

Supplementary material

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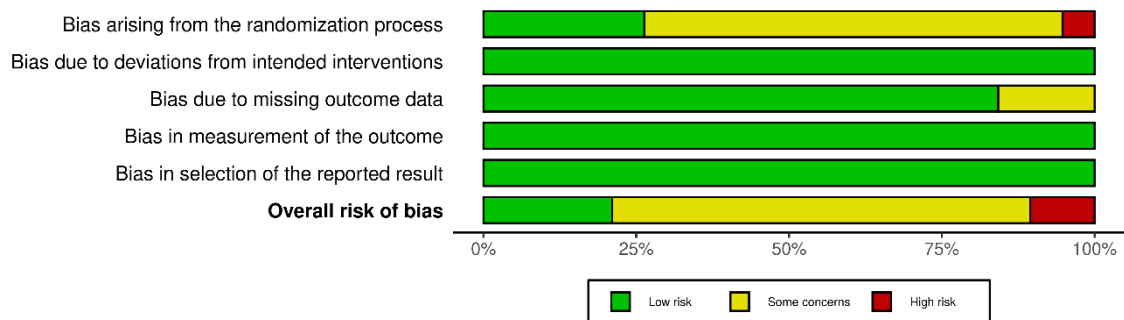
1. Supplementary Figure S2. Risk of bias in each trial.

		Risk of bias domains					
		D1	D2	D3	D4	D5	Overall
Study	Alemo Munters et al., 2013a	⊖	⊕	⊕	⊕	⊕	⊖
	Alemo Munters et al., 2013b	⊖	⊕	⊕	⊕	⊕	⊖
	Alexanderson et al., 2014	⊕	⊕	⊖	⊕	⊕	⊖
	Ayyildiz et al., 2023	⊕	⊕	⊕	⊕	⊕	⊕
	Boehler et al., 2017	⊖	⊕	⊕	⊕	⊕	⊖
	Boström et al., 2017	⊕	⊕	⊕	⊕	⊕	⊕
	García et al., 2021	⊕	⊕	⊕	⊕	⊕	⊕
	Hashemi et al., 2024	⊖	⊕	⊕	⊕	⊕	⊖
	Janse van Rensburg et al., 2012	⊖	⊕	⊕	⊕	⊕	⊖
	Miossi et al., 2012	⊖	⊕	⊖	⊕	⊕	⊗
	Misra et al., 2021	⊖	⊕	⊕	⊕	⊕	⊖
	Naz et al., 2018	⊖	⊕	⊕	⊕	⊕	⊖
	Rodrigues et al., 2020	⊖	⊕	⊕	⊕	⊕	⊖
	Shapoorabadi et al., 2016	⊖	⊕	⊕	⊕	⊕	⊖
	Siqueira et al., 2017	⊖	⊕	⊕	⊕	⊕	⊖
	Strasser et al., 2011	⊖	⊕	⊕	⊕	⊕	⊖
	Tiffreau et al., 2017	⊖	⊕	⊕	⊕	⊕	⊖
	Wallaert et al., 2019	⊕	⊕	⊕	⊕	⊕	⊕
	Westby et al., 2000	⊗	⊕	⊖	⊕	⊕	⊗

