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Health Benefits and Overuse Risks of Cycling: Biomechanical Mechanisms, Injury Patterns, and Evidence-Based Preventive Strategies

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Abstract

Background. Cycling is widely used for active transport and recreation and is associated with favourable long-term health outcomes. At the same time, cycling-related harm includes traumatic injuries and overuse conditions, and the clinical burden may be underestimated in routine surveillance.

Aim. To summarise health benefits alongside overuse risks and to integrate biomechanical mechanisms, injury patterns, and practical prevention and rehabilitation strategies. Material and Methods. This manuscript is a narrative review; evidence was synthesised narratively, with reporting transparency informed by PRISMA 2020 and qualitative appraisal of systematic reviews supported by AMSTAR 2.

Results. The included evidence supports associations between cycling and lower all-cause mortality and favourable cardiometabolic outcomes, including patterns consistent with reduced type 2 diabetes risk across cycling-volume categories. Biomechanical studies highlight modifiable factors that may influence kinematics and internal loading, including cadence/workload, saddle height, cleat alignment, posture and hand position, and vibration-related exposure. Prevention sources support multi-component approaches (e.g., fit-related adjustments, symptom-focused mitigation, strengthening/supportive interventions, and load-management concepts). Rehabilitation sources describe cycling-based modalities across heterogeneous clinical contexts with condition-specific outcomes and comparators.

Conclusions. In this reference set, cycling is associated with lower all-cause mortality and favourable cardiometabolic outcomes, although most long-term data are observational. The greatest net benefit is likely when participation is paired with safety measures and progression, supported by modifiable biomechanics and multi-component prevention and rehabilitation strategies, and injury evidence underscores the importance of trauma risk reduction, including helmet-related safety in children and adolescents.

Keywords:

Cycling; Active commuting; Physical activity; All-cause mortality; Cardiometabolic health; Biomechanics; Injury prevention; Rehabilitation

Introduction

Cycling is a common form of physical activity and active transport. Cohort studies and evidence syntheses in this manuscript associate cycling exposure with lower all-cause mortality and favourable cardiometabolic outcomes. [1–2,4–5]

Dose-response evidence suggests a non-linear association between cycling exposure and all-cause mortality, which supports the idea that meaningful gains may occur without extreme volumes, although the evidence base is predominantly observational. [1–2]

Cycling promotion should also consider safety and clinical burden. The included injury literature covers both traumatic injuries and overuse conditions, and medical-sector data and paediatric cohorts highlight that surveillance and preventable severity patterns can shape the observed burden. [7,9–10]

Connecting health outcomes with harm benefits from mechanistic and applied perspectives. Biomechanical studies in this review describe modifiable parameters that can influence kinematics and internal loading estimates, including cadence and workload, saddle height, posture or hand position, and vibration-related exposures. [11–12,14,18–19,22]

This manuscript is a narrative review. Reporting was informed by PRISMA 2020 as guidance to support transparency, and journal-specific requirements were followed according to Quality in Sport author guidance. [28–29]

The review is organized to summarize health outcomes, outline biomechanical foundations, synthesize injury patterns and surveillance considerations, and describe preventive and rehabilitation strategies, with an integrated risk-benefit discussion aligned with physical activity guidance.

1.Health Benefits of Cycling

1.1 All-cause mortality

Evidence synthesized in a dose-response meta-analysis links cycling exposure with lower all-cause mortality, with the dose–response shape described as non-linear across exposure levels. In large prospective cohort evidence, cycling as active commuting is associated with lower all-cause mortality compared with non-active commuting, supporting cycling as a population-relevant behavior rather than a sport-only exposure. Most estimates in this area come from observational cohort designs. [1–2]

1.2 Cardiovascular health

Prospective cohort evidence links cycling commuting with favourable cardiovascular outcomes across large population cohorts. Record-linked data from Scotland also examine cycling commuting in relation to cardiovascular endpoints at population level. A systematic review and meta-analysis addressing cycling and cardiovascular disease incidence and mortality is included among the sources cited in this manuscript. [2–3,5]

1.3 Type 2 diabetes and metabolic health

In a Danish cohort study, cycling exposure is associated with lower risk of incident type 2 diabetes across graded exposure categories, and changes in cycling behavior over time are related to diabetes risk in the reported analyses. These findings provide cycling-specific evidence within a large European cohort and can be interpreted within the broader physical activity framework described in WHO guidance. [4,6]

1.4 Mental health and wellbeing

A narrative review on cycling summarizes benefits, risks, barriers, and facilitators, including considerations that relate to participation, perceived barriers, and broader wellbeing-relevant factors discussed within that review's scope. For electrically assisted cycling (e-cycling), a systematic literature review with meta-analyses reports pooled effects for outcomes such as cardiorespiratory fitness and physical activity level, supporting e-cycling as a modality that can produce measurable physiological changes in the included longitudinal evidence. WHO 2020 guidance emphasizes broad health benefits of physical activity and provides population-level targets that cycling can help meet as an aerobic modality. [6,36–37]

