International Platform of Registered Systematic Review and Meta-analysis Protocols

INPLASY

INPLASY202640021

doi: 10.37766/inplasy2026.4.0021

Received: 7 April 2026

Published: 7 April 2026

Effects of Neuromuscular Training on Balance Performance in Female Athletes: A Systematic Review, Meta-Analysis and Dose–Response Analysis

Zhong, YJ; Liu, YH; Guo, WH; Chen, PW; Chen, S; Huang, L.

Corresponding author:
Yuanji zhong

zhongyuanji@jxust.edu.cn

Author Affiliation:
School of Physical Education and Art, Jiangxi University of Science and Technology.

ADMINISTRATIVE INFORMATION

Support - None.

Review Stage at time of this submission - Preliminary searches.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY202640021

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 7 April 2026 and was last updated on 7 April 2026.

INTRODUCTION

Review question / Objective This systematic review and meta – analysis is intended to assess the impacts of neuromuscular training (NMT) on the balance performance of healthy female athletes, with the composite score of the Y Balance Test (YBT) serving as the primary outcome. A secondary objective is to carry out an exploratory dose – effect analysis to investigate whether the total training volume, measured as the total training time in minutes (weeks × sessions per week × minutes per session), is correlated with the magnitude of improvement in YBT performance. The dose – effect analysis is regarded as exploratory due to the limited number of eligible studies and the heterogeneity in dose reporting across the existing literature.

Rationale Balance performance is a fundamental key skill for athletes. It directly affects sports performance and the risk of lower – limb injury. Female athletes face a higher risk of knee and ankle injuries than male athletes in most sports. Poor balance is one of the main reasons for this disparity.

Neuromuscular training (NMT) is a common approach to improving balance. It consists of a wide variety of structured exercise programs, including those involving jumping and power exercises, programs focusing on single – leg stability and unstable surfaces, programs using whole – body vibration platforms, and multi – component warm – up programs such as FIFA 11+. All of these are classified as NMT in this review.

Many studies show that NMT is effective. However, no review has clearly defined how much training is required to achieve the best results. It remains unclear whether a greater total training time or more training weeks consistently leads to better balance outcomes.

This review aims to fill this gap. The findings will assist coaches and athletes in planning NMT programs with the appropriate training dose to enhance balance performance and reduce injury risk.

Condition being studied This review will examine balance performance in healthy female athletes. Balance is defined as the ability to maintain bodily stability during athletic movements. In contemporary research, the Y Balance Test (YBT) and Star Excursion Balance Test (SEBT) are the most widely used assessment tools for dynamic balance. Both tests require athletes to perform a single – leg stance while reaching maximally in three directions, with greater reach distances indicating superior balance capacity.
Static balance, measured via centre of pressure (COP) parameters, will also be included as a secondary outcome measure.
Female athletes exhibit a significantly higher risk of lower extremity sports injuries compared to their male counterparts, with impaired balance performance identified as a key contributing factor. Neuromuscular training (NMT) has been shown to improve balance performance; however, no prior systematic review has established the optimal training dosage for this specific population. This review aims to address this gap by synthesising available evidence and conducting an exploratory dose – effect analysis.

METHODS

Search strategy Five electronic databases will be searched: PubMed, Web of Science, Cochrane Library, Embase, and EBSCOhost. No start – date restriction will be applied; the search end date is March 2025. The reference lists of all included studies will also be manually checked for additional eligible records.
The search will use combinations of the following terms: ("neuromuscular training" OR "plyometric training" OR "balance training" OR "whole – body vibration training" OR "FIFA 11+") AND ("balance performance" OR "Y Balance Test" OR "Star Excursion Balance Test" OR "YBT" OR "SEBT" OR "center of pressure" OR "postural control") AND ("female athlete*" OR "female player*" OR "women" OR "girl*") AND ("randomized controlled trial" OR "RCT" OR "controlled trial").

Participant or population Population: Eligible participants will be healthy female athletes of any age who regularly participate in organized sports training and have no current lower – limb injury that prevents training. Studies involving athletes from sports including, but not limited to, basketball, soccer, handball, and volleyball will be considered.
Intervention: Eligible studies will use a structured neuromuscular training (NMT) program lasting at least 4 weeks. NMT is defined broadly in this review and includes all structured exercise programs that target neuromuscular control of the lower limbs, regardless of the specific exercise method used.
Outcome: Eligible studies must report at least one quantitative outcome related to balance performance (YBT, SEBT, COP, or other validated balance measures).
Study design: Eligible studies must be randomized controlled trials (RCTs) or cluster randomized controlled trials.

