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Review

Are changes in pain intensity related to changes in balance control in individuals with chronic non-specific low back pain? A systematic review and meta-analysis

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Abstract

Purpose: The aim of this study was to summarize the evidence regarding whether pain reduction in individuals with chronic non-specific low back pain (CNSLBP) following conservative interventions is related to corresponding improvements in balance control.
Methods: Randomized controlled trials were identified from 5 databases (MEDLINE, Cochrane Library, Embase, Web of Science, and PsycINFO). Two reviewers independently screened and identified relevant studies that investigated the effects of non-surgical or non-pharmacological CNSLBP treatments on both pain intensity and balance control. Meta-regression analyses were performed to establish the associations between post-treatment changes in these 2 variables.
Results: Thirty one studies involving 1280 participants with CNSLBP were included. Moderate-quality evidence suggested that pain reduction was associated with and explained 34%−45% of decreases in body sway, as measured by center-of-pressure (CoP) area and CoP velocity with eyes open. However, no significant association was observed between pain reduction and CoP area or velocity in anteroposterior/mediolateral directions. Similarly, there was no significant association between pain reduction and CoP distance or radius. Low-quality evidence indicated that pain relief explained a 15% improvement in one-leg stance with eyes open but not in the eyes-closed condition. Additionally, very low-quality evidence suggested that pain relief explained a 44% decrease in the static anteroposterior stability index with eyes closed but not in the eyes-open, mediolateral, or overall conditions. Furthermore, low-quality evidence indicated that reduced pain was associated with and accounted for 25%−43% of the improved composite and posteromedial scores of the star-excursion balance test, rather than the anterior and posterolateral scores.
Conclusion: Depending on the type of balance assessment, pain relief following conservative interventions may slightly to moderately enhance balance control in individuals with CNSLBP. Clinicians should pay close attention to the balance control in patients with CNSLBP, particularly among older adults.

Keywords: Conservative interventions; Balance control; Low back pain; Meta-regression; Pain relief

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1. Introduction

Low back pain (LBP) is a common musculoskeletal condition, affecting up to 80% of individuals at least once in their lifetime.[1–3] Most people with LBP recover without medical treatment within 6 weeks. However, approximately 20% progress to chronic low back pain (CLBP)[4] and, of these, the majority are diagnosed as having chronic non-specific low back pain (CNSLBP) because of the absence of a specific identifiable etiology.[5] The prevalence of CNSLBP is the highest among older adults, with rates nearly double that of working-age adults, reaching as high as 39%.[3,6]

Balance control refers to an individual's ability to maintain or restore their center of mass within their base of support.[7] Maintaining optimal balance control is crucial for daily activities. Many individuals with CNSLBP demonstrate impaired balance control, resulting in reduced mobility,[8] functional disabilities,[9] and an increased risk of falls and fall-related hospitalizations.[10]

Several studies have reported that pain intensity is significantly associated with balance control,[9] and it has been postulated that this association reflects "pain interference".[11,12] Specifically, when individuals experience pain, their central nervous system allocates cognitive resources to prioritize pain perception over balance control, leading to diminished attention and performance in maintaining balance.[10] Additionally, pain can increase the inhibition of muscle afferents and central proprioceptive processing, causing delays in postural control.[13,14] Further, individuals with CNSLBP may adopt a sub-optimal postural control strategy to avoid pain, such as increased co-contraction of superficial trunk muscles to enhance trunk stability.[14–16]

Theoretically, if the presence of pain results in impaired balance control in individuals with CNSLBP, rehabilitation prioritizing pain relief should also restore balance control in these people.[17,18] However, it remains uncertain whether pain relief results in improved postural control. While some studies have found a moderate association between decreases in LBP intensity and reduced postural sway,[11,12,19] others have reported contrasting findings, showing no significant association between these variables.[13,20–22] These conflicting results underscore the need for a systematic review to summarize the evidence regarding the temporal association between pain reduction and changes in balance control among individuals with CNSLBP.

Given non-surgical and non-pharmacological interventions are often considered as first-line treatment options for individuals with CNSLBP,[10,23] our review focused on these interventions. Therefore, the current systematic review and meta-analysis aimed to synthesize the evidence on the temporal association between changes in pain intensity and changes in balance control among individuals with CNSLBP following non-surgical and non-pharmacological interventions.

2. Methods

2.1. Registration of protocol

The current review was conducted and reported according to the Cochrane Collaboration Guideline and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations.[24] The protocol was registered with PROSPERO (CRD42023447861).