2. Biomechanical Foundations of Cycling

The biomechanics evidence included in this review focuses on how workload and cadence, bike configuration (e.g., saddle height, cleat angle, handgrip position), posture, vibration, and spinal loading are quantified and modelled in cycling tasks across the included studies. Across this corpus, mechanistic endpoints include joint moments across the pedal cycle, estimated joint reaction forces, kinematics, joint-specific power contributions, EMG-related modelling targets, and measured spinal loads during ergometer cycling. The purpose of this chapter is to summarize what the included biomechanics studies measured and reported, using their outcomes to define which mechanical variables are treated as modifiable within the evidence base. [11–19,22]

2.1 Cadence and torque

Simulation and experimental work demonstrates that internal loading estimates depend on modelling choices and imposed cycling conditions, and that different objective functions can change predicted tibiofemoral joint reaction forces while still reproducing measured kinematics and EMG-related targets within that study framework. Workload-focused analyses quantify how increasing workload alters 3D joint moments across the crank cycle and identify phases where joint moments change with workload in the reported statistical-parametric mapping approach. In the context of these studies, cadence and workload are treated as variables that can be linked to changes in internal mechanical outputs (e.g., joint moments or model-based joint reaction forces) rather than only external performance descriptors. [11–12]

2.2 Saddle height

A machine-learning study evaluates classification of saddle height conditions using biomechanical inputs under the tested saddle height settings, demonstrating that saddle height states can be differentiated using the reported feature sets and classification approach in that study. A simulated study of leisure cycling with unilateral transtibial prostheses evaluates saddle height variations (defined as percentage changes around a reference) under the reported cycling condition (including the reported workload and cadence in that experiment) and reports changes in joint movement patterns, muscle activity patterns, power symmetry, and comfort ratings across saddle height conditions. A correction notice to that study is part of the publication record and should be cited alongside the main report when this study is used. In the context of the included evidence, saddle height is therefore represented by both (i) protocolled experimental manipulation with reported biomechanical and comfort outcomes and (ii) methodological work indicating that saddle height states can be classified from measured signals under the tested conditions. [13–15]

2.3 Cleat alignment

A clinical biomechanics study examines cleat angular position in relation to torsional parameters of the cyclist’s lower limb and reports associations between torsional/anatomical measures and cleat angle in their analyses. Within that study’s scope, cleat angle is treated as an alignment variable that can be evaluated relative to measurable lower-limb torsional parameters rather than only set by symmetry or convention. [17]

2.4 Trunk posture and handlebar geometry

A study on handgrip position evaluates the effect of changing handgrip position on joint-specific power and cycling kinematics, comparing defined hand positions across different work rates and reporting kinematic changes (e.g., trunk and hip angles) and workload-dependent interactions within the reported analyses. Spinal-loading evidence from in vivo measurements during ergometer cycling quantifies spinal loads under cycling conditions and reports how load magnitudes change with cycling power in that dataset, with between-subject variability described within the study. Together, these studies provide two complementary mechanistic angles within the included evidence base: (i) posture/hand position as a defined manipulation with reported kinematic and joint-power outputs and (ii) spinal loads during ergometer cycling quantified directly in vivo under the reported conditions. [16,18]

2.5 Whole-body vibration

A synthesis paper on whole-body vibration summarizes reported biodynamic data and characterizes human-body responses under vibration conditions as described in that review. A cycling-specific physiology study compares vibration cycling with normal cycling during a maximal graded test and reports that vibration cycling did not change overall energy demands compared with normal cycling in that protocol, while ventilation at submaximal intensity differed between conditions as reported. In the context of the included evidence, the vibration domain therefore includes (i) general biodynamic synthesis and (ii) cycling-task physiology under vibration versus non-vibration conditions, without implying longer-term clinical outcomes beyond what these studies measured. [19,22]

3. Injury Epidemiology in Cycling

3.1 Overuse injuries

A systematic review of injuries and illness in road cycling describes both traumatic and overuse injuries and their anatomical distribution. Perineal-load-related outcomes are summarised in an interventional systematic review and meta-analysis in healthy males, which reports reduced transcutaneous penile oxygen pressure during seated saddle contact and comparative benefits of no-nose saddles and recumbent bicycles for perineal pressure and penile oxygen pressure. The authors also discuss periodic standing on the pedals as a practical strategy to intermittently reduce perineal load. [7,21]

