



DOSSIER · THERAPY

Endurance Training

Endurance training is widely researched as a training modality: controlled human studies form the largest block, with emphases on the musculoskeletal system and cognition. Notably, the most cited work is a foundational study on the temporal dynamics of the multi-omics response to endurance training — and that where compared against strength training, endurance training was not superior.

1,453
STUDIES IN
TOTAL

978
IN HUMANS

676
OF WHICH
CONTROLLED

90
IN ANIMALS

2
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

Aerobic Exercise at a Glance

ORIGIN:

Aerobic exercise is not a substance but a training method: a structured, partly supervised load performed continuously or interval-based. It was tested in randomised studies with intervention durations from four weeks to 24 months and two to three sessions per week; the heterogeneous protocols are made comparable via MET-minutes per week.

EVIDENCE BASE:

1.453 evaluated papers · 676 controlled human studies · 302 observational studies · 134 reviews · 90 animal studies · 2 cell-culture studies

STRONGEST EVIDENCE:

- Mental health: 63 papers, 81 meta-analyses and 79 551 participants; exercise reduced depressive symptoms (SMD = -0,61) and anxiety (SMD = -0,47), with aerobic exercise showing the strongest effect.
- Transdiagnostic: Moderate to vigorous aerobic exercise was effective across eleven disorders and four spectra on core symptoms, with medium effect size (SMD = -0,67).
- Cancer: In 49 studies with 4738 participants aerobic exercise ranked highest against depression (SUCRA 68,4 %), ahead of combined training (66,4 %) and resistance training (55,7 %).
- Frailty in older age: 44 studies with 4011 participants aged 60 and over; aerobic exercise improved frailty status (g = 0,34), depressive symptoms (g = 0,37) and cognitive function (g = 0,67).

LIMITATIONS:

- The dose question is at the beginning: concrete thresholds exist for children and adolescents (360 MET-minutes per week) and the perinatal period; for other endpoints they remain to be determined.
- In several populations aerobic exercise ranks behind combined training, group training or mind-body interventions; its independent contribution within combination programmes needs clarification.
- At high training volumes male athletes show greater coronary calcification; whether this increases cardiovascular risk is unanswered.

CLASSIFICATION:

Aerobic exercise is broadly researched as a training modality and contributes most clearly to depressive and anxiety symptoms, yet in several populations it ranks behind combined and mind-body interventions.

1. What Aerobic Exercise Is and How It Is Performed

Aerobic exercise is a training form in which large muscle groups are loaded rhythmically over an extended period. Common implementations include running, cycling, swimming, rowing or the use of ergometers. The load is controlled via duration, frequency and intensity, with intensity set by heart rate, lactate, oxygen uptake or subjective perceived exertion. Training is usually performed in sessions lasting from several minutes to several hours, in some programmes daily and in others on only a few days per week. Aerobic exercise is used as a stand-alone measure, as an adjunct to resistance training and within multimodal programmes. Unlike a medicinal product it is not a uniform quantity: two studies that both examine aerobic exercise may set different stimuli.

For the evaluation of all studies it is decisive that aerobic exercise cannot be treated as a uniform exposure. The training modality itself already alters the stimulus; intensity, volume, progression and whether sessions are supervised or performed at home must also be considered. Comparison groups are equally diverse: they range from wait-list and usual care through everyday activity to resistance training or other exercise modalities, which fundamentally changes the meaning of a study. Target outcomes also differ: performance tests, laboratory values, questionnaires on fatigue and cognition, imaging or clinical endpoints. A laboratory value demonstrates a response of the organism, not a changed disease course. Anyone comparing studies on aerobic exercise is therefore comparing programmes, measurement methods and comparison conditions — not a single substance.

2. What the Studies Show in Detail

The human studies, ordered by application and the controlled studies first — with participants, duration, preparation, outcome measure and result as reported in the original papers. Numbers appear only where the work states them.

Distribution of **controlled human studies** by field of application — the numbers are not additive because one paper may be assigned to several fields:

FIELD OF APPLICATION	CONTROLLED STUDIES
Musculoskeletal system	215
Cognition and psyche	214
Fatigue and stress	152
Metabolism	136
Safety and tolerability	124

FIELD OF APPLICATION	CONTROLLED STUDIES
Heart and circulation	120
Oncology	62
Inflammatory processes	57

Aerobic Exercise: Human Studies

The most robust foundation is provided by a meta-meta-analysis of randomised controlled trials on exercise and mental health ¹⁷. It included 63 papers with 81 meta-analyses, 1079 individual studies and 79 551 participants; chronically physically ill populations were excluded to avoid overlap. Exercise reduced depressive symptoms (standardised mean difference SMD = -0,61, 95 % CI -0,69 to -0,54) and anxiety symptoms (SMD = -0,47, 95 % CI -0,59 to -0,36). Aerobic exercise showed the strongest effect on both endpoints. The work covers children and adults with clinically diagnosed as well as subclinical complaints; the statement therefore applies across age groups and severity levels. Which concrete dose parameters within aerobic exercise carry the largest effects remains open.

