Prevalence and predictors of dropout from high-intensity interval training in sedentary individuals: A meta-analysis

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Recent evidence suggests that high-intensity interval training (HIIT) is an effective method to improve fitness and various health markers. However, the tolerability and acceptability of HIIT among sedentary individuals is currently controversially discussed. Therefore, our objective was to investigate the prevalence and predictors of dropout among sedentary individuals in HIIT-based exercise interventions. MEDLINE/PubMed, SPORTDiscus, and Web of Science were searched systematically for relevant articles until 06/2018. Studies included were required to (a) be written in English, (b) include sedentary healthy adults, (c) use some form of HIIT without any complementary intervention, (d) last ≥4 weeks, (e) report detailed description of the applied HIIT protocol, and (f) report data that allow calculation of a dropout rate. Fifty-five studies reporting results from 67 HIIT interventions with 1318 participants met the eligibility criteria. The trim and fill adjusted pooled dropout rate across all interventions was 17.6% (95% confidence interval 14.2-21.5%). Dropout rates were significantly lower in cycling-based interventions compared with studies using running/walking as exercise modality (P < 0.001). Longer session time (β = 0.02, P < 0.05), higher time effort/week (β = 0.005, P < 0.05), and overall time effort/intervention (β = 0.0003, P < 0.05) predicted greater dropout. Exercise intensity was not related to dropout. Our data suggest that HIIT-based interventions are tolerable and acceptable for previously sedentary individuals, exhibiting generally lower dropout rates than commonly reported for traditional exercise programs. Given the association between HIIT volume and dropouts, future studies should further focus on identifying the minimally effective dose of practical HIIT for improving health status. Such efforts would be important to increase implementation and public health impact of HIIT.

KEYWORDS
cardiorespiratory fitness, exercise adherence, feasibility, health promotion, public health, sprint interval training
INTRODUCTION

There is ample evidence that regular physical activity significantly contributes to preventing a wide range of health problems. It has been documented, for example, that physical inactivity substantially increases the risk for developing major chronic diseases, including cardiovascular disease, type 2 diabetes, or certain types of cancer.1-3 The degree of cardiorespiratory fitness (CRF) is commonly used as an objective and reproducible marker of physical activity habits and regarded as an independent predictor of mortality—much stronger than other well-recognized risk factors, such as smoking or obesity.1,2,4,5 Public health guidelines recommend that adults should accumulate a minimum volume of 150 minutes of moderate physical activity or 75 minutes of vigorous aerobic exercise per week in order to maintain and/or improve CRF and other health outcomes.3,6

However, despite vast evidence for the numerous health benefits of physical activity, recent surveys demonstrate that many individuals do not meet these recommendations.7,8 In European countries, for example, recent estimates indicate that approximately 60% of citizens rarely or never participate in sports activities and more than half the population seldom or never engages in other kinds of regular physical activity (e.g., walking or gardening).7 Moreover, it is frequently reported that 30-50% of people who enroll in supervised exercise programs typically drop out after only a few months,9-14 mostly within the first 6-8 weeks.15 The underlying reasons for not participating in regular physical activity or dropping out from exercise programs are manifold and complex and may include intrapersonal as well as environmental causes.16

According to the social cognitive theory,17 self-efficacy, outcome expectations, and perceived barriers are key factors that influence adoption and long-term maintenance of behavior change.16 However, specifically for exercising, one of the most commonly cited reasons for insufficient physical activity and exercise dropout is “a perceived lack of time.”18

Against this background, high-intensity interval training (HIIT) has emerged as a promising, novel exercise strategy, potentially allowing shorter training times for achieving health-relevant benefits. HIIT is characterized by brief, repeated bouts of high-intensity exercise interspersed with recovery periods of low-intensity activity or rest.19 Elite athletes have used this type of training for decades to enhance their exercise performance.20 However, recent application in sedentary individuals has revealed the potential of HIIT to improve various aspects of cardiovascular and metabolic health.19,21-24 It was demonstrated, for example, that HIIT can improve CRF (usually expressed as maximum oxygen uptake, VO2max) and specific cardiometabolic risk markers (e.g., insulin sensitivity, blood pressure, or cholesterol levels) effectively within only a few weeks.19,21-26 One of the most unexpected findings was that HIIT has shown similar or even superior benefits compared with traditional, moderate-intensity continuous training (MICT) despite a substantially lower training volume.19,21-25,27

Notwithstanding, the public health value of HIIT to the general, largely sedentary population is currently a major subject of debate. Recently, it has been argued that HIIT, in particular sprint interval training (SIT, a specific, more intense form of HIIT involving supramaximal/all-out exercise bouts),26,28 is inappropriate for sedentary individuals because it is perceived as too strenuous and most likely would result in high dropout rates.29,30 In contrast, other researchers have challenged this position and highlighted the potential of HIIT as a viable strategy for health promotion.30-33 Indeed, it might be hypothesized that the time-saving aspect of HIIT could be helpful in overcoming time-related barriers to uptake and maintenance of physical activity. However, to the best of our knowledge, the dropout rates in HIIT trials conducted with previously untrained individuals have not yet been systematically reviewed and, thus, dropout patterns in HIIT interventions among sedentary populations are currently unclear.

The purpose of this systematic review and meta-analysis was, therefore, to thoroughly determine the dropout rates and related factors (e.g., exercise intensity, exercise mode, or duration of exercise session) in HIIT studies with previously sedentary individuals. Addressing these important issues will help resolve ongoing debates regarding the feasibility of HIIT for population-level health promotion programs. Furthermore, identification of factors contributing to dropout in HIIT interventions will provide useful information to assist in the further development of more effective exercise protocols.

METHODS

This review was conducted in accordance with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).34 This review was not registered with PROSPERO since none of the outcomes were related to patient or clinical outcome.35

2.1 Data sources and search strategy

We performed a computerized systematic search of electronic databases including MEDLINE/PubMed, SPORTDiscus, and Web of Science until June 2018. These databases were selected due to their sensitivity and specificity to detect relevant articles in the field of sports medicine and sports science.36 A rapid update was undertaken in August 2018 prior to submission. In consultation with a librarian specialist at the university, a combination of the following key terms was used: “high-intensity interval training” OR “interval training” OR “sprint interval training” AND “untrained” OR...
“sedentary” OR “health promotion” OR “public health” OR “primary prevention” OR “weight loss.” Additionally, reference lists of included papers and relevant review articles were screened to identify other potentially appropriate studies for inclusion. In the first stage of the search, all duplicate records were identified and removed. In the second stage, titles and abstracts of the articles were screened for relevance using predetermined selection criteria outlined below. Finally, full-text articles of the remaining records were retrieved and thoroughly analyzed to elucidate their eligibility. Two independent reviewers (DR and DL) completed the literature search and selection of eligible studies based on the defined inclusion/exclusion criteria. Disagreements were resolved by discussion and subsequent consensus.

