIT: 120% VO₂&lt;sub&gt;PEAK&lt;/sub&gt;, MICT: 50%–65% VO₂&lt;sub&gt;PEAK&lt;/sub&gt;</td>
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<td>Kemmler et al</td>
<td>65 Ov–MetS ♀♂</td>
<td>Running HIIT: 95%–110% HR&lt;sub&gt;AT&lt;/sub&gt;, MICT: 70%–82.5% HR&lt;sub&gt;AT&lt;/sub&gt;</td>
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<td>Kong et al</td>
<td>26 Ob ♀</td>
<td>Ergocycle HIIT: max VO₂&lt;sub&gt;PEAK&lt;/sub&gt;, MICT: 60%–80% VO₂&lt;sub&gt;PEAK&lt;/sub&gt;</td>
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<td>TC, TRG, HDL-C, LDL-C</td>
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<td>Lee, et al</td>
<td>20 healthy ♀♂</td>
<td>Ergocycle HIIT: 85%–90% VO₂&lt;sub&gt;MAX&lt;/sub&gt;, MICT: not stated</td>
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<td>Maillard et al</td>
<td>16 Ov–Ob, T2D♀</td>
<td>Ergocycle HIIT: 80% MHR, MICT: 55%–60% target HR</td>
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<td>Matsuo et al</td>
<td>26 Ov–MetS ♀♂</td>
<td>Ergocycle HIIT: 85% VO₂&lt;sub&gt;PEAK&lt;/sub&gt;, MICT: 60%–65% VO₂&lt;sub&gt;PEAK&lt;/sub&gt;</td>
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<td>Mohr et al</td>
<td>42 hours, Ov ♀</td>
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<td>Morales-Palermo et al</td>
<td>50 MetS ♀♂</td>
<td>Ergocycle HIIT4: 90% MHR, MICT: 70% MHR</td>
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<td>Morales-Palermo et al</td>
<td>49 MetS ♀♂</td>
<td>Ergocycle HIIT1:100% MHR, MICT: 70% MHR</td>
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<td>Moreira et al</td>
<td>16 Ob ♀♂</td>
<td>Ergocycle HIIT: 60%–72% VO₂&lt;sub&gt;MAX&lt;/sub&gt;, MICT: 55%–66% VO₂&lt;sub&gt;MAX&lt;/sub&gt;</td>
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<td>TC, HDL-C, LDL-C, TC/HDL-C</td>
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<td>Study (A–Z)</td>
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<td>Ramos et al&lt;sup&gt;26&lt;/sup&gt;</td>
<td>32 MetS, T2D ♀♂</td>
<td>Walking/running, ergocycle/cycling, swimming HIIT: 85%–95% HR&lt;sub&gt;PEAK&lt;/sub&gt;, MICT: 60%–70% HR&lt;sub&gt;PEAK&lt;/sub&gt;</td>
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<td>Ruffino et al&lt;sup&gt;28&lt;/sup&gt;</td>
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<td>Ergocycle, walking HIIT: 80%–90% MHR, MICT: 50%–55% HRR</td>
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<td>Shepherd et al&lt;sup&gt;74&lt;/sup&gt;</td>
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<td>Thomas et al&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14 healthy ♀♂</td>
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<td>Thomas et al&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14 healthy ♀♂</td>
<td>Running HIIT: 90%–100% MHR, MICT: 75%–85% MHR</td>
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<td>Tjønna et al&lt;sup&gt;75&lt;/sup&gt;</td>
<td>19 MetS ♀♂</td>
<td>Treadmill walking and running HIIT: 90% MHR, MICT: 70% MHR</td>
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<td>Vella et al&lt;sup&gt;25&lt;/sup&gt;</td>
<td>17 Ov–Ob ♀♂</td>
<td>Treadmill, ergocycle, elliptical HIIT: 75%–80% HRR, MICT: 55%–59% HRR</td>
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<td>Winding et al&lt;sup&gt;30&lt;/sup&gt;</td>
<td>25 Ov, T2D ♀♂</td>
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<td>Winn et al&lt;sup&gt;61&lt;/sup&gt;</td>
<td>16 Ob ♀♂†</td>
<td>Treadmill walking and running HIIT: 80% VO&lt;sub&gt;2PEAK&lt;/sub&gt;, MICT: 55% VO&lt;sub&gt;2PEAK&lt;/sub&gt;</td>
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<td>TC, TRG, HDL-C, LDL-C</td>
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<td>Zhang et al&lt;sup&gt;62&lt;/sup&gt;</td>
<td>24 Ob ♀</td>
<td>Treadmill running HIIT: 50%–95% HR&lt;sub&gt;PEAK&lt;/sub&gt;, MICT: 60%–70% HR&lt;sub&gt;PEAK&lt;/sub&gt;</td>
<td>4</td>
<td>12</td>
<td>TC, TRG</td>
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<sup>*HR<sub>IAF</sub>—HR at individual aerobic threshold IAt (minimum lactate 2.0 mmol/L). </sup>
<sup>†Assumed. Gender not specified.</sup>