An umbrella review examined exercise as a transdiagnostic intervention in mental disorders defined according to ICD or DSM ⁹. Moderate to vigorous aerobic exercise proved effective on the disease-specific core symptoms across all eleven disorders and four spectra, with a medium effect size (SMD = -0,67, 95 % CI -0,84 to -0,50). This is the strongest evidence that aerobic exercise works not only in individual diagnoses but across diagnoses. The authors explicitly tested transferability across disorder boundaries; which intensity levels within the moderate-to-vigorous range achieve the most remains an open question.

The evaluation considered well-being, anxiety, depression, stress and sleep quality. Physical activity was associated with improvements in mental health, with a large positive effect on the overall rating. The work is based exclusively on randomised controlled trials up to March 2025 and classifies exercise as a rehabilitative approach. Since the endpoints were measured using multiple instruments, it remains to be clarified what proportion of the overall effect is attributable to endurance exercise in the narrower sense.

In coronary heart disease, a network meta-analysis compared transmission modalities across the phases of cardiac rehabilitation ²⁵. Randomised controlled trials in adults with coronary heart disease were evaluated, separated by phase I (inpatient), phase II (early outpatient) and phase III (long-term care). Endpoints were peak oxygen uptake (VO₂peak in mL·kg⁻¹·min⁻¹) and the six-minute walk distance (6MWD in metres). The authors compared direct and indirect evidence within each phase and tested global inconsistency. The optimal modality may therefore differ between phases; the ranks of the procedures were determined using the SUCRA method. Which modality leads in which phase is thus a testable, phase-specific question.

In type 2 diabetes, a meta-analysis examined how training characteristics affect HbA1c and accompanying cardiovascular risk factors ¹⁸. One hundred randomised controlled trials with 7195 participants and 136 interventions were included. All training types lowered HbA1c; the largest reductions were shown by combined training (-0.74 %, 95 % CI -0.91 to -0.57, n = 38) and high-intensity interval training (-0.71 %, 95 % CI -1.07 to -0.35, n = 13), followed by continuous endurance training (-0.62 %, 95 % CI -0.84 to -0.41, n = 57) and strength training (-0.36 %, 95 % CI -0.51 to -0.20, n = 38). Continuous endurance training therefore contributes substantially, but trails combined and interval-based forms. The work thus provides concrete indications for the selection of training form in this cohort.

For weight reduction, a dose-response meta-analysis clarified the relationship between endurance training and body-fat measures ¹. Included were randomised clinical trials with at least eight weeks of intervention duration that examined supervised endurance training in adults with overweight or obesity. Body weight, waist circumference, body fat, adverse events, reduction in medication use and health-related quality of life were evaluated. Effects were estimated per 30 minutes of endurance training per week and the curve shape of the relationship was determined. This provides the first robust dose-response curve for this area; the exact thresholds at which additional benefit plateaus are to be taken from the work.

In knee osteoarthritis, a network meta-analysis compared different endurance-training forms from randomised studies ²². Five databases were searched up to June 2024; included were studies that examined endurance interventions in knee osteoarthritis. Two reviewers independently selected the studies, extracted demographic characteristics, intervention protocols and endpoints, and assessed risk of bias with the Cochrane Risk of Bias Tool 2.0. The analysis was performed frequentist with the network meta-analysis package in Stata 17.0. The work ranks the various endurance protocols relative to one another; which protocol leads at which osteoarthritis grade remains to be clarified.

In Parkinson's disease, a network meta-analysis examined exercise against motor symptoms ⁷. Fifty-six studies with 2740 participants aged between 57.6 and 77.7 years were included and the interventions were divided into nine categories, including endurance, strength, combined training, balance, dance and sensorimotor approaches. Sensorimotor training with an endurance component showed the largest effect size (ES -1.09; 95 % CI -1.68 to -0.50), followed by strength training (ES -0.82; 95 % CI -1.23 to -0.41) and dance (ES -0.64; 95 % CI -1.24 to -0.05). Endurance loading therefore contributes here primarily in combination with sensorimotor tasks. Whether pure endurance training without this addition works comparably is not answered.

In type 2 diabetes, a further network meta-analysis examined the effect of different training forms on lipid metabolism ⁴⁴. Thirty-five randomised controlled trials with 2771 patients were included. Versus control, Chinese traditional fitness training, strength training and endurance training lowered total cholesterol; the same three plus whole-body vibration training lowered triglycerides; Chinese fitness training, whole-body vibration and endurance training raised HDL cholesterol; and Chinese fitness training, strength training and endurance training lowered LDL cholesterol. In the SUCRA ranking, Chinese fitness training was most effective at lowering total cholesterol (SMD = -0.57, 95 % CI -0.83 to -0.31, p < 0.001). Endurance training therefore acts on all four lipid parameters in a favourable direction, without leading in every case.

In depression, a network meta-analysis examined how different therapies work in combination with endurance training ³⁷. According to the area under the cumulative ranking curve, the order for the Hamilton Depression Scale was electroconvulsive therapy plus endurance training, repetitive transcranial magnetic stimulation plus endurance training, traditional Chinese medicine plus endurance training, selective serotonin-reuptake inhibitors plus endurance training and cognitive behavioural therapy plus endurance training. Endurance training appears here as an enhancer of established treatments; the independent contribution it makes in each combination cannot be derived from this ranking.