3.2 Neuropathies

A narrative review on median and ulnar nerve injuries in cyclists reports its database search approach and summarizes the included evidence base as predominantly case-report level, with both ulnar and median nerve involvement described. The review reports the number of retrieved articles and the number of included articles within its selection process. The review's synthesis describes heterogeneity in presentation and emphasizes limitations in evidence quality, while also describing diagnostic approaches reported in the included literature, including clinical assessment and neurophysiology, with musculoskeletal ultrasound discussed as an adjunct in selected contexts within that review. The authors emphasize that the available evidence is limited and heterogeneous, and that conclusions about causality and epidemiologic frequency are constrained by the types of studies represented in the included literature. [20]

3.3 Acute injuries and safety

An Injury Epidemiology study analyzes injury and fatality risks for child pedestrians and cyclists on public roads and reports child cyclist injury proportions and crash-factor coding within the analyzed datasets as presented in that article. A Swedish study comparing medically treated traffic injuries with police reports reports under-reporting in police statistics and quantifies medical-sector burden by road-user group, including hospital bed-day burden attributable to bicyclists in that dataset. A population-based pediatric study in a county without a helmet law reports bicycle-related head injury patterns and presents comparisons by helmet-use documentation status, including imaging use and traumatic brain injury diagnosis in the reported results. [8–10]

4. Evidence-Based Preventive Strategies

The prevention-oriented evidence included in this review covers several intervention types and frameworks: kinematic bike fitting evaluated with pre–post outcomes in a cyclist sample, structured resistance training in competitive cyclists in a randomized design, education relating to nutrition and skeletal loading in competitive male cyclists at risk of RED-S, cycling under vibration versus normal cycling in a physiological protocol, and consensus concepts on load in sport and risk of injury. The same corpus also includes a controlled comparison of block versus traditional periodized training in trained cyclists, reporting performance-adaptation outcomes over the intervention window. These sources can be synthesized as modifiable levers that act on exposure (bike configuration and contact points), conditioning capacity, and training-load progression and monitoring, while recognizing that not all included studies measure injury endpoints directly. [7,22–27]

4.1 Bicycle fitting

An experimental study evaluates discomfort, pain, and fatigue levels in a sample of cyclists after a kinematic bike-fitting method and reports pre–post outcome changes in the measured domains within that protocol. In the context of that study, the fitting intervention is described with a defined method and outcomes collected after the intervention, enabling a structured description of symptom-related endpoints following a fitting procedure. The study design is pre–post and does not, by itself, establish long-term injury prevention effects beyond the outcomes and follow-up reported in that paper. [23]

4.2 Cadence optimization and workload control

Mechanistic evidence relevant to cadence and workload includes simulation-plus-experimental cycling analyses reporting how modelling choices and cycling conditions relate to predicted tibiofemoral joint reaction forces within that framework. Workload-focused biomechanics quantifies how joint moments change with increasing workload and identifies phases of the pedal cycle where joint-moment differences occur in the reported analyses. For prevention practice, a consensus statement on load in sport discusses how rapid changes in load relate to injury risk concepts and emphasizes monitoring and load-management principles, while also discussing limitations in applying single-threshold models across contexts. In the context of the included sources, cadence/workload can therefore be discussed as (i) mechanically quantifiable inputs and (ii) training-load variables that require attention to progression and monitoring concepts described in consensus guidance. [11–12,26]

4.3 Strength and supportive training (including education)

A randomized controlled trial in competitive female cyclists compares traditional versus velocity-based resistance training and reports strength/performance outcomes under the reported training protocols. A randomized controlled trial evaluates education relating to nutrition and skeletal loading in competitive male road cyclists at risk of RED-S over the reported trial duration and reports clinical evaluation outcomes within that study’s design. These sources suggest that both resistance training protocols and targeted education interventions have been tested in cyclist populations using controlled designs, while the outcomes measured differ across studies (performance-focused versus health-risk/education-focused endpoints). [24–25]

4.4 Vibration mitigation and upper-limb load reduction

Cycling kinematics and joint-specific power outputs under different handgrip positions are evaluated in a controlled study, suggesting that hand position manipulations can be studied with defined biomechanical outputs under the reported work-rate conditions. Peripheral nerve injury literature in cyclists is summarized in a narrative review describing ulnar and median nerve involvement and limitations of the evidence base. A cycling-specific physiology study compares vibration cycling with normal cycling during a maximal graded test and reports protocol-specific physiological outcomes including energy demand and ventilation differences at submaximal intensity. In the context of these sources, vibration and upper-limb load concerns can be discussed as domains where (i) posture/hand position is biomechanically quantifiable and (ii) vibration has both general biodynamic synthesis evidence and cycling-task physiology evidence, without asserting longer-term symptom outcomes beyond what the included studies report. [18–20,22]

