International Platform of Registered Systematic Review and Meta-analysis Protocols

INPLASY

The association between gait symmetry and variability in healthy adults: A protocol for a systematic review and meta-analysis

INPLASY202610071
doi: 10.37766/inplasy2026.1.0071
Received: 21 January 2026
Published: 21 January 2026

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ADMINISTRATIVE INFORMATION

Support - None.

Review Stage at time of this submission - Preliminary searches.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY202610071

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 21 January 2026 and was last updated on 21 January 2026.

INTRODUCTION

Review question / Objective To evaluate the association between gait symmetry and gait variability (or stability) in healthy adults during steady-state walking. Specifically, this review aims to:
1. Assess the overall correlation between symmetry metrics (e.g., step length asymmetry) and variability metrics (e.g., stride time CV, Phase Coordination Index).
2. Investigate how this relationship is moderated by external constraints, including walking speed, cognitive dual-tasking, and mechanical perturbations.

Rationale Gait symmetry and variability are two fundamental markers of gait quality and are often treated as independent predictors of fall risk. Symmetry reflects the rhythmic output of spinal Central Pattern Generators (CPGs), while variability often indicates the stability and consistency of higher-level motor control. However, the functional relationship between these two domains remains controversial.
While some Principal Component Analysis (PCA) models suggest they are independent domains governed by distinct neural mechanisms, experimental studies indicate a dynamic coupling under specific conditions (e.g., mechanical perturbations or cognitive loads). It remains unclear whether asymmetry acts as a precursor to instability or as a compensatory strategy to maintain balance. Furthermore, evidence regarding how walking speed and dual-tasking moderate this relationship is inconsistent.
This systematic review is necessary to synthesize existing evidence on the association between gait symmetry and variability in healthy adults. Clarifying this relationship is critical for resolving theoretical debates on gait control mechanisms and for informing rehabilitation strategies—specifically, determining whether clinicians should prioritize symmetry correction or stability training to reduce fall risk.

Condition being studied Human Gait Control and Stability. This review focuses on the interaction between gait symmetry (the rhythmicity of stepping) and gait variability (the fluctuation in stepping parameters) in healthy adults during steady-state walking. These two domains are fundamental markers of gait quality and motor control integrity. Symmetry is often associated with the automaticity of spinal Central Pattern Generators (CPGs), while variability reflects the system's dynamic stability and adaptation capability. Understanding the relationship between these markers in healthy individuals provides a critical baseline for identifying preclinical mobility decline and establishing reference values for fall risk assessment.

METHODS

Search strategy Electronic databases including PubMed, Web of Science, Scopus, and Airiti Library will be searched from inception to the date of the search. The search strategy combines Medical Subject Headings (MeSH) and free-text terms using Boolean operators.
Key search terms cover four main concepts:
1. Gait: "Gait", "Walking", "Locomotion", "Step*", "Stride*".
2. Symmetry: "Symmetry", "Asymmetry", "Bilateral".
3. Variability/Stability: "Variability", "Stability", "Instability", "Consistency", "Fluctuation", "Postural Balance".
4. Population: "Healthy Volunteers", "Healthy", "Normal", "Able-bodied".
Animal studies will be excluded using the syntax "NOT (Animals NOT Humans)". The search strategy was refined based on a pilot search.

Participant or population This review will include healthy adults aged 18 years or older.
Participants must be free from any known neurological, musculoskeletal, or orthopedic disorders that affect gait patterns. Studies involving mixed populations (e.g., comparing patients to healthy controls) will be included only if data for the healthy control group are reported separately.
We will exclude studies involving children or adolescents (<18 years), animal studies, and studies that only recruit patient populations without a healthy control group.

Intervention This review focuses on observational and experimental studies; therefore, there is no therapeutic intervention. The primary phenomenon of interest (Exposure) is Gait Symmetry (or Asymmetry).
Specifically, we will evaluate gait parameters under various walking conditions, including:
1. Steady-state walking (at preferred, slow, or fast speeds).
2. Experimental manipulations intended to alter gait symmetry or stability (as moderators), such as:
○ Mechanical perturbations (e.g., split-belt treadmill walking, unilateral leg weighting).
○ Cognitive dual-tasking (e.g., walking while performing arithmetic or memory tasks).

Comparator Comparisons will be made in two primary ways:
1. Between-condition comparisons: Comparing gait parameters during normal steady-state walking (baseline) versus walking under challenged conditions (e.g., cognitive dual-tasking, mechanical perturbations, or different walking speeds).
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Study designs to be included This review will primarily include observational studies, specifically analytical cross-sectional studies. We will also include baseline data from longitudinal studies (e.g., cohort studies) or control group data from experimental studies (e.g., RCTs) if they report steady-state gait parameters for healthy adults. Studies must be original research articles. We will exclude reviews, meta-analyses, case reports, editorials, conference abstracts, and dissertations.

Eligibility criteria Inclusion Criteria:
1. Language: Studies published in English or Chinese (as specified in the search strategy covering Airiti Library).
2. Publication Type: Original peer-reviewed articles.
3. Data Availability: Studies involving mixed populations (patients and healthy controls) will be included only if data for the healthy control group are reported separately.
Exclusion Criteria:
1. Study Design: Systematic reviews, meta-analyses, conference abstracts, editorials, case reports, and dissertations/theses.
2. Subjects: Animal studies and studies involving children or adolescents (<18 years).
3. Data: Studies that fail to report statistical associations between symmetry and variability (e.g., measuring only one domain) or studies with insufficient data where authors do not respond to requests.