2.2. Deviation from the protocol

We did not evaluate the predictive value of the baseline pain intensity in determining the changes in balance control after treatment as none of the studies included in our study conducted this specific predictive analysis.

2.3. Search strategy

MEDLINE, Cochrane Library, Embase, Web of Science, and PsycINFO databases were systematically searched without language restrictions from their inception to July 11, 2023. The search terms were keywords or medical subject headings related to "chronic low back pain" and "balance/falls". The search strategies were reviewed by an experienced librarian (KE) and presented in Supplementary Material 1. Additionally, reference lists of the included studies were screened, and Embase (with Google Scholar as a backup) was used for forward citation tracking to identify potential eligible publications.[25]

2.4. Eligibility criteria

The inclusion criteria were randomized controlled trials (RCTs) that involved: (a) adults aged ≥18 years with CNSLBP (duration ≥3 months);[5,26] (b) conservative LBP interventions (non-surgical and non-pharmacological); and (c) reporting both temporal changes in pain intensity (measured by Visual Analog Scale (VAS) or Numeric Pain Rating Scale (NPRS)) and changes in at least 1 balance parameter (e.g., center-of-pressure area/distance/radius/velocity, one-leg stance (OLS), dynamic/static stability indices, star-excursion balance test (SEBT), Y-balance test (YBT)) in each study (Supplementary Material 2). The exclusion criteria were studies involving individuals with: (a) acute/subacute LBP or other types of pain; (b) neurological disorders, a history of prior surgery, or specific spinal conditions (e.g., fractures, deformities, infections, malignancies); and (c) medical conditions that cause balance deficits (e.g., vertigo or Parkinson's disease). Additionally, review articles, conference abstracts, dissertations, animal studies, and grey literature were also excluded.

2.5. Study selection

After removing duplicates using Endnote 20 (Clarivate Analytics, Philadelphia, PA, USA), 2 reviewers independently screened the titles and abstracts to determine eligibility for full-text screening (DKYZ screened all identified citations, while CKCC, JQJL, and JCYN separately screened one-third of these citations). Before the screening process, all reviewers underwent training to standardize the screening content and methods. Any inter-reviewer disagreements were resolved through discussion with a senior reviewer (AYLW). The full-text screening followed the same procedures.

2.6. Data extraction

Two independent authors (DKYZ and JQJL) conducted the data extraction and validation. The extracted data included: authors, study design, participants' demographic characteristics, sample size, intervention details, as well as pain and balance outcomes. If data were exclusively presented in graphical form, Origin 2022 (OriginLab Corporation, Northampton, MA, USA) was used to extract relevant values.[27] The corresponding authors were contacted via email to request any missing data. Each pair of pre-test (baseline) and post-test results (including measurements taken during the intervention process, post-intervention, or follow-up) from each study group was treated as a separate subset, regardless of the experimental or control group (e.g., no intervention). Changes in pain intensity and balance control parameters were calculated as the difference between pre-test and post-test values, including center-of-pressure area/distance/radius/velocity, and dynamic/static stability indices. To ensure consistency and comparability of the direction across all studies (including OLS, SEBT, and YBT) where higher scores indicated better outcomes, the change scores were reversed by multiplying them by −1. In summary, a positive value means pain reduction or improved balance control.

2.7. Risk-of-bias assessments

The risk of bias (RoB) of the included studies was assessed using the Cochrane Risk of Bias tool 2.0 (RoB 2.0).[28] The RoB 2.0 assesses 5 domains of bias, including the randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Each domain was rated as "high RoB" (indicating a high RoB), "some concerns" (indicating some potential for bias), or "low RoB" (indicating a low RoB). The overall risk of bias for each study was determined based on the ratings in the 5 domains. If all domains were judged as low RoB, the overall RoB was considered as "low risk". If at least 1 domain raised some concerns, but the remaining domains were rated as low RoB, the overall RoB was classified as "some concerns". Finally, if at least 1 domain was rated as high RoB or multiple domains were rated as "some concerns", the overall RoB was considered "high risk".[29] Two authors (DKYZ and JW) independently assessed each study. Any discrepancies were resolved through discussion with a senior reviewer (AYLW).

