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High-Intensity Interval Training (HIIT)

HIIT alternates short, very intense efforts with recovery phases. This page organises the controlled human studies by application areas and by strength of evidence. The most striking finding: among the most frequently cited controlled studies is one showing greater enjoyment with interval training than with continuous moderate exercise.

1,722

STUDIES IN
TOTAL

1,137

IN HUMANS

813

OF WHICH
CONTROLLED

32

IN ANIMALS

3

IN THE LAB

Figures from the IHR study database · Last updated 2026-10-15

How to Read This Dossier

ESTABLISHED

measured in humans, with a comparison group

PLAUSIBLE

supported by mechanism, animal studies or observation

HYPOTHESIS

a likely connection that still needs to be tested

High-Intensity Interval Training (HIIT) at a Glance

ORIGIN:

High-intensity interval training is an exercise format, not a preparation: short sections of high intensity, interspersed with recovery phases with low load or pause. The sections range from a few seconds in sprint interval training to several minutes in classic HIIT, whereby HIT, HIIT and sprint interval training sometimes designate the same structure. The evaluated works start in 2012.

EVIDENCE BASE:

1,722 evaluated works · 813 controlled human studies · 324 observational studies · 155 review articles · 32 animal experiments · 3 cell culture studies

STRONGEST EVIDENCE:

- **Proven:** Metabolism — meta-analysis of 18 randomised controlled trials in obesity: HIT improved VO₂max and reduced body fat percentage more than continuous training; no difference in BMI.
- **Metabolism:** Meta-analysis on prediabetes and type 2 diabetes: HIIT increased VO₂max by 3.02 mL/kg/min (95 % CI 1.42 to 4.61) more than MICT; no difference for HbA_{1c}, blood pressure, cholesterol, BMI and waist-hip ratio.
- **Metabolism:** Meta-analysis with 13 studies and 345 patients with type 2 diabetes: greater reduction versus MICT in body weight (mean difference -1.22 kg), BMI (-0.40 kg/m²) and HbA_{1c} (-0.37).
- **Further investigations:** Randomised controlled trial with twelve recreationally active adults showed: enjoyment after HIIT higher (103.8 ± 9.4) than after MICT (84.2 ± 19.1; p = 0.013), eleven of twelve preferred HIIT.

LIMITATIONS:

- The endpoints are predominantly markers such as maximal oxygen uptake, body composition or blood glucose control, not disease progression or mortality.
- Adaptation varies strongly between individuals; mean values mask persons without measurable adaptation; the protocols are hardly comparable; some of the studies examine low-volume variants.
- One controlled study on inflammation is available in 26 people with insulin resistance; the extract reports neither sample size calculation nor training volume, and figures on the gut microbiota are not included therein.

CLASSIFICATION:

HIIT is an exercise format consisting of short intense sections; the controlled works examine mainly fitness and metabolism, the most frequently cited ones the experience of training.

1. What High-Intensity Interval Training Is

High-intensity interval training is an exercise format, not a preparation. It consists of short sections of high intensity, between which recovery phases with low load or pause are inserted. The sections range from a few seconds, as in sprint interval training, to several minutes in classic HIIT. The literature does not separate the forms uniformly: HIT, HIIT and sprint interval training sometimes designate the same structure. The evaluated works start in 2012; a review article with historical perspective traces the development of the procedure. It is examined in supervised programmes, in cardiac rehabilitation, in school programmes and as walking rehabilitation with prescribed intensity, for example after stroke.

Crucial for the understanding of all works is how intensity is defined. It is usually defined relative to individual performance capacity, that is as a proportion of maximal oxygen uptake or maximal heart rate. Consequently the same specification depends on the person: what constitutes a moderate load for a trained individual can be the upper limit for an untrained one. Secondly, the protocols are hardly comparable. Interval length, number of repetitions, duration and intensity of recovery and total volume are chosen differently; some of the studies explicitly examine low-volume variants. Thirdly, the comparison group is almost always another form of training, usually continuous moderate or vigorous load, not inactivity. Statements about intervals are therefore mostly statements about the difference from another load. Fourthly, adaptation varies considerably between individuals.

2. What the Studies Show in Detail

The supporting human studies and the most important reviews — by application area, with population, duration, preparation, measured variable and result, as the original works report them. Numbers appear only where the work states them.