In perinatal depressive symptoms, a network meta-analysis with dose-response analysis compared the modalities ²⁶. Forty-six randomised controlled trials with 5719 participants were included. Pilates achieved the highest rank (SMD = -1.25, 95 % CI -2.14 to -0.364), followed by yoga, endurance training and flexibility training, which also showed clear effects. Approximately 360 MET-minutes per week were identified as the optimal dose for substantial benefit, practically two 30-minute sessions per week. Endurance training therefore belongs to the effective options, but ranks behind Pilates and yoga. The transferability of the dose specification to individual pregnancy and lactation phases remains open.

A further work on perinatal mental health compared the modalities separately for the prenatal and postnatal phases ³⁰. Exercise lowered the risk of prenatal (p = 0.02) and postnatal (p = 0.036) depression, was effective in the treatment of prenatal (p = 0.003) and postnatal (p = 0.01) depression and prevented prenatal anxiety (p = 0.007). The subgroup analysis showed a phase-specific effect of the modalities. This is therefore one of the few works that considered prenatal and postnatal periods separately; which modality leads in which phase is to be taken from the work in detail.

Specifically for the puerperium, a meta-analysis with dose-response analysis examined the effect of endurance training on depression, anxiety and quality of life ⁴². Included were randomised controlled trials with at least four weeks' duration that compared structured endurance training with inactive or minimal control. Depressive symptoms, anxiety and health-related quality of life were recorded using validated instruments. The authors additionally modelled the dose-response relationship. Endurance training is classified in this work as a low-risk behavioural strategy that improves mood, reduces stress and influences neurobiological pathways. The concrete thresholds at which benefit plateaus in the puerperium remain to be determined.

In older people, a network meta-analysis compared exercise interventions against depressive symptoms ²⁷. Sixty-five studies with 5536 participants were included. Versus wait-list and active controls, positive effects were shown (SMD = -0.69; 95 % CI -0.90 to -0.48; p < 0.001 versus wait-list; SMD = -0.42; 95 % CI -0.48 to -0.36; p < 0.001 versus active control). The pairwise analyses ranked individual procedures; the work is preregistered in the international register for systematic reviews under number CRD42024542830. Endurance training belongs to the procedures examined, but does not rank at the top. Which modality leads at which degree of depressive symptoms remains open.

In postmenopausal women, a network meta-analysis with model-based dose-response analysis determined the optimal modality and dose ⁴⁵. All four modalities examined – strength training, mind-body procedures, endurance training and combined training – alleviated depressive symptoms versus control; for strength training the effect size was SMD = -0.90. Endurance training is therefore one of several effective options, without being the strongest in this population. The optimal dose for postmenopausal women is to be taken from the work and remains a testable question for practice.

In children and adolescents, a Bayesian network meta-analysis determined comparative efficacy and the non-linear dose-response relationship ³⁴. Group training (SMD = -1.58, 95 % CI -2.54 to -0.62) and endurance training (SMD = -0.60, 95 % CI -1.10 to -0.10) were effective against depressive symptoms. For mixed training and mind-body procedures, no statistically significant effects were shown; the evidence for these modalities remained inconclusive. The dose-response modelling yielded a non-linear, curved pattern without indication of deterioration at higher doses; the minimal dose with statistically significant effect was 360 MET-minutes per week. Endurance training therefore works, but ranks behind group training.

In cancer, a network meta-analysis compared different forms of exercise against depression ²⁸. Forty-nine studies with 4738 participants were included and the interventions were divided into mind-body procedures, endurance training, anaerobic training, strength training, combined training and progressive muscle relaxation. In the network meta-analysis, endurance training achieved the highest rank (SUCRA 68.4 %), followed by combined training (SUCRA 66.4 %) and strength training (SUCRA 55.7 %). Endurance training therefore ranks at the top of the ranking in this population. The ranks rest on indirect comparisons; the confidence of the estimates is to be taken from the work.

In cancer, a further network meta-analysis examined the effect on cognitive function, separated by short-term and long-term course ⁴³. Exercise-based interventions improved subjective cognitive function in the short and long term (SMD 0.44, 95 % CI 0.27 to 0.61; SMD 0.37, 95 % CI 0.16 to 0.57), executive function (SMD -0.28, 95 % CI -0.43 to -0.14; SMD -0.32, 95 % CI -0.56 to -0.08), working memory (SMD 0.27, 95 % CI 0.14 to 0.41; SMD 0.31, 95 % CI 0.06 to 0.55) and processing speed. The ranks of the modalities were determined via SUCRA. What proportion endurance training in the narrower sense contributes to these effects is to be taken from the work in detail.

After stroke, a meta-analysis examined the effect of different forms of exercise on cognition and biomarkers ²⁹. The largest effect sizes were shown when endurance training was combined with task-based interventions, i.e. cognitive-motor dual-task training and functional movement training (SMD = 1.18, 95 % CI 0.68 to 1.68). In addition, motor function (MD = 13.98, 95 % CI 10.06 to 17.89) and activities of daily living improved. Endurance training therefore contributes here primarily in combination with cognitive tasks. Whether it works comparably alone is not clarified.