2.8. Quality-of-evidence assessment

The quality of evidence for each pooled analysis was assessed by 2 independent authors (DKYZ and JQJL) using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system.[30,31] Any discrepancies were resolved through consensus discussions or further consultations with a senior reviewer (AYLW). The quality of evidence was categorized as "high", "moderate", "low", or "very low" (Supplementary Material 3). Notably, evidence derived from RCTs was considered to be high quality. However, the quality of evidence could be downgraded based on 5 aspects: RoB, inconsistency of results, indirectness of evidence, imprecision, and publication bias. Conversely, the quality could be upgraded based on 3 aspects: a large effect, the potential for plausible confounding to alter the effect, and the presence of a dose−response effect.

2.9. Statistical analysis

When each pooled outcome had 3 or more subsets,[32] random-effects meta-regression was performed in Stata (Version 17.0; Stata Corp., College Station, TX, USA) to examine the association between mean changes in pain intensity (independent predictor variable) and mean changes in balance outcomes (target variable).[33] Subgroup analyses were conducted to compare working-age adults (18−64 years) and older adults (≥65 years) when possible. Meta-regressions were performed using the normalized mean values and the standard error for the changes in the outcomes of interest. The regression lines were plotted along with their corresponding 95% prediction intervals. The percentage of the mean change in balance control accounted for by the mean change in back pain was determined using adjusted R-squared (Adj R^2).[33,34] Individual data circles represent results from study subsets (ie, the mean changes in independent variable (pain intensity) and mean changes in target variable (balance outcome)). The size of each circle signifies the precision of the mean change in the balance outcomes (i.e., the reciprocal of the standard error squared).[34] A positive slope value of the fitted line indicated that pain relief was associated with greater improvements in balance control, while a negative slope value indicated that pain relief was associated with less improvement in balance control. If the meta-regression reached statistical significance ($p < 0.05$), a fitted meta-regression equation was generated. The statistical heterogeneity among the included studies was assessed using Higgins' I^2 measure, with I^2 exceeding 50% indicating high heterogeneity and $I^2 \leq 50\%$ indicating low heterogeneity.[35]

3. Results

3.1. Characteristics of the included studies

A total of 9224 articles were identified from the initial search. After the title and abstract screening, 266 articles were retrieved for full-text screening. Of these, 235 articles were excluded due to being conference abstracts, dissertations, or duplications; due to ineligible outcome measures, participants, or study designs; and due to the use of medications or because of missing data without the corresponding authors' responses. Finally, 31 studies involving 1280 participants were included (Fig. 1).[20,36−65] All included studies assessed pain intensity using either VAS or NPRS, while the balance measurements (including static balance and dynamic balance) varied across studies