Distribution of **controlled human studies** by application area — the numbers are not additive, as one work may be assigned to several areas:

APPLICATION AREA	CONTROLLED STUDIES
Metabolism	294
Heart and circulation	272
Musculoskeletal system	217
Safety and tolerability	189
Fatigue and stress	131

APPLICATION AREA	CONTROLLED STUDIES
Cognition and psyche	129
Inflammatory processes	85
Oncology	73

Inflammatory Processes

The work present in the material on this area is a controlled study in 26 sedentary people with insulin resistance (prediabetes $n = 9$, type 2 diabetes $n = 17$; age 49 [SD 4] years; body-mass index 30.5 [SD 3]), who were randomised to either sprint interval training (SIT) or moderate-intensity continuous training (MICT). Measured were insulin-stimulated intestinal glucose uptake and uptake of free fatty acids from the circulation by positron emission tomography, composition of the gut microbiota by 16S-rRNA gene sequencing, and serum inflammatory markers by multiplex assays and an ELISA kit.

After training, VO_{2peak} improved only in the SIT group ($P = 0.01$). Both training forms lowered systemic and intestinal inflammatory markers (tumour necrosis factor- α , lipopolysaccharide-binding protein; time $P < 0.05$). For this study period the work therefore shows that the reduction of the inflammatory markers was not tied to the higher intensity, whereas the improvement in endurance capacity occurred only under SIT. **Hypothesis:** That the markers declined in both arms could mean that training volume or training duration and not intensity is decisive; this question is to be examined in a design that varies intensity and volume separately.

The number of participants is small at 26, and the present excerpt reports neither a sample size calculation nor the training volume completed by the two arms. The excerpt ends in the results presentation after the information on the inflammatory markers; figures on intestinal glucose and fatty acid uptake and on the microbiota composition after training are not included therein. It remains open whether the observed marker changes exist independently of weight changes and how long they persist after the end of training; this is to be clarified by follow-up measurements beyond the intervention phase.

Safety and Tolerability

The 2014 study compared, in a randomised balanced repeated-measures design, the tolerability and affective response during high-intensity interval training (HIT), continuous moderate-intensity training (CMI) and continuous vigorous-intensity training (CVI) ¹. Forty-four participants attended the laboratory on four occasions; at the first visit peak power output in watts (W peak) was determined via an exercise test, and at the three subsequent visits they completed, in randomised order, one session each: HIT with 1 minute at approximately 100 % W peak and 1 minute at approximately 20 % W peak for 20 minutes, CMI at approximately 40 % W peak for 40 minutes and CVI at approximately 80 % W peak for 20 minutes ¹.

Affective responses were recorded before, during and after each session, and task self-efficacy, intentions, enjoyment and preference were recorded afterwards ¹. Participants reported greater enjoyment with HIT than with CMI and CVI, and over 50 % expressed a preference for HIT ¹. For interpretation it is decisive that the affective response and tolerability of HIT were less well studied at the time of the investigation and that a comparison between HIT, CVI and CMI had not previously been available ¹. The excerpt ends at this description of results; data on the affective values during the sessions and on reasons for dropout are not included therein ¹.

It remains open whether the reported preference holds with longer training duration and in clinical populations and whether it translates into actual training participation; the study recorded enjoyment and preference, not training behaviour over weeks ¹. **Hypothesis:** The higher enjoyment of short intervals could be mediated by perceived time commitment; this is to be tested in a design that measures enjoyment and perceived time commitment separately.

Further Investigations

In a randomised controlled study, twelve recreationally active men and women (age 29.5 ± 10.7 years, VO_{2max} 41.4 ± 4.1 mL/kg/min, BMI 23.1 ± 2.1 kg/m²) completed, after a VO_{2max} test on a cycle ergometer, two further sessions in randomised order: HIIT with eight 1-minute bouts at 85 % of maximal power (W_{max}) and one minute of active recovery between each, or MICT with 20 minutes at 45 % W_{max} ². During exercise, rating of perceived exertion (RPE), affect and blood lactate concentration were measured; after exercise the Physical Activity Enjoyment Scale (PACES) was completed ². Enjoyment was higher after HIIT (103.8 ± 9.4) than after MICT (84.2 ± 19.1 ; $p = 0.013$), and eleven of twelve participants (92 %) preferred HIIT ². The authors note that approximately 50 % of people drop out of an exercise programme within the first 6 months and cite lack of time as the main reason ².