Intervention The intervention of interest is any structured neuromuscular training (NMT) program lasting at least 4 weeks. NMT is defined broadly in this review. It includes multi – component warm – up programs (e.g., FIFA 11+), plyometric exercise programs, single – leg balance and stability programs, whole – body vibration programs, and any other structured program that targets lower limb neuromuscular control. All such programs will be classified as NMT and compared against a control group as a single intervention category.
For each eligible study, four dose variables will be extracted: total training weeks, sessions per week, minutes per session, and total training time in minutes (weeks × sessions per week × minutes per session). Total training time is expected to vary considerably across included studies and will serve as the primary dose variable for the exploratory dose – effect analysis.

Comparator The comparator will be either regular sports training without the specific NMT program (passive control) or other physical training that does not involve the structured NMT program described above (active control). Both types will be treated as the control condition in the pairwise meta – analysis.
Multi – arm studies will be split into separate pairwise comparisons. The control group sample size in multi – arm studies will be adjusted using the method of Gleser and Olkin (1994) to avoid double – counting.

Study designs to be included This review will include randomized controlled trials (RCTs) and cluster randomized controlled trials. Studies without a control group, observational studies, case reports, conference abstracts without full data, and systematic reviews will not be included.

Eligibility criteria Studies will be included if they meet all four of the following conditions: participants are healthy female athletes who participate in organized sports training; the intervention is a structured NMT program lasting at least 4 weeks; the study has a control group; and the study reports at least one quantitative balance

outcome such as YBT composite score, SEBT reach distance, or COP measures.
Studies will be excluded if participants are not athletes or are currently injured, if the intervention lasts less than 4 weeks (acute effect only), if no usable balance data are reported, if the full – text is unavailable, or if the study design is not a controlled trial.

Information sources Five electronic databases will be searched: PubMed, Web of Science, EBSCOhost, Embase, and Cochrane Library. The reference lists of all included studies will also be manually reviewed to identify any additional eligible records not captured by the database search.

Main outcome(s) The primary outcome will be the Y Balance Test (YBT) composite score, expressed as a percentage of leg length. When composite scores are unavailable, reach distances in the anterior, posteromedial, and posterolateral directions will be used. YBT scores will also serve as the outcome variable for the exploratory dose – effect analysis.
The secondary outcomes will be:
(1) Star Excursion Balance Test (SEBT) or modified SEBT (mSEBT) reach distances, expressed in centimetres or as a percentage of leg length, as a further measure of dynamic balance;
(2) Centre of pressure (COP) parameters — including path length, velocity, or displacement in the anteroposterior and mediolateral directions — as a measure of static postural stability.
For the exploratory dose – effect analysis, total training time in minutes will be the primary dose variable of interest. A LOESS (locally estimated scatterplot smoothing) curve and meta – regression will be used to explore whether total training volume is associated with effect size (Hedges' g) for YBT outcomes. Given that the number of eligible studies is likely to be limited and dose is not randomly distributed across study characteristics, results will be interpreted as hypothesis – generating rather than confirmatory.

Data management Two reviewers will independently screen records and extract data. Study information will be organized in a structured data extraction table. Disagreements will be resolved through discussion; a third reviewer will be consulted when consensus cannot be reached. The data extraction table will record study characteristics, participant information, intervention details (including all four dose variables), outcome data (mean, SD, and sample size for both groups at pre- and post-test), and risk of bias ratings.

Quality assessment / Risk of bias analysis The methodological quality and risk of bias of all included studies will be assessed using the Cochrane Risk of Bias 2.0 (RoB 2.0) tool. The assessment will cover five domains: the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selective reporting of results. Two reviewers will assess each study independently. Disagreements will be resolved by discussion or third – party adjudication.

