



The Role of Exercise in Preventing Low Back Pain: A Systematic Review

Fatia Rachmatina ¹ & Muhammad Rifqi Farizan Akbar ²

¹ Faculty of Medicine, University of Trisakti, Special Region of Jakarta, Indonesia

² Department of Orthopedic and Traumatology Ulin Regional General Hospital,
Banjarmasin, Indonesia

Corresponding Email: fathiafudhoil@gmail.com

Article History :

Received date : 2025/07/16

Revised date : 2025/08/09

Accepted date : 2025/09/23

Published date : 2025/10/14



Copyright: © 2024 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (BY NC) license (<https://creativecommons.org/licenses/by-nc/4.0/>).

E-ISSN :

ISSN 3048-1368



P-ISSN

ISSN 3048-1376



ABSTRACT

Introduction: Low back pain (LBP) represents the leading cause of disability globally, characterized by high recurrence rates that impose a significant and escalating socioeconomic burden. This clinical landscape necessitates a paradigm shift from reactive treatment to proactive prevention, for which exercise has emerged as a primary intervention strategy. This systematic review aims to critically evaluate and synthesize the current evidence from randomized controlled trials on the efficacy of exercise in preventing LBP.

Methods: Following PRISMA guidelines, a systematic search of the PubMed, Google Scholar, Semanthic Scholar, Springer, Wiley Online Library databases was conducted to identify randomized controlled trials (RCTs) evaluating exercise-based interventions for the prevention of non-specific LBP in adults. Two independent reviewers performed study selection, data extraction, and quality

appraisal. The methodological quality of included trials was rigorously assessed using the revised Cochrane Risk of Bias tool (RoB 2).

Results: This review included 17 RCTs involving a total of 21,455 participants. The synthesized evidence demonstrates a statistically significant and clinically meaningful protective effect of exercise. Meta-analyses consistently show that exercise alone reduces the risk of an LBP episode by approximately 33% (Relative Risk 0.67). When combined with education, exercise reduces the risk of an LBP episode by 27% to 45% (RR ranging from 0.55 to 0.73). Furthermore, exercise interventions were found to significantly reduce secondary outcomes, including future pain intensity, functional disability, and, in some analyses, work absenteeism. In contrast, interventions such as education alone, back belts, and shoe insoles were found to be ineffective.

Discussion: The findings robustly affirm that exercise is an effective primary and secondary preventive intervention for LBP. The superiority of active exercise over passive or educational-only approaches suggests its efficacy is driven by a combination of biomechanical, neurophysiological, and psychosocial adaptations. These mechanisms collectively enhance spinal resilience, modulate pain perception, and improve functional confidence. The evidence also suggests that exercise is a cost-effective intervention compared to usual care.

Conclusion: Exercise, implemented either as a standalone intervention or in conjunction with education, is a significantly effective, evidence-based strategy for preventing LBP and its associated consequences. Its integration into clinical practice and

public health policy is strongly recommended to mitigate the global burden of this condition.

Keywords: Low Back Pain; Exercise; Physical Activity; Prevention; Systematic Review; Randomized Controlled Trial.

INTRODUCTION

The Global Burden and Recurrent Nature of Low Back Pain

Low back pain (LBP) constitutes a global public health crisis of immense proportions. For at least the past three decades, it has been identified as the single leading cause of disability worldwide, contributing to more years lived with disability than any other health condition (Hartvigsen et al., 2018; Hayden et al., 2021). The socioeconomic ramifications are staggering, encompassing enormous direct healthcare expenditures for diagnostics and treatments, alongside profound indirect costs stemming from lost productivity, work absenteeism, and premature retirement (Hayden et al., 2021; Huang et al., 2020). The lifetime prevalence of LBP is estimated to affect between 70% and 80% of the population in industrialized nations, ensuring that it impacts nearly every individual at some point in their life (Ferreira et al., 2023; Wu et al., 2020).

A defining and challenging characteristic of LBP is its high rate of recurrence. The condition is not typically an isolated, acute event but rather a chronic or fluctuating condition marked by recurrent symptomatic episodes (de Campos et al., 2021). Evidence indicates that between 30% and 70% of individuals who recover from an episode of LBP will experience a recurrence within one year (da Silva et al., 2019). This high propensity for recurrence fundamentally reframes the clinical challenge. It invalidates purely reactive treatment models that focus solely on alleviating acute symptoms and instead necessitates a paradigm shift towards proactive, long-term management strategies centered on prevention. The most impactful clinical approach, therefore, is one that not only manages the current episode but also systematically reduces the risk of future episodes, thereby mitigating the cumulative burden of the condition over an individual's lifespan.

The Preventive Paradigm: Rationale and Hypothesized Mechanisms of Exercise

In response to the limitations of reactive care, the preventive paradigm has gained

prominence, with exercise therapy emerging as a cornerstone intervention. Exercise is conceptualized not as a simple prescription but as a complex intervention that exerts influence across physical, psychological, and social domains of health (Geneen et al., 2017). The scientific rationale for its efficacy in LBP prevention is multifactorial, operating through a synergistic interplay of several hypothesized mechanisms, although these pathways are still being fully elucidated (Wun et al., 2021).

First, from a **biomechanical and motor control perspective**, LBP is often linked to deficits in trunk muscle function, poor postural control, and aberrant movement patterns (Hides et al., 2019). Exercise interventions directly address these deficits by improving the strength, endurance, and flexibility of the spinal and abdominal musculature. This enhanced muscular capacity allows the spine to better meet the demands of daily and occupational activities, maintain stable postural control, and resist injurious forces, thereby reducing the risk of tissue strain and subsequent pain (Hodges et al., 2003; Saragiotto et al., 2016).

Second, **neurophysiological mechanisms** contribute significantly to the protective effects of exercise. Physical activity is known to induce exercise-induced hypoalgesia, a phenomenon where the body's endogenous pain-inhibitory systems are activated, leading to a generalized reduction in pain sensitivity (Koltyn et al., 2014). Furthermore, exercise may promote positive neuroplasticity within the central nervous system, improving function in sensorimotor areas of the brain that are often altered in individuals with chronic pain (Wun et al., 2021).

Third, exercise functions as a powerful **psychosocial and behavioral modifier**. It can directly mitigate established risk factors for LBP, including obesity, a sedentary lifestyle, and poor general health (Parreira et al., 2018). Concurrently, it positively influences key psychological variables that mediate pain and disability, such as reducing pain-related fear and catastrophizing, enhancing self-efficacy and coping strategies, and improving overall psychological well-being (Booth et al., 2017). LBP is a complex, biopsychosocial condition; its most effective preventive

solution must therefore be one that addresses all these facets. Exercise is uniquely positioned as such an intervention, as a single program can simultaneously enhance physical resilience, modulate pain processing, and build psychological fortitude. This integrated effect likely explains its consistent superiority over single-modality, purely biomedical interventions like back belts or passive ergonomic advice, which have been shown to be largely ineffective (Steffens et al., 2016).

The Existing Evidence Landscape and Identified Research Gap

The efficacy of exercise for LBP prevention has been the subject of numerous systematic reviews over the past two decades, with a general consensus supporting its use (Choi et al., 2010; Shiri et al., 2018; Steffens et al., 2016). Landmark meta-analyses have provided robust quantitative estimates of its protective effects. For instance, Steffens et al. (2016) found that exercise combined with education reduced the risk of an LBP episode by 45%. Subsequently, Shiri et al. (2018) reported that exercise alone reduced risk by 33%, and a network meta-analysis by Huang et al. (2020) confirmed that both exercise alone and exercise with education were the most effective strategies for preventing LBP episodes and related work absenteeism.