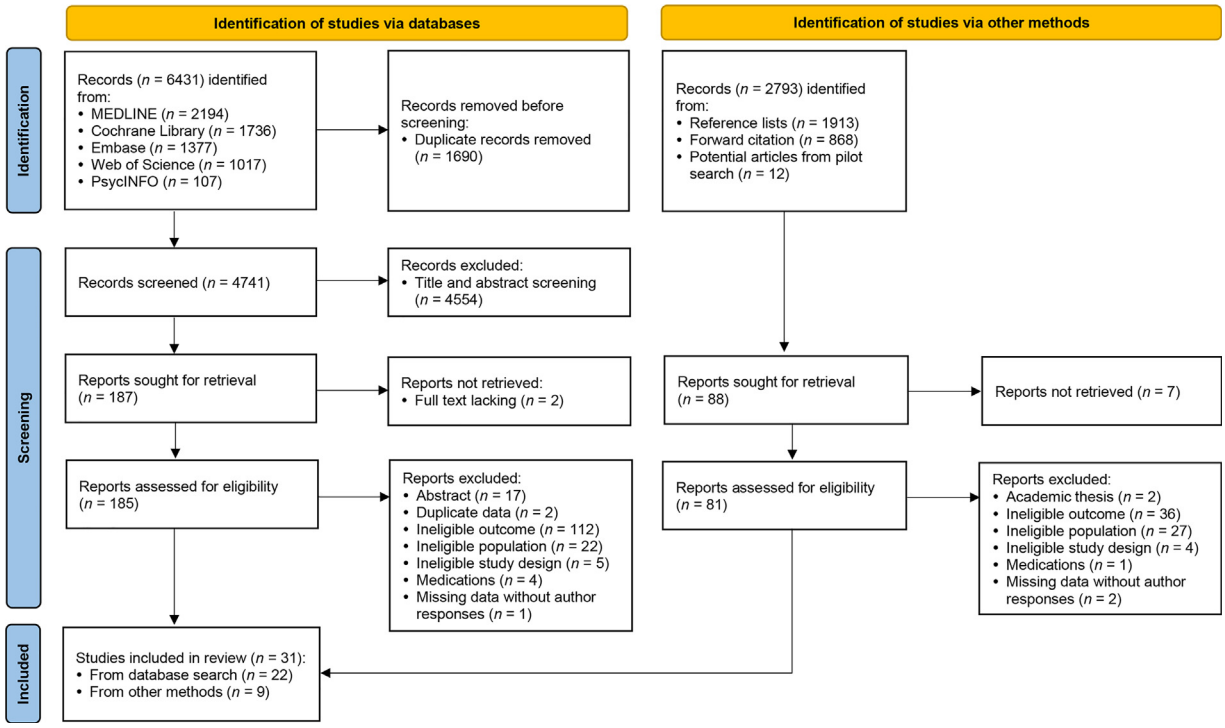


Fig. 1. Flow diagram.

(Supplementary Material 4). The various balance-control outcomes used in the included studies, along with their descriptions, are listed in Supplementary Material 2. The included studies were published between 2015 and 2023 in 12 countries. Notably, Iran ($n = 8$), Brazil ($n = 5$), and the Republic of Korea ($n = 5$) had the highest numbers of relevant publications. Supplementary Material 5 shows the individual data used for meta-regressions. Four (13%), 8 (26%), and 19 (61%) included studies demonstrated low, some concern, and high RoB, respectively (Supplementary Material 6). The evidence assessment using the GRADE system for each pooled analysis is summarized in Supplementary Material 3.

3.2. Meta-regression analyses

3.2.1. Static balance tests

3.2.1.1. Center-of-pressure area (CoPA). Moderate-quality evidence demonstrated a significant association between decreases in CNSLBP intensity and reductions in the CoPA with eyes open (CoPA-O) ($p = 0.032$; fitted meta-regression line: mean changes in CoPA-O (%) = 0.68 × mean changes in pain (%) − 31.37%; Adj $R^2 = 45.17\%$; $I^2 = 0\%$) (Fig. 2). That is, 45.17% of the mean change in CoPA-O was explained by the mean change in pain intensity. In contrast, no significant association was noted between mean changes in CNSLBP intensity and mean changes in CoPA with eyes closed (CoPA-C) ($p = 0.762$).

3.2.1.2. Center-of-pressure distance (CoPD) and radius (CoPR). No significant association was found between mean changes in CNSLBP intensity and mean changes in CoPD/CoPR in any direction (anteroposterior, mediolateral, or overall) or under conditions with eyes open or closed (Supplementary Materials 7 and 8).

3.2.1.3. Center-of-pressure velocity (CoPV). No statistically significant association was observed between the mean changes in CNSLBP intensity and the mean changes in center-of-pressure anteroposterior/mediolateral velocities, either with eyes open or closed (CoPAPV-O, CoPAPV-C, CoPMLV-O, CoPMLV-C), as well as CoPV-C (Fig. 3). However, moderate-quality evidence indicated a significant association between pain relief and decreased CoPV-O ($p < 0.001$; fitted line: mean change in CoPV-O (%) = 2.03 × mean change in pain (%) − 87.87%; Adj $R^2 = 33.65\%$; $I^2 = 98.09\%$).

3.2.1.4. OLS. The results of the meta-regression analysis examining the association between mean changes in pain intensity and mean changes in the OLS duration are displayed in Fig. 4. No significant association was noted between the mean changes in CNSLBP intensity and the mean changes in OLS with eyes closed (OLS-C) ($p = 0.217$). Conversely, low-quality evidence showed a significant association between decreases in CNSLBP intensity and increases in OLS with eyes open (OLS-O) ($p = 0.031$; fitted line: mean change in OLS-O (%) = 1.06 × mean change in pain (%) + 48.69%; Adj $R^2 = 14.61\%$; $I^2 = 99.79\%$).