HDL-C, High-density lipoprotein cholesterol; HIIT, High intensity interval training; HR, Heart rate; HR<sub>PEAK</sub>, Peak heart rate; HRR, Heart rate reserve; IAT, individual anaerobic threshold; LDL-C, Low-density lipoprotein cholesterol; MetS, Metabolic Syndrome; MHR, maximal heart rate; MICT, Moderate intensity continuous training; Ob, Obesity; Ov, Overweight; PICO, Participants, Intervention, Comparator, Outcome; TC, Total cholesterol; T2D, Type 2 diabetes mellitus; TRG, Triglycerides; VO<sub>2PEAK</sub>, VO<sub>2MAX</sub>, Peak oxygen consumption; W<sub>PEAK</sub>, Workload or watts.
**Figure 2.** Total cholesterol. MD and SD expressed as mmol/L; Total = number of participants. HIIT, high intensity interval training; MICT, moderate intensity continuous training, MD, mean difference.

**MD (0.04 mmol/L (0.00 to 0.08), p=0.06, I²=0%), see online supplementary files table 2.**

With the exception of age (all) and gender (females), subanalyses remained significant for HIIT. Applying sensitivity analysis (K–1) to subanalyses resulted in insignificance for the weight-bearing grouping only, see online supplementary files table 2.

**Low-density lipoprotein cholesterol**

Twenty data sets of 580 (313 HIIT, 267 MICT) subjects reported on LDL-C MD (0.05 mmol/L (−0.06 to 0.17), p=0.37, I²=0%), shown in figure 5. No significance was found. Sensitivity analysis (K–1) did not change significance.

Subanalyses did not change significance, see online supplementary files table 2.

**TC/HDL-C ratio**

As shown in figure 6, three studies with a total of 72 subjects reported on the TC/HDL-C ratio MD (−0.03 mmol/L (−0.36 to 0.29), p=0.85, I²=0%).

**Heterogeneity and publication bias**

Meta-analyses indicated zero heterogeneity for all lipid fractions, and the TC/HDL-C ratio. Visual inspection of funnel plots showed moderate-to-high likelihood of publication bias for TC and TRG, and low-to-moderate likelihood for HDL-C and LDL-C, see online supplementary files figures 2-6.

**Study quality and reporting**

A median TESTEX score of 11 out of 15 was obtained (range 7 to 13). TESTEX scores (≥10 or<10) did not alter significance and heterogeneity, moreover sensitivity analysis (K–1) did not affect these results, see online supplementary files table 3. No study was excluded based on its TESTEX score.

**Lipid assessment**

Lipid assay details are provided in online supplementary files table 4. No study was excluded based on lipid assay reporting.

**DISCUSSION**

**Meta-analysis**

This systematic review and meta-analysis aimed to compare the effects of HIIT and MICT on adult blood lipid profiles in subclinical populations and to examine whether one protocol was superior to the other. Our review is the first to include more than eight trials and compare the effect size of intermittent high–low intensity
and continuous moderate intensity in positively altering TC, TRG, HDL-C, LDL-C and the ratio of TC/HDL-C in subclinical populations. Our analysis, of 29 data sets from 26 studies, assessed the effects on lipids of weight-bearing and non-weight bearing HIIT and MICT exercise therapies excluding concurrent dietary or pharmaceutical interventions. Although HIIT and MICT appear to induce positive changes, our analysis did not demonstrate that intermittent high-intensity outperformed continuous moderate-intensity protocols in achieving better lipid outcomes.

**Outcome measures**

**Total cholesterol**

We found no statistically significant evidence showing a benefit in favour of HIIT or MICT in reducing TC. Our results are similar to a previous qualitative review comparing exercise with no exercise. Our results differ from the findings of others who worked at differentiating between continuous or interval protocols.

We also included papers with intervention duration of 4–6 weeks; these are arguably of insufficient duration to effect change. MICT has been shown to prioritise fat as a primary substrate fuel in subclinical populations, hence it could be reasonably expected that MICT would outperform HIIT. However, a weekly energy expenditure is required before impacts on lipids can be observed, and a number of included protocols likely fell short of this threshold. We excluded studies including dietary intervention which may have impacted our results.