In older people after stroke, a network meta-analysis compared the efficacy of different exercise interventions on depression, anxiety and cognition ³¹. For depression, dual-task training, mind-body procedures and balance and coordination training achieved the highest ranks and showed statistically credible advantages versus usual care. For anxiety, mind-body procedures, strength training and dual-task training achieved the highest ranks, with credible advantages for strength training and dual-task training, while one particular procedure was associated with worse anxiety outcomes. Endurance training does not rank at the top in this ranking; the confidence of the estimates was assessed with CiNeMA.

In frail older people, a dose-response meta-analysis determined the optimal endurance dose ³². Forty-four studies with 4011 participants aged 60 years and over with frailty or pre-frailty were included; the heterogeneous protocols were standardised in MET-minutes per week. Endurance training improved frailty status (Hedges' g = 0.34), depressive symptoms (Hedges' g = 0.37), muscle strength (Hedges' g = 0.21), cognitive function (Hedges' g = 0.67), quality of life (Hedges' g = 0.57) and lower-extremity function (Hedges' g = 0.29 for the Timed Up and Go test; Hedges' g = 0.40 for the 30-second chair-stand test) versus usual care. The subgroup analysis showed consistent efficacy across modalities, without any single form being superior. The certainty of the evidence was assessed with GRADE.

In adults, a network meta-analysis examined the effect of different forms of exercise on endothelial function of the brachial artery, measured via flow-mediated dilatation ³³. Included were randomised controlled trials in adults up to February 2025. Primarily endurance training, strength training and combined training were compared; secondarily continuous endurance training, interval endurance training, dynamic strength training and combined training. The ranking was determined via the area under the cumulative ranking curve. Flow-mediated dilatation is regarded as a surrogate measure of coronary endothelial function and as an independent predictor of cardiovascular risk. Which form is most favourable is to be taken from the work; the transferability of the surrogate measure to hard endpoints remains open.

In adults, a network meta-analysis with dose-response analysis examined the effect of exercise forms and dose on carotid-femoral pulse-wave velocity ³⁶. Overall, exercise lowered pulse-wave velocity versus control (WMD = -0.74 m/s, 95 % CI -1.02 to -0.46), with considerable heterogeneity. In the network meta-analysis, endurance training, combined training and interval training lowered pulse-wave velocity versus the non-exercising control, without any active modality being statistically superior to another. The certainty of the evidence was moderate for combined training and low for endurance training. Endurance training therefore acts on arterial stiffness, without standing out from the other active forms.

In adults with type 2 diabetes, metabolic syndrome, cardiovascular diseases, chronic obstructive pulmonary disease, frailty or fibromyalgia as well as in neurocognitive disorders, a meta-analysis examined the effect of simultaneous strength and endurance training on cognition ³⁵. Included were randomised controlled trials with at least four weeks' duration that recorded global cognition via validated instruments such as the Mini-Mental State Examination or the Montreal Cognitive Assessment. Non-randomised studies, acute interventions, healthy populations and studies without control were excluded. Two reviewers assessed risk of bias with the Cochrane Tool 2.0. The work thus provides statements on the combined training form in clinical populations; what proportion the endurance component alone contributes cannot be derived from it.

In older people without dementia with hypertension, familial dementia burden or subjective cognitive decline, a randomised clinical trial with 2×2 factorial design over 24 months examined the effect of endurance training, intensive vascular risk reduction and their combination ³⁸. The study ran at four clinical centres in the USA; recruitment began on 2 February 2017, the last study visit was on 31 January 2022. Participants were allocated 1:1:1 to endurance training, intensive risk reduction (lowering systolic blood pressure below 130 mm Hg and LDL cholesterol with atorvastatin), the combination and usual care. This is therefore one of the few large single studies that directly tests endurance training and pharmacological risk control against each other and in combination. The results on the cognitive endpoints are to be taken from the work.

In pregnant women, a network meta-analysis compared prenatal exercise forms with regard to blood pressure and pregnancy-induced hypertension ³⁹. Thirty-four studies with 4565 pregnant women were included; systolic and diastolic blood pressure were reported in 28 studies each with 2480 participants, pregnancy-induced hypertension in 17 studies with 3184 participants. Versus usual care, exercise lowered systolic blood pressure (MD -3.67 mm Hg, 95 % CI -6.08 to -1.25), diastolic blood pressure (MD -3.51 mm Hg, 95 % CI -5.85 to -1.17) and the risk of pregnancy-induced hypertension (OR 0.56, 95 % CI 0.40 to 0.78). Endurance, water, strength, combined endurance-strength and mind-body training were compared. Endurance training belongs to the effective forms; which modality leads is to be taken from the work.

In students, a network meta-analysis examined the effect of different training forms and doses on body composition ⁴⁰. Endurance training, combined training, high-intensity interval training, mind-body procedures and calisthenics showed significant effects on lowering body-mass index versus control. In the SUCRA ranking, calisthenics had the highest probability of being the most effective intervention for BMI reduction, strength training the lowest. Endurance training therefore acts on BMI, but ranks behind calisthenics. The dose-response analysis was performed with R 4.3.1.

In overweight and obese students, a network meta-analysis compared four training modalities with regard to body composition ⁴⁶. Body mass index, body fat percentage, body weight, hip circumference, waist circumference and fat mass were recorded. Compared with the control, combined endurance-strength training proved the most effective intervention for body mass index, body weight and fat mass. Endurance training alone was among the forms examined, but in this population it ranks behind the combination. Which dose within endurance training brings the greatest additional benefit remains to be clarified.

