INPLASY

Dose-Response Relationships of Sensorimotor-Based Interventions on Balance performance in Older Adults: A Systematic Review and Meta-Regression Analysis

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INTRODUCTION

*R*eview question / Objective This systematic review and meta-regression analysis aims to conduct an in-depth non-linear deconstruction of the dose-response relationship between sensorimotor-based interventions and improvements in dynamic and static balance among older adults. By utilizing a restricted cubic spline (RCS) model, the objective is to quantify the physiological adaptive trajectories, identify potential optimal dose windows or saturation plateaus, and evaluate the moderating effects of age to inform precise, threshold-based exercise prescriptions for fall prevention.

Condition being studied As the global demographic structure shifts toward an aging society, falls and their associated complications have emerged as a severe public health challenge threatening the health and quality of life of older adults. The progressive decline in balance performance is a critical modifiable risk factor, fundamentally reflecting the functional degradation of the central nervous system regarding multisensory integration and motor strategy execution. Sensorimotor-based interventions aim to reverse this neuromuscular decline, but current clinical prescriptions frequently fall into the fallacy of blindly accumulating doses without understanding quantitative dose-response trajectories.

METHODS

Participant or population Population (P): Participants aged 55 years and older (or with a mean age ≥ 55 years). The included population comprises healthy community-dwelling middle-aged and older adults, as well as individuals with stable chronic non-communicable conditions (e.g., frailty, sarcopenia, or those at risk of falls) capable of participating in exercise interventions.

Intervention Intervention (I): The experimental group received standardized sensorimotor-based interventions. Specifically, these interventions

emphasize the coupling of proprioceptive input and motor output, encompassing core paradigms such as sensorimotor training (ST), proprioceptive training (PT), or proprioceptive neuromuscular facilitation (PNF).

Comparator Comparison (C): Control conditions involve no intervention, usual activities, or alternative exercise training. These are categorized into three groups: (1) passive control (e.g., unstructured training or no-treatment control); (2) usual care or routine exercise; and (3) active control (e.g., strength or aerobic training).

Study designs to be included Study Design (S): Only randomized controlled trials (RCTs) will be included to ensure methodological rigor.

Eligibility criteria In addition to the standard PICOS framework, the following inclusion and exclusion criteria were applied to ensure the methodological quality and clinical relevance of the included studies:
Additional Inclusion Criteria:
Population: Participants aged 55 years and older (or with a mean age ≥ 55 years) were included. Although the traditional definition of the older population typically specifies individuals over 65, current epidemiological and sports science evidence indicates that the physiological decline of human postural control often begins around the age of 50. Consequently, this study adopted a broader age threshold to capture the entire continuum from the early decline of balance function to advanced aging. The included population comprised healthy community-dwelling middle-aged and older adults, as well as individuals with stable chronic non-communicable conditions (e.g., frailty, sarcopenia, or those at risk of falls).
Intervention: The experimental group received standardized sensorimotor-based interventions. Specifically, these included ST, PT, or PNF.
Comparison: Control conditions involved no intervention, usual activities, or alternative exercise training. Control types were categorized into three groups: (1) passive control (e.g., unstructured training or no-treatment control); (2) usual care or routine exercise; and (3) active control (e.g., strength or aerobic training).
Outcomes: Studies were required to report at least one objective outcome related to balance control. These included: (1) dynamic balance, such as the TUGT; (2) static balance, such as the BBS; and (3) neural adaptation and sensorimotor control metrics, namely COP sway parameters.
Study design: Only randomized controlled trials (RCTs) were included.

Exclusion Criteria:
The following exclusion criteria were applied: (1) non-original research, such as review articles, dissertations, conference abstracts, or proceedings; (2) studies failing to report any objective indicators of neural adaptation or balance control, rendering the analysis incompatible with the research objectives; (3) duplicate publications or analyses (selecting the most recent or highest-quality version); (4) unavailable full texts; (5) non-English literature; (6) studies lacking mean and standard deviation data for outcome measures, where such values could neither be imputed from the text nor obtained from the authors; (7) non-randomized study designs; (8) unpublished research; and (9) exercise modalities deviating significantly from sensorimotor mechanisms, such as yoga, Tai Chi, or isolated resistance training.

Information sources A comprehensive literature search was conducted across five electronic databases: PubMed, EBSCOhost, Embase, the Cochrane Library, and Web of Science. The search timeframe spanned from database inception to February 5, 2026.

Main outcome(s) The outcomes objectively measure balance control and neural adaptation across distinct dimensions:
(1) Dynamic balance: Measured primarily by the Timed Up and Go Test (TUGT).
(2) Static balance: Measured primarily by the Berg Balance Scale (BBS).
(3) Neural adaptation and sensorimotor control: Measured by Center of Pressure (COP) sway parameters under both eyes-open (COP-EO) and eyes-closed (COP-EC) conditions.
Continuous outcomes will be pooled using the standardized mean difference (SMD), subsequently converted to Hedges' g to correct for potential estimation bias associated with small sample sizes.

Quality assessment / Risk of bias analysis The methodological quality and potential risk of bias for all included RCTs will be systematically appraised by two independent reviewers using the Revised Cochrane Risk-of-Bias Tool for Randomized Trials (RoB 2.0). Domains assessed include bias arising from the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Disagreements will be resolved through negotiated discussion or arbitration by a third reviewer.

Strategy of data synthesis All synthesis procedures will be executed within the R computing environment (e.g., version 4.5.2) utilizing packages such as meta, metafor, and dmetar. A random-effects model based on restricted maximum likelihood (REML) estimation will be uniformly applied. Between-study heterogeneity will be assessed using Cochran's Q test and the I^2 statistic. To analyze the dose-response relationship of intervention duration, a restricted cubic spline (RCS) model will be adopted to perform non-linear fitting on the total training dose. Additionally, a univariate random-effects meta-regression model will be utilized to quantify the moderating direction of continuous baseline characteristics such as age.

Subgroup analysis Predefined multidimensional subgroup analyses will be conducted to trace potential drivers of heterogeneity. Strata will encompass participants' health condition, intervention total sessions, intervention total dose, and age categories.

Sensitivity analysis To confirm the stability of the overall conclusions, a leave-one-out sensitivity analysis will be conducted by sequentially removing a single study and recalculating the pooled effect. Furthermore, publication bias will be assessed via contour-enhanced funnel plots and Egger's linear regression test; if significant bias is detected, the non-parametric trim-and-fill method will be employed to adjust the pooled effect size.

Country(ies) involved China.

Keywords Sensorimotor-based interventions; Balance performance; Dose-response relationship; Older adults; Meta-regression analysis.

Contributions of each author
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