2.2 | Criteria for study inclusion/exclusion

Only full-text articles published in peer-reviewed English language journals were considered. Each study had to meet the following inclusion criteria: (a) participants must be healthy adults (18+ years old) and classified as “sedentary,” “untrained,” or “not engaged in regular physical activity.” Studies with overweight/obese but otherwise healthy subjects were also considered. Studies with patients, chronically ill subjects, or individuals receiving medical treatment were excluded due to the numerous factors unrelated to exercise that may influence dropout rates in these specific groups, such as changes in therapy/medication, aggravation of disease, or attrition due to the death of study participants. Studies with athletes, trained, or physically active subjects were also excluded; (b) the duration of the intervention must be ≥4 weeks in order to ensure comparability to traditional exercise programs, which typically report that the greatest rate of dropout occurs during the first 6-8 weeks15; (c) the study must not involve any other exercise method, dietary changes, nutritional supplements, or any other application in addition to the prescribed HIIT protocol; (d) the exercise intensity must be at least 80% of maximum heart rate (HR_max) or maximum power (W_max) as previously proposed to specify HIIT protocols21,24; (e) a detailed description of the applied HIIT protocol must be provided to allow an estimation of exercise volume (time effort per session, week, and total intervention); and (f) information on dropouts/study completers must be reported. If the dropout rate was not reported in an article, the corresponding author was contacted by e-mail. Nonresponders received a reminder after 4 weeks and if there was no reply, the study was not included in the analysis.

2.3 | Data extraction

All data were extracted using standardized Excel spreadsheets and included: first author, year of publication, sample size, dropouts, participants’ characteristics, study duration, exercise type, exercise sessions/week, HIIT protocol characteristics (intensity, number and duration of HIIT bouts, and recovery phases), and total time/session (the sum of HIIT, recovery phases plus warm-up and cooldown). One reviewer (DR) performed all data extraction, with a second reviewer (FW) checking the data for completeness and accuracy. The dropout rate was defined as the proportion of participants enrolled in each intervention that did not complete the study. For each study, the dropout rate was calculated by extracting the baseline sample and the number of completers/dropouts. Furthermore, we collected the underlying reasons for dropout, occurring adverse events, and adherence rates (defined as the percentage of the scheduled exercise sessions that the participants completed), insofar as these have been reported. Some studies defined exercise intensity as a percentage of VO2max. For purposes of comparison across studies, we converted these values into %HR_max using the following equation: %HR_max = 0.64 × %VO2max + 37.37 Accordingly, only studies in which the training stimulus reached at least 67% of VO2max (corresponding to 80% HR_max) were included in the analysis.

Given that a plenty of studies used supramaximal HIIT protocols (without stating precise HR- or W-values), we categorized the studies for further analyses into the following four subgroups: (a) <90%, (b) 90-94%, (c) 95-100% of HR_max/W_max and (d) supramaximal (if exercise intensity was specified as “all-out,” “sprint,” or >100% of HR_max, W_max, or VO2max). If total time per session was not explicitly stated in the paper, we calculated the amount by adding up the reported time spent in HIIT (the number of intervals multiplied with interval duration), recovery phases, warm-up, and cooldown. Subsequently, we calculated the time effort per week (by multiplying the number of sessions per week with total session time) and total time effort per intervention (by multiplying time effort per week with the number of study weeks). If values were reported as ranges, we used the mean value in the calculation of this variable.

2.4 | Quality assessment

Two reviewers (DR and DL) independently evaluated the risk of bias in all eligible studies according to the Physiotherapy Evidence Database (PEDro) Scale. This tool rates the methodological quality of clinical trials on a scale from 0 (high risk of bias) to 10 (low risk of bias).38 The validity and reliability of the scale have been demonstrated in past research,38 and it has been used to rate the quality of over 3000 trials as well as in several systematic reviews.39 Discrepancies in scoring were discussed, and consensus was reached in all cases.
2.5 | Statistical analysis

All data were analyzed using SPSS version 21 (SPSS Inc), Comprehensive Meta-Analysis version 3.0 (Biostat), and OpenMeta (Analyst). Descriptive statistics were used to summarize study characteristics including means and ranges. Due to anticipated heterogeneity across studies, we conducted a random-effects meta-analysis to estimate the pooled dropout rates together with 95% confidence intervals (95% CIs). Heterogeneity was measured with the Cochran $Q$ and Higgins $I^2$ statistics. A $P$-value of <0.10 for the $Q$ test and an $I^2$-value >50% was regarded as evidence for significant heterogeneity. Subgroup analyses were carried out to compare dropout rates across all studies according to gender, exercise type (cycling vs running or walking), and exercise intensity (<90%, 90-94%, 95-100% of HR$_{\text{max}}$/W$_{\text{max}}$, or supramaximal). Between-group differences were tested using $Q$-statistics. Moreover, we conducted meta-regression analyses to examine the association between potential predictors and dropout rates across all studies. The dependent variable was the dropout rate, which was converted into logit event rates as suggested previously. Independent variables included participants' mean age, study duration, time effort per session, time effort per week, and total time effort per intervention. The level of statistical significance was set at $P < 0.05$. Publication bias was assessed with visual inspection of funnel plots. Additionally, funnel plot asymmetry was statistically tested by Begg-Mazumdar Kendall’s tau and the Egger’s test, in which $P < 0.05$ was considered significant. Any potential publication bias was adjusted with a trim and fill method to correct for funnel plot asymmetry.

3 | RESULTS

3.1 | Study characteristics

The electronic database search yielded 1732 potentially relevant studies. Twenty-one additional studies were identified through a manual reference list search. After removal of duplicates and studies not meeting inclusion criteria based on title, abstract, and full-text review, the final selection consisted of 55 studies of which 12 trials included two different HIIT protocols (two exercise arms). Thus, overall, 67 HIIT interventions with a total of 1318 participants were included in our review (Figure 1).