A randomised crossover study with 21 recreationally active adults examined individual adaptation to endurance training (END) and sprint interval training (SIT) ⁴. Both programmes lasted three weeks with four days per week; END consisted of 30 minutes at approximately 65 % of VO_{2peak} power, SIT of eight 20-second intervals at approximately 170 % of VO_{2peak} power with 10 seconds of active recovery each, with a three-month washout period between training phases ⁴. For VO_{2peak} , lactate threshold and submaximal heart rate a main effect of training was observed, yet individual responses varied considerably and no significant positive association of individual changes was found between END and SIT for any variable ⁴. Non-response was defined as twice the typical error of measurement: 0.107 L/min for VO_{2peak} , 15.7 W for lactate threshold and 10.7 bpm for submaximal heart rate; non-responders occurred after both programmes, yet their patterns differed, and all participants responded under at least one of the two programmes in at least one variable ⁴.

PROVEN A meta-analysis of 18 randomised controlled trials compared high-intensity training (HIT) with traditional high-volume continuous training in adults with obesity ²⁹. HIT achieved a greater improvement in cardiorespiratory fitness (VO_{2max} ; mean difference 1.83, 95 % CI 0.70 to 2.96, $p < 0.005$; $I^2 = 31$ %) and a greater reduction in body fat percentage (mean difference -1.69, 95 % CI -3.10 to -0.27, $p = 0.02$; $I^2 = 30$ %); BMI did not differ between the two approaches ²⁹. The authors note that future studies must develop specific HIT programmes for this group ²⁹.

A 2024 review on dose-response relationships, physical activity intensity and mortality risk summarises the evidence: observational studies consistently show associations between activity and lower mortality, lower risk of non-communicable diseases and better mental health, and randomised controlled trials as well as Mendelian randomisation studies support causal relationships ¹⁶. At the same time the work identifies the scarcity of randomised evidence and its difficulties such as exposure contrasts, healthy-volunteer bias, losses to follow-up and limited real-world dose-response data ¹⁶. Newer observational studies with device-measured activity emphasise that every minute counts and that all intensity levels confer health benefits, with high intensity possibly

requiring lower volumes; future guidelines could refine age-specific recommendations, emphasise high intensity and incorporate daily step counts¹⁶. It remains open whether this relationship can be tested directly for HIIT with hard endpoints such as mortality; randomised designs of sufficient duration are still lacking for that purpose.

Metabolism

A meta-analysis compared HIIT and moderate-intensity continuous training (MICT) in prediabetes and type 2 diabetes; from 818 hits, seven studies were included in the systematic review (64 patients with prediabetes and 120 with type 2 diabetes), and five studies with type 2 diabetes were meta-analysed⁸. HIIT increased VO₂max as a measure of functional capacity by 3.02 mL/kg/min (95 % CI 1.42 to 4.61) more than MICT; no difference was found for HbA_{1c}, systolic and diastolic blood pressure, total cholesterol, HDL and LDL cholesterol, triglycerides, BMI or waist-to-hip ratio⁸. Most included studies had unclear risk of bias; evidence quality was low to very low⁸. A second meta-analysis with 13 studies and 345 patients with type 2 diabetes found significant changes under HIIT in BMI, body fat, HbA_{1c}, fasting insulin and VO₂peak; compared with MICT the reduction in body weight was greater (mean difference -1.22 kg, 95 % CI -2.23 to -0.18, *P* = 0.02), as was the reduction in BMI (mean difference -0.40 kg/m², 95 % CI -0.78 to -0.02, *P* = 0.04), and a corresponding difference was observed for HbA_{1c} (mean difference -0.37)¹⁰.

In a study with 31 inactive adults with obesity (age 31 ± 6 years, BMI 33 ± 3 kg/m²) participants completed twelve weeks of four sessions per week of either HIIT (10 × 1 minute at 90 % HR_{max} with 1 minute active recovery; *n* = 16) or MICT (45 minutes at 70 % HR_{max}; *n* = 15), with body weight kept constant¹⁹. Peak oxygen uptake rose by approximately 10 % in both groups (*P* < 0.0001), body weight and fat mass remained unchanged; peripheral insulin sensitivity, measured by hyperinsulinaemic-euglycaemic clamp, was approximately 20 % higher the day after the final session than before training (*P* < 0.01), with no difference between HIIT and MICT, and returned to baseline in both groups after four days without training¹⁹. The abundance of numerous muscle proteins of mitochondrial respiration as well as of lipid and carbohydrate metabolism also increased similarly in both groups, as did the training-induced changes in the muscle lipid profile¹⁹.