**Triglycerides**

We found no difference in effect size between HIIT and MICT in positively altering TRG except for subanalyses. Our results broadly agree with a recent meta-analysis, although we excluded trials of cardiac patients. Our results also agree with a previous qualitative review. We differ from the work of others possibly because we included mixed populations or because we differentiated for protocol and intensity. A systematic review suggested TRG responded favourably to increased exercise intensity in MetS populations, agreeing with a previous meta-analysis, and our subanalysis (MetS or MetS factors/risk) found HIIT significantly lowered TRG more than MICT.

**High-density lipoprotein cholesterol**

HIIT showed significance compared with MICT for affecting HDL-C, however sensitivity analysis (K–1) contradicted this result. Our findings agree with a previous meta-analysis, although this work compared...
exercise with no exercise only and focussed on overweight and obese populations. We also agree with the results of a recent meta-analysis comparing intensity, although this work focussed on studies of subjects with cardiovascular conditions.85 Our results are dissimilar to other systematic reviews,16 33 36 and two (one female and one male) meta-analyses,38 40 although none of these works compared for intensity. Given the greater impact on cardiorespiratory fitness of HIIT compared with MICT,23 55 our result is not unexpected, as HIIT would most likely outperform MICT in optimising lipid transport via an improved microvascular capillary network. However, both HIIT and MICT have been shown to equally improve muscle microvascular density.86

**Low-density lipoprotein cholesterol**

We found no significance for preferring HIIT to MICT for positively changing LDL-C. Our findings agree with other meta-analyses,39 85 We differ from two meta-analyses comparing exercise with no exercise and examining general populations,38 40 as well as a meta-analysis comparing intensity and examining LDL-C in overweight and obese populations.87 We surmise this is a corollary of our inclusion of studies with healthy participants, although our subanalyses of clinical and subclinical participants did not affect significance. Previous work showing that LDL-C falls when accompanied by weight loss has been corroborated by a later meta-analysis comparing exercise with no exercise in overweight and obese groups.30 39 A recent meta-analysis of HIIT compared with MICT in these populations showed no preference for either protocol in achieving weight loss.86 88 Existing higher base levels of lipids in these populations may have led to sufficient decrease in LDL-C to demonstrate significance for HIIT protocols.14 According to one systematic review, increasing intensity is required to impact LDL-C,16 hence MICT by its nature should have shown inferiority to HIIT. Insufficient intervention duration and probable similar overall intensity in the protocols of included studies may have obfuscated our results.

**TC/HDL-C ratio**

HIIT and MICT were equivalent in reducing TC/HDL-C ratio.

**Clinical significance and future research**

Our meta-analysis results indicate HIIT seems to be superior to MICT in affecting HDL-C. Either HIIT or MICT can be prescribed to positively affect TC, TRG, LDL-C and the TC/HDL ratio, as part of efforts to increase exercise participation to meet current aerobic physical activity guidelines.89 Further, given the increasing prevalence of metabolic syndrome and type 2 diabetes,90 91 future research should focus on the impact of HIIT and MICT on cardiovascular endpoints.
activity guidelines. Previous studies and reviews suggest a weekly minimum EEE of >1200 kcals and time commitment >150 min of aerobic physical activity at vigorous intensity is necessary to positively impact lipids. These indicative minimum requirements exceed current weekly aerobic physical activity guidelines of 150 min at moderate intensity or 75 min at vigorous intensity. Sharing the results of these studies and reviews may motivate some demographics to participate in and/or increase aerobic physical activity.

Based on the number of HIIT or MICT sessions per week, our included studies generally met the minimum weekly time requirements of current aerobic physical activity guidelines. The EEE, effort, session duration and frequency achieved in several studies were unlikely to meet the levels required to positively impact lipids. We propose that future research should address the following criteria to ascertain whether HIIT or MICT is better in inducing desirable changes in TC, TRG and LDL-C for varying populations: interventions should aim for duration >8 weeks (excluding familiarization sessions) as previously established; protocols should achieve a weekly EEE threshold >1200 kcals; and minimum session duration and frequency; and