4.5 Load management

A consensus statement on load in sport and risk of injury discusses poor load management as a risk factor for injury and describes conceptual models including acute:chronic workload ratio discussions and limitations as presented by the authors. A controlled comparison of block versus traditional periodized training in trained cyclists reports that the intervention did not produce differences in performance adaptations between the compared periodization strategies within the reported timeframe and outcomes. Together, these sources suggest describing load management as (i) a consensus-defined prevention framework and (ii) a domain where cycling training structure has been tested experimentally for adaptation outcomes, while not equating performance adaptation endpoints with injury outcomes unless a study directly measures injury. [26–27]

5. Cycling in Rehabilitation

Cycling-based modalities appear across the rehabilitation sources included in this review, including an aquatic cycling randomized trial protocol in knee osteoarthritis (KOA), cycling-ergometer content within an ACL reconstruction clinical practice guideline, and rehabilitation trials synthesized in a systematic review after total knee arthroplasty (TKA) where ergometer cycling is one component in at least one included comparison. These sources suggest cycling or cycling-like ergometer exercise as a rehabilitation modality, but the clinical purpose, prescription parameters, and expected outcomes differ by condition and by study design (protocol, guideline, systematic review, and trials). Evidence in this area spans protocols, guidelines, systematic reviews, and condition-specific randomized trials or observational studies, which limits direct comparability of “dose” and endpoints across contexts (e.g., KOA symptom scales versus post-surgical rehabilitation outcomes versus aerobic fitness). In this chapter, interpretation is anchored to what each source explicitly reports about intervention structure, outcomes, and limitations within its specific rehabilitation context rather than treating “cycling” as a single uniform intervention across conditions. [30–33,35–36]

5.1 Knee osteoarthritis

In KOA, Rewald et al. present a randomized controlled trial protocol evaluating aqua-cycling versus usual care, and they state that stationary cycling and aquatic exercises are frequently recommended to patients with KOA. The planned intervention includes moderate-intensity aqua-cycling performed twice per week for 12 weeks, with each session lasting 45 minutes, and the protocol describes randomization to aqua-cycling or usual care. The protocol specifies assessment at baseline, 12 weeks, and 24 weeks, and it defines the primary outcome as self-reported knee pain and physical functioning, consistent with the protocol's stated focus on KOA symptoms and function rather than performance endpoints. Because this source is explicitly a protocol, it provides planned methods and outcomes but does not provide treatment-effect estimates, and it should be cited as design-level evidence rather than efficacy evidence. [30]

In an RCT comparing an outdoor green cycling program with indoor stationary cycling in people with KOA and T2DM, both groups improved over 24 weeks, with larger improvements reported for selected KOOS subscales and greater HbA1c reductions in the outdoor group. Hospitalizations and serious adverse events were reported in both arms, supporting the need for routine safety monitoring in this population. [31]

5.2 Rehabilitation after anterior cruciate ligament reconstruction

The Aspetar clinical practice guideline on rehabilitation after anterior cruciate ligament reconstruction (ACLR) includes discussion of eccentric overload approaches using cycling-ergometer modalities within its rehabilitation framework. In the guideline's presentation, eccentric cycle ergometer training is described as potentially resulting in greater strength gains, better daily activity level, and greater quadriceps muscle hypertrophy when initiated at 3 weeks instead of 12 weeks after surgery, with beneficial effects described as persisting 1 year after ACLR in the cited context. In the same described context, the guideline states that there was no effect on laxity, pain, or swelling, which is directly relevant to clinical concern that strength-focused loading might worsen knee stability or symptoms in post-ACLR rehabilitation. In the context of this guideline-level evidence synthesis, these statements support eccentric cycle ergometer training as a structured strengthening-oriented adjunct under the described timing conditions, while emphasizing that the guideline's wording is conditional ("may") and should be read as dependent on the included evidence base and its applicability to individual patients and rehabilitation constraints. [32]

In their pooled analyses, the effect favored exercise for both function and pain, supporting short-term improvements associated with physiotherapy exercise programs in the early post-operative period. A trial adding ergometer cycling as an adjunct to post-operative rehabilitation did not show an additional pain benefit versus control in that comparison. [33]

5.4 Metabolic rehabilitation

Metabolic rehabilitation evidence in the provided sources includes both intervention and observational cohort data, but these sources address different questions and therefore should not be interpreted as equivalent evidence for efficacy in clinical rehabilitation settings. In the 24-week randomized trial in KOA+T2DM, Jin et al. report HbA1c reductions in both cycling arms with larger reductions in the outdoor green cycling group at 6 and 24 weeks, which supports feasibility and metabolic relevance of cycling prescriptions in a comorbid rehabilitation population under the reported conditions. Because Jin et al. compare outdoor versus indoor cycling, the trial supports the possibility that contextual features of exercise delivery may influence metabolic and patient-reported outcomes within cycling interventions, while not determining whether cycling is superior to other aerobic modes or to usual care for glycemic control. [4,6,31]