3.2.1.5. Static stability index. Very low-quality evidence suggested a significant association between pain reduction and improved static anteroposterior stability index with eyes

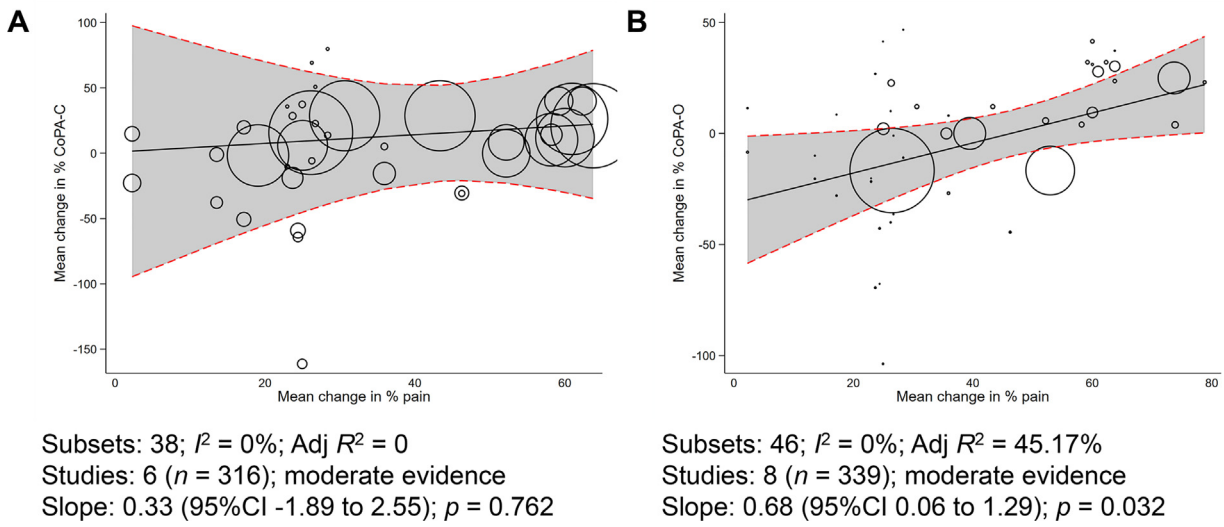


Fig. 2. Meta-regression of relationship between the mean change in pain intensity and the mean change in CoPA. (A) Pain intensity *vs.* CoPA-C; (B) pain intensity *vs.* CoPA-O. Individual data circles represent results from study subsets. The size of each circle reflects the precision of the mean change in balance outcomes, with larger circles signifying greater precision (i.e., the reciprocal of the squared standard error). 95%CI = 95% confidence interval; Adj = adjusted; CoPA = center-of-pressure area; CoPA-C = center-of-pressure area with eyes closed; CoPA-O = center-of-pressure area with eyes open.

closed (SAPSI-C) ($p = 0.043$; fitted line: mean change in SAPSI-C (%) = 0.69 × mean change in pain (%) − 12.28%; Adj $R^2 = 44.26\%$; $I^2 = 99.96\%$) (Fig. 5). Nevertheless, no significant association was noted between the mean changes in CNSLBP intensity and the mean changes in the static anteroposterior stability index with eyes open, as well as static mediolateral/overall stability indices under conditions with eyes open or closed.

3.2.2. Dynamic balance tests

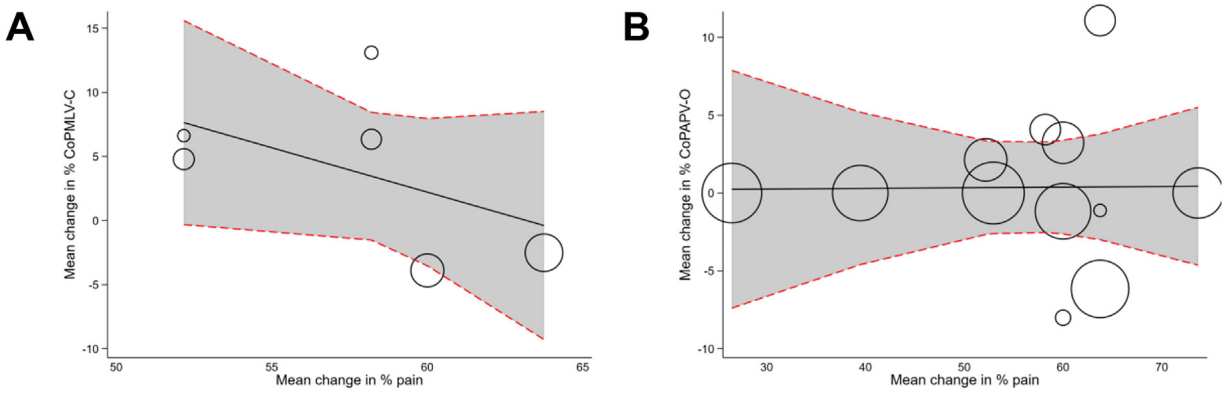
3.2.2.1. Dynamic stability index. Greater decreases in dynamic stability index indicated more improvements in balance control. No significant association existed between the mean changes in CNSLBP intensity and the mean changes in dynamic anteroposterior/mediolateral stability indices, regardless of eyes open or closed, and the dynamic overall stability index with eyes open (Fig. 6). However, there was low-quality evidence from only 1 involved study supporting a negative association between CNSLBP reduction and decreases in dynamic overall stability index with eyes closed (DOSI-C) ($p = 0.029$; fitted line: mean change in DOSI-C (%) = −0.33 × mean change in pain (%) + 51.77%; Adj $R^2 = 72.23\%$; $I^2 = 93.78\%$).