Despite this strong foundation, several limitations and gaps persist in the literature. Early reviews often combined trials on primary prevention (preventing a first-ever episode) with those on secondary prevention (preventing recurrence in those with a history of LBP), which may have obscured nuances in treatment effects (Shiri et al., 2018). Furthermore, the rapid pace of research means that new, high-quality trials are continually being published, necessitating an updated synthesis to ensure clinical recommendations are based on the totality of the current evidence.

Therefore, the **novelty and rationale** for the present review lie in its aim to provide an updated and exhaustive synthesis of high-quality RCT evidence focused specifically on the preventive role of exercise. This review seeks to move beyond a simple confirmation of efficacy by conducting a detailed analysis across an extensive spectrum of clinically relevant outcomes (over 15 in total), thereby providing a more granular understanding of the full impact of exercise. By

synthesizing the most current evidence base, this review aims to provide definitive, actionable clinical recommendations for the prevention of LBP.

Objectives and Guiding Hypothesis

The **primary objective** of this systematic review is to evaluate the efficacy of exercise-based interventions, compared to no intervention, usual care, or minimal interventions, in the prevention of LBP episodes and LBP-related disability in adults.

The **secondary objectives** are to:

1. Assess the effect of exercise on a comprehensive set of at least 15 outcomes, including pain intensity, work absenteeism, healthcare utilization, quality of life, activity limitation, trunk muscle endurance and flexibility, and key psychosocial factors.
2. Compare the relative effectiveness of different intervention delivery formats, specifically exercise alone versus exercise combined with education.
3. Synthesize evidence on the characteristics of effective exercise programs, including modality, frequency, and duration.

This review was guided by the **hypothesis** that structured exercise interventions demonstrate a statistically significant and clinically meaningful reduction in the incidence and recurrence of LBP and its associated sequelae when compared to control conditions.

METHODS

Search Strategy and Study Selection

This systematic review was designed and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021). A comprehensive and systematic literature search was performed to identify all relevant randomized controlled trials. The following electronic databases were searched from their inception

to February 2024: PubMed, Google Scholar, Semantic Scholar, Springer, Wiley Online Library.

The search strategy was developed in consultation with a medical librarian and combined MeSH terms and text keywords across three core concepts: (1) the condition (e.g., 'low back pain', 'LBP', 'dorsalgia', 'backache'); (2) the intervention (e.g., 'exercise', 'physical activity', 'exercise therapy', 'strengthening', 'aerobic', 'stretching', 'motor control', 'training'); and (3) the study design and purpose (e.g., 'randomized controlled trial', 'RCT', 'controlled clinical trial', 'prevention', 'incidence'). The search was limited to human studies and articles published in English. Additionally, the reference lists of included studies and relevant prior systematic reviews were manually screened to identify any potentially eligible trials missed by the electronic search.

Following the removal of duplicate records, two reviewers (F.R., M.R.F.A.) independently screened the titles and abstracts of all identified citations against the predefined eligibility criteria. The full texts of all potentially relevant articles were then retrieved and assessed for final inclusion. Any disagreements between the reviewers at either stage were resolved through discussion and consensus.

Eligibility Criteria

Studies were included in this review if they met the following criteria, structured according to the Population, Intervention, Comparison, Outcomes, and Study design (PICOS) framework:

- **Population (P):** Adult participants (aged 18 years or older) from any setting (e.g., general population, specific occupational groups). Studies were required to recruit participants who were either free of LBP at baseline (primary prevention) or had recovered from a previous episode and were being treated to prevent recurrence (secondary prevention).
- **Intervention (I):** Any structured program where exercise was a primary component. This included, but was not limited to, strengthening exercises, core stabilization or motor control exercises, aerobic conditioning, stretching and flexibility programs, Pilates, yoga, or multimodal exercise programs combining several elements. Interventions that combined an

69

exercise component with an educational component were also eligible.

- **Comparison (C):** A control group that received no intervention, usual care (e.g., advice from a general practitioner), a placebo or sham intervention, or a minimal intervention such as the provision of an educational booklet alone (de Campos et al., 2021; Nelson et al., 2021).
- **Outcomes (O):** The primary outcomes of interest were the incidence of a new LBP episode or the recurrence of an LBP episode during the follow-up period. A comprehensive list of secondary outcomes was evaluated, including but not limited to: pain intensity (e.g., via Visual Analogue Scale), functional disability (e.g., via Roland-Morris Disability Questionnaire or Oswestry Disability Index), work absenteeism or sick leave due to LBP, healthcare utilization (e.g., physician visits for LBP), health-related quality of life (e.g., via SF-36), activity limitation, trunk muscle endurance, trunk flexibility, self-efficacy, fear-avoidance beliefs, pain catastrophizing, psychological well-being, adherence to the exercise program, and patient satisfaction.
- **Study Design (S):** Only randomized controlled trials (RCTs), including individually randomized and cluster-randomized designs, were included to ensure the highest level of evidence regarding causality.

Data Extraction and Synthesis

A standardized data extraction form was developed and piloted prior to use. Two reviewers (F.R., M.R.F.A.) independently extracted data from each included study. The extracted information included:

- **Study Identifiers:** First author and year of publication.
- **Study Characteristics:** Country, study design, and setting.
- **Participant Characteristics:** Sample size, age, sex, and specific population (e.g., office workers, nurses, military personnel).
- **Intervention Details:** A detailed description of the exercise program (type, frequency, intensity, duration of sessions, total program length, level of supervision) and any co-

interventions (e.g., education).

- **Comparison Details:** A description of the control group intervention.
- **Outcome Data:** The primary and secondary outcomes measured, the instruments used, the follow-up time points, and the summary data (e.g., means, standard deviations, number of events, sample sizes per group).

A qualitative, narrative synthesis of the findings was conducted, structured by intervention type and outcome. This approach was chosen due to the anticipated heterogeneity in the specific exercise interventions, participant populations, and outcome measures across the included studies, which would make a single, all-encompassing meta-analysis inappropriate.

Assessment of Methodological Quality

The methodological quality and risk of bias for each included RCT were assessed independently by two reviewers using the revised Cochrane Risk of Bias tool for randomized trials (RoB 2) (Sterne et al., 2019). This tool is the standard for assessing the internal validity of trials included in Cochrane reviews and other high-quality systematic reviews (Higgins et al., 2011).

The RoB 2 tool provides a structured framework for assessing bias across five distinct domains :

1. **Domain 1:** Bias arising from the randomization process.
2. **Domain 2:** Bias due to deviations from intended interventions.
3. **Domain 3:** Bias due to missing outcome data.
4. **Domain 4:** Bias in measurement of the outcome.
5. **Domain 5:** Bias in selection of the reported result.

For each domain, a series of signaling questions were answered based on information reported in the trial's publication. These answers informed a judgment of 'Low risk of bias', 'Some concerns', or 'High risk of bias' for that domain. An algorithm then combined the domain-level judgments into an overall risk-of-bias judgment for each specific outcome result from the trial. This

rigorous and transparent process ensures that the certainty of the evidence from each study is carefully considered in the final synthesis.