The average sample size per intervention was $n = 20 \pm 20$ (range = 6-147), and participants' mean age was $35.8 \pm 14.1$ years (range = 19.6-73.0 years). Most studies included both male and female participants ($n = 31, 46\%$), while the remaining studies enrolled either...
**TABLE 1** Summary of characteristics of all interventions meeting the inclusion criteria

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants' characteristics and mean age (y)</th>
<th>Study wk</th>
<th>Exercise type</th>
<th>Exercise intensity</th>
<th>Min/ Session</th>
<th>Sessions/ wk</th>
<th>Min/ wk</th>
<th>Intervals (repetitions and duration), recovery periods in-between</th>
<th>Sample size/ Dropouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen et al (2017) Group-1</td>
<td>Middle-aged, sedentary adults (49 ± 6 y)</td>
<td>9</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>31</td>
<td>3</td>
<td>93</td>
<td>4:8x 30 s, 3:5 min passive rest</td>
<td>21/1 (4.8%)</td>
</tr>
<tr>
<td>Allen et al (2017) Group-2</td>
<td>Middle-aged, sedentary adults (49 ± 6 y)</td>
<td>9</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>52</td>
<td>3</td>
<td>156</td>
<td>10-24x 10 s, 2:3 min 75%-80% HRmax</td>
<td>21/0 (0%)</td>
</tr>
<tr>
<td>Allison et al (2017)</td>
<td>Sedentary women (26 ± 11 y)</td>
<td>6</td>
<td>stair climbing</td>
<td>all-out</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>3x 20 s, 2 min walking around</td>
<td>21/0 (0%)</td>
</tr>
<tr>
<td>Astorino et al (2013)</td>
<td>Sedentary women (22.7 ± 5.4 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>85% Wmax</td>
<td>23.75</td>
<td>3</td>
<td>71.25</td>
<td>6-10x 1 min, 75-s at 40-W</td>
<td>11/1 (9.1%)</td>
</tr>
<tr>
<td>Baekkerud et al (2016) Group-1</td>
<td>Overweight/obese men and women (39 ± 10 y)</td>
<td>6</td>
<td>Treadmill</td>
<td>90% HRmax</td>
<td>38</td>
<td>3</td>
<td>114</td>
<td>4x 4 min, 3 min 70% HRmax</td>
<td>12/4 (33.3%)</td>
</tr>
<tr>
<td>Baekkerud et al (2016) Group-2</td>
<td>Overweight/obese men and women (45 ± 8 y)</td>
<td>6</td>
<td>Treadmill</td>
<td>90% HRmax</td>
<td>32</td>
<td>3</td>
<td>96</td>
<td>10x 1 min, 1 min walking around</td>
<td>9/0 (0%)</td>
</tr>
<tr>
<td>Berger et al (2006)</td>
<td>Untrained subjects (23 ± 4 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>95% HRmax</td>
<td>29</td>
<td>3.5</td>
<td>101.5</td>
<td>20x 1 min, 1 min rest periods</td>
<td>8/0 (0%)</td>
</tr>
<tr>
<td>Bracken et al (2010)</td>
<td>Non-active males (20 ± 2 y)</td>
<td>7</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>26.3</td>
<td>3</td>
<td>78.9</td>
<td>20-50x 6-18s (varying), 12-30 s (varying)</td>
<td>10/0 (0%)</td>
</tr>
<tr>
<td>Ciolak et al (2010)</td>
<td>Women at risk for hypertension (24.4 ± 3.8 y)</td>
<td>16</td>
<td>Treadmill</td>
<td>91% HRmax</td>
<td>60</td>
<td>3</td>
<td>180</td>
<td>14x 1 min, 2 min at 55% VO2max</td>
<td>16/5 (31.3%)</td>
</tr>
<tr>
<td>Connolly et al (2016)</td>
<td>Untrained premenopausal women (44 ± 5 y)</td>
<td>6</td>
<td>freestyle swimming</td>
<td>all-out</td>
<td>20</td>
<td>3</td>
<td>58</td>
<td>6-10x 30 s, 2 min passive recovery</td>
<td>21/0 (0%)</td>
</tr>
<tr>
<td>Cooper et al (2016) Group-1</td>
<td>Sedentary middle-aged men (49.1 ± 5.3 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>31.5</td>
<td>3</td>
<td>94.5</td>
<td>4-10x 30 s, 3 min passive recovery</td>
<td>16/1 (6.3%)</td>
</tr>
<tr>
<td>Cooper et al (2016) Group-2</td>
<td>Sedentary middle-aged men (47.2 ± 5.1 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>31.5</td>
<td>3</td>
<td>94.5</td>
<td>4-10x 30 s, 3 min active recovery</td>
<td>16/1 (6%)</td>
</tr>
<tr>
<td>Eguchi et al (2012)</td>
<td>Women free of CVD (50.8 ± 11.2 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>85% HRmax</td>
<td>30</td>
<td>3</td>
<td>90</td>
<td>9x 30s, 2.5 min 45% VO2max</td>
<td>10/0 (0%)</td>
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<tr>
<td>Elmer et al (2016)</td>
<td>Sedentary men (21.4 ± 1.1 y)</td>
<td>8</td>
<td>Treadmill</td>
<td>100% HRmax</td>
<td>30</td>
<td>3</td>
<td>90</td>
<td>12x 1 min, 1 min 50% VO2max</td>
<td>6/0 (0%)</td>
</tr>
<tr>
<td>Fisher et al (2015)</td>
<td>Sedentary overweight men (20 ± 1.5 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>85% Wmax</td>
<td>20</td>
<td>3</td>
<td>60</td>
<td>4x 30s, 4 min 15% Wmax</td>
<td>15/2 (13.3%)</td>
</tr>
<tr>
<td>Foster et al (2015) Group-1</td>
<td>Sedentary men (20 ± 2 y) and women (20 ± 1 y)</td>
<td>8</td>
<td>cycle ergometer</td>
<td>all-out</td>
<td>14</td>
<td>3</td>
<td>42</td>
<td>8x 20 s, 10s active recovery</td>
<td>24/3 (12.5%)</td>
</tr>
<tr>
<td>Foster et al (2015) Group-2</td>
<td>Sedentary men (19 ± 1 y) and women (20 ± 3 y)</td>
<td>8</td>
<td>cycle ergometer</td>
<td>100% HRmax</td>
<td>30</td>
<td>3</td>
<td>90</td>
<td>13x 30 s, 60 s active recovery</td>
<td>21/6 (28.6%)</td>
</tr>
</tbody>
</table>