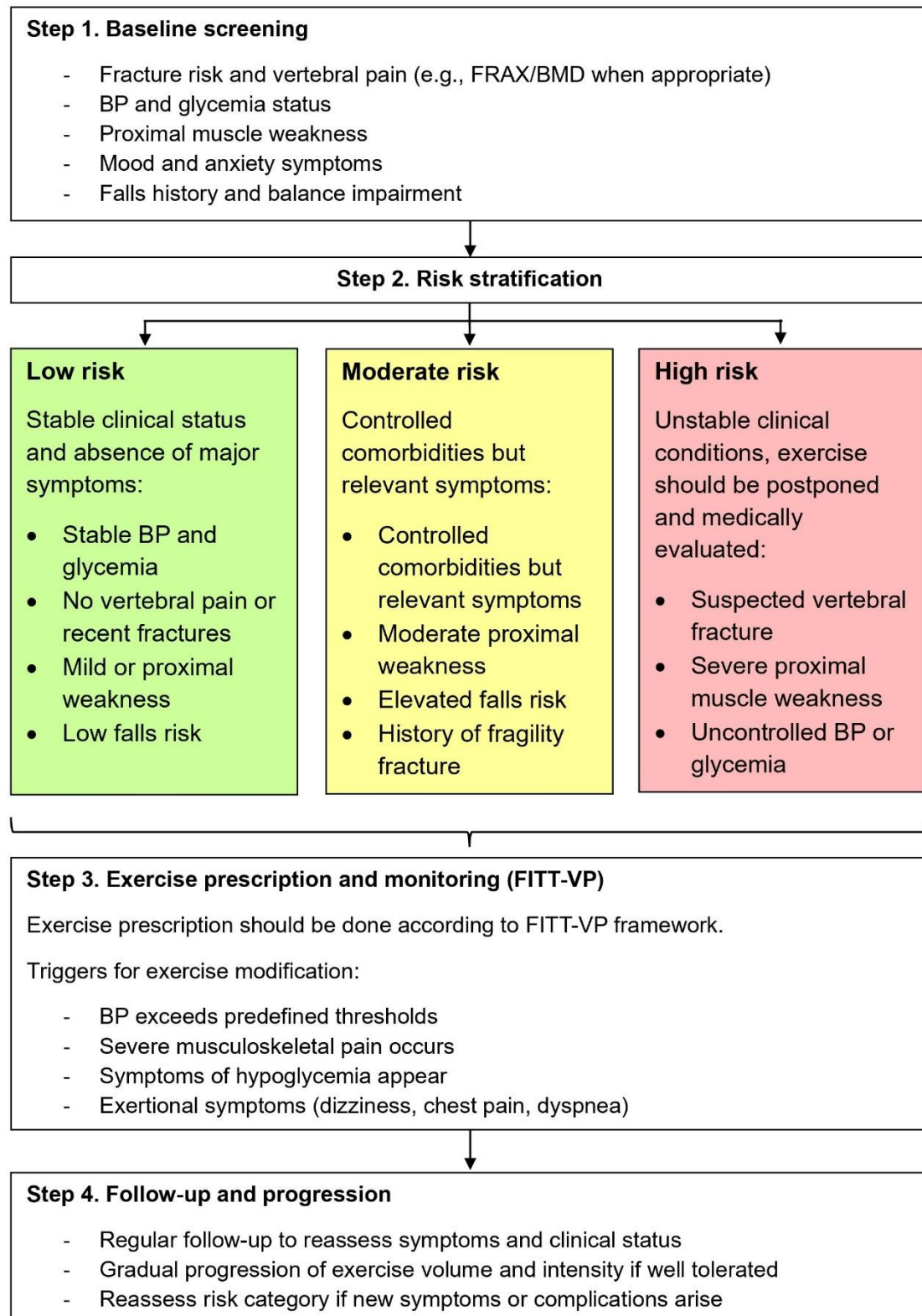
Domains:
D1: Bias arising from the randomization process.
D2: Bias due to deviations from intended intervention.
D3: Bias due to missing outcome data.
D4: Bias in measurement of the outcome.
D5: Bias in selection of the reported result.

Judgement
⊗ High
⊖ Some concerns
⊕ Low

2. Supplementary Figure S3. Risk of bias graph.



3. Supplementary Figure S3. Clinical pathway for exercise prescription during systemic glucocorticoid therapy.



4. Supplementary Table S1. Glucocorticoid-induced adverse effects and their interactions with exercise capacity, engagement, and adaptation.