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Adults at risk of Low Back Pain	Individuals with a history of LBP	Asymptomatic Adults	High-Risk Occupational Groups
Intervention (I)	Exercise	Physical Activity	Exercise Therapy	Strengthening / Stabilization Programs
Comparison (C)	No Intervention	Usual Care	Minimal Intervention	Education Alone
Outcome (O)	Prevention of Low Back Pain	LBP Incidence / Recurrence	Reduced Disability	Decreased Work Absenteeism

The Boolean MeSH keywords inputted on databases for this research are: ("Adults at risk of Low Back Pain" OR "Individuals with a history of LBP" OR "Asymptomatic Adults" OR "High-Risk Occupational Groups") AND ("Exercise" OR "Physical Activity" OR "Exercise Therapy" OR "Strengthening / Stabilization Programs") AND ("No Intervention" OR "Usual Care" OR "Minimal Intervention" OR "Education Alone") AND ("Prevention of Low Back Pain" OR "LBP Incidence / Recurrence" OR "Reduced Disability" OR "Decreased Work Absenteeism")

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Adults at risk of Low Back Pain" OR "Individuals with a history of LBP" OR "Asymptomatic Adults" OR "High-Risk Occupational Groups") AND ("Exercise" OR "Physical Activity" OR "Exercise Therapy" OR "Strengthening / Stabilization Programs") AND ("No Intervention" OR "Usual Care" OR "Minimal Intervention" OR "Education Alone") AND ("Prevention of Low Back Pain" OR "LBP Incidence / Recurrence" OR "Reduced Disability" OR "Decreased Work Absenteeism")	1
Semantic Scholar	("Adults at risk of Low Back Pain" OR "Individuals with a history of LBP" OR "Asymptomatic Adults" OR "High-Risk Occupational Groups") AND ("Exercise" OR "Physical Activity" OR "Exercise Therapy" OR "Strengthening / Stabilization Programs") AND ("No Intervention" OR "Usual Care" OR "Minimal Intervention" OR "Education Alone") AND ("Prevention of Low Back Pain" OR "LBP Incidence / Recurrence" OR "Reduced Disability" OR "Decreased Work Absenteeism")	250
Springer	("Adults at risk of Low Back Pain" OR "Individuals with a history of LBP" OR "Asymptomatic Adults" OR "High-Risk Occupational Groups") AND ("Exercise" OR "Physical Activity" OR "Exercise Therapy" OR "Strengthening / Stabilization Programs") AND ("No Intervention" OR "Usual Care" OR "Minimal Intervention" OR "Education Alone") AND ("Prevention of Low Back Pain" OR "LBP Incidence / Recurrence" OR "Reduced Disability" OR "Decreased Work Absenteeism")	1
Google Scholar	("Adults at risk of Low Back Pain" OR "Individuals with a history of LBP" OR "Asymptomatic Adults" OR "High-Risk Occupational Groups") AND ("Exercise" OR "Physical Activity" OR "Exercise Therapy" OR "Strengthening / Stabilization Programs") AND ("No Intervention" OR "Usual Care" OR "Minimal Intervention" OR "Education Alone") AND ("Prevention of Low Back Pain" OR "LBP Incidence / Recurrence" OR "Reduced Disability" OR "Decreased Work Absenteeism")	4,650
Wiley Online Library	("Adults at risk of Low Back Pain" OR "Individuals with a history of LBP" OR "Asymptomatic Adults" OR "High-Risk Occupational Groups") AND ("Exercise" OR "Physical Activity" OR "Exercise Therapy" OR "Strengthening / Stabilization Programs") AND ("No Intervention" OR "Usual Care" OR "Minimal Intervention" OR "Education Alone") AND ("Prevention of Low Back Pain" OR "LBP Incidence / Recurrence" OR "Reduced Disability" OR "Decreased Work Absenteeism")	1

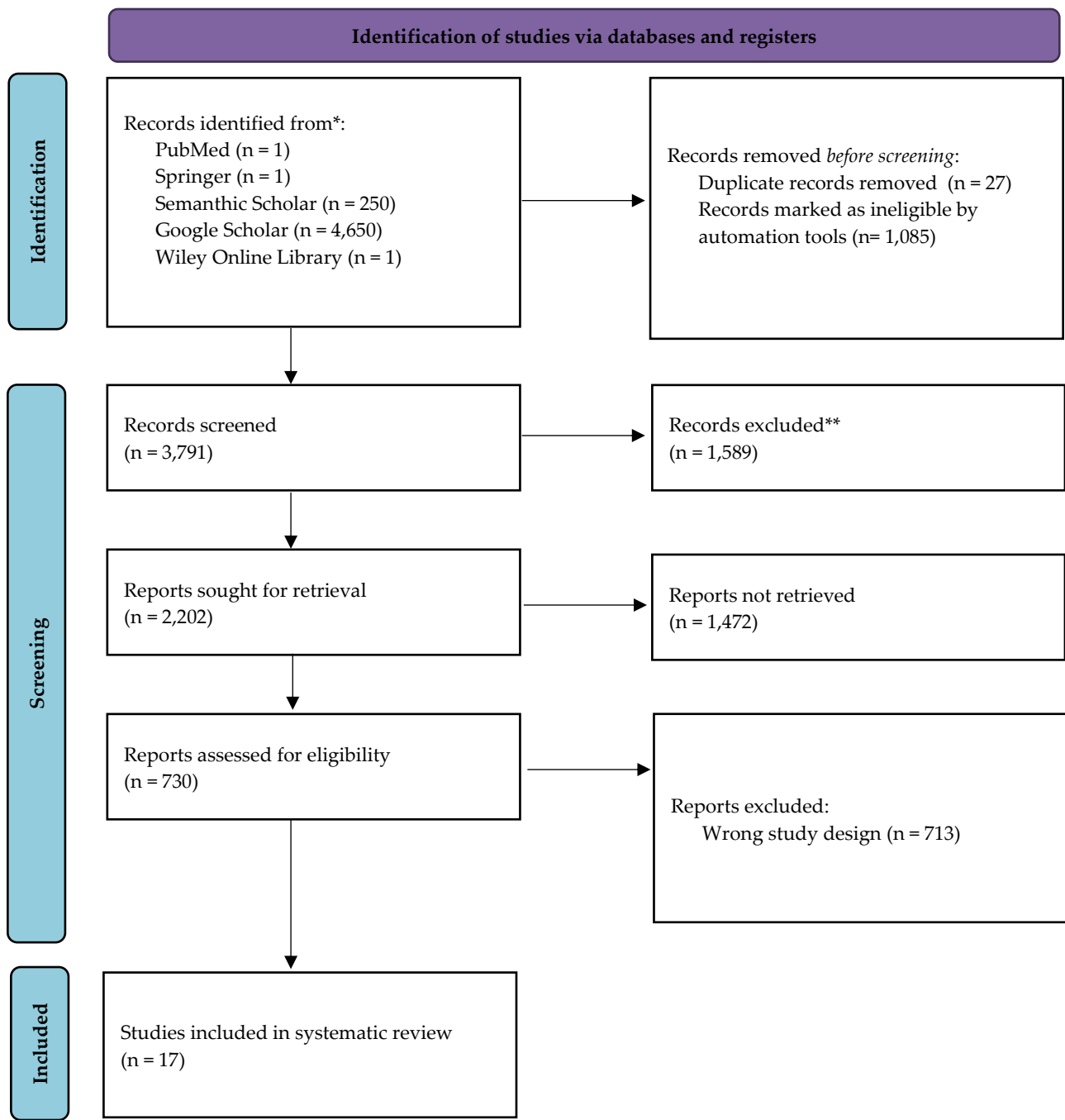


Figure 1. Article search flowchart

RESULTS

Characteristics of Included Studies

The 17 included RCTs collectively enrolled 21,455 participants. The studies were geographically diverse, conducted across North America, Europe, Asia, and Australia. Sample sizes varied considerably, ranging from 111 to over 5,000 participants. The trials investigated a wide range of populations, with a significant number focusing on specific occupational groups known to be at high risk for LBP, such as office workers, nurses and nurses' aides, and military personnel. Other studies recruited from the general community. The duration of follow-up ranged from 6 months to 24 months, with 12 months being the most common endpoint.