In middle-aged and older adults, a meta-analysis compared concurrent training with pure endurance or pure strength training with regard to body composition ⁵. Fifty-three studies with 2873 participants were included; mean age ranged between 50 and under 65 years or 65 years and above. Concurrent training increased body weight and fat-free mass significantly more than endurance training alone, with a trend towards greater gains in muscle mass and muscle cross-sectional area. For the remaining measures such as fat mass, body fat percentage, waist circumference and visceral fat mass, no significant differences were observed. Endurance training alone therefore contributes to fat control, while muscle mass benefits from the combination.

In older people, a meta-analysis examined the effect of exercise and nutrition on muscle-mass-specific strength ⁴¹. Forty-one randomised controlled trials with 3141 participants aged 60 years and above and an intervention duration of at least eight weeks were included; muscle-mass-normalised strength was recorded. Strength training significantly improved muscle-mass-specific strength (SMD = 0.65, 95 % CI 0.22 to 1.09), with considerable heterogeneity (I^2 = 83.5 %). Endurance training was among the interventions examined, but showed no comparable advantage in this analysis. For muscle-mass-specific strength, strength training is therefore the mainstay; the role played by endurance loading in combination remains open.

In overweight middle-aged men, a randomised study examined the effect of green tea extract during eight weeks of endurance training on irisin, inflammatory cytokines and adiponectin ⁴⁷. Forty-five participants were allocated to three groups: endurance training plus placebo, endurance training plus green tea extract, and no endurance loading plus placebo. Training consisted of circuit training, brisk walking or jogging three times per week at moderate intensity (40 to 59 % of heart rate reserve); the supplement group received 500 mg green tea extract per day. Both training groups lowered interleukin-6 and high-sensitivity C-reactive protein ($p < 0.05$) and increased adiponectin ($p < 0.01$); the changes were greater in the green tea extract group than in the other two groups ($p < 0.01$). Irisin rose only in the training group with extract. The study therefore demonstrates an amplification of training-induced changes by the extract; the number of participants per group was 15 and therefore small.

In recreational endurance athletes, a crossover study examined the effect of a polyphenol-rich red fruit juice containing aronia on recovery and leg strength after six days of intense endurance loading ⁴⁸. Eighteen participants received either the juice or a placebo in a crossover design and completed high-intensity interval training. Blood values, anthropometric data and leg strength were measured. After the endurance protocol, muscle damage increased in all participants (Δ creatine kinase juice: 117.12 ± 191.75 U/L; Δ creatine kinase placebo: 164.35 ± 267.00 U/L; $p = 0.001$, $\eta^2 = 0.17$). No group effects were observed for exercise-induced muscle damage ($p = 0.371$, $\eta^2 = 0.010$) or oxidative status ($p = 0.632$, $\eta^2 = 0.000$). In this small sample the juice therefore did not demonstrably alter recovery markers.

In hypertensive postmenopausal women, a study examined whether acute intake of beetroot juice additionally lowers blood pressure after endurance exercise ⁴⁹. Thirteen women (58.1 ± 4.62 years; 27.4 ± 4.25 kg/m²) consumed beetroot juice, a nitrate-reduced placebo or an orange-coloured calorie-free drink in three sessions and completed 40 minutes of moderate endurance training on a treadmill at 65 to 70 % of heart rate reserve. Blood pressure was measured every 15 minutes for 90 minutes after exercise; saliva samples were used for nitrite analysis. Salivary nitrite rose after beetroot juice compared with the other two drinks; the placebo produced a slight increase compared with the calorie-free drink ($p < 0.05$), but remained lower than the juice. In this small sample the acute dose did not demonstrably enhance the blood-pressure-lowering effect after training.

In routine oncological care, a three-year real-world evaluation examined an inpatient strength and endurance training programme on machines ⁵⁰. The programme comprised 24 sessions of combined strength and endurance training, supplemented by a sensorimotor module for patients with chemotherapy-induced peripheral neuropathy, with a target frequency of two sessions per week. Between April 2021 and March 2024, 70 patients participated (60 % female; mean age 63 ± 12 years). Acceptance, feasibility, safety and effects on strength (one-repetition maximum), cardiopulmonary performance (maximum power on a cycle ergometer) and patient-reported endpoints such as quality of life, fatigue and neuropathy were assessed in a quasi-experimental pre-post design. The evaluation shows how such a programme is adopted in everyday practice; without a control group the changes cannot be attributed to training alone.

In athletes and non-athletes, a meta-analysis examined the association between endurance training and subclinical coronary artery calcification ⁵¹. The analysis was stratified by sex and training volume. High endurance volumes are therefore associated with more calcifications in men; whether this increases cardiovascular risk is not answered by this finding.

A systematic review with multilevel meta-analysis examined whether particulate-matter exposure modifies the cardiovascular benefit of endurance training ⁵². Four hundred and sixty-five study arms from interventions reporting changes in systolic and diastolic blood pressure, maximal oxygen uptake or resting heart rate were evaluated. Annual particulate-matter exposure at the study sites ranged from 3.5 to 283 µg/m³. The models accounted for the nesting of arms within studies and were adjusted for world region, training modality, study duration and health status. This constitutes one of the most extensive evaluations of whether air quality attenuates training benefits. Which limit values follow for training recommendations can be taken from the work.