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>HIIT Mean</th>
<th>HIIT SD</th>
<th>HIIT Total</th>
<th>MICT Mean</th>
<th>MICT SD</th>
<th>MICT Total</th>
<th>Weight</th>
<th>IV, Random, 95% CI</th>
<th>Mean Difference</th>
<th>IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connolly 2017</td>
<td>0.08</td>
<td>0.5611</td>
<td>15</td>
<td>0.06</td>
<td>0.5611</td>
<td>15</td>
<td>62.0%</td>
<td>0.02 [-0.39, 0.43]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maillard 2016</td>
<td>-0.4</td>
<td>0.274</td>
<td>8</td>
<td>-0.2</td>
<td>0.274</td>
<td>8</td>
<td>23.8%</td>
<td>-0.20 [-1.08, 0.68]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matsuo 2015</td>
<td>-0.24</td>
<td>0.5106</td>
<td>13</td>
<td>-0.17</td>
<td>0.5106</td>
<td>13</td>
<td>24.2%</td>
<td>-0.07 [-0.73, 0.59]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total (95% CI) 36 36 100.0% -0.03 [-0.36, 0.29]

Heterogeneity: Tau^2 = 0.00; Ch^2 = 0.21, df = 2 (P = 0.90); I^2 = 0%
Test for overall effect: Z = 0.19 (P = 0.85)

Figure 6 TC/HDL-C ratio. MD and SD; Total = number of participants. HDL-C, high-density lipoprotein cholesterol; HIIT, high intensity interval training; MICT, moderate intensity continuous training; MD, mean difference; TC, total cholesterol.
HIIT interventions should ensure that the overall effort (work:recovery ratio and repetitions) remains at or close to vigorous intensity per session, since higher intensity has been shown to impact more favourably on lipids than lower intensity.

Strengths and limitations in the systematic review and meta-analyses

This review has a number of strengths. To our knowledge, this review and quantitative meta-analysis is the first to compare the effects of intermittent high-intensity and continuous moderate-intensity weight-bearing and non-weight bearing protocols on cholesterol fractions and the TC/HDL-C ratio in healthy, subclinical and clinical adult populations.

Previous systematic reviews did not use the validated exercise study evaluation tool TESTEX to measure the quality of included studies. We followed a rigorous inclusion and exclusion protocol to ensure minimisation of confounding factors among the study populations.

A major limitation of this review is the relatively small number of studies used in our subanalyses. This is compounded by the varying populations studied and the different exercise protocols (number and length of effort and recovery intervals, intensities, session and intervention duration, session frequency and energy expenditure) used for comparing HIIT against MICT. Some studies did not report all lipid fractions. In addition, reporting of protocol adherence and intensity used objective for example, electronic devices as well as subjective measures for example, Borg scale, self-reported HR, log books, denoted by different indices of intensity (energy expenditure, VO_{2max}, MHR, METs, Borg scale).

Aerobic physical activity protocols mainly consisted of running, swimming, walking, or cycling, which could have influenced results. While the majority of studies included in the analysis specified intervention duration \( \geq \)8 weeks, a small number of included studies used an intervention duration of 4–6 weeks, which may have weakened results.

With respect to data pooling, we measured the difference between preintervention and postintervention means; in cases where the MD SDs were not available, we imputed the SD using pre–post SDs, p values, and 95% CIs, and hence statistical analyses depended on extrapolated data. Our imputation was conservative, and sensitivity analyses (leave-one-out) were conducted. This approach may have weakened results.

The results of our analysis may have been affected because some of the studies measured lipids as secondary and not as primary outcomes. We therefore infer that some studies were perhaps not designed with the primary goal of lipid lowering. In the paragraph on clinical significance above, we have demonstrated that earlier reviews suggest a minimum weekly EEE of >1200 kcals, thus some of the studies that met our inclusion criteria may have failed to meet the minimum applicable EEE, session duration and session frequency required to positively impact lipids.

CONCLUSION

Pooled analysis indicated that aerobic physical activity intensity did not influence effect size for change in TC, TRG, LDL-C and TG/HDL-C. Change in the effect size of lipids seems to be sensitive to physical activity volume rather than intensity. The exception to this appears to be HDL-C which improved more with HIIT than MICT. Our findings suggest that HIIT protocols do not confer greater improvements in lipid profiles over MICT protocols. Clinicians and allied health specialists should therefore endeavour to encourage people to undertake aerobic physical activity at or above the minimum threshold (about 1200 kcal weekly) as a treatment or prevention strategy likely to be effective in managing lipid profiles and reducing CVD risk.

Contributors GW and NS designed the systematic review and meta-analysis, and performed searches. TwdT reviewed search results. Data extraction was performed by GW and AM. Data validation was performed by GW, AM, NS and TwdT. Data synthesis was performed by GW and AM. The article was written by GW with revisions suggested by AM, NS and TwdT.

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Patient consent for publication Not required.

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Provenance and peer review Not commissioned; externally peer reviewed.

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