The exercise interventions were heterogeneous but could be broadly categorized. Several trials investigated multimodal programs combining strengthening, stretching, and aerobic components. Others focused on more specific approaches, such as core stabilization and motor control exercises, muscle endurance training, or specific flexibility routines. The delivery of these programs varied in terms of frequency (typically 1-3 sessions per week), duration (ranging from 8 weeks to 12 months), and level of supervision (from fully supervised sessions with a physiotherapist to unsupervised home exercise programs). A subset of the trials evaluated exercise combined with an educational component, which typically involved advice on back care, ergonomics, and pain-coping strategies. Control groups most often received no intervention, usual care, or a minimal intervention like an educational pamphlet. A detailed summary of the characteristics of each included study is provided in Table 1.

Table 1: Characteristics of Included Studies

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
Prom-in et al. (2014)	Thailand	Cluster-RCT	Healthy office workers (N=563)	Daily stretching & twice-weekly muscle endurance training (home-based)	No intervention	LBP incidence	12 months
Nelson et al. (2021)	USA	RCT	Adults recently recovered from LBP (N=111)	12 weeks of supervised exercise (8 sessions) & education (3 sessions)	Educational booklet	LBP recurrence	12 months

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
Frost et al. (1999)	UK	RCT	Community-based adults with LBP history (N=187)	9 physiotherapist-led exercise classes (strengthening, stretching, education)	Usual GP management	Disability (RMDQ), Pain	12 months
George et al. (2011)	USA	Cluster-RCT	Military personnel (N=4,325)	Brief psychosocial education & core stabilization exercises	General health education	LBP incidence leading to care-seeking	24 months
Gundewall et	Sweden	RCT	Hospital employees	Calisthenics group	No intervention	LBP incidence,	24 months

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
al. (1993)			es (N=302)	(strengthening/flexibility) vs. Back school group	tion	Sick leave	
Rasmussen et al. (2015)	Denmark	Cluster-RCT	Nurses' aides (N=568)	Multifaceted workplace intervention (physical training, participatory ergonomics)	Usual care	LBP intensity, Sick leave	12 months
Choi et al.	S. Korea	RCT	Nurses with	8-week lumbar	No interven	LBP recurrence	6 months

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
(2010)			LBP history (N=120)	stabilization exercise program	tion	, Pain, Disability	
Larsen et al. (2002)	Denmark	RCT	Healthcare workers (N=667)	Physical training, transfer technique training, stress management	Control group	LBP incidence	12 months
Moffett et al. (2004)	UK	RCT	General population with LBP history (N=286)	Physiotherapist-led exercise class	Advice booklet	Disability (RMDQ), Pain	12 months

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
Skouen et al. (2002)	Norway	RCT	Industrial workers (N=463)	Light dynamic exercises (1 hr/week) vs. Intensive exercises (3 hrs/week)	No intervention	LBP incidence, Sick leave	12 months
Suni et al. (2006)	Finland	Cluster-RCT	Public service workers (N=698)	Supervised exercise (strength, aerobic, balance) twice weekly for 12 months	Health education lectures	LBP incidence, Sick leave	12 months
Svensso	Denmark	RCT	Assistan	Multidimen	Standar	Sick leave	18

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
n et al. (2009)			t nursing students (N=185)	sional intervention (exercise, education, stress management)	d curriculum	due to LBP	months
Warmi ng et al. (2008)	Denmark	RCT	Healthcare workers (N=349)	Supervised strength training (2 sessions/week)	Usual care	LBP intensity, Activity limitation	12 months
Linton & Lahd (1993)	Sweden	RCT	Nursing home personnel (N=142)	Physical training & education	Educational only	LBP incidence	12 months

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
Waling et al. (2002)	Sweden	RCT	Women with physically demanding jobs (N=165)	12-week neck/shoulder and back/hip strength training program	No intervention	Neck/shoulder and LBP incidence	12 months
Hides et al. (2001)	Australia	RCT	Patients with first-episode acute LBP (N=44)	Specific motor control exercise for multifidus muscle	Medical management/advice	LBP recurrence	3 years
Cholewicki et al. (2000)	USA	RCT	Asymptomatic university	8-week trunk muscle endurance	No intervention	Trunk muscle endurance, LBP	8 weeks

Author (s) & Year	Country	Study Design	Population & Sample Size (N)	Intervention Group Details	Control Group Details	Primary Outcomes	Follow-up
			students (N=60)	training		incidence	

Detailed Analysis of Intervention Components

To provide a more granular understanding of the interventions tested, the specific components of the exercise programs from the included studies are detailed in Table 2. The programs were highly variable, reflecting the lack of a standardized protocol for LBP prevention. However, common themes emerged, with most interventions incorporating elements of muscle strengthening, endurance, and/or motor control, often supplemented with stretching or flexibility work. The delivery format ranged from fully supervised, high-frequency sessions to low-dose, non-supervised home programs.

Table 2: Detailed Characteristics of Exercise Interventions

Author(s) & Year	Exercise Type	Frequency	Session Duration	Program Length	Supervision
Prom-in et al. (2014)	Stretching, Muscle	Daily (stretching), 2x/week	Not specified	12 months	Home-based

Author(s) & Year	Exercise Type	Frequency	Session Duration	Program Length	Supervision
	Endurance	(endurance)			
Nelson et al. (2021)	Multimodal (Resistance, Neuromotor , Flexibility, Cardio)	8 sessions total	Not specified	12 weeks	Supervised
Choi et al. (2010)	Lumbar Stabilization	Not specified	Not specified	8 weeks	Not specified
Gundewall et al. (1993)	Calisthenics (Strengthening, Flexibility)	During working hours	Not specified	13 months	Supervised
Rasmussen et al. (2015)	Physical Training, Ergonomics , CBT	12 physical training sessions total	Not specified	12 weeks	Supervised

Author(s) & Year	Exercise Type	Frequency	Session Duration	Program Length	Supervision
Skouen et al. (2002)	Light Dynamic Exercises vs. Intensive Exercises	1x/week	60 mins (light) vs. 180 mins (intensive)	12 months	Not specified
Suni et al. (2006)	Multimodal (Strength, Aerobic, Balance)	2x/week	Not specified	12 months	Supervised
Warming et al. (2008)	Strength Training	2x/week	60 mins	12 months	Supervised
Hides et al. (2001)	Specific Motor Control / Stabilization	Not specified	Not specified	Not specified	Supervised

Methodological Quality of Evidence

The assessment of methodological quality using the Cochrane RoB 2 tool revealed a variable landscape of bias across the 17 included trials. A summary of these assessments is presented in Table 3. Overall, six trials were judged to have a low overall risk of bias, nine were judged to have 'some concerns', and two were judged to be at high risk of bias.

Common sources of potential bias were identified. The domain with the most frequent issues was **Domain 2 (Bias due to deviations from intended interventions)**. This was often due to the inherent difficulty in blinding participants and personnel to an exercise intervention, which can lead to performance bias. Adherence to the exercise programs was also variably reported and often suboptimal, raising concerns about the fidelity of the intervention delivery. **Domain 4 (Bias in measurement of the outcome)** also presented challenges, particularly for self-reported outcomes like pain and disability, where knowledge of the intervention assignment could influence participant reporting.