(Continues)
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants' characteristics and mean age (y)</th>
<th>Study wk</th>
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<th>Min/ Session</th>
<th>Sessions/ wk</th>
<th>Min/ wk</th>
<th>Intervals (repetitions and duration), recovery periods in-between</th>
<th>Sample size/ Dropouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freese et al (2014)</td>
<td>Inactive women (51.7 ± 10.4 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>32</td>
<td>3</td>
<td>96</td>
<td>4-8 x 30 s, 4 min active recovery</td>
<td>29/6 (20.7%)</td>
</tr>
<tr>
<td>Gillen et al (2016)</td>
<td>Sedentary men (27 ± 7 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>all-out</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>3x 20 s, 2 min 50-W</td>
<td>10/1 (10%)</td>
</tr>
<tr>
<td>Gillen et al (2014)</td>
<td>Sedentary overweight men and women (29 ± 9 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>all-out</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>3x 20 s, 2 min 50-W</td>
<td>14/0 (0%)</td>
</tr>
<tr>
<td>Hadle et al (2014)</td>
<td>Females not doing regular training (23.1 ± 2.3 y)</td>
<td>8</td>
<td>Treadmill</td>
<td>92.5% HRmax</td>
<td>40</td>
<td>3</td>
<td>120</td>
<td>4x 4 min, 3 min 70% HRmax</td>
<td>10/0 (0%)</td>
</tr>
<tr>
<td>Heisz et al (2016)</td>
<td>Sedentary young adults (27 ± 7 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>85% HRmax</td>
<td>30</td>
<td>3</td>
<td>90</td>
<td>8x intervals, 12 s active recovery (for 20 min)</td>
<td>25/5 (20%)</td>
</tr>
<tr>
<td>Howarth et al (2007)</td>
<td>Men and women not doing regular exercise (24 ± 1 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>all-out</td>
<td>20.5</td>
<td>3</td>
<td>61.5</td>
<td>4-6x 30 s, 4.5 min 30-W</td>
<td>10/0 (0%)</td>
</tr>
<tr>
<td>Hwang et al (2016)</td>
<td>Sedentary older adults (64.8 ± 1.4 y)</td>
<td>8</td>
<td>all-extremity ergometer</td>
<td>90% HRmax</td>
<td>40</td>
<td>4</td>
<td>160</td>
<td>4x 4 min, 3 min 70% HRmax</td>
<td>17/2 (11.8%)</td>
</tr>
<tr>
<td>Jakobsen et al (2011)</td>
<td>Sedentary men (36.9 ± 5 y)</td>
<td>12</td>
<td>running track</td>
<td>92.5% HRmax</td>
<td>14</td>
<td>2</td>
<td>28</td>
<td>5x 2 min, 1 min rest</td>
<td>9/0 (0%)</td>
</tr>
<tr>
<td>Keating et al (2014)</td>
<td>Inactive overweight adults (41.8 ± 2.7 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>supramax</td>
<td>23</td>
<td>3</td>
<td>69</td>
<td>4-6x 30-60 s, 2-3 min active recovery</td>
<td>13/2 (15.4%)</td>
</tr>
<tr>
<td>Kong et al (2016a)</td>
<td>Obese young women (18-30 y)</td>
<td>5</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>26</td>
<td>4</td>
<td>104</td>
<td>60 x 8 s, 12 s active recovery</td>
<td>15/2 (13.3%)</td>
</tr>
<tr>
<td>Kong et al (2016b)</td>
<td>Obese young women (19.8 ± 0.8 y)</td>
<td>5</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>20</td>
<td>4</td>
<td>80</td>
<td>60 x 8 s, 12 s active recovery</td>
<td>10/1 (10%)</td>
</tr>
<tr>
<td>Koubaa et al (2015)</td>
<td>Sedentary male smokers/ non-smokers (44.5 ± 1.3 y)</td>
<td>12</td>
<td>running track</td>
<td>82% HRmax</td>
<td>40</td>
<td>3</td>
<td>120</td>
<td>2 min intervals, 1 min recovery (for 30 min)</td>
<td>35/0 (0%)</td>
</tr>
<tr>
<td>Lunt et al (2014)</td>
<td>Inactive overweight adults (48.2 ± 5.6 y)</td>
<td>12</td>
<td>walking/ jogging</td>
<td>90% HRmax</td>
<td>40</td>
<td>3</td>
<td>120</td>
<td>4x 4 min, 3 min 65%-75% HRmax</td>
<td>16/7 (43.8%)</td>
</tr>
<tr>
<td>Lunt et al (2014)</td>
<td>Inactive overweight adults (50.3 ± 8 y)</td>
<td>12</td>
<td>walking/ jogging</td>
<td>all-out</td>
<td>32.25</td>
<td>3</td>
<td>96.75</td>
<td>3x 30 s, 4 min active recovery</td>
<td>16/7 (43.8%)</td>
</tr>
<tr>
<td>Madsen et al (2015)</td>
<td>Inactive individuals (52 ± 2 y)</td>
<td>8</td>
<td>cycle ergometer</td>
<td>92.5% HRmax</td>
<td>30</td>
<td>3</td>
<td>90</td>
<td>10x 1 min, 1 min active or passive</td>
<td>13/0 (0%)</td>
</tr>
<tr>
<td>Matsuo et al (2014)</td>
<td>Sedentary male adults (26.4 ± 6.5 y)</td>
<td>8</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>10</td>
<td>5</td>
<td>50</td>
<td>7x 30 s, 15 s rest</td>
<td>14/0 (0%)</td>
</tr>
</tbody>
</table>