Twenty-eight sedentary overweight or obese men (age 20 ± 1.5 years, BMI 29.5 ± 3.3 kg/m²) were randomised to HIIT or moderate-intensity continuous training (MIT) for six weeks, with HIIT prescribing one hour and MIT five hours of activity per week³. Body composition by DXA, cardiovascular fitness by treadmill test, insulin sensitivity by oral glucose tolerance, lipoprotein particles by nuclear magnetic resonance spectroscopy and blood pressure by automated auscultation were recorded³. In the complete-case analysis the improvement in VO₂peak was greater under MIT than under HIIT (11.1 % vs. 2.83 %, *P* = 0.0185); in the intention-to-treat analysis no difference was observed, and no group differences were found for the remaining outcomes³. A randomised study with 31 obese women (18 to 30 years) compared five weeks of HIIT (20 minutes of repeated 8-second bouts with 12 seconds recovery) with moderate-to-vigorous continuous training (MVCT; 40 minutes at 60 to 80 % of VO₂peak), each on four days per week⁵. VO₂peak increased in both programmes (9.1 % under HIIT and 10.3 % under MVCT; *p* = 0.010, *η*² = 0.41); the MVCT group reduced total body weight (-1.8 %, *p* = 0.034), fat mass (-4.7 %, *p* = 0.002) and body fat percentage (-2.9 %, *p* = 0.016), while no significant between-group differences in change were observed⁵.

Forty-five boys with obesity (age 11.2 ± 0.7 years, BMI 24.2 ± 1.0 kg/m²) were randomised to HIIT (*n* = 15), moderate-intensity continuous training (MICT, *n* = 15) or a control group (*n* = 15) and trained for twelve weeks with three sessions per week in the school setting⁹. The HIIT group completed two sets of eight 15-second runs at 90 to 100 % of maximal aerobic speed (MAS) with eight 15-second recovery runs at 50 % MAS, the MICT group 30 minutes of running at 60 to 70 % MAS, and the control group maintained usual behaviour; body composition, cardiorespiratory fitness and cardiometabolic markers were recorded before and after the intervention⁹. The present excerpt ends at the beginning of the results presentation on BMI and body fat; effect sizes are not included therein⁹. **Proven:** A meta-analysis of randomised trials in older adults found a greater improvement in VO₂peak under HIIT than under MICT (weighted mean difference 1.74, 95 % CI 0.80 to 2.69, *p* < 0.001)²⁸. Subgroup analyses showed larger effects with training periods longer than 12 weeks, two sessions per week, sessions of 40 minutes, six sets and repetitions, bout durations longer than 60 seconds and rest intervals shorter than 90 seconds²⁸.

Between low-volume HIIT and control no difference was found in total body fat mass (effect size -0.129)²⁶. A review of twelve systematic reviews with meta-analysis (149 studies) reports for exercise programmes in adults with overweight or obesity a significant weight loss (mean differences of -1.5 to -3.5 kg), fat loss (-1.3 to -2.6 kg) and visceral fat loss (standardised mean differences -0.33 to -0.56); between endurance training and HIIT at equal energy expenditure no difference existed, resistance training reduced loss of fat-free mass (mean difference 0.8 kg, 95 % CI 0.4 to 1.3), and no significant effect on weight maintenance was observed²⁵.

The meta-analysis across 13 studies on the effect on VO₂max yielded a weighted mean effect size of *g* = 0.63 (95 % CI 0.39 to 0.87) and VO₂max increases of 4.2 to 13.4 %; peripheral adaptations that increase the oxidative potential of muscle were well supported, while evidence on central adaptations was limited and inconsistent²⁴. Some indications pointed to changes in substrate oxidation at rest and during exercise after SIT²⁴. The recommendations of the European Association for the Study of Obesity Physical Activity Working Group (Grade A) list every form of exercise including high-intensity interval training for improving insulin sensitivity and cardiorespiratory fitness, the latter after thorough cardiovascular risk assessment and under supervision; the expected weight loss averages no more than 2 to 3 kg²⁰. The 2018 Physical Activity Guidelines Advisory Committee rated the evidence on HIIT and cardiometabolic risk as moderate: HIIT can improve insulin sensitivity, blood pressure and body composition in adults with group means from approximately 20 to approximately 77 years, the effects are comparable to those of MICT and occur more probably in adults at higher risk for cardiovascular disease and diabetes than in healthy individuals²¹.