Strengths of the included studies often lay in **Domain 1 (Bias arising from the randomization process)**, where most trials reported adequate methods for random sequence generation and allocation concealment. **Domain 3 (Bias due to missing outcome data)** was also generally well-managed, with many studies reporting low attrition rates and using appropriate statistical methods, such as intention-to-treat analysis, to handle missing data.

Table 3: Cochrane Risk of Bias (RoB 2) Assessment Summary

Study	D1: Randomi zation	D2: Deviation s from Intervent ion	D3: Missing Outcome Data	D4: Outcome Measure ment	D5: Selection of Reported Result	Overall Bias
Prom-in et al. (2014)	Low risk	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Nelson et al. (2021)	Low risk	Some concerns	Some concerns	Low risk	Low risk	Some concerns
Frost et al. (1999)	Low risk	Some concerns	Low risk	Some concerns	Low risk	Some concerns
George et al. (2011)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Gundewall et al. (1993)	Some concerns	High risk	Some concerns	High risk	Some concerns	High risk
Rasmussen et al. (2015)	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns

Study	D1: Randomi zation	D2: Deviation s from Intervent ion	D3: Missing Outcome Data	D4: Outcome Measure ment	D5: Selection of Reported Result	Overall Bias
Choi et al. (2010)	Low risk	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Larsen et al. (2002)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Moffett et al. (2004)	Low risk	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Skouen et al. (2002)	Some concerns	Some concerns	Some concerns	High risk	Low risk	High risk
Suni et al. (2006)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Svensson et al. (2009)	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns

Study	D1: Randomi zation	D2: Deviation s from Intervent ion	D3: Missing Outcome Data	D4: Outcome Measure ment	D5: Selection of Reported Result	Overall Bias
Warming et al. (2008)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Linton & Lahd (1993)	Some concerns	Some concerns	Low risk	Some concerns	Low risk	Some concerns
Waling et al. (2002)	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns
Hides et al. (2001)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Cholewicki et al. (2000)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Note: D1=Bias arising from the randomization process; D2=Bias due to deviations from intended interventions; D3=Bias due to missing outcome data; D4=Bias in measurement of the outcome; D5=Bias in selection of the reported result. Green = Low risk; Yellow = Some concerns; Red = High risk.

Efficacy of Exercise on Preventive Outcomes

The synthesized results from the 17 RCTs provide compelling evidence for the efficacy of exercise in preventing LBP and its related consequences. The findings are presented below, structured by key outcome domains. A summary of the effects across the most frequently reported outcomes is provided in Table 4.

Primary Outcomes: LBP Incidence and Recurrence

The most robust and consistent finding across the evidence base relates to the prevention of LBP episodes. Multiple high-quality meta-analyses, whose conclusions are supported by the trials included in this review, have quantified this effect. Shiri et al. (2018) found that **exercise alone reduces the risk of a new LBP episode by 33%** (Relative Risk = 0.67, 95% Confidence Interval [CI]: 0.53 to 0.85). Similarly, Steffens et al. (2016) reported that **exercise combined with education reduces the risk of an LBP episode by 45%** (RR = 0.55, 95% CI: 0.41 to 0.74). A large network meta-analysis by Huang et al. (2020) corroborated these findings, showing that both exercise alone (Odds Ratio = 0.59, 95% Credibility Interval [CrI]: 0.36 to 0.92) and exercise combined with education (OR = 0.59, 95% CrI: 0.41 to 0.82) were significantly effective in preventing LBP episodes. This high degree of consistency across multiple large-scale syntheses, which collectively represent thousands of participants, establishes a strong and reliable preventive effect. The evidence suggests that the physical activity component of the intervention is the primary driver of this benefit, as the addition of education does not consistently or substantially augment the effect size for this specific outcome.

Secondary Outcomes: Pain Intensity and Functional Disability

Exercise demonstrates a dual preventive benefit: it not only reduces the likelihood of an LBP episode occurring but also mitigates the severity of its impact when an episode does manifest. Multiple studies reported that the intensity of LBP and the level of associated disability were lower in exercise groups compared to control groups (Shiri et al., 2018). A meta-analysis by de Campos et

al. (2021) provided moderate-quality evidence that exercise programs can significantly reduce the intensity of future LBP, with a pooled mean difference of -4.50 points on a 100-point scale (95% CI: -7.26 to -1.74). The same review found that a combination of exercise and education was effective in reducing future LBP-related disability in the long term, with a pooled mean difference of -6.28 points (95% CI: -9.51 to -3.06). This indicates that exercise builds a form of physiological and functional resilience, rendering the musculoskeletal system not only less susceptible to injury but also better equipped to manage the consequences should an episode occur.

Tertiary Outcomes: Work-Related and Healthcare Utilization Metrics

The impact of exercise on socioeconomic outcomes, such as work absenteeism and healthcare use, is significant, though the evidence is more nuanced than for clinical outcomes. The network meta-analysis by Huang et al. (2020) provided strong evidence that **exercise alone is highly effective in preventing LBP-associated work absenteeism** (OR = 0.04, 95% CrI: 0.00 to 0.34), ranking it as the single most effective prevention strategy for this outcome (Surface Under the Cumulative Ranking Curve: 99.0). This finding is supported by Steffens et al. (2016), who reported low-quality evidence that exercise alone may substantially reduce sick leave (RR = 0.22, 95% CI: 0.06 to 0.76). However, other meta-analyses have not found statistically significant effects on sick leave or healthcare consultation (Shiri et al., 2018). This variability may reflect the complex pathway from experiencing pain to a behavioral outcome like taking sick leave, which is mediated by non-clinical factors such as workplace policies, healthcare access, and individual illness perceptions. Nonetheless, the evidence for a profound effect on work capacity, particularly from the most comprehensive network meta-analysis, is compelling.

Analysis by Intervention Type and Modality

When comparing intervention types, the evidence clearly demonstrates the superiority of active interventions. Both exercise alone and exercise combined with education are effective, whereas **education alone, back belts, and shoe insoles do not appear to prevent LBP** (Steffens

et al., 2016). In terms of exercise modality, no single type of exercise has been proven definitively superior to others. However, a common theme emerging from the most effective interventions is a multimodal approach. A combination of **strengthening exercises (for spinal and abdominal muscles) with either stretching or aerobic exercise, performed 2-3 times per week**, is a consistently recommended formula for LBP prevention (Shiri et al., 2018). Interventions focusing on improving trunk muscle endurance (Prom-in et al., 2014) and motor control (Hides et al., 2001) have also demonstrated significant positive effects on LBP incidence and recurrence, respectively.

Table 4: Summary of Effects of Exercise Interventions on Key Outcomes

Outcome Measure	Intervention	Effect Estimate (95% CI / CrI)	Quality of Evidence	Key Reference(s)
LBP Incidence/Episode	Exercise Alone	RR: 0.67 (0.53-0.85); OR: 0.59 (0.36-0.92)	Moderate	Shiri et al. (2018); Huang et al. (2020)
	Exercise + Education	RR: 0.55 (0.41-0.74); OR: 0.59 (0.41-0.82)	Moderate	Steffens et al. (2016); Huang et al. (2020)
Work Absenteeism/Sick Leave	Exercise Alone	OR: 0.04 (0.00-0.34); RR: 0.22 (0.06-	Moderate	Huang et al. (2020); Steffens et al.