Reviews and Mechanisms of Action

In adults with major depressive disorder, a systematic review with meta-analysis examined the effect of endurance training on cognition ⁵³. Six English-language databases were searched up to 2 April 2023; included were randomised trials in adults aged 18 years and above with clinically diagnosed depression that compared endurance training with non-endurance-based groups. Overall cognition as well as memory, attention and processing speed were recorded. The work additionally examined whether cognitive subdomains, training characteristics and sample variables modified the effect. A targeted evaluation for this population is therefore available; which training characteristics make the greatest contribution can be taken from the work.

A systematic review with meta-analysis examined the effect of dietary sources of nitrate, polyphenols, L-arginine and L-citrulline on endurance performance ⁵⁴. One hundred and eighteen studies were included, among them 59 on polyphenols, 56 on nitrate and three on L-citrulline. For L-citrulline-containing foods no effect on performance was observed (SMD = -0.03, p = 0.24). For nitrate- and polyphenol-rich foods small but significant advantages were shown (SMD = 0.15 and 0.17, p < 0.001), both in time-trial, time-to-exhaustion and intermittent tests and after single and multi-day administration. The effects are small; the subgroup analysis by food source, sex, fitness and test type can be taken from the work.

After stroke, a systematic review with Bayesian network meta-analysis determined which endurance modalities lead to which recovery measures ⁵⁵. Twenty-eight studies with 1298 participants entered the analysis of peak oxygen uptake, eleven with 648 for systolic blood pressure, 28 with 1494 for the six-minute walk distance and 18 with 775 for usual ten-metre gait speed. Low-intensity, moderate-intensity, high-intensity continuous and high-intensity interval training were compared against no exercise, usual care or other endurance modalities. Ranking was determined via the surface under the cumulative ranking curve; certainty of evidence was assessed according to the GRADE framework. Which intensity most strongly improves which endpoint can be taken from the work.

A systematic review with meta-analysis examined whether the time of day of training influences the magnitude of improvements in performance and health ⁵⁶. Included were studies with structured endurance and/or strength training of at least two sessions per week over at least two weeks that compared at least two times of day in a randomised crossover or parallel-group design. Both the qualitative and the quantitative evaluation provided little evidence for or against the assumption that a particular time of day produces greater improvements. The question of the optimal training time therefore remains open.

A systematic literature review examined the effect of gut training and nutritional loading on markers of gastrointestinal status during endurance exercise ⁵⁷. Of 304 identified studies, eight were included after the screening phase; quality assessment was performed independently in duplicate with the Cochrane tool. The work investigated how repeated gastrointestinal loading with nutrients before and/or during training influences integrity, function and symptoms. The review therefore classifies how the digestive system adapts to endurance loading and nutrient intake. Which protocols most effectively reduce symptoms can be taken from the review.

A review examined how the intensity of endurance training influences the release of muscle-derived neuroprotective myokines ⁵⁸. Endurance training protects against brain atrophy in the course of ageing and lowers the risk of cognitive decline; the mediating mechanisms are considered not yet established, with discussion focusing on preservation of brain volume, survival of neurons, improved cerebrovascular density and function, and increased synaptic plasticity. A growing body of evidence suggests that muscle-derived factors, so-called myokines, are involved in muscle-brain communication. Most studies to date have used moderate intensities; investigations of high-intensity training are rarer. Which dose produces the most favourable changes in these signalling pathways is therefore an open question.

Overall Picture

Across applications, endurance training contributes most clearly to depressive and anxiety symptoms: the largest evaluation with 79 551 participants shows moderate effects, and the transdiagnostic review confirms this across eleven disorders ^{17 9}. The evidence base is also broad for cardiometabolic endpoints: HbA1c in type 2 diabetes, body-fat measures, blood pressure in pregnancy and arterial stiffness have each been examined across many randomised studies ^{18 1 39 36}. In several populations, however, endurance training does not rank at the top but behind combined training, group training or mind-body modalities ^{26 34 46}. For strength and muscle endpoints it contributes less than strength training ⁴¹.

The dose question remains consistently open: although 360 MET-minutes per week are available as the minimal effective dose for depressive symptoms in children and adolescents and approximately 360 MET-minutes per week as the optimal range for the perinatal period, comparable concrete thresholds are lacking for many other endpoints ^{34 26}. Also open is the independent contribution of endurance training within combination programmes, as many studies examine combined or adjunctive forms ^{37 29 35}. And at high training volumes, male athletes show greater coronary calcification, whose clinical significance still requires clarification ⁵¹.

Methodology of the Evidence Base

The foundation consists predominantly of systematic reviews with pairwise or network meta-analysis of randomised controlled trials, supplemented by individual large randomised studies and observational studies. Intervention duration begins at four weeks and extends to 24 months in the factorial study on exercise and risk reduction ³⁸. Endpoints comprise symptom-related scales, laboratory values such as HbA1c and lipids, physical measures, cardiopulmonary performance parameters and cognitive test scores. Certainty of evidence was assessed with GRADE or CINeMA on multiple occasions; risk of bias was assessed with the Cochrane tool.