Two reviews on the role of exercise in the treatment of type 2 diabetes note that HIIT is effective and time-efficient and that the sustainability of exercise recommendations for patients remains difficult to achieve¹⁸, and that HIIT can lower blood glucose while optimal recommendations in interplay with nutrition and medication remain open²³. A review with historical perspective describes high-intensity interval training as repeated short peaks of exertion with near-maximal or maximal effort corresponding to ≥ 90 % of maximal oxygen uptake or > 75 % of maximal power, interrupted by rest or low-intensity exertion, and traces the development back to the early 1920s²⁷. A meta-analysis on physical training in type 2 diabetes included 21 studies (9 randomised) with a total of 523 patients, 472 with training and 151 without; the interventions were endurance training (14 studies), resistance training (2 studies) and combinations of endurance and resistance training, with HIIT not pooled as a separate group¹¹. It remains open which HIIT dosages (interval length, exercise intensity, training duration) support the metabolic effects in which population and to what extent they can be separated from MICT at equal energy expenditure; this is to be clarified in studies with standardised energy expenditure and robust endpoints.

Musculoskeletal System

A multicentre randomised clinical trial with intention-to-treat analysis (January 2019 to April 2022) examined, in survivors of a single stroke aged 40 to 80 years with existing gait limitation at least six months after the event, which training intensity and which minimum duration maximise the immediate improvement in walking ability⁶. Participants were randomised 1:1 to high-intensity interval training (HIIT) or moderate-intensity aerobic training (MAT), each consisting of 45 minutes of walking exercise three times per week for 12 weeks⁶. The HIIT protocol used repeated 30-second bouts of walking at maximal safe speed, alternating with 30 to 60 seconds of rest, with a mean aerobic intensity above 60 % of heart rate reserve; the MAT protocol used continuous walking with an initial intensity of 40 % of heart rate reserve and progression up to 60 % if tolerated⁶. The primary outcome was walking distance in the 6-minute walk test⁶.

The present excerpt of a study on gait rehabilitation after chronic stroke ends at this point of the methods description; the results for the three training durations of 4, 8 and 12 weeks are not included therein⁶. It therefore remains open which intensity-duration combination of gait rehabilitation after chronic stroke yields the greatest immediate gain in walking distance and whether the effect persists beyond the intervention duration; this is to be clarified with the fully reported longitudinal data.

A systematic review with meta-analyses examined the effect of exercise interventions on physical fitness in adults with overweight or obesity and compared different types of training¹². All types of training increased VO₂max (mean difference 3.82 mL/min/kg, 95 % CI 3.17 to 4.48, $P < 0.00001$; $I^2 = 48\%$); in direct comparisons resistance training was less effective than endurance training, HIIT was marginally more effective than endurance training, and no difference was found between endurance training and combined endurance plus resistance training¹². For strength gains the inclusion of resistance training in the programme is indicated according to these data¹². It remains open whether the small advantage of HIIT is reproduced with longer intervention durations and in different age groups; this is to be tested in direct comparison studies with uniform training duration.

Heart and Circulation

The FITR-Heart study was a single-centre randomised clinical trial with 96 participants with angiographically confirmed coronary heart disease aged 18 to 80 years, of whom 93 were medically cleared for participation after a cardiopulmonary exercise test; data collection ran from May 2016 to December 2018⁷. After four weeks of supervised training sessions in a cardiac rehabilitation programme, home-based training and 12-month follow-up followed⁷. A 4 × 4-minute HIIT programme and a 40-minute MICT programme as usual care were compared; patients completed three sessions per week (two supervised, one at home) for four weeks and thereafter three home-based sessions per week for 48 weeks⁷. The primary outcome was change in VO₂peak⁷. The present excerpt ends at this point; the results on feasibility, safety, adherence and efficacy are not included therein⁷.

A systematic review with meta-analysis compared the blood-pressure effect of MICT and HIIT in hypertensive individuals¹⁴. Both interventions differed significantly from the control group in systolic blood pressure (MICT: mean difference 3.7 mmHg, 95 % CI 2.57 to 4.82, $p < 0.00001$; HIIT: mean difference 5.64 mmHg, 95 % CI 1.69 to 9.52, $p = 0.005$) and in diastolic blood pressure (MICT: mean difference 2.41 mmHg, 95 % CI 1.09 to 3.72, $p = 0.0003$; HIIT: mean difference 4.8 mmHg, 95 % CI 2.9 to 6.7, $p < 0.00001$)¹⁴. Between the groups no difference was found in systolic blood pressure (mean difference 1.13 mmHg, 95 % CI -0.01 to 2.27, $p = 0.05$), but a difference was found in diastolic blood pressure (mean difference 1.63 mmHg, 95 % CI 0.83 to 2.44, $p = 0.0001$)¹⁴. In the secondary outcome both interventions increased maximal oxygen uptake; this analysis is not fully contained in the present excerpt¹⁴. It remains open whether the small advantage in diastolic blood pressure is clinically meaningful and how it behaves under different blood-pressure medication.