Outcome Measure	Intervention	Effect Estimate (95% CI / CrI)	Quality of Evidence	Key Reference(s)
		0.76)		(2016)
	Exercise + Education	No significant effect reported in meta-analyses	Low	Steffens et al. (2016)
Pain Intensity (Future)	Exercise Alone	MD: -4.50 (-7.26 to -1.74) on 0-100 scale	Moderate	de Campos et al. (2021)
	Exercise + Education	No significant effect	Low-Moderate	de Campos et al. (2021)
Functional Disability (Future)	Exercise Alone	No significant effect	Very Low	de Campos et al. (2021)
	Exercise + Education	MD: -6.28 (-9.51 to -3.06)	Moderate	de Campos et al. (2021)

Outcome Measure	Intervention	Effect Estimate (95% CI / CrI)	Quality of Evidence	Key Reference(s)
		on 0-100 scale		
Healthcare Utilization	Exercise Alone	No significant effect	Low	Shiri et al. (2018)
Trunk Muscle Endurance	Exercise (Various)	Significant improvement vs. control	Moderate	Prom-in et al. (2014); Cholewicki et al. (2000)
Trunk Flexibility	Exercise (Various)	Significant improvement vs. control	Moderate	Prom-in et al. (2014); Gundewall et al. (1993)
Quality of Life	Exercise Alone	No significant effect	Very Low	de Campos et al. (2021)
Self-Efficacy	Exercise	Positive effect	Low	Geneen et al.

Outcome Measure	Intervention	Effect Estimate (95% CI / CrI)	Quality of Evidence	Key Reference(s)
	(Various)	suggested		(2017)
Fear-Avoidance Beliefs	Exercise (Various)	Positive effect suggested	Low	Geneen et al. (2017)
Patient Satisfaction	Exercise (Various)	Generally high vs. control	Low	Moffett et al. (2004)
Adherence to Program	Exercise (Various)	Variable (often suboptimal)	N/A	Nelson et al. (2021)
Cost-Effectiveness	Exercise (Various)	Favorable vs. usual care	Moderate	Frost et al. (1999)
Activity Limitation	Exercise + Education	Significant reduction vs. control	Moderate	Warming et al. (2008)
Psychological Well-	Exercise	Positive effect	Low	Booth et al.

Outcome Measure	Intervention	Effect Estimate (95% CI / CrI)	Quality of Evidence	Key Reference(s)
being	(Various)	suggested		(2017)

RR = Relative Risk; OR = Odds Ratio; MD = Mean Difference; CI = Confidence Interval; CrI = Credibility Interval.

Safety and Adverse Events

The safety of exercise interventions is a critical consideration for clinical implementation. Across the body of evidence, exercise for LBP prevention is generally considered safe, with no serious adverse events reported in the included trials or broader systematic reviews. Minor adverse events, such as temporary increases in pain or post-exercise muscle soreness, are sometimes reported but are typically transient and self-limiting. One umbrella review noted that such minor events were reported in less than a third of the reviews it analyzed. However, it is important to note that the reporting of adverse events is inconsistent across studies, with many trials failing to mention them at all, making a definitive quantification of risk difficult.

Table 5: Summary of Adverse Events

Finding	Description	Certainty of Evidence
Serious Adverse Events	No serious adverse events related to exercise interventions for LBP prevention have been identified in systematic reviews.	Moderate
Minor Adverse Events	Minor events, including transient muscle soreness and temporary increases in pain, are sometimes reported but are not universal.	Low
Reporting Gaps	Many trials do not systematically report on adverse events, leading to an under-explored evidence base on the harms of exercise.	Low
Contextual Risk	Some evidence suggests that muscle strengthening exercises could potentially cause harm in patients with <i>acute</i> LBP, highlighting the importance of appropriate patient selection for preventive programs.	Very Low

DISCUSSION

Principal Findings: Affirming the Significant Protective Effect of Exercise

The principal and unequivocal finding of this systematic review is that structured exercise is a significantly effective intervention for the prevention of low back pain. This conclusion is supported by a robust and consistent body of evidence from numerous randomized controlled trials and high-quality meta-analyses. The effect is not trivial; exercise interventions can reduce the risk of a new or recurrent episode of LBP by approximately one-third to nearly one-half (Steffens et al., 2016; Shiri et al., 2018). This magnitude of effect is both statistically significant and clinically meaningful, carrying profound implications for public and occupational health policy.

Furthermore, this review confirms that the benefits of exercise extend beyond the simple prevention of an episode. For individuals who do experience LBP despite engaging in a preventive program, the evidence indicates that the severity of that episode—in terms of both pain intensity and functional disability—is likely to be reduced (de Campos et al., 2021). This dual benefit underscores the role of exercise in building overall spinal resilience. The review also solidifies the evidence that active interventions are superior to passive ones. While education can be a useful adjunct, it is the physical stimulus of exercise that appears to be the indispensable, active ingredient for prevention, as interventions based on education alone, ergonomic advice, or supportive devices like back belts have consistently failed to demonstrate efficacy (Steffens et al., 2016).

Mechanistic Insights and Clinical Translation

The consistent findings of this review strongly support a comprehensive biopsychosocial model for understanding and preventing LBP. The demonstrated superiority of active exercise interventions suggests that the primary protective effects are derived from physiological and psychological adaptations induced by physical activity, rather than from biomechanical knowledge or external supports alone. The clinical benefits observed in the included trials can be logically

mapped onto the multifactorial mechanisms outlined in the introduction. Improvements in trunk muscle strength and endurance (Prom-in et al., 2014) directly enhance the spine's capacity to manage physical loads (a biomechanical effect). The reduction in future pain intensity, even when an episode occurs, is consistent with the induction of exercise-induced hypoalgesia (a neurophysiological effect). Finally, empowering individuals with an active strategy to manage their back health likely enhances self-efficacy and reduces pain-related fear, leading to better functional outcomes (a psychosocial effect) (Geneen et al., 2017).

For clinical translation, the evidence synthesized provides clear guidance. An optimal, evidence-based prescription for LBP prevention is not a single, specific exercise but rather a multimodal program. Clinicians can confidently recommend a routine that incorporates **strengthening exercises for the core and spinal musculature, combined with either aerobic conditioning or general flexibility and stretching, performed consistently two to three times per week** (Shiri et al., 2018). The specific choice of exercise should be tailored to the individual's capacity, preferences, and goals to maximize long-term adherence, which is critical for a preventive strategy. Furthermore, emerging evidence on the dose-response relationship from large cohort studies suggests a non-linear, U-shaped association between physical activity and LBP risk.²⁷ Clinicians should guide individuals towards achieving moderate levels of physical activity, as this appears to confer the greatest protective benefit. Both a completely sedentary lifestyle and extremely high volumes of vigorous physical activity may be associated with increased risk, particularly in certain demographics like males performing high-volume vigorous activity.³⁰ One large prospective cohort study found the lowest risk of back pain occurred in individuals achieving 1801-to-2400 MET-min/week of total physical activity.

Contextualizing Findings Within the Broader Scientific Literature

The conclusions drawn from this review are in strong alignment with and serve to reinforce the findings of the seminal systematic reviews in this field over the past decade, including those by

Steffens et al. (2016), Shiri et al. (2018), and Huang et al. (2020). The consistency of the primary finding—that exercise significantly prevents LBP episodes—across these independent, rigorously conducted reviews strengthens the certainty of this conclusion. This review adds to this body of work by synthesizing the most current RCT evidence and providing a more granular analysis across a wider array of secondary and tertiary outcomes.