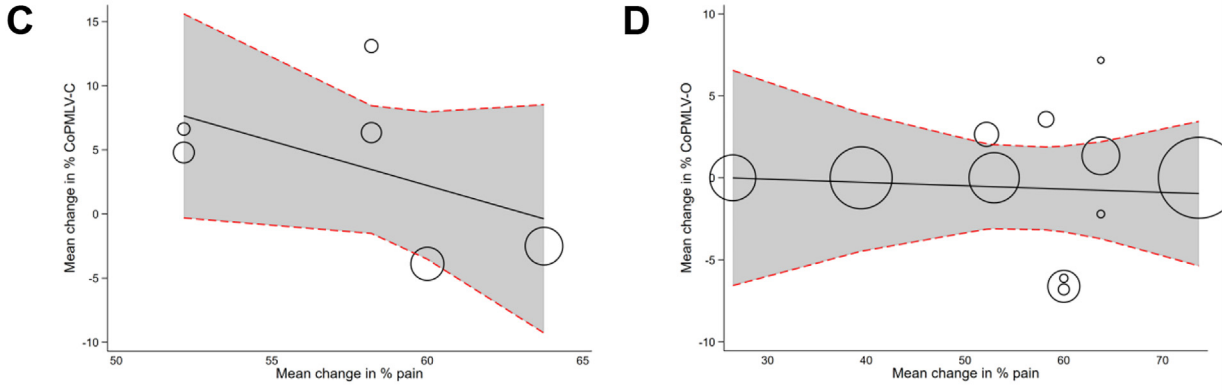
3.2.2.2. SEBT. Six included studies reported YBT,[36–38,42,60,65] while 2 studies focused on the SEBT.[20,57] Because the YBT was developed as a simplified version of the SEBT,[66] we conducted meta-regression analyses using the combined results of both tests. No significant temporal association was found between the changes in CNSLBP intensity and the corresponding changes in the anterior score of SEBT (SEBT-ANT) ($p = 0.568$) and posterolateral score of SEBT (SEBT-PL) ($p = 0.052$) (Fig. 7). Low-quality evidence demonstrated significant associations between pain reduction and improvements in the composite score of the SEBT (SEBT-CS) ($p = 0.034$; fitted line: mean change in SEBT-CS (%) = 0.11 × mean change in pain (%) + 2.49%; Adj $R^2 = 43.25\%$; $I^2 = 69.25\%$) and the posteromedial score of the SEBT (SEBT-PM) ($p = 0.012$; fitted line: mean change in SEBT-PM (%) = 0.11 × mean change in pain (%) + 2.75%; Adj $R^2 = 25.05\%$; $I^2 = 63.25\%$).

4. Discussion

The current systematic review represents the first endeavor to consolidate evidence on the association between changes in pain intensity following conservative treatments and the corresponding changes in balance control among adults with CNSLBP. Our meta-regression analyses revealed evidence of moderate to very low quality indicating that the alleviation of CNSLBP could potentially lead to and account for improvements in static and dynamic balance ranging from 15 % to 45%. However, it is important to note that a high heterogeneity was observed among the included studies.