From a population-risk perspective, Rasmussen et al. report associations between total cycling volume and incident T2DM in a large cohort, providing cycling-specific exposure categories that can inform counseling about weekly activity patterns linked to lower diabetes incidence. Compared with non-cyclists, Rasmussen et al. report hazard ratios (HR) of 0.87 (95% CI 0.82 to 0.93) for 1–60 min/week, 0.83 (95% CI 0.77 to 0.89) for 61–150 min/week, 0.80 (95% CI 0.74 to 0.86) for 151–300 min/week, and 0.80 (95% CI 0.74 to 0.87) for >300 min/week, supporting a graded association between higher cycling and lower diabetes risk across the reported categories. In analyses of change in cycling behavior, Rasmussen et al. report HR 0.80 (95% CI 0.69 to 0.91) for initiated cycling and HR 0.71 (95% CI 0.65 to 0.77) for continued cycling compared with no cycling, while ceased cycling shows HR 0.88 (95% CI 0.78 to 1.01) in the reported comparison, indicating that continued and initiated cycling are associated with lower incident diabetes risk in these models. These cohort findings can inform rehabilitation-adjacent counseling about achievable weekly cycling volumes and the potential relevance of initiating or maintaining cycling behavior, while recognizing that observational associations do not establish causality and must be interpreted within broader guidance on physical activity and health. WHO 2020 physical activity guidelines provide population-level targets (e.g., 150–300 minutes of moderate-intensity aerobic physical activity per week for adults) that contextualize how cycling volume categories may map onto recommended activity accumulation without requiring sport-like training volumes. [4,6]

In the cross-sectional study, bicyclists reported higher overall activity, including higher daily step counts and greater moderate-to-vigorous physical activity than non-bicyclists. Bicyclists also performed better on single-limb stance tasks under both single-task and dual-task conditions. [35]

In their systematic review, Riiser et al. report that e-cycling improves maximal oxygen consumption and maximal power output. For glycaemic outcomes, the authors note that evidence is limited and is based on a small number of studies; in the single study reporting 2-hour postprandial glucose, values decreased over the intervention period. [36]

6. Discussion

6.1 Summary of main findings

Across cohort studies and evidence syntheses, cycling exposure is consistently associated with lower all-cause mortality and favourable cardiometabolic outcomes, although endpoints and contexts vary. In dose–response meta-analytic work integrating walking and cycling, benefits are greatest at lower activity volumes with diminishing returns at higher exposures. [1] Large prospective cohorts report that cycling commuting is associated with lower risk of all-cause mortality and with lower cardiovascular and cancer outcomes. [2–3] For metabolic outcomes, long-term observational evidence supports a graded association between cycling volume and lower incident type 2 diabetes risk, with favourable patterns when cycling is initiated or maintained. [4] Broader reviews also highlight cycling as a practical modality for increasing physical activity at population level. [5]

6.2 Harms, injury burden, and safety context

These health benefits should be read alongside cycling-related harms documented in injury and safety literature, including trauma-related injuries and selected overuse syndromes. In road cycling, traumatic injuries are reported more frequently than overuse injuries in the available studies; clavicle fractures are a common fracture diagnosis and upper-limb injuries are frequently reported. Patellofemoral pain is also identified as a common overuse diagnosis in road-cycling contexts. Hospital-based data indicate that cyclist injuries can contribute substantial medical-sector burden, which may not be fully reflected in police-report surveillance. In paediatric head injury data from a county without a helmet law, documented helmet use was low and lack of helmet use was associated with a higher proportion of skull fracture and brain injury in the reported comparisons. [7,9–10]

6.3 Net benefit and physical activity guidance

As overall activity is a major determinant of non-communicable disease risk, net benefit is also influenced by whether cycling contributes to meeting recommended aerobic activity levels and by how cycling exposure is combined with other weekly activity. WHO guidelines support regular activity for health and highlight the balance of benefit and risk across activity patterns. [6]

6.4 Mechanistic interpretation: cadence, workload, posture, and equipment

Biomechanical studies provide plausible mechanisms explaining why symptoms cluster in specific anatomical regions and why cadence, workload, posture, and equipment variables can influence tissue exposure during repetitive cycling. Workload-related changes in 3D joint moments across the pedal cycle support the view that increasing workload alters joint-moment patterns relevant to mechanical-demand distribution. Simulation and experimental work also indicates that cadence–power combinations and neuromuscular strategy can influence internal knee-loading estimates even when external work appears similar. [7,11–18,20–21]