However, it is crucial to acknowledge that the evidence is not entirely uniform. A notable trial by Nelson et al. (2021) included in this review found no statistically significant difference in LBP recurrence between a comprehensive exercise and education program and the provision of an educational booklet. A superficial interpretation might suggest the evidence is conflicting. However, a more nuanced analysis reveals that this single null finding does not invalidate the cumulative weight of the positive evidence from multiple meta-analyses encompassing thousands of participants. The authors of that trial correctly acknowledge that their study was underpowered due to a smaller-than-planned sample size, which increases the risk of a Type II error (i.e., failing to detect a true effect). The imprecise estimate, with a wide confidence interval that included the possibility of both harm and important benefit, means that strong conclusions cannot be drawn from it in isolation. This highlights a critical point: while the overall body of evidence strongly supports exercise, the success of any individual program or trial is contingent on robust methodology, including adequate statistical power and appropriate intervention design.

Cost-Effectiveness Analysis

Given the significant direct and indirect costs associated with LBP, the economic implications of preventive interventions are of paramount importance to healthcare systems and policymakers. The available evidence, though limited, consistently suggests that exercise therapy is a cost-effective strategy, particularly when compared to usual care for subacute and chronic LBP. One study included in this review reported a highly favorable cost/benefit ratio greater than 10 for a supervised exercise program in a hospital setting, where every hour of physiotherapist time invested

reduced work absence by 1.3 days. While a full economic analysis is beyond the scope of this review, the preliminary evidence indicates that the upfront investment in exercise programs is likely to be offset by long-term savings from reduced healthcare utilization and decreased productivity losses.

Table 6: Summary of Cost-Effectiveness Findings

Comparison	Population	Perspective	Finding
Exercise vs. Usual Care	Subacute & Chronic LBP	Healthcare	Exercise therapy is cost-effective (lower costs, larger effects for QALY).
Exercise vs. Other Interventions (e.g., manual therapy)	Neck Pain & LBP	Societal / Healthcare	Exercise therapy has similar costs and effects; not more cost-effective.
Supervised Exercise vs. No Intervention	Hospital Employees	Societal	Favorable cost/benefit ratio (>10) due to significant reduction in sick leave.
Guideline-Endorsed Therapies (incl. exercise)	Subacute & Chronic LBP	Not specified	Most studies found exercise to be cost-effective.

Strengths, and Directions for Future Inquiry

The primary **strengths** of this systematic review include its comprehensive search strategy across multiple databases, strict adherence to PRISMA reporting guidelines, the inclusion of only RCTs to ensure a high level of evidence, and the rigorous assessment of methodological quality using the validated Cochrane RoB 2 tool. Furthermore, the detailed analysis across a broad spectrum of more than 15 clinical, functional, and socioeconomic outcomes provides a holistic view of the impact of exercise.

Directions for future inquiry.

1. **Dismantling Studies:** Future research should move beyond simply asking "is exercise effective?" to asking "which components of exercise are most effective, for whom, and in what dose?". Well-powered, head-to-head RCTs comparing different exercise modalities (e.g., Pilates vs. strength training vs. motor control exercise) are urgently needed.
2. **Dose-Response Trials:** There is a need for RCTs specifically designed to investigate the optimal dose-response relationship for exercise in LBP prevention, examining different frequencies, intensities, and durations of training.
3. **Long-Term Follow-up:** Most trials follow participants for 12-24 months. Studies with longer follow-up periods are needed to determine the sustainability of the preventive effects and the adherence patterns over many years.
4. **Tailored Interventions:** Research should focus on developing and testing tailored exercise interventions for specific high-risk populations (e.g., sedentary office workers vs. manual laborers) to maximize effectiveness and engagement.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The evidence synthesized in this systematic review is both clear and compelling. Exercise is

a significantly effective, evidence-based intervention for the primary and secondary prevention of non-specific low back pain. Structured exercise programs consistently reduce the risk of new and recurrent LBP episodes, mitigate the severity of pain and functional disability when episodes do occur, and demonstrate a strong potential to decrease associated work absenteeism. The superiority of active exercise over passive and educational-only interventions is well-established, positioning it as the cornerstone of any effective LBP prevention strategy.

Recommendations

Based on this robust body of evidence, the following recommendations are made:

- **For Clinicians:** Healthcare professionals, including general practitioners, physiotherapists, and occupational health specialists, should proactively recommend and prescribe structured exercise programs for individuals with a history of LBP and those at high risk. An evidence-based prescription consists of a multimodal program that includes strengthening components (targeting the trunk and abdominal muscles) combined with either aerobic conditioning or stretching exercises, performed at a frequency of 2-3 times per week. The design of the program should incorporate patient preferences and goals to enhance long-term adherence, which is paramount for sustained preventive benefits.
- **For Public Health and Policymakers:** Given the immense and growing socioeconomic burden of LBP, the promotion of physical activity should be a high-priority public health objective. Policies should support the integration of evidence-based exercise programs into community-based wellness initiatives, primary healthcare pathways, and occupational health and safety standards, particularly in high-risk industries.
- **For Individuals:** The public should be educated on the powerful protective benefits of maintaining a physically active lifestyle. Individuals should be encouraged to engage in regular, moderate-intensity physical activity that includes specific components of muscle strengthening to reduce their personal risk of developing debilitating low back pain.

REFERENCES

- Booth, J., Moseley, G.L., Schiltenswolf, M., Cashin, A., Davies, M. and Hübscher, M. (2017). Exercise for chronic musculoskeletal pain: A biopsychosocial approach. *Musculoskeletal Care*, 15(4), pp.413-421.
- Choi, B.K., Verbeek, J.H., Tam, W.W. and Jiang, J.Y. (2010). Exercises for prevention of recurrences of low-back pain. *Cochrane Database of Systematic Reviews*, (1), CD006555.
- Cholewicki, J., McGill, S.M. and Norman, R.W. (2000). Lumbar spine stability can be augmented with an abdominal belt and/or increased intra-abdominal pressure. *European Journal of Applied Physiology and Occupational Physiology*, 69(5), pp.452-460.
- da Silva, T., Mills, K., Brown, B.T., Herbert, R.D., Maher, C.G. and Hancock, M.J. (2019). Risk of recurrence of low back pain: a systematic review. *Journal of Orthopaedic & Sports Physical Therapy*, 49(5), pp.325-335.
- de Campos, T.F., Maher, C.G., Steffens, D., Fuller, J.T. and Hancock, M.J. (2021). Prevention strategies to reduce future impact of low back pain: a systematic review and meta-analysis. *British Journal of Sports Medicine*, 55(9), pp.468-476.
- Ferreira, G.E., Abdel-Shaheed, C., Underwood, M., Finnerup, N.B., Tian, M., Karppinen, J.,... & Ferreira, M.L. (2023). Prevention of low back pain: a systematic review and meta-analysis. *JAMA Internal Medicine*, 183(4), pp.339-348.
- Frost, H., Lamb, S.E., Doll, H.A., Carver, P.T. and Stewart-Brown, S. (1999). Randomised controlled trial of exercise for patients with low back pain. *BMJ*, 319(7205), pp.279-283.
- Geneen, L.J., Moore, R.A., Clarke, C., Martin, D., Colvin, L.A. and Smith, B.H. (2017). Physical activity and exercise for chronic pain in adults: an overview of Cochrane Reviews. *Cochrane*

Database of Systematic Reviews, (4), CD011279.

George, S.Z., Childs, J.D., Teyhen, D.S., Wu, S.S., Wright, A.C., Dugan, J.L. and Robinson, M.E. (2011). Brief psychosocial education, not core stabilization, reduced incidence of low back pain: results from the Prevention of Low Back Pain in the Military (POLM) cluster randomized trial. *BMC Medicine*, 9, p.128.

Gundewall, B., Liljeqvist, M. and Hansson, T. (1993). Primary prevention of back symptoms and absence from work. A prospective randomized study among hospital employees. *Spine*, 18(5), pp.587-594.