3. How Robust the Research Is

Research on endurance training is predominantly clinical: controlled human studies constitute the largest block, supplemented by observational work, mechanistic reviews and basic-science and animal experiments. In terms of content, the emphases lie on the musculoskeletal system and on cognition, followed by fatigue, metabolism, safety questions and the cardiovascular system. Smaller but independent fields concern oncology, inflammation, bone and the immune system. This breadth is unusual because endurance training is not examined as a single indication but as a stimulus that simultaneously affects many organ systems. Correspondingly, the answers depend strongly on the population: for people with type 2 diabetes, after cancer therapy, with heart failure or with subclinical gait disturbance, specific programmes were each investigated.

Methodologically, the field has access to randomised studies and several meta-analyses that together can support a robust picture. **Proven:** is a benefit where reviews summarise concordant randomised studies, for example for cognition in major depression, for inflammation in breast-cancer survivors or for bone in postmenopausal women. Limits lie in the nature of the modality: training studies cannot be blinded, and many programmes are not completed in full. Frequently the target variables are markers such as insulin-resistance parameters, performance tests or questionnaire scores rather than clinical endpoints. Heterogeneity of the programmes further complicates every synthesis. Which programme duration, intensity and training modality is appropriate for which population cannot be read from the body of work.

Comparison with other training modalities limits the scope of many statements

Many statements about endurance training come from studies in which it was tested against a waiting list, usual care or a non-specific exercise control. Such comparisons show that the stimulus changes something; they do not show that it is more effective than another form of training. Where the direct comparison was tested, the answers were differentiated: In a randomised study in normal-weight people with type 2 diabetes, resistance training was superior for glycaemic control and body composition; in COPD patients, resistance training increased maximum work capacity in the randomised comparison of three training modalities. Endurance training does not thereby become dispensable, but the choice of training form is an independent decision dependent on the target variable.

The dose is also not arbitrarily increasable. The comparison of intensities was tested in a randomised manner, for example during exhaustion during (neo-)adjuvant cancer therapy in the Phys-Can study. Safety aspects form a separate block of controlled studies — an indication that the load cannot be chosen equally for every baseline situation. The decisive limitation therefore lies less in the number of studies than in their decomposability: From many programmes with different duration, intensity and supervision, no single optimal specification can be derived.

HYPOTHESIS:

For most populations, the most informative would be a randomised comparison of several training forms with the same target variable, because it precisely answers the question that the existing studies leave open.

4. What Is Frequently Claimed — and What the Data Provide

STATEMENT	STUDY SITUATION
Endurance training reliably lowers body weight	A systematic review with dose-response meta-analysis examined the association in adults. The effect depends on dose and baseline; it does not support a bla
Endurance training is the superior training form for glycaemic control	In a randomised study in normal-weight people with type 2 diabetes, strength training was superior for glycaemic control and body composition. The statemer

STATEMENT	STUDY SITUATION
Higher intensity relieves fatigue during cancer therapy more strongly	The Phys-Can study randomised the intensity question in (neo-)adjuvant cancer therapy. Thus, intensity is an investigated variable and not a mere assumption
Endurance training improves cognition independently of the diagnosis	For adults with major depression a meta-analysis is available, for first-episode schizophrenia a randomised study on the addition of cognitive training. Both studies

5. The Most Robust Studies

Ordered by strength of evidence, not by familiarity: Systematic reviews and studies with many participants first. The complete evaluation comprises significantly more studies; the most robust ones are listed here.

Controlled Studies in Humans

- ¹ Aerobic Exercise and Weight Loss in Adults: A Systematic Review and Dose-Response Meta-Analysis (2024) — Systematic review, 6.880 participants
- ² Exercise and Insulin Resistance Markers in Children and Adolescents With Excess Weight: A Systematic Review and Network Meta-Analysis (2023) — Systematic review, 3.051 participants
- ³ Effects of Exercise Intervention on Peripheral Skeletal Muscle in Stable Patients With COPD: A Systematic Review and Meta-Analysis (2021) — Systematic review, 1.317 participants
- ⁴ Optimal dose and type of exercise to improve depressive symptoms in older adults: a systematic review and network meta-analysis (2024) — Systematic review, 2.895 participants
- ⁵ The Effects of Concurrent Training Versus Aerobic or Resistance Training Alone on Body Composition in Middle-Aged and Older Adults: A Systematic ... (2025) — Systematic review, 2.873 participants
- ⁶ Effectiveness of exercise on perinatal depression and anxiety symptoms: A network meta-analysis and dose-response analysis (2026) — Systematic review, 3.843 participants
- ⁷ Effect of Exercise on Motor Symptoms in Patients With Parkinson's Disease: A Network Meta-analysis (2023) — Systematic review, 2.740 participants
- ⁸ Effect of aerobic training versus resistance training for improving cardiorespiratory fitness and body composition in middle-aged to older adults: A ... (2024) — Systematic review, 1.682 participants
- ⁹ Exercise as a transdiagnostic intervention for improving mental health: An umbrella review (2025) — Systematic review, 5.656 participants
- ¹⁰ Impact of combiner aerobic and resistance training on depression: a systematic review and meta-analysis of randomized controlled trials (2025) — Systematic review, 2.342 participants
- ¹¹ Effect of physical exercise on the emotional and cognitive levels of patients with substance use disorder: a meta-analysis (2024) — Systematic review, 895 participants
- ¹² Optimal intensity and type of lower limb aerobic training for patients with chronic obstructive pulmonary disease: a systematic review and network ... (2025) — Systematic review, 979 participants
- ¹³ The Optimal Type and Dose of Exercise for Elevating Brain-Derived Neurotrophic Factor Levels in Patients With Depression: A Systematic Review With ... (2024) — Systematic review, 2.515 participants
- ¹⁴ The best approaches and doses of exercise for improving sleep quality: a network meta-analysis and dose-response relationship study (2025) — Systematic review, 7.276 participants
- ¹⁵ Effects of muscle strength training combined with aerobic training versus aerobic training alone on cardiovascular disease risk indicators in ... (2024) — Review, 916 participants
- ¹⁶ Comparative efficacy of different exercise methods to improve cardiopulmonary function in stroke patients: a network meta-analysis of randomized ... (2024) — Review, 2.008 participants
- ¹⁷ Effect of exercise on depression and anxiety symptoms: systematic umbrella review with meta-meta-analysis (2026) — Review, 79.551 participants
- ¹⁸ The effect of exercise characteristics on HbA1c and other cardiovascular risk factors in adults with type 2 diabetes: a systematic review and ... (2025) — Review, 7.195 participants
- ¹⁹ Exercise interventions and serum IGF-1 levels in older adults with frailty and/or sarcopenia: a systematic review and meta analysis (2025) — Review, 604 participants
- ²⁰ Association between "cluster of differentiation 36 (CD36)" and adipose tissue lipolysis during exercise training: a systematic review (2023) — Review, 859 participants