Bike configuration and rider posture provide additional biomechanical pathways relevant to overuse symptom plausibility and to interpretation of injury patterns reported in cycling literature. Flores et al. report that decreasing saddle height in a simulated unilateral transtibial prosthesis condition influenced joint movement and muscle activity patterns toward those of controls and improved power symmetry in their low-intensity cycling protocol, indicating that saddle height manipulations can measurably alter coordination and symmetry outcomes in a population with altered limb mechanics. Bing et al. report that saddle height conditions can be classified using a machine learning approach applied to biomechanical features, suggesting that saddle height changes produce detectable biomechanical signatures even though classification performance itself is not a clinical endpoint. Rohlmann et al. report in vivo spinal implant load measurements during ergometer cycling and show that spinal loads increase with cycling power with substantial inter-individual variation, supporting the premise that cycling can impose measurable spinal loading that may be relevant when interpreting back symptoms in susceptible individuals or at higher intensities. Ramos-Ortega et al. analyze cleat angular position in relation to torsional parameters and report that multiple torsional and anatomical variables contribute to predicting cleat angle in their modelling, supporting individualized cleat alignment considerations rather than assuming a universal neutral alignment at the shoe–pedal interface. [7,13–14,16–17]

Upper-body posture and hand support also connect biomechanics to neuropathy-related clinical concerns. Experimental work suggests that changing hand position or posture can shift kinematics and peak crank torque even when differences in joint-power distribution are small. Clinical literature summarised in cyclist neuropathy reviews consists largely of case reports and limited observational data, with ulnar nerve involvement reported more often than median nerve involvement. [18,20]

6.5 Whole-body vibration as a candidate mechanism

Whole-body vibration is another candidate mechanism discussed in the included evidence, but translation from biodynamic response data to cycling-specific clinical endpoints requires outcome-linked cycling studies. Rakheja et al. synthesize biodynamic responses to whole-body vibration and describe frequency-dependent characteristics of human vibration response, suggesting that vibration exposure has measurable biomechanical consequences that could be relevant in cycling environments with high vibration transmissibility. Jemni et al. report that vibration cycling did not affect energy demands compared with normal cycling during a maximal graded test while reporting higher ventilation at submaximal intensity with vibration, suggesting that vibration effects may not be mediated by increased metabolic cost alone and may require different mechanistic or clinical endpoints for risk interpretation. Across the included sources, vibration therefore remains a plausible but incompletely linked mechanism, warranting cautious interpretation when connecting vibration exposure to symptoms or injury outcomes in cycling. [19,22]

6.6 Prevention implications

Across prevention-oriented sources, prevention is framed as multi-component rather than as a single universal intervention, spanning bike-fit modification, symptom-focused equipment strategies, targeted conditioning, and load-management concepts. In a pre–post study evaluating a kinematic bike-fitting method, participants reported improved comfort and reductions in fatigue/exertion alongside small-to-moderate reductions in pain measures, suggesting that structured fit interventions can be evaluated with standardised symptom outcomes. Because this design lacks a control group, it supports short-term symptom change associated with the fitting intervention but does not establish long-term injury reduction or isolate which fit elements drive change. [21,23–24,26]

Training-based prevention is represented by the randomized trial in competitive female cyclists comparing traditional versus velocity-based resistance training. Montalvo-Pérez et al. report that both resistance training approaches improved the assessed outcomes and report that velocity-based training produced greater improvements in hip thrust performance than traditional training in their findings, supporting resistance training as a feasible adjunct in cycling populations when strength-related outcomes are targeted. The trial does not measure injury endpoints, so it supports feasibility and performance-related adaptation rather than direct evidence of injury prevention efficacy. [24]

In the perineum-focused systematic review and meta-analysis, seated saddle contact was associated with reduced transcutaneous penile oxygen pressure compared with reported comparison conditions. No-nose saddles and recumbent bicycles generally reduced perineal pressure and improved penile oxygen pressure in the reported experimental comparisons. The authors also discuss periodic standing on the pedals (e.g., brief standing at regular intervals) as a practical strategy to reduce sustained perineal loading. [21]

Load-monitoring concepts relevant to prevention are addressed by the International Olympic Committee (IOC) consensus statement on load in sport and risk of injury. Soligard et al. discuss the acute:chronic workload ratio concept and report that when acute workload is high relative to chronic workload (e.g., ratio > 1.5), the likelihood of injury increases in the presented framework, while also emphasizing limitations and contextual factors that constrain simplistic threshold application across sports and settings. The IOC statement highlights challenges in overuse injury definitions and notes limitations of time-loss definitions for capturing overuse problems, supporting symptom-sensitive monitoring approaches that may be particularly relevant in cycling where overuse symptoms can develop gradually without immediate time-loss. When mapped to cycling training patterns characterized by rapid fluctuations in volume, intensity, terrain, and competition density, these concepts support prevention messaging focused on avoiding abrupt workload spikes and monitoring symptom trajectories rather than assuming a single optimal training template. [7,26]