(Continues)
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants’ characteristics and mean age (y)</th>
<th>Study wk</th>
<th>Exercise type</th>
<th>Exercise intensity</th>
<th>Min/ Session</th>
<th>Sessions/ wk</th>
<th>Min/ wk</th>
<th>Intervals (repetitions and duration), recovery periods in-between</th>
<th>Sample size/ Dropouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matsuo et al (2014)²⁴</td>
<td>Sedentary male adults (27.2 ± 6.4 y)</td>
<td>8</td>
<td>cycle ergometer</td>
<td>91% HR_max</td>
<td>18</td>
<td>5</td>
<td>90</td>
<td>3x 3 min, 2 min 50% VO2max</td>
<td>14/0 (0%)</td>
</tr>
<tr>
<td>Metcalfe et al (2016)²⁶</td>
<td>Sedentary men (33 ± 9 y) and women (36 ± 9 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>all-out</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>2x 10-20 s, 4 min 60-W</td>
<td>43/8 (18.6%)</td>
</tr>
<tr>
<td>Molmen et al (2012)²³</td>
<td>Healthy seniors (73 ± 3 y)</td>
<td>12</td>
<td>Treadmill</td>
<td>92.5% HR_max</td>
<td>38</td>
<td>3</td>
<td>114</td>
<td>4x 4 min, 3 min 60-70 HR_max</td>
<td>19/3 (15.8%)</td>
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<tr>
<td>Musa et al (2009)²⁴</td>
<td>Untrained men (29.8 ± 4.5 y)</td>
<td>8</td>
<td>running</td>
<td>90% HR_max</td>
<td>50</td>
<td>3</td>
<td>150</td>
<td>4x 800 m, 1:1 work/rest ratio (for 40 min)</td>
<td>20/3 (13%)</td>
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<tr>
<td>Nybo et al (2010)²⁵</td>
<td>Untrained men (37 ± 3 y)</td>
<td>12</td>
<td>treadmill</td>
<td>95% HR_max</td>
<td>20</td>
<td>2</td>
<td>40</td>
<td>5x 2 min, recovery not stated</td>
<td>8/0 (0%)</td>
</tr>
<tr>
<td>Osteras et al (2005)²⁶</td>
<td>Older untrained individuals (68.9 ± 2.8 y)</td>
<td>10</td>
<td>outdoor running</td>
<td>90% HR_max</td>
<td>60</td>
<td>3</td>
<td>180</td>
<td>4x 4 min, 4 min 60%-70% HR_max</td>
<td>13/3 (23.1%)</td>
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<tr>
<td>Panissi et al (2016)²⁷</td>
<td>Untrained women (30.6 ± 15.1 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>90% HR_max</td>
<td>28</td>
<td>3</td>
<td>84</td>
<td>15x 1 min, 30 s 60% HR_max</td>
<td>11/0 (0%)</td>
</tr>
<tr>
<td>Phillips et al (2017)²⁸</td>
<td>Sedentary subjects at risk for diabetes T2 (37 ± 10 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>100% HR_max</td>
<td>16</td>
<td>3</td>
<td>48</td>
<td>7x 1 min, 60 s recovery</td>
<td>41/1 (2.4%)</td>
</tr>
<tr>
<td>Phillips et al (2017)²⁹</td>
<td>Sedentary subjects at risk for diabetes T2 (39 ± 9 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>supramax</td>
<td>13</td>
<td>3</td>
<td>39</td>
<td>5x 1 min, 90 s recovery</td>
<td>147/1 (7.5%)</td>
</tr>
<tr>
<td>Prieur et al (2013)³⁰</td>
<td>Untrained men (19.7 ± 1.7 y)</td>
<td>6</td>
<td>outdoor running</td>
<td>supramax</td>
<td>43.5</td>
<td>3</td>
<td>130.5</td>
<td>3 sets 6x 30 s, 30 s active rest; 6 min between sets</td>
<td>11/0 (0%)</td>
</tr>
<tr>
<td>Reljic et al (2018)³¹</td>
<td>Sedentary men and women (29.2 ± 6.0 y)</td>
<td>8</td>
<td>spinning bikes</td>
<td>90% HR_max</td>
<td>14</td>
<td>2</td>
<td>28</td>
<td>5x 1 min, 1 min active recovery</td>
<td>12/1 (8.3%)</td>
</tr>
<tr>
<td>Reljic et al (2018)³¹</td>
<td>Sedentary men and women (29.9 ± 7.2 y)</td>
<td>8</td>
<td>spinning bikes</td>
<td>90% HR_max</td>
<td>15</td>
<td>2</td>
<td>30</td>
<td>2x 4 min, 2 min active recovery</td>
<td>12/2 (16.7%)</td>
</tr>
<tr>
<td>Saadatnia et al (2016)³²</td>
<td>Untrained men (23.3 ± 2.6 y)</td>
<td>10</td>
<td>outdoor running</td>
<td>all-out</td>
<td>20.5</td>
<td>3</td>
<td>61.5</td>
<td>4-8x 30 s, 90 s passive recovery</td>
<td>0/13 (0%)</td>
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<tr>
<td>Sawyer et al (2016)³³</td>
<td>Sedentary obese men and women (35.1 ± 8.1 y)</td>
<td>8</td>
<td>cycle ergometer</td>
<td>92.5% HR_max</td>
<td>29</td>
<td>3</td>
<td>87</td>
<td>10x 1 min, 1 min 20-25-W</td>
<td>11/2 (18.2%)</td>
</tr>
<tr>
<td>Shenouda et al (2017)³⁴</td>
<td>Sedentary men (27 ± 7 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>all-out</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>3x 20 s, 2 min 50-W</td>
<td>10/1 (10%)</td>
</tr>
<tr>
<td>Sheperd et al (2015)³⁵</td>
<td>Inactive males and females (42 ± 11 y)</td>
<td>10</td>
<td>spinning bikes</td>
<td>90% HR_max</td>
<td>21.5</td>
<td>3</td>
<td>55</td>
<td>15-60 s bouts, 45-120 s recovery (for 18-25 min)</td>
<td>46/4 (8.7%)</td>
</tr>
<tr>
<td>Study</td>
<td>Participants' characteristics and mean age (y)</td>
<td>Study wk</td>
<td>Exercise type</td>
<td>Exercise intensity</td>
<td>Min/ Session</td>
<td>Sessions/ wk</td>
<td>Min/ wk</td>
<td>Intervals (repetitions and duration), recovery periods in-between</td>
<td>Sample size/ Dropouts</td>
</tr>
<tr>
<td>-------</td>
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<td>---------</td>
<td>-------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Sijie et al (2012)</td>
<td>Overweight young women (19.8 ± 1 y)</td>
<td>12</td>
<td>outdoor running</td>
<td>91% HR_{max}</td>
<td>42</td>
<td>5</td>
<td>210</td>
<td>5x 3 min, 3 min 50% VO_{2max}</td>
<td>20/3 (15%)</td>
</tr>
<tr>
<td>Sim et al (2015)</td>
<td>Overweight inactive men (31 ± 8 y)</td>
<td>12</td>
<td>cycle ergometer</td>
<td>supramax</td>
<td>37.5</td>
<td>3</td>
<td>112.5</td>
<td>repeated 15 s bouts, 1 min 32% VO_{peak}</td>
<td>10/0 (0%)</td>
</tr>
<tr>
<td>Songsorn et al (2016)</td>
<td>Sedentary men and women (24 ± 6 y)</td>
<td>4</td>
<td>cycle ergometer</td>
<td>all-out</td>
<td>0.33</td>
<td>3</td>
<td>1</td>
<td>1x 20 s</td>
<td>15/0 (0%)</td>
</tr>
<tr>
<td>Søgaard et al (2016)</td>
<td>Untrained women (22 ± 1 y)</td>
<td>6</td>
<td>cycle ergometer</td>
<td>97% HR_{max}</td>
<td>14.5</td>
<td>3</td>
<td>43.5</td>
<td>5x 1 min, 90 s 25-W</td>
<td>22/0 (0%)</td>
</tr>
<tr>
<td>Tjonna et al (2013)</td>
<td>Inactive overweight men (42.2 ± 2.4 y)</td>
<td>10</td>
<td>treadmill</td>
<td>90% HR_{max}</td>
<td>40</td>
<td>3</td>
<td>120</td>
<td>4x 4 min, 3 min 70% HR_{max}</td>
<td>13/0 (0%)</td>
</tr>
<tr>
<td>Tjonna et al (2013)</td>
<td>Inactive overweight men (41.8 ± 3.6 y)</td>
<td>10</td>
<td>treadmill</td>
<td>90% HR_{max}</td>
<td>19</td>
<td>3</td>
<td>57</td>
<td>1x 4 min</td>
<td>13/2 (15.4%)</td>
</tr>
<tr>
<td>Trapp et al (2008)</td>
<td>Inactive woman (22.4 ± 0.7 y)</td>
<td>15</td>
<td>cycle ergometer</td>
<td>sprint</td>
<td>30</td>
<td>3</td>
<td>90</td>
<td>60x 8 s, 12 s active recovery</td>
<td>15/4 (26.7%)</td>
</tr>
<tr>
<td>Tsekouras et al (2008)</td>
<td>Sedentary men (20-40 y)</td>
<td>8</td>
<td>treadmill</td>
<td>95% HR_{max}</td>
<td>37</td>
<td>3</td>
<td>111</td>
<td>4x 4 min, 4 min 60% VO_{peak}</td>
<td>8/1 (12.5%)</td>
</tr>
<tr>
<td>Vogel et al (2011)</td>
<td>Elderly men and women (young seniors, 52-64 y)</td>
<td>9</td>
<td>cycle ergometer</td>
<td>90% W_{max}</td>
<td>36</td>
<td>2</td>
<td>72</td>
<td>6x 1 min, 6x 4 min VT</td>
<td>68/0 (0%)</td>
</tr>
<tr>
<td>Vogel et al (2011)</td>
<td>Elderly men and women (older seniors, 65-79 y)</td>
<td>9</td>
<td>cycle ergometer</td>
<td>90% W_{max}</td>
<td>36</td>
<td>2</td>
<td>72</td>
<td>6x 1 min, 6x 4 min VT</td>
<td>82/0 (0%)</td>
</tr>
<tr>
<td>Wallman et al (2009)</td>
<td>Overweight/obese men and women (40.9 ± 11.7 y)</td>
<td>8</td>
<td>cycle ergometer</td>
<td>100% HR_{max}</td>
<td>30</td>
<td>4</td>
<td>120</td>
<td>30 min work-rest (30%-45% VO_{peak}) ratio 1:2</td>
<td>8/1 (12.5%)</td>
</tr>
<tr>
<td>Weng et al (2013)</td>
<td>Sedentary men (22.3 ± 0.2 y)</td>
<td>5</td>
<td>cycle ergometer</td>
<td>88% HR_{max}</td>
<td>33</td>
<td>5</td>
<td>165</td>
<td>5x 3 min, 3 min 40% VO_{peak}</td>
<td>10/0 (0%)</td>
</tr>
<tr>
<td>Willoughby et al (2016)</td>
<td>Inactive middle-aged adults (40-50 y)</td>
<td>4</td>
<td>treadmill</td>
<td>all-out</td>
<td>28.5</td>
<td>3</td>
<td>85.5</td>
<td>4-6x 30 s, 4 min light walking</td>
<td>23/9 (39.1%)</td>
</tr>
<tr>
<td>Willoughby et al (2016)</td>
<td>Inactive adults, (20-30 y)</td>
<td>4</td>
<td>treadmill</td>
<td>all-out</td>
<td>28.5</td>
<td>3</td>
<td>85.5</td>
<td>4-6x 30 s, 4 min light walking</td>
<td>17/3 (17.6%)</td>
</tr>
<tr>
<td>Zhang et al (2015)</td>
<td>Overweight women (21 ± 1 y)</td>
<td>12</td>
<td>treadmill</td>
<td>90% HR_{max}</td>
<td>61</td>
<td>4</td>
<td>244</td>
<td>4x 4 min, 3 min 50%-60% HR_{max}</td>
<td>14/2 (14.3%)</td>
</tr>
<tr>
<td>Zisko et al (2015)</td>
<td>Men not doing regular exercise (39 ± 5 y)</td>
<td>6</td>
<td>treadmill</td>
<td>92.5% HR_{max}</td>
<td>19</td>
<td>3</td>
<td>57</td>
<td>1x 4 min</td>
<td>2/10 (20%)</td>
</tr>
<tr>
<td>Zisko et al (2015)</td>
<td>Men not doing regular exercise (37 ± 4 y)</td>
<td>6</td>
<td>treadmill</td>
<td>92.5% HR_{max}</td>
<td>40</td>
<td>3</td>
<td>120</td>
<td>4x 4 min, 3 min 70% HR_{max}</td>
<td>3/10 (30%)</td>
</tr>
</tbody>
</table>