A review article classifies the protocols of high-intensity interval training for cardiological care and distinguishes aerobic HIIT and anaerobic HIIT, usually called sprint interval training (SIT), according to effect, target group, adaptability, mechanisms of action and safety²². The starting point is that peak oxygen uptake (VO₂peak) is an independent predictor of all-cause mortality and cardiovascular prognosis, even in people with coronary risk factors and cardiovascular diseases, and that the guidelines of most professional societies recommend 150 minutes of moderate or 75 minutes of vigorous activity per week²². The author notes that selecting the appropriate protocol for the individual patient favours greater improvements in VO₂peak with higher adherence and quality of life²². It remains open on the basis of which characteristics patients should be assigned to the aerobic or the anaerobic protocol; this is a question for comparative studies with predefined assignment criteria.

Cognition and Psyche

The HIIT-Stroke study was a single-blind, multicentre, parallel-group randomised controlled trial at specialised rehabilitation units of three Norwegian clinics with 70 adults three months to five years after a first stroke (mean age 57.6 ± 9.2 years in the intervention group and 58.7 ± 9.2 years in the control group)¹⁵. Participants were randomised to standard treatment plus additional 4 × 4-minute treadmill HIIT at 85 to 95 % of peak heart rate or to standard treatment alone¹⁵. It remains open whether the cognitive effects extend beyond the tested attention and executive function; this requires studies with broader cognitive test batteries and longer follow-up.

The CRX study was a randomised controlled trial that compared three programmes twice weekly over 12 weeks in patients with coronary heart disease after revascularisation: HIIT (4 × 4 minutes at 85 to 95 % of peak heart rate), Nordic Walking (resting heart rate + 20 to 40 bpm) and MICT (resting heart rate + 20 to 40 bpm)¹³. Functional capacity in the 6-minute walk test, depression severity via the Beck Depression Inventory-II, brain-derived neurotrophic factor from a blood sample, general quality of life via the Short-Form 36 and disease-specific quality of life via the HeartQoL were recorded¹³. The present excerpt ends after the description of the measurement instruments; results on functional capacity, depression, BDNF and quality of life are not included therein¹³. It remains open whether the depression and quality-of-life scores differ between HIIT, Nordic Walking and MICT and whether they are linked to changes in BDNF; this is to be clarified from the fully reported group comparisons.

Gut and Microbiome

The work is a substudy of the Exercise-for-Type-2-Diabetes-Study, a prospective, randomised controlled trial at one centre¹⁷. Twelve participants completed eight weeks of combined endurance and strength training, either as moderate-intensity continuous training (C-MICT) or as high-intensity interval training (C-HIIT)¹⁷. Stool samples were collected before and after the intervention to determine the composition of the gut microbiome and metabolic pathways via metagenomic shotgun sequencing as well as short-chain fatty acids¹⁷.

After training, α -diversity differed between the groups, as did the relative abundance of individual taxa ($p < 0.05$)¹⁷. At lower training intensity, *Bifidobacterium*, *A. muciphila* and the butyrate producers *Lachnospira eligens*, *Enterococcus* spp. and *Clostridium* Cluster IV were detectable at higher relative abundance; at higher intensity, other butyrate producers (from the orders *Erysipelothrichales* and *Oscillospirales*) as well as the methane producer *Methanobrevibacter smithii* were present at higher relative abundance¹⁷. The present excerpt ends in this presentation of results; information on short-chain fatty acids and on the metabolic pathways is not included therein¹⁷.

With twelve participants the substudy is small, and the statement refers to composition of the microbiome after eight weeks of combined training, not to an isolated effect of the interval scheme¹⁷. It remains open whether the intensity-dependent differences in the butyrate producers and the methane producer persist beyond the training phase and whether they are associated with inflammatory markers or glycaemic control; this is to be clarified in studies with larger sample size and parallel measurement of both parameters.

Overall Picture

Across the areas, improvement in endurance capacity contributes: meta-analyses in adults with obesity (VO₂max mean difference 1.83, 95 % CI 0.70 to 2.96)²⁹, in older adults (weighted mean difference 1.74, 95 % CI 0.80 to 2.69)²⁸ and in prediabetes and type 2 diabetes (3.02 mL/kg/min, 95 % CI 1.42 to 4.61)⁸ show consistent advantages for HIIT over continuous moderate-intensity training, whereas for HbA_{1c}, blood pressure and blood lipids in the diabetes meta-analysis there was no difference between the two forms⁸ and insulin sensitivity in a twelve-week study rose by approximately 20 % in both arms¹⁹. In a review of many training forms and studies, no difference was found in weight, fat and visceral fat loss at equal energy expenditure²⁵.