No significant association was found between changes in CNSLBP intensity and corresponding changes in most of the static balance scores (e.g., CoPA-C, CoPAPV-C, CoPAPV-O, CoPMLV-C, CoPMLV-O, CoPV-C, and OLS-C). This lack of significance may be due to a floor effect observed in higher-level tests (e.g., CoPA-C, CoPAPV-C, CoPMLV-C, CoPV-C, and OLS-C), making it difficult to detect significant temporal associations. Similarly, Mikkonen et al.[67] discovered that individuals with and without CNSLBP did not show a significant difference in CoPV-C. Moreover, different balance tests exhibit varying sensitivities in detecting balance deficits. Notably, among various center of pressure parameters (i.e., CoPA, CoPD, CoPR, CoPV), CoPA and CoPV are more sensitive and have been recommended for detecting balance





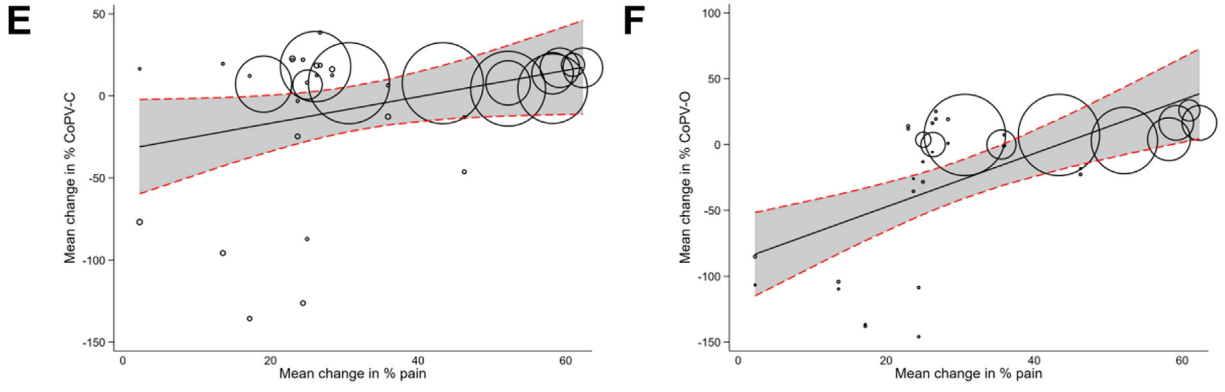


Fig. 3. Meta-regression of relationship between the mean change in pain intensity and the mean change in CoPV. (A) Pain intensity *vs.* CoPAPV-C; (B) pain intensity *vs.* CoPAPV-O; (C) pain intensity *vs.* CoPMLV-C; (D) pain intensity *vs.* CoPMLV-O; (E) pain intensity *vs.* CoPV-C; (F) pain intensity *vs.* CoPV-O. Individual data circles represent results from study subsets. The size of each circle reflects the precision of the mean change in balance outcomes, with larger circles signifying greater precision (i.e., the reciprocal of the squared standard error). 95%CI = 95% confidence interval; CoPAPV-C = center-of-pressure anteroposterior velocity with eyes closed; CoPAPV-O = center-of-pressure anteroposterior velocity with eyes open; CoPMLV-C = center-of-pressure mediolateral velocity with eyes closed; CoPMLV-O = center-of-pressure mediolateral velocity with eyes open; CoPV = center-of-pressure velocity; CoPV-C = center-of-pressure velocity with eyes closed; CoPV-O = center-of-pressure velocity with eyes open.