*aMin per session = net HIIT time plus recovery phases, warm-up, and cooldown.*
Figure 2: Forest plot
only men (n = 23, 34%) or only women (n = 13, 19%). The average intervention duration was 8.7 ± 2.9 weeks (range = 4-16 weeks), and most studies implemented 3.0 ± 0.6 sessions per week (range = 2-5 sessions). The exercise sessions lasted on average 28.2 ± 12.8 minutes (range = 0.33-61 minutes), resulting in an average weekly time effort of 88.5 ± 46.1 minutes (range = 1-244 minutes). The total time effort per intervention averaged 799 ± 582 minutes (range = 4-2928 minutes). The majority of interventions used either cycling (stationary cycle ergometers or indoor spinning bikes, n = 40) or running/walking (treadmill, outdoor trails, or stair climbing, n = 25) as exercise type. One intervention applied an all-extremity air-braked ergometer for synchronous arm-leg exercise, and one study implemented high-intensity swim training. In 48% of interventions, participants exercised with a mean intensity of <95% HRmax/Wattmax (95-100%: n = 8, supramaximal/all-out: n = 27; Table 1).

3.2 | Quality assessment

The mean methodological quality for all 55 included studies, based on the PEDro scale, was 5.7 ± 1.4 (range = 3-9). Thirty-five studies yielded a score of ≥6, while only five studies scored below the suggested cutoff value of four, which can be interpreted as an overall high methodological quality and low risk of bias of the included studies.