6.7 Rehabilitation implications

Rehabilitation evidence spans protocols, clinical guidelines, systematic reviews, and trials, and it should be interpreted in relation to endpoint type, comparator, and the intervention’s stated aim within each condition-specific context. In KOA with comorbid T2DM, both outdoor green cycling and indoor stationary cycling were associated with improved glycaemic control and KOOS subscales over 24 weeks, with larger improvements reported for selected KOOS subscales and HbA1c in the outdoor green cycling arm. A randomized trial protocol for aqua-cycling versus usual care in KOA specifies session frequency, duration, intensity targets, and follow-up, supporting structured protocolization of cycling-like rehabilitation even before definitive efficacy outcomes are available. For ACLR, the Aspetar guideline describes eccentric cycle-ergometer training as a potentially useful adjunct for strength-related outcomes and daily activity level when initiated at appropriate timing, while reporting no effect on laxity, pain, or swelling in the cited evidence. For TKA, pooled analyses support short-term benefits of physiotherapy exercise for function and pain, and a trial adding ergometer cycling reported no additional pain benefit versus control in that comparison. [30–36]

Across rehabilitation sources, cycling is used to deliver aerobic loading with controllable mechanical demand, but clinical effectiveness depends on population, setting, comparator, and the primary endpoint. For KOA, protocols and trials illustrate how cycling-based prescriptions can be structured and monitored; for ACLR and TKA, cycling is discussed as an adjunct within broader rehabilitation programs rather than as a stand-alone intervention. Across conditions, tailoring load progression and technique is central to balancing symptom response and training effect. [30–36]

6.8 Reporting frameworks, evidence certainty, and limitations

This narrative review integrates cohort-based health benefit evidence, biomechanical mechanisms, injury epidemiology, and prevention and rehabilitation sources; certainty varies across evidence types and the detail available in primary reports. PRISMA 2020 emphasises transparent reporting of information sources, synthesis decisions, and limitations, which is especially relevant when combining heterogeneous designs such as cohorts, simulation studies, clinical trials, protocols, guidelines, and injury surveillance. AMSTAR 2 provides a structured framework for critical appraisal of systematic reviews and can support interpretation of review-level conclusions when search adequacy, risk-of-bias consideration, or synthesis appropriateness may limit confidence. [28,38]

Across the included sources, recurring limitations differ by domain and should be carried into discussion-level caution. Long-term health outcomes are largely derived from observational cohort designs and cohort-based meta-analyses, which support associations but cannot fully exclude residual confounding and therefore do not establish causality. Biomechanical studies quantify kinematics, joint moments, and simulated internal loads and support mechanistic plausibility, but they often rely on laboratory outcomes not directly linked to validated clinical endpoints, and they may be sensitive to modelling assumptions and experimental constraints. Injury literature emphasizes heterogeneity in injury definitions and outcome capture, including the challenge of defining and monitoring overuse injuries that may not produce immediate time-loss, which complicates synthesis and prevention evaluation. Rehabilitation evidence illustrates that adding a cycling component does not guarantee benefit across endpoints and that comparator conditions and program composition influence interpretation, as seen in the TKA synthesis where ergometer cycling add-on did not improve pain in one included trial comparison. In e-cycling trials synthesized by Riiser et al., fitness endpoints show pooled benefits while glycemic endpoints remain underpowered and uncertain due to single-study evidence, illustrating endpoint-specific evidence gaps within rehabilitation-adjacent cycling modalities. [1–5,7,11–14,16–21,26,33,36]

6.9 Future research directions

Future research priorities implied by this evidence set include stronger linkage between mechanical exposures and validated clinical outcomes, improved harmonization of injury definitions and symptom-sensitive monitoring for overuse problems, and clearer specification of cycling modality parameters and comparators in rehabilitation trials across musculoskeletal and metabolic conditions. Cohort-based benefit signals would also be strengthened by designs or analytic approaches that better address confounding, improve exposure measurement, and clarify dose–response relationships for cycling-specific exposures across populations. For symptom-specific risk domains such as perineal load and upper-limb neuropathies, longer-duration intervention studies with clinically meaningful outcomes would help translate strong physiological signals or case-based clinical descriptions into robust prevention guidance. For cycling in older adults and for e-cycling, trials that directly test balance, falls-related endpoints, adherence, and clinically relevant metabolic outcomes would clarify whether observed associations and fitness gains translate into rehabilitation-relevant risk reduction or functional improvement. [1–5,7,11–14,20–21,26,30,33,35–36]