In several areas research is at an early stage: on the effect on inflammatory markers there is one controlled study with 26 participants in which both training forms lowered the markers; on the microbiome a substudy with twelve participants¹⁷; on depressivity and quality of life in coronary heart disease a randomised study whose results are not reported in the present material¹³. Individual responses to endurance and sprint interval training vary considerably, non-responders occur in both programmes, and all participants responded under at least one programme in at least one variable⁴. Next to be clarified is which dosage works in which population, how long the effects persist after the end of training and whether they appear in hard endpoints such as mortality and cardiovascular events; randomised studies with long duration are still outstanding for this purpose¹⁶.

Methodology of the Evidence Base

The material comprises randomised controlled trials, crossover designs, controlled comparative studies, meta-analyses and review articles. Intervention durations are three weeks⁴, five weeks⁵, six weeks³, eight weeks¹⁷ and twelve weeks^{9 19 15 13}; one cardiological study combines four weeks of supervised training with 48 weeks of home-based training and 12-month follow-up⁷. The outcomes recorded are predominantly VO₂peak or VO₂max, body composition by DXA or bioimpedance, insulin sensitivity by clamp or oral glucose tolerance test, HbA_{1c}, blood pressure, blood lipids, lactate threshold, muscle proteins, inflammatory markers, microbiome by 16S-rRNA and shotgun sequencing, cognitive tests such as the Trail Making Test Part B¹⁵, depression scales¹³ and enjoyment by PACES². Hard clinical endpoints, standardised comparisons at exactly the same energy expenditure across all endpoints, and follow-up beyond the intervention period are not recorded in the studies presented; the question of which patient should receive which interval protocol also remains to be clarified²².

Acceptability in the test is not adherence in everyday life

Among the most frequently cited controlled studies are works that measure perceived enjoyment and affective response during exercise. They compare intervals with continuous moderate or vigorous exertion; one of these studies finds higher enjoyment for the intervals. The finding is well secured, yet it answers a narrower question than it often appears to: it describes the experience within the examined session or programme, not the number of people who remain adherent over months. Enjoyment is a measurement value; adherence is a trajectory.

In addition, the comparisons are relative. Being more pleasant than a continuous moderate session of equal duration does not mean the format is pleasant overall; the reference is continuous exertion, not rest. The variability study further shows that adaptation varies widely between individuals, so that a mean enjoyment score can include participants for whom the format is unsuitable. The feasibility and safety data from cardiac rehabilitation are the more robust source because they capture dropout and tolerability across the programme duration.

HYPOTHESIS:

Favourable affect data and adherence outside supervised programmes can be reconciled when supervision itself is the active component. This would be clarified by a comparison of supervised and unsupervised interval training.

3. How Robust the Research Is

The controlled human studies focus on two main areas: metabolism and cardiovascular system form the largest groups, followed by the musculoskeletal system. These are followed by studies on safety, fatigue and cognition. For inflammation, oncology, gut and immune system there are markedly fewer controlled studies. In addition there are numerous observational studies and basic research investigations that describe mechanisms and adaptive responses. The thematic focus of the most frequently cited controlled studies is striking: they deal predominantly not with metabolic markers but with the affective response to training and with perceived enjoyment. The most-read controlled studies therefore examine how the format is experienced.

The methodological basis for a training format is broad. Several systematic reviews with meta-analysis summarise randomised studies, predominantly on cardiorespiratory fitness, body composition and metabolic parameters; separate analyses exist for older adults and for people with type 2 diabetes. **Proven:** Cardiorespiratory fitness is the endpoint most frequently examined by meta-analysis. The limitations lie in the endpoints: these are predominantly markers

such as maximal oxygen uptake, body composition or glycaemic control, not disease course or mortality. The programmes are short, many comparisons derive from supervised laboratory and clinical settings, and adaptation varies so widely between individuals that mean values conceal participants without measurable adaptation.