Interaction type	Adverse effect	Impact on Exercise
Glucocorticoid-exercise capacity interactions	Osteoporosis	- Increased risk of fragility fractures. Balance deficits due to vertebral deformity or pain. - Reduced mobility and confidence in movement.
	Osteonecrosis	Pain-induced movement limitation. Risk of joint collapse under load-bearing activities.
	Hypertension	Reduced cardiovascular tolerance. - Need for blood pressure monitoring before, during, and after sessions. - Elevated CV risk.
	Impaired cognitive function	Reduced executive function, memory, and attention. - Challenges in following instructions or complex routines.
Glucocorticoid-exercise engagement interactions	Anxiety	- Risk of non-adherence. Fear of physical symptoms (e.g., dyspnoea). - Avoidance of exertion. - Heightened sensitivity to bodily cues.
	Depression	Low intrinsic motivation. - Persistent apathy. Negative perception of exercise.
	Neuropsychiatric symptoms	Unpredictable mood or behaviour. - Potential safety risks during unsupervised activity.
	Increased adiposity	Low self-efficacy. - Body image dissatisfaction. Social withdrawal from group exercise contexts.
Glucocorticoid-exercise adaptation interactions	Myopathy	- Decreased muscle mass and strength. - Reduced fatigue tolerance. Blunted responses to PRT.
	Hyperglycemia/Insulin resistance	- Impaired muscle glucose uptake. - Reduced anabolic signaling. - Increased oxidative stress.
	Weight gain/Metabolic dysregulation	- Lower aerobic efficiency. Difficulty progressing intensity. Altered energy balance response.
	Bone turnover suppression	Reduced osteogenic response. Delayed adaptation to mechanical loading.

5. Supplementary Table S2. Tailored exercise recommendations for managing glucocorticoid-induced adverse effects.

System	Condition/ Complication	Tailored exercise strategies
Musculo-skeletal	Osteoporosis	- Resistance training 2–3×/week (focus on major muscle groups) - Balance training 2×/week - Guidance on safe movements (spine-sparing techniques) - Emphasis on spinal extensor strength - Avoid deep spinal flexion; use spine-sparing techniques Individualised impact exercise prescription based on pain, joint status, and fracture risk
	Myopathy	- Whole-body progressive resistance training - Functional balance training to reduce fall risk - Adherence to progressive overload principles
Cardiovascular	Hypertension	- Daily aerobic exercise at moderate intensity (40–60% of HRR), ≥30 min - Resistance training ≥2×/week at 40–60% 1RM - Incorporate extended cooldowns and proper breathing (avoid Valsalva) Monitor blood pressure at rest and during exercise - Observe for alarm symptoms (e.g., chest pain, dizziness)
Endocrine/metabolic	Weight gain	≥150 min/week moderate- or ≥60 min/week vigorous-intensity activity - Combined aerobic and resistance training - Foster autonomy and positive body image - Avoid stigmatizing language - Set realistic, health-centered goals rather than focusing solely on weight loss
	Hyperglycaemia	150 min/week of moderate-to-vigorous aerobic exercise, spread over ≥3 days/week ≥2×/week resistance training (major muscle groups) - Emphasize post-meal exercise timing - Include frequent breaks from sedentary behaviour throughout the day
Mental health	Anxiety	- Consider high-intensity training if appropriate - Address autonomy, competence, and relatedness to enhance intrinsic motivation
	Depression	- Adapt training to individual preferences - Prioritise supervised, group-based, and recreational settings
	Impaired cognitive function	- Machine-based resistance training (2×/week, 30–60’). Power training with embedded cognitive tasks (reaction-based) - Use of exergames to enhance motivation and adherence

HRR: heart rate reserve

6. Supplementary Methods S1. Effects of glucocorticoids on exercise capacity, engagement, and physiological adaptations.

References for this section of the review were identified through searches of Pubmed, Web of Science, and Scopus. We performed one search for each glucocorticoid-induced effect, selecting the most relevant and representative articles of each search. The full search strategy for each effect was as follows:

- Osteoporosis: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (osteoporosis[Title] OR bone[Title])
- Osteonecrosis: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (osteonecrosis[Title] OR "avascular necrosis"[Title])
- Fractures: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (fracture*[Title])
- Hypertension and cardiovascular risk: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (hypertension[Title] OR "blood pressure"[Title] OR cardiovascular[Title])
- Cognitive/mood disorders: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (anxiety[Title] OR depression[Title] OR mood[Title] OR cognitive[Title] OR psychiatric[Title] OR neuropsychiatric[Title])
- Weight gain: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (dyslipidemia[Title] OR adipose[Title] OR "weight gain"[Title] OR fat[Title] OR "body composition"[Title])
- Myopathy: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (myopathy[Title] OR muscle[Title] OR atrophy[Title])
- Falls: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (fall*[Title/Abstract])
- Hyperglycaemia: (glucocorticoid*[Title] OR glucocorticosteroid*[Title] OR corticosteroid*[Title] OR hydrocortisone[Title] OR cortisone[Title] OR prednisone[Title] OR prednisolone[Title] OR methylprednisolone[Title] OR betamethasone[Title] OR dexamethasone[Title] OR deflazacort[Title]) AND (hyperglycemia[Title] OR hyperglycaemia[Title] OR insulin[Title] OR diabetes[Title] OR glucose[Title])

7. Supplementary Methods S2. Systematic review of RCTs assessing exercise interventions in adults taking oral glucocorticoids.

7.1. Search strategy

This systematic review with meta-analysis adhered to the guidelines outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement [1]. It was registered in PROSPERO (CRD420251049238). The search for studies was conducted on May 10, 2025. Articles were gathered from Medline (PubMed), Web of Science, and Scopus. Two authors (PE-U and MLSA) independently performed systematic searches, and disagreements were resolved through discussion with a third author (MI). To standardize the quality and reporting of the studies, we established a methodological search filter to extract only the results published from 2000 onwards. Language filters were not used in this study. The full search strategy was as follows: (exercise[Title] OR training[Title] OR "physical activity"[Title]) AND (glucocorticoid* OR glucocorticosteroid* OR corticosteroid* OR cortisone OR prednisone OR prednisolone OR methylprednisolone OR dexamethasone OR deflazacort OR "rheumatoid arthritis"[Title/Abstract] OR "polymyalgia rheumatica"[Title/Abstract] OR vasculitis[Title/Abstract] OR "inflammatory myopath*" [Title/Abstract] OR polymyositis[Title/Abstract] OR dermatomyositis[Title/Abstract] OR "systemic lupus erythematosus"[Title/Abstract] OR "inflammatory bowel disease"[Title/Abstract] OR "ulcerative colitis"[Title/Abstract] OR "Crohn's disease"[Title/Abstract] OR "autoimmune hepatitis"[Title/Abstract] OR sarcoidosis[Title/Abstract]) AND (control*[Title/Abstract] OR random*[Title/Abstract]).

7.2. Selection criteria

The inclusion criteria were defined using the PICOS model (Population, Intervention, Comparison, Outcome, Study type) [2]. Articles were included if they met the following criteria: (a) included adults 18 years and over with autoimmune diseases, with at least half of them taking oral glucocorticoids; (b) evaluated a physical exercise intervention, including aerobic or resistance training; (c) included a group following usual care or participating in general care interventions; (d) assessed outcomes related to glucocorticoid-induced adverse effects; and (e) were randomized controlled trials (RCT). We did not include reviews, meeting abstracts, conference proceedings, or editorials. Additionally, we excluded studies that compared two structured exercise programs.

The search strategy gathered results from three databases. In addition, the reference lists of the most relevant articles were checked. Then, duplicates were eliminated. Initially, articles were screened by title and abstract, and studies that did not meet the inclusion criteria were excluded after a full-text review.