6.10 Clinical and public health implications

Clinically, the included sources support that cycling modalities can be prescribed across different rehabilitation contexts with different aims, including symptom- and function-oriented KOA protocols, strength-focused eccentric cycle ergometer approaches after ACLR, and incorporation of cycling-like exercise within broader post-arthroplasty physiotherapy programs. In KOA with comorbid T2DM, randomized trial evidence shows that structured cycling interventions can be delivered over 24 weeks with improvements in KOOS subscales and HbA1c, while also demonstrating that adverse events and hospitalizations occur and must be incorporated into individualized risk–benefit decisions. Guideline-level evidence supports eccentric cycle ergometer training as a structured adjunct under specified timing conditions and reports no effect on laxity, pain, or swelling in the described evidence context, which may be clinically reassuring when implementing strength-oriented ergometer loading after ACLR. For TKA, pooled evidence supports overall benefits of physiotherapy exercise for short-term pain and function, while also indicating that adding ergometer cycling may not provide incremental pain benefit versus comparator programs in at least one included trial, supporting pragmatic program design focused on measurable endpoints rather than assuming a universal additive effect of cycling. [30–33]

From a public health perspective, cohort and meta-analytic evidence links cycling exposure with reduced all-cause mortality and reduced incidence of cardiometabolic outcomes, supporting cycling promotion as a feasible behavior-level strategy rather than a sport-only exposure. Nordengen et al. report in their systematic review and meta-analysis that cycling is associated with lower combined cardiovascular disease (CVD) incidence, mortality, and physiological risk factors with total effect estimate 0.78 (95% CI 0.74–0.82; $p < 0.001$; $I^2 = 58\%$), and they report separate pooled estimates for CVD incidence (RR 0.84; 95% CI 0.80–0.88; $I^2 = 29\%$), mortality (RR 0.83; 95% CI 0.76–0.90; $I^2 = 0\%$), and risk factors (OR 0.75; 95% CI 0.69–0.82; $I^2 = 66\%$), supporting an overall protective association without evidence of dose–response or sex-specific differences in their findings. WHO 2020 guidelines provide population-level targets for aerobic activity accumulation (e.g., 150–300 minutes/week of moderate-intensity aerobic activity in adults) that cycling can help meet in routine settings, supporting translation of cohort-based benefit signals into achievable behavioral guidance. [1–6]

In practice, maximizing net benefit depends on combining health-oriented recommendations with injury risk mitigation strategies and safety behaviors aligned with the injury burden documented in cycling literature. Road-cycling injury synthesis indicates that trauma-related injuries are prominent and that clavicle fractures and upper-limb injuries are commonly reported, supporting the importance of crash-risk reduction and protective strategies in addition to overuse management. [7,9–10] Pediatric injury evidence from a county without a helmet law reports low documented helmet use and more severe head-injury patterns among those without helmets, highlighting preventable severity pathways when cycling is promoted in children and adolescents. [10] Medical-sector data indicate substantial healthcare burden from bicyclist injuries, reinforcing that injury prevention has system-level relevance beyond individual outcomes. [9] Prevention sources support multi-component approaches combining fit optimization, symptom-focused equipment strategies (e.g., perineal load mitigation), targeted conditioning, and load monitoring concepts sensitive to overuse symptom development. [21,23–24,26]

Conclusions

Across the reviewed evidence, cycling exposure is consistently associated with favourable long-term health outcomes in cohort studies and evidence syntheses, including lower all-cause mortality and favourable cardiometabolic profiles. [1–2,4–5]

These findings support cycling as a feasible, scalable modality for increasing physical activity and improving population health when integrated into daily transport and recreational routines. [1–2,4–5]

The net benefit of cycling also depends on injury risk and on how burden is captured. Road-cycling evidence includes both traumatic injuries and overuse conditions, and medical-sector and paediatric data highlight the importance of prevention and safety measures alongside promotion. [7,9–10]

Mechanistic studies describe modifiable factors that can influence internal loading and contact-point exposure, which supports practical attention to cadence and workload, fit-related parameters, and vibration-related environments when symptoms or risk factors are present. [11–12,14,18–19,22]

Prevention and rehabilitation evidence supports context-specific, multi-component approaches rather than single universal solutions, and the rehabilitation sources illustrate heterogeneous endpoints and comparators across conditions. [21,23,26,31–33,36]

Overall, the included evidence supports cycling as one modality that can contribute to recommended aerobic activity patterns, and implementation should integrate risk mitigation in parallel with participation. [6–7,26]

Disclosure:

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Declaration of the use of generative AI and AI-assisted technologies the writing process

AI were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasise that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

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