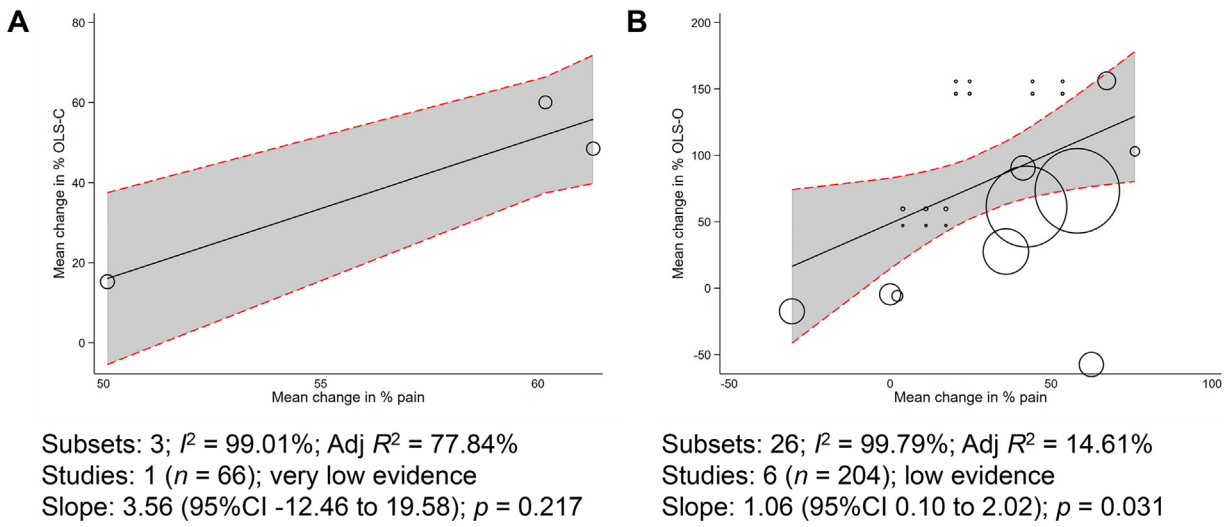


Fig. 4. Meta-regression of relationship between the mean change in pain intensity and the mean change in OLS. (A) Pain intensity *vs.* OLS-C; (B) pain intensity *vs.* OLS-O. Individual data circles represent results from study subsets. The size of each circle reflects the precision of the mean change in balance outcomes, with larger circles signifying greater precision (i.e., the reciprocal of the squared standard error). 95%CI = 95% confidence interval; OLS = one-leg stance; OLS-C = one-leg stance with eyes closed; OLS-O = one-leg stance with eyes open.

impairment in individuals with CNSLBP.[11,12,39,68,69] Therefore, it is plausible that in our review, significant associations were observed between changes in pain intensity and changes in CoPA-O and CoPV-O, while no significant associations were observed in CoPD and CoPR, regardless of whether eyes were open or closed and regardless of direction. Furthermore, it is worth noting that decreases in postural sway may not necessarily indicate improved balance control but can also reflect a reduced margin of stability, which should be interpreted as lower balance control capacity.[70–72] However, all included studies in our systematic review reported that their observed decreases in postural sway indicated improvements in balance control.

Regarding the stability index, the majority of static and dynamic stability indices showed no association with pain relief, while pain reduction was significantly associated with greater decreases in SAPSI-C (2 studies; I^2 = 99.96%; Adj R^2 = 44.26%; very low-quality evidence) and a lesser decrease in DOSI-C (1 study; I^2 = 93.78%; Adj R^2 = 72.23%; low-quality evidence). However, these results should be interpreted with caution due to the limited number of studies involved and the presence of high heterogeneity. To validate these findings, further studies with greater homogeneity are required.

Conversely, based on low-quality evidence and heterogeneous data, our findings demonstrated that pain relief was significantly associated with improvements in SEBT-CS, SEBT-PM, and marginally in SEBT-PL, but not in SEBT-ANT. This discrepancy may be due to SEBT-ANT being less sensitive in detecting balance changes compared to SEBT-PM and SEBT-PL, possibly because visual compensation during leg reaching in the anterior direction.[9,21] Therefore, further studies are warranted to investigate the temporal association between changes in CNSLBP and dynamic balance control.

Although pain remains a primary contributor to impaired balance control in individuals with CNSLBP, the linear association between changes in pain intensity and changes in balance control is only partially maintained following conservative intervention. Several potential factors may explain this observation. First, as pain is a distracting factor and balance requires attention, pain reduction may enable individuals to allocate more brain resources to monitor the quality, precision, and control of their balance.[10,20,73] Second, research has shown that reduced pain in individuals with CLBP can lead to thickened grey matter in the left dorsolateral prefrontal cortex and primary motor cortex. These changes are associated with improved performance in attention-demanding cognitive tasks and reduced physical disability, respectively.[74] Third, fear of pain, a common factor associated with chronic pain, may not diminish effectively even after pain reduction, which may hinder balance control improvements.[14] Previous research found that fear of pain could impede improvements in physical activity, even after pain relief in individuals with CLBP.[75,76] Furthermore, our findings indicate that pain relief alone cannot fully account for the enhancements observed in static and dynamic balance, as evidenced by Adj R^2 ranging from 15% to 45%. Balance improvements may be confounded by other factors, such as muscle atrophy of the lumbar multifidus muscle,[14,77] impaired proprioception,[78,79] cognitive impairment (e.g., attention and executive functions),[80–82] and emotional distress (e.g., anxiety and depression).[9] Further investigation is warranted to explore the relative impacts of these factors on balance improvement.[83]

Several limitations should be considered when interpreting our results. First, our analysis did not consider the details of treatment types, durations, or doses, as well as the specific types of balance instruments used. Second, although 31 studies were included, some balance control outcomes were reported