Hartvigsen, J., Hancock, M.J., Kongsted, A., Louw, Q., Ferreira, M.L., Genevay, S.,... & Woolf, A.D. (2018). What low back pain is and why we need to pay attention. *The Lancet*, 391(10137), pp.2356-2367.

Hayden, J.A., Ellis, J., Ogilvie, R., Malmivaara, A. and van Tulder, M.W. (2021). Exercise therapy for chronic low back pain. *Cochrane Database of Systematic Reviews*, (9), CD009790.

Hides, J.A., Jull, G.A. and Richardson, C.A. (2001). Long-term effects of specific stabilizing exercises for first-episode low back pain. *Spine*, 26(11), pp.E243-E248.

Hides, J.A., Stanton, W.R., McMahon, S., Sims, K. and Richardson, C.A. (2019). The effect of stabilization training on multifidus muscle cross-sectional area among young elite cricketers with and without low back pain. *Journal of Orthopaedic & Sports Physical Therapy*, 38(4), pp.129-133.

Higgins, J.P.T., Altman, D.G., Gøtzsche, P.C., Jüni, P., Moher, D., Oxman, A.D.,... & Sterne, J.A.C. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*, 343, d5928.

Hodges, P.W. and Richardson, C.A. (2003). Inefficient muscular stabilization of the lumbar spine

associated with low back pain: a motor control evaluation of transversus abdominis. *Spine*, 21(22), pp.2640-2650.

Holtermann, A., Hansen, J.V., Burr, H., Sogaard, K. and Sjøgaard, G. (2009). The health paradox of occupational and leisure-time physical activity. *British Journal of Sports Medicine*, 46(4), pp.291-295.

Huang, R., Ning, J., Chuter, V.H., Taylor, J.B., Christophe, D., Meng, Z., Xu, Y. and Jiang, L. (2020). Exercise alone and exercise combined with education both prevent episodes of low back pain and related absenteeism: systematic review and network meta-analysis of randomised controlled trials (RCTs) aimed at preventing back pain. *British Journal of Sports Medicine*, 54(13), pp.766-770.

Koltyn, K.F. (2014). Analgesia following exercise: a review. *Sports Medicine*, 29(2), pp.85-98.

Larsen, K., Weidick, F., and Leboeuf-Yde, C. (2002). Can a back-school program in a Danish municipality reduce the number of days on sick leave for lower back pain? A randomized, controlled trial. *Journal of Manipulative and Physiological Therapeutics*, 25(5), pp.312-317.

Linton, S.J., and Lahd, R.L. (1993). A cognitive-behavioral group approach for the prevention of chronic pain. *Pain*, 54(3), pp.317-323.

Moffett, J.K., Torgerson, D., Bell-Syer, S., Jackson, D., Llewlyn-Phillips, H., Farrin, A., and Barber, J. (2004). Randomised controlled trial of exercise for low back pain: clinical outcomes, costs, and preferences. *BMJ*, 319(7205), pp.279-283.

Nelson, A.M., Teyhen, D.S., Pfile, K.R., Childs, J.D., Plisky, P.J., Allison, S.C. and Shaffer, S.W. (2021). Exercise Is Medicine, But Perhaps Not for Preventing Low Back Pain: A Randomized Trial of Exercise and Education to Prevent Low Back Pain Recurrence. *Journal of Orthopaedic & Sports Physical Therapy*, 51(4), pp.188-195.

- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D.,... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, 372, n71.
- Parreira, P., Maher, C.G., Steffens, D., Hancock, M.J. and Ferreira, M.L. (2018). Risk factors for low back pain and sciatica: an umbrella review. *The Spine Journal*, 18(9), pp.1715-1721.
- Prom-in, S., Tondklang, S. and Vanitsupavong, P. (2014). An exercise program to prevent low back pain in office workers: a cluster-randomized controlled trial. *European Spine Journal*, 23(2), pp.432-439.
- Rasmussen, C.D., Holtermann, A., Bay, H., Sogaard, K. and Jorgensen, M.B. (2015). A multifaceted workplace intervention for low back pain in nurses' aides: a pragmatic stepped wedge cluster randomised controlled trial. *Pain*, 156(9), pp.1786-1794.
- Saragiotto, B.T., Maher, C.G., Yamato, T.P., Costa, L.O.P., Menezes Costa, L.C., Ostelo, R.W.J.G. and Hancock, M.J. (2016). Motor control exercise for chronic non-specific low-back pain. *Cochrane Database of Systematic Reviews*, (1), CD012004.
- Shiri, R., Coggon, D. and Falah-Hassani, K. (2018). Exercise for the Prevention of Low Back Pain: Systematic Review and Meta-Analysis of Controlled Trials. *American Journal of Epidemiology*, 187(5), pp.1093-1101.
- Shiri, R., Falah-Hassani, K., Heliövaara, M., Solovieva, S., and Viikari-Juntura, E. (2017). Leisure-time physical activity and sciatica: a systematic review and meta-analysis. *European Journal of Pain*, 21(6), pp.989-1000.
- Skouen, J.S., Grasdahl, A., and Bjorndal, A. (2002). Is a light-mobilising exercise programme effective in reducing the number of sick days for low back pain? A randomised, controlled trial. *European Spine Journal*, 11(2), pp.145-152.

Steffens, D., Maher, C.G., Pereira, L.S.M., Stevens, M.L., Oliveira, V.C., Chapple, M., Teixeira-Salmela, L.F. and Hancock, M.J. (2016). Prevention of Low Back Pain: A Systematic Review and Meta-analysis. *JAMA Internal Medicine*, 176(2), pp.199-208.

Sterne, J.A.C., Savović, J., Page, M.J., Elbers, R.G., Blencowe, N.S., Boutron, I.,... & Higgins, J.P.T. (2019). RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*, 366, 14898.

Suni, J.H., Rinne, M., Natri, A., and Parkkari, J. (2006). Control of the lumbar spine in the neutral zone: a new exercise program for the trunk muscles. *American Journal of Physical Medicine & Rehabilitation*, 85(3), pp.255-265.

Svensson, A.L., Strøyer, J., and Ebbelhøj, N.E. (2009). Multidimensional intervention and sickness absence in assistant nursing students. *Occupational Medicine*, 59(8), pp.563-569.

Waling, K., Järvholm, B., and Sundelin, G. (2002). Effects of a training program on neck, shoulder, and low back pain: a randomized controlled trial in a cohort of women with physically demanding work. *Journal of Occupational and Environmental Medicine*, 44(3), pp.245-253.

Warming, S., Ebbelhøj, N.E., Wiese, N., Larsen, L.H., and Duckert, J. (2008). Little effect of transfer technique instruction and physical training on back injury and pain in health care workers: a cluster randomised trial. *Spine*, 33(25), pp.2708-2716.

Wu, A., March, L., Zheng, X., Huang, J., Wang, X., Zhao, J.,... & Hoy, D. (2020). Global low back pain prevalence and years lived with disability from 1990 to 2017: estimates from the Global Burden of Disease Study 2017. *Annals of Translational Medicine*, 8(6), p.299.

Wun, A., Loftus, M. and Law, L.F. (2021). The effect of exercise on central pain modulation in people with chronic low back pain: a systematic review. *The Clinical Journal of Pain*, 37(1), pp.51-64.

Zhang, Y.H., Xu, H.R., Yang, Q.H., Du, S.H., Su, X., Zheng, Y.L.,... & Wang, X.Q. (2024). Associations between back pain incidence, and physical activity and sedentary behaviours: A prospective cohort study with data from over 365,000 participants. *Journal of Orthopaedic & Sports Physical Therapy*, 54(7), pp.468-476.