Strategy of data synthesis This review will employ a pairwise meta – analysis method to synthesize the data. All included studies will compare NMT against a control group. Effect sizes will be calculated as Hedges' g using a random – effects model.
The mean change score (post minus pre) and its standard deviation will be computed for both the NMT group and the control group in each study. The standard deviation of the change score will be calculated from the pre – test and post – test standard deviations using a correlation coefficient of r = 0.8, following the method of Borenstein et al. (2009). Statistical heterogeneity will be assessed using the I^2 statistic and Cochran's Q test. All analyses will be performed using the meta package in R (version 4.5.3).
For the exploratory dose – effect analysis, total training time in minutes will be used as the primary dose variable. A LOESS (locally estimated scatterplot smoothing) curve will be applied to visualize the potential non – linear relationship between total dose and effect size across eligible YBT studies. A univariable meta – regression (metareg function) will additionally be run to test whether total training time predicts effect size.
Given the likely limited number of studies available for this analysis and the heterogeneity in dose distribution across studies, results will be interpreted as exploratory and hypothesis – generating. A categorical subgroup analysis by training dose (low: 1,200 min) will also be conducted to complement the continuous dose analysis.

Subgroup analysis Researchers will conduct four subgroup analyses. The first analysis compares two types of control groups: passive control (no additional training) and active control (alternative training). Active controls tend to produce smaller effect sizes and may suppress the apparent dose – response signal.
The second analysis compares two types of balance outcomes: dynamic balance (YBT or SEBT) and static balance (COP measures).

The third analysis divides studies into three groups based on training duration: short (≤6 weeks), medium (7–12 weeks), and long (>12 weeks), to explore whether training duration moderates the effect of NMT on balance performance.
The fourth analysis divides studies into three groups according to total training dose: low (1,200 min), to complement the continuous LOESS dose – effect analysis and provide a more interpretable categorical comparison. Between – subgroup differences are tested using the Q statistic for subgroup heterogeneity.

Sensitivity analysis Three sensitivity analyses will be conducted to test the robustness of the results. The first will exclude studies rated as having a high or unclear risk of bias, retaining only those rated as having a low risk, to assess whether study quality influences the overall conclusions. The second will apply a leave-one-out method to examine whether any single study exerts a disproportionate influence on the pooled effect size. The third will exclude multi – arm studies and re – run the main analysis to determine whether the sample – size adjustment method for double – counting affects the conclusions.

Language restriction Researchers will only include studies published in English. Studies in other languages will not be included.

Country(ies) involved China.

Keywords Neuromuscular training; Balance performance; Female athletes; Dose–Response Analysis meta - analysis; Meta - regression; Y Balance Test; Star Excursion Balance.

Dissemination plans The findings of this review will be compiled into an academic manuscript and submitted for publication in an English-language peer-reviewed journal within the fields of sports medicine, exercise science, or rehabilitation medicine. The results will also be presented at relevant academic conferences when appropriate. The findings are intended to guide evidence-based practice for coaches and sports medicine practitioners and to offer a scientific foundation for the planning of NMT programs designed to enhance balance performance and mitigate injury risk among female athletes.

Contributions of each author

Author 1 - Yuanji zhong - Proposes the core research question and overall study design, drafts the INPLASY registration protocol and initial manuscript, and oversees project coordination, progress and final quality control.
Email: zhongyuanji@jxust.edu.cn
Author 2 - Yuhao Liu - Provides full statistical expertise for this meta-analysis, designs the complete data analysis plan, and develops procedures for effect pooling, heterogeneity, sensitivity and subgroup analyses.
Email: 15563520423@163.com
Author 3 - Wenhao Guo - Leads the development of rigorous literature inclusion/exclusion criteria, designs and validates the risk of bias strategy, and defines study quality evaluation tools and scoring rules.
Email: gwh@bsu.edu.cn
Author 4 - Pengwei Chen - Designs and cross-validates Chinese/English database search strategies, conducts systematic searches across all sources, and manages initial screening, deduplication and result archiving.
Email: 1920225676@mail.jxust.edu.cn
Author 5 - Song Chen - Designs and pilot-optimizes the standardized data extraction form, extracts baseline and outcome data, organizes double independent cross-checking and maintains the full dataset.
Email: chensong890928@126.com
Author 6 - Lu Huang - Comprehensively reviews the INPLASY protocol and all study methodologies, provides critical revisions for design flaws, and approves the final submitted documents and manuscript.
Email: huanglu_5586@163.com