3.3 | Meta-analysis of dropout rates in HIIT interventions

Across the 67 HIIT interventions, the pooled dropout rate was 13.4% (95% CI 10.8-16.4%). A forest plot with the results from each intervention is shown in Figure 2. Visual inspection of the funnel plot (Figure 3) and additional statistical tests (Kendall’s tau = −0.39, P < 0.001; Egger = −1.82, P < 0.001) revealed evidence for publication bias. The trim and fill adjusted dropout rate was 17.6% (95% CI 14.2-21.5%) with 25 adjusted studies.

3.4 | Reported reasons for dropout and adherence rates

Specific reasons for dropout were only reported in 26 studies. Among these, 46 participants dropped out due to personal reasons (eg, loss of interest, lack of time) and 20 discontinued participation due to injuries/orthopedic complaints (n = 9: site not further specified, n = 2: muscle injuries, n = 3: shin, n = 2: foot/ankle, n = 2: back, n = 1: hip, and n = 1: knee). Most orthopedic problems occurred in studies using running/walking as exercise type (n = 18 vs n = 2 in cycling-studies). Twenty participants dropped out due to illnesses or injuries, which were not related to the exercise intervention. No serious adverse events were reported in any of the studies included in this review. Adherence rates were only reported in 36 studies and averaged 94.1% (95% CI 91.6-96.6%).

3.5 | Subgroup analyses

Subgroup analyses are shown in Table 2. Significantly higher dropout rates were observed in HIIT interventions using running/walking as exercise type compared with cycling-based trials (P < 0.001). There were no significant differences between subgroups when dropouts were portioned according to exercise intensity and gender.

3.6 | Meta-regression analyses

Meta-regression results revealed that longer session duration, higher time effort/week, and higher total time effort/intervention were significantly associated with greater dropout rates. No statistically significant associations were observed for any of the other potential predictors (Table 3).
4 | DISCUSSION

To our knowledge, this is the first systematic review to evaluate dropout rates and predictors in HIIT interventions with previously sedentary/untrained individuals. Our results demonstrate that 13.4% (corrected to 17.6% in a trim and fill analysis) of participants, who were enrolled in HIIT trials of ≥4 weeks duration dropped out. Given that the literature commonly reports dropout rates ranging between 30% and 50% for traditional supervised exercise programs,9,14 this finding suggests that HIIT appears to be well tolerated and accepted by previously untrained individuals. Our results challenge recent concerns that HIIT is inappropriate for sedentary individuals29,30 and support opposing viewpoints, advocating that there is promising potential for HIIT-based exercise interventions to contribute to public health promotion.29,31-33

The relatively low prevalence of dropouts in HIIT trials when compared with traditional exercise programs could be due to several reasons. First, it is widely accepted that feelings of pleasure and enjoyment are crucial factors for adherence to exercise programs.102 Although it has been argued that untrained individuals typically tend to avoid participating in strenuous exercise and thus, one would expect that HIIT could be viewed negatively by sedentary individuals,29,30 there is growing evidence, however, that HIIT seems to be more enjoyable than MICT.33,58,62,102-104 These findings were observed in recreationally active individuals103,104 as well as in untrained participants,58,62,102 and it was assumed that the higher perceptions of enjoyment during HIIT may be attributed to the varied protocol characteristics, leading to less boredom compared to rather monotonous MICT.

Second, unsatisfactory results or lack of training success typically lead to loss of motivation and may particularly play an important role in dropout from exercise interventions.11 In weight loss programs, for example, failure to achieve a satisfactory reduction in body weight during the first weeks of intervention and slow rates of weight loss were important predictors of dropout.105 In this context, previous work demonstrated that HIIT may induce similar56,106,107 or even superior74,108,109 reductions in body fat and waist circumference than other types of exercise, but with far less time commitment, possibly due to higher excess post-exercise oxygen consumption (EPOC) responses.110 Moreover, recent reviews report that improvements in CRF and other health-related markers occur faster and possibly to a greater extent following HIIT compared with MICT.19,21-26 Given that physiological adaptations to HIIT have been extensively previously reviewed,19,21-26 we did not specifically analyze the effects of HIIT on fitness and health markers (ie, “training success”) in our review. However, it is conceivable that faster (and perhaps greater) training results with HIIT contribute to increased motivation and prevent early dropouts occurring within the first weeks of exercise.

Third, our data indicate that time efficiency appears to be a crucial contributory factor to low dropout rates in HIIT interventions. Recent surveys clearly demonstrate that many individuals do not meet the recommended physical activity levels of 150 minutes per week,7,8 and there is considerable evidence that “lack of time” is the most frequently mentioned reason for not participating in regular physical activity and dropout from exercise programs.18 In the current review, the average time effort across all included studies was 88.5 minutes per week, which is considerably less than general physical activity recommendations. Thus, it is reasonable to assume that HIIT may circumvent perceived time-related barriers and enables greater maintenance of physical activity regimes over time.

Furthermore, we identified significant moderators that influence the prevalence of dropouts in HIIT interventions. Longer session duration, higher weekly time effort, and higher overall time effort per intervention were associated with greater dropout rates, underscoring the importance of time-related factors in affecting participants’ decisions to quit exercise programs. Although time efficiency is typically considered a major advantage of HIIT compared with traditional exercise methods, it has recently been argued that the true timesaving of distinctive HIIT protocols is quite small when warm-up, cooldown, and recovery phases are added to the net HIIT time.56,57,65,66 As a result, recent research has focused on developing more time-efficient HIIT protocols, typically referred to as low-volume HIIT.19,21,24,56,57,65,66,72

Given the association between exercise volume (time effort) and dropouts, our results support the concept of low-volume HIIT as a viable exercise strategy to facilitate overcoming time-related constraints for exercise maintenance. It must be mentioned, however, that most studies applying low-volume HIIT—typically by means of so-called “all-out” protocols—used specialized laboratory cycle ergometers, at costs impeding large-scale rollout, rendering them unsuitable for broad uptake in population-based health promotion interventions. A recent study, for example, suggests that brief, intense stair climbing may be a feasible and readily accessible exercise strategy to improve CRF in previously untrained individuals.92 However, more research is required to identify the minimally effective dose of practical or “equipment-free” HIIT protocols needed to improve health status in sedentary populations.

Of further relevance, we found a higher prevalence of orthopedic complaints and significantly greater dropout rates in running/walking- vs cycling-based HIIT interventions, suggesting that HIIT is probably better tolerated by untrained individuals when using non-weightbearing exercise modes compared with higher-impact exercises. These findings are in line with a recent study indicating that intensified running exercise over a short-term period induced substantially more muscle damage, soreness, and systemic...
inflammation when compared with cycling. In addition, higher coordinative demands of treadmill running (especially at higher speeds) could place excessive strain on untrained individuals and therefore lead to a higher injury risk or reduced motivation. However, these assumptions should not exclude that use of running/walking-based HIIT protocols may also provide certain advantages over cycling, which cannot be discussed in detail here since this would exceed the scope of this review.