7.3. Data analysis

Two authors (PE-U and MLSA) independently extracted the summary data based on key observations. We recorded the following information for each study: study information (e.g., author name), population (e.g., age and number of participants), intervention (e.g., settings, supervision level, duration, and type of exercise), measurement methods, and outcomes (e.g., physical function, cognitive function, quality of life, risk of readmission or mortality, and cost-effectiveness).

Two authors (PE-U and MLSA) independently evaluated the risk of bias for each trial using the Risk of Bias 2 (RoB2) tool [3].

8. Supplemental Methods S3. Exercise recommendations.

The search for studies was conducted on May 10, 2025. Articles published from 2000 onwards were gathered from Medline (PubMed), Web of Science, and Scopus. We performed one search for each glucocorticoid-induced adverse effect, selecting the most relevant and representative articles of each search. The full search strategy for each effect was as follows:

- Osteoporosis, fractures and falls: (exercise[Title] OR "physical activity"[Title] OR training[Title]) AND (guidelines[Title] OR recommendations[Title] OR prescription[Title] OR consensus[Title] OR position stand[Title]) AND (osteoporosis[Title] OR fall*[Title] OR fracture*[Title] OR bone[Title])
- Myopathy: (exercise[Title] OR "physical activity"[Title] OR training[Title]) AND (guidelines[Title] OR recommendations[Title] OR prescription[Title] OR consensus[Title] OR position stand[Title] OR statement[Title]) AND (myopathy[Title] OR sarcopenia[Title] OR muscle[Title] OR strength[Title] OR fall*[Title])
- Hypertension and cardiovascular risk: (exercise[Title] OR "physical activity"[Title] OR training[Title]) AND (guidelines[Title] OR recommendations[Title] OR prescription[Title] OR consensus[Title] OR position stand[Title] OR statement[Title]) AND (hypertension[Title] OR cardiovascular[Title])
- Increased adipose tissue: (exercise[Title] OR "physical activity"[Title] OR training[Title]) AND (guidelines[Title] OR recommendations[Title] OR prescription[Title] OR consensus[Title] OR position stand[Title] OR statement[Title]) AND (fat[Title] OR "body composition"[Title] OR weight[Title])
- Hyperglycaemia: (exercise[Title] OR "physical activity"[Title] OR training[Title]) AND (guidelines[Title] OR recommendations[Title] OR prescription[Title] OR consensus[Title] OR position stand[Title] OR statement[Title]) AND (hyperglycemia[Title] OR hyperglycaemia[Title] OR insulin[Title] OR diabetes[Title])
- Mood disorders: (exercise[Title] OR "physical activity"[Title] OR training[Title]) AND (guidelines[Title] OR recommendations[Title] OR prescription[Title] OR consensus[Title] OR position stand[Title] OR statement[Title]) AND (mood[Title] OR depression[Title] OR anxiety[Title])
- Cognitive function: (exercise[Title] OR "physical activity"[Title] OR training[Title]) AND (guidelines[Title] OR recommendations[Title] OR prescription[Title] OR consensus[Title] OR position stand[Title] OR statement[Title]) AND (cognitive[Title] OR executive[Title])

9. References.

1. Page MJ, McKenzie JE, Bossuyt PM et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:71; <https://doi.org/10.1136/bmj.n71>
2. Methley AM, Campbell S, Chew-Graham C, McNally R, Cheraghi-Sohi S. PICO, PICOS and SPIDER: a comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. *BMC Health Serv Res*. 2014;14:579; <https://doi.org/10.1186/s12913-014-0579-0>
3. Sterne J A C, SavoviÄž J, Page M J, Elbers R G, Blencowe N S, Boutron I et al. RoB 2: a revised tool for assessing risk of bias in randomised trials *BMJ*. 2019; 366:l4898; <https://doi.org/10.1136/bmj.l4898>