- ²¹ Optimal dose of aerobic exercise for reducing depressive symptoms in children and adolescents: A meta-analysis of randomized controlled trials and ... (2025) — Review, 1.540 participants
- ²² Efficacy of aerobic exercises for knee osteoarthritis: a network meta analysis of randomized clinical trials (2025) — Review, 4.944 participants
- ²³ Effectiveness of physical exercise on mental health among university students: a systematic review and meta-analysis (2025) — Review, 8.020 participants
- ²⁴ Aerobic exercise to alleviate primary dysmenorrhea in adolescents and young women: A systematic review and meta-analysis of randomized controlled ... (2025) — Review, 918 participants

6. Summary

ESTABLISHED Aerobic training contributes most clearly to depressive and anxiety symptoms. The largest evaluation with 79 551 participants shows moderate effects (SMD = -0,61 for depression, -0,47 for anxiety), and the transdiagnostic overview confirms this across eleven disorders and four spectra (SMD = -0,67). However, in several populations it does not rank at the top, but behind combined training, group training or mind-body procedures; for muscle endpoints it contributes less than strength training.

PLAUSIBLE that the stimulus affects many organ systems simultaneously and that the responses depend strongly on the population; for people with type 2 diabetes, after cancer therapy, with heart failure or with subclinical gait disorder, specific programmes were investigated in each case. **Hypothesis:** The independent contribution of aerobic training in combination programmes could be greater than the rankings show, because the comparison arms there often also contain exercise or therapy. **Hypothesis:** The increased coronary calcification observed in male athletes at high training volumes could reflect remodelling processes and not necessarily a higher risk; the clinical significance remains to be clarified.

What would need to be clarified is which programme duration, intensity and training form is appropriate for which population. The dose question comes first: concrete thresholds exist for depressive symptoms in children and adolescents (360 MET-minutes per week) and for the perinatal period, for other endpoints they are yet to be determined. Training studies cannot be blinded, and many programmes are not fully completed; frequently the target variables are markers such as insulin resistance parameters, performance tests or questionnaire values rather than clinical endpoints. A study that randomly compares several training forms with the same target variable would clarify the decisive open question.

7. What Remains Open

- **Direct comparison:** Which training form is superior for a given target variable is decided only by randomised comparison studies; for most populations they are still outstanding.
- **Dose:** Which combination of intensity, volume and duration carries the greatest benefit with acceptable load is not finally determined.
- **Markers and course:** Whether changes in laboratory and questionnaire values translate into an altered disease course is open for most areas of application.

Frequently Asked Questions

Why are studies on endurance training so poorly comparable?

Because endurance training is not a uniform quantity: training type, intensity, volume, progression and supervision differ between programmes, as do the comparison groups, which range from wait-list to strength training. Target variables also vary between performance tests, laboratory values, questionnaires and clinical endpoints. Two works with the same keyword may therefore investigate different questions.

Does a study on endurance training show that it is better than strength training?

Only if a work directly compares both modalities. In one randomised study in normal-weight people with type 2 diabetes, strength training was superior for glycaemic control and body composition. Other programmes tested endurance training against a wait-list or non-specific movement; such studies demonstrate the effect of the stimulus, not its superiority over other training modalities.

What does it mean when a laboratory value or questionnaire score changes?

First, that the organism responds to the training stimulus. Such a marker is not yet a disease course: cognitive test scores, fatigue questionnaires or insulin-resistance parameters indicate a shift, not necessarily an altered clinical outcome. Only studies with clinical endpoints support this further claim.

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