Information sources We will search the following electronic bibliographic databases from inception to the date of the search: PubMed, Web of Science, Scopus, and Airiti Library.

In addition to database searching, we will attempt to contact the corresponding authors of included studies via email to request missing data if necessary. We will also screen the reference lists of eligible studies to identify further relevant publications.

Main outcome(s) The primary outcome is the statistical association between gait symmetry and gait variability (or stability) measures in healthy adults.
Relevant gait metrics include:
• Symmetry: Spatiotemporal asymmetry indices (e.g., Step Length Asymmetry, Stance Time Asymmetry).
• Variability/Stability: Coefficient of Variation (CV) of stride parameters, Phase Coordination Index (PCI), or dynamic stability metrics (e.g., Lyapunov Exponent).
Effect measures will be extracted in the following forms:
1. Correlation Coefficients: Pearson's r or Spearman's ρ (representing the overall strength of the relationship).
2. Regression Coefficients: β values or R^2 from regression models (determining if asymmetry predicts variability).
3. Group Differences: Standardized mean differences (Cohen's d or η_p^2) if studies compare distinct "high asymmetry" vs. "low asymmetry" groups.
Timing: Outcomes are assessed during steady-state walking tasks (cross-sectional observation).

Data management Search results will be managed using EndNote 2025 and imported into Covidence systematic review software for the review process.
The mechanism includes:
1. Deduplication: Automatic deduplication will be performed by Covidence upon import, followed by manual verification to remove any remaining duplicates.
2. Screening: Title/abstract and full-text screening will be performed independently by two reviewers within the Covidence platform to ensure data integrity.
3. Data Extraction: A standardized data extraction form will be implemented in Covidence to record study characteristics and outcome data securely.

Quality assessment / Risk of bias analysis Quality assessment will be performed using the JBI Critical Appraisal Checklist for Analytical Cross Sectional Studies. Two reviewers will independently assess the methodological quality of each included study. Disagreements will be resolved through discussion or consultation with a third reviewer.
The assessment will focus on four specific domains relevant to this review:
1. Selection Bias: Evaluating the representativeness of the sample (e.g., convenience sampling).
2. Confounding Factors: Checking if studies identified and controlled for key confounders, specifically walking speed and age.
3. Validity and Reliability: Verifying if the measurement equipment (e.g., GAITRite, force plates, or IMUs) and outcomes were valid and reliable.
4. Statistical Analysis: Assessing the appropriateness of statistical methods, particularly ensuring that bilateral data (left/right steps) were handled correctly to avoid unit-of-analysis errors.
Risk of bias results will be presented in a table or visualized using the robvis tool. Studies judged to be at high risk of bias will be considered in sensitivity analyses to test the robustness of the results.

Strategy of data synthesis Data synthesis will be conducted in two stages:
1. Narrative Synthesis: A narrative synthesis will be provided for all included studies to describe the target populations, task conditions, and the direction/significance of the associations. This is particularly relevant for studies where data are insufficient for pooling (e.g., only p-values reported).
2. Quantitative Synthesis (Meta-analysis): If sufficient homogenous data are available, we will perform a meta-analysis using a random-effects model.
• Effect Measures: We will pool correlation coefficients (Pearson's r or Spearman's ρ) and regression coefficients (β). For studies comparing distinct groups (high vs. low asymmetry), we will calculate Standardized Mean Differences (Cohen's d).
• Heterogeneity: We will assess statistical heterogeneity using the I^2 statistic and Chi-squared test.
• Missing Data: We will attempt to contact authors for missing data. If numerical data are not reported but scatter plots are available, we will extract raw data points using digitization software (e.g., WebPlotDigitizer).

Subgroup analysis If sufficient data are available, we will conduct subgroup analyses to explore potential sources of heterogeneity and evaluate the moderating effects of task constraints. Subgroups will be defined by:

1. Task Conditions: We will compare the strength of the association under cognitive dual-tasking (e.g., arithmetic tasks) versus mechanical perturbations (e.g., split-belt treadmills, unilateral weighting) versus baseline steady-state walking.
2. Walking Speed: We will stratify results by speed (e.g., slow vs. preferred vs. fast walking) to test if the relationship is non-linearly regulated by speed.
3. Measurement Type: We will distinguish between spatiotemporal parameters (e.g., step length/time) and kinetic parameters (e.g., ground reaction forces).
4. Age Groups: If data permits, we will compare young adults versus older adults to account for age-related decline in gait control.

Sensitivity analysis Sensitivity analyses will be performed to test the robustness of the meta-analysis results. We will repeat the primary analysis by excluding:
1. Studies assessed as having a high risk of bias (based on the JBI Critical Appraisal Checklist).
2. Studies where data were extracted from figures (e.g., scatter plots using WebPlotDigitizer) rather than explicitly reported in tables.
3. Outliers identified during the visual inspection of forest plots.

Language restriction English and Chinese.

Country(ies) involved Taiwan.

Keywords Gait; Gait symmetry; Gait variability; Healthy adults; Locomotion; Motor control.

Contributions of each author
Author 1 - Hao Ye - Conceived the study, drafted the protocol and search strategy. Will act as the primary reviewer for screening, data extraction, and manuscript writing.
Email: yehaofight@gmail.com
Author 2 - Ssu Han Ho - Will serve as the second independent reviewer for screening studies and assessing risk of bias. Will assist in data extraction and cross-checking results.
Email: steven910920@gmail.com
Author 3 - Wen-Hsin Chiu - Provided supervision and reviewed the protocol. Will act as the arbitrator to resolve disagreements during the screening and quality assessment process.
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