Interestingly, we did not find evidence that exercise intensity moderated dropouts in HIIT interventions. Critics of HIIT typically question whether sedentary individuals would be willing to engage in strenuous exercise and argue that large proportions of those who participate in HIIT would drop out because of concerns for rapid exhaustion. Our findings do not support these assumptions, as we observed no significant differences in dropout rates when studies were stratified according to exercise intensity. In this context, it is to note that 13 studies that applied supramaximal/all-out intensities used very low-volume protocols (eg, 2x 10-20 seconds sprints). In line with previous research, we therefore speculate that supramaximal/all-out HIIT will most likely be well tolerated by untrained individuals if exercise duration remains at a low level.

Taken together, the results of the current review are useful in guiding the translation of research into practice. Our data suggest, for example, that exercise and health professionals planning to develop and implement HIIT-based programs for previously sedentary individuals should carefully consider exercise volume and type, and focus on the use of low-volume, non-weightbearing HIIT protocols to maximize tolerability. Finally, it is worth noting that participants’ age was not associated with dropout rates. Given that many industrialized countries worldwide are experiencing a shift in the age distribution of their populations, early preventive efforts and tolerable exercise programs for older adults are becoming increasingly important. Our results suggest that HIIT is tolerable and independent of age, and thus, it may also represent a promising exercise option for older adults.

### 4.1 Study limitations and implications for future research

There are several limitations that should be considered when interpreting our results. First, we identified 32 further studies that may have been eligible for inclusion in this review but were excluded because they did not report dropout rates. Thus, the possibility cannot be excluded that

#### TABLE 3 Meta-regression results for dropouts

<table>
<thead>
<tr>
<th></th>
<th>β</th>
<th>95% CI</th>
<th>P-value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants’ mean age</td>
<td>−0.0013</td>
<td>−0.019 −0.016</td>
<td>0.442</td>
<td>0</td>
</tr>
<tr>
<td>Study duration</td>
<td>0.038</td>
<td>−0.040 −0.116</td>
<td>0.170</td>
<td>0</td>
</tr>
<tr>
<td>Time effort/session</td>
<td>0.02</td>
<td>0.002 −0.037</td>
<td>0.013</td>
<td>0.25</td>
</tr>
<tr>
<td>Time effort/week</td>
<td>0.005</td>
<td>−0.0002 −0.010</td>
<td>0.031</td>
<td>0.16</td>
</tr>
<tr>
<td>Total time effort/intervention</td>
<td>0.0003</td>
<td>0 −0.0007</td>
<td>0.037</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Abbreviations: HRmax = maximum heart rate, Wmax = maximum watts.
we underreport the frequency of dropouts. This observation suggests the importance of routine reporting of dropouts in future studies to facilitate the evaluation of HIIT interventions.

Second, relatively few studies have provided specific reasons for dropout, which makes it impossible to draw more comprehensive conclusions on why individuals decide to quit participation in HIIT interventions. Moreover, the specific reasons for dropout are typically based on self-report of the participants and have probably not been checked by the examiners in most studies. Therefore, it would be useful for future studies to report detailed information on specific characteristics of study completers and dropouts. Third, while we were able to identify several important moderators of dropout, all related to study/protocol characteristics, many other potentially predictive determinants of exercise maintenance (eg, education, social support, self-efficacy) were not assessed in most studies, hampering a more refined and differentiated analysis. Ideally, this would be addressed in future research. Fourth, the possibility of publication bias exists in which a risk for drawing misleading conclusions may be present. Use of trim and fill analyses may be useful up to a point in reducing this bias.

Fifth, sample sizes in many studies were rather small, contributing to an overall limited power in our meta-analysis. Moreover, given that the included studies lasted on average approximately 9 weeks and none of the trials exceeded a duration of 16 weeks, the long-term adherence to HIIT remains unclear. Therefore, large-scale studies involving long-term intervention periods are clearly needed to answer such questions. Sixth, given that the studies we identified were limited to sedentary/untrained but otherwise healthy subjects, the results of this meta-analysis cannot be generalized to other populations such as individuals with chronic diseases. Although emerging evidence suggests that HIIT also appears to be feasible and effective for various clinical settings (eg, cardiac rehabilitation or type 2 diabetes patients),22-24,27,112 current evidence regarding safety and medical concerns in patients is still insufficient to allow for definitive conclusions to be reached.

Seventh, we note that the vast majority of included studies were conducted in well-controlled laboratory settings. However, clinical drug research, for example, suggests that maintenance rates in “real-world” settings are substantially lower than those reported from laboratory trials and this trend is even more apparent in lifestyle change interventions,113 rendering the translation from evidence of laboratory efficacy to public health impact uncertain. Slight differences in modalities and delivery of the intervention may lead to substantial differences in real-world efficacy. To date, the few studies addressing this issue have yielded conflicting results. Lunt et al93 reported low adherence rates and only modest improvements in CRF during a 12 week HIIT intervention, consisting of walking/running uphill-intervals in a community park. In contrast, Shepherd et al79 observed significant improvements in VO2max after 10 weeks of HIIT carried out on indoor spinning bikes in a gym setting plus greater adherence among participants in the HIIT group than in those who performed MICT. Two more recent studies investigating the effects of an intense stair climbing exercise protocol over 6 weeks99 or an 8-week exercise intervention in a community-based fitness-center conducted as group-based classes on spinning bikes78 have also found significant increases in VO2max and provide indication that HIIT may be a feasible exercise option outside of laboratory conditions. This supports recent recommendations114 that more studies conducted in the community, at workplaces, or in home settings are needed to establish the applicability and potential utility of HIIT value in real-world conditions.

Finally, it should be pointed out that all included studies implemented supervised or laboratory-based HIIT, respectively. However, compliance with attending supervised exercise sessions can be very different than adhering to a prescription of unsupervised exercise. Data on adherence to unsupervised HIIT (eg, home-based HIIT) are currently lacking, and this important issue should be addressed in the future.

5 | PERSPECTIVES

Our results suggest that HIIT is well tolerated and accepted in previously sedentary individuals, as evidenced by lower dropout rates than those typically reported for traditional exercise programs. Given the significant association between exercise volume and dropout rates, future research should establish the minimally effective amount of practical HIIT protocols needed to improve health status. Such efforts will be invaluable in ensuring the sustainability and public health impact of this approach to physical activity.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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