4. What Is Often Claimed — and What the Data Support

CLAIM	EVIDENCE BASE
Intervals are the most efficient method for weight loss	The review article on weight loss, body composition and weight maintenance compiles systematic reviews on training in general, not on interval training. It makes
Intervals replace endurance training	Almost all controlled studies compare intervals with continuous moderate or vigorous exertion and measure markers. This therefore tests a comparison of two for
The format is too risky for cardiac patients	Safety is one of the largest study areas. A randomised study has examined the feasibility and safety of interval training in cardiac rehabilitation over short and lon
Intervals alter the gut microbiota	A highly regarded controlled study examines the influence of training on gut flora and endotoxaemia; the title mentions training in general, not intervals. There are

5. The Most Robust Studies

Ordered by strength of evidence, not by popularity. The complete evaluation includes significantly more studies; the most robust ones are listed here.

Controlled Studies in Humans

- Exercise Training Modulates Gut Microbiota Profile and Improves Endotoxemia (2020)
- ¹ Where does HIT fit? An examination of the affective response to high-intensity intervals in comparison to continuous moderate- and continuous ... (2014)
- ² High-Intensity Interval Training Elicits Higher Enjoyment than Moderate Intensity Continuous Exercise (2017)
- ³ High Intensity Interval- vs Moderate Intensity- Training for Improving Cardiometabolic Health in Overweight or Obese Males: A Randomized Controlled ... (2015)
- ⁴ Inter-Individual Variability in the Adaptive Responses to Endurance and Sprint Interval Training: A Randomized Crossover Study (2016)
- ⁵ Comparison of High-Intensity Interval Training and Moderate-to-Vigorous Continuous Training for Cardiometabolic Health and Exercise Enjoyment in ... (2016)
- ⁶ Optimal Intensity and Duration of Walking Rehabilitation in Patients With Chronic Stroke: A Randomized Clinical Trial (2023)
- ⁷ Short-term and Long-term Feasibility, Safety, and Efficacy of High-Intensity Interval Training in Cardiac Rehabilitation: The FITR Heart Study ... (2020)
- ⁸ High-intensity interval training versus continuous training on physiological and metabolic variables in prediabetes and type 2 diabetes: A ... (2018)
- ⁹ Effects of school-based high-intensity interval training on body composition, cardiorespiratory fitness and cardiometabolic markers in adolescent ... (2022)
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6. Summary

The controlled human studies are distributed across metabolism (294), heart and circulation (272) and the musculoskeletal system (217), followed by safety, exhaustion and cognition.

Plausible is that the format acts via the affective response to duration: Over 50 % of participants preferred HIT over CMI and CVI, and in the second study eleven of twelve participants preferred HIIT; the authors note that approximately 50 % of people discontinue a training programme within the first 6 months and cite lack of time as the main reason. **Hypothesis:** That inflammatory markers decreased in both training arms could mean that training volume or training duration and not the intensity is decisive.

What remains to be clarified is whether the reported preference holds with longer training duration and in clinical populations and whether it translates into actual training participation; the 2014 study recorded enjoyment and preference, not training behaviour over weeks. For the inflammatory markers it is open whether the changes exist independently of weight changes and how long they persist after the end of training; this requires follow-up measurements beyond the intervention phase and a design that varies intensity and volume separately. Whether the association between activity and mortality for HIIT can be tested with hard endpoints is open; randomised designs with sufficient duration are still lacking for this.

7. What Remains Open

- **Long-term adherence:** How many people continue with intervals over years when the training is not supervised? The available data come predominantly from supervised programmes.
- **Responder:** Which characteristics predict before the first session who responds to intervals and who does not? The variability studies show the spread, not its causes.
- **Dosage:** Which combination of interval length, intensity and recovery is favourable at which baseline? The protocols are too varied for a common answer.

Frequently Asked Questions

How is intensity defined in the studies?

As a percentage of individual maximal oxygen uptake or maximal heart rate. The prescription is therefore relative, not absolute. The same figure represents a different load for a trained person and an untrained person. Anyone prescribing intervals therefore first establishes the individual reference value, not the interval duration.

Can interval training be used in cardiac rehabilitation?

Safety is one of the largest areas of study, and one randomised trial has examined feasibility and safety in cardiac rehabilitation over short and long periods. Further studies investigate walking rehabilitation with prescribed intensity, for example after stroke. The question has been researched; what remains open is patient selection.

Has interval training been studied in untrained individuals and in obesity?

Yes. There are randomised studies in overweight and obese adults, in obese young women and a school programme in obese adolescents. Intensity is set relative to individual performance capacity. The decisive factor is therefore the baseline assessment, not the interval prescription itself.

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Research, put in context. Every statement leads to the original paper; the decision in the individual case rests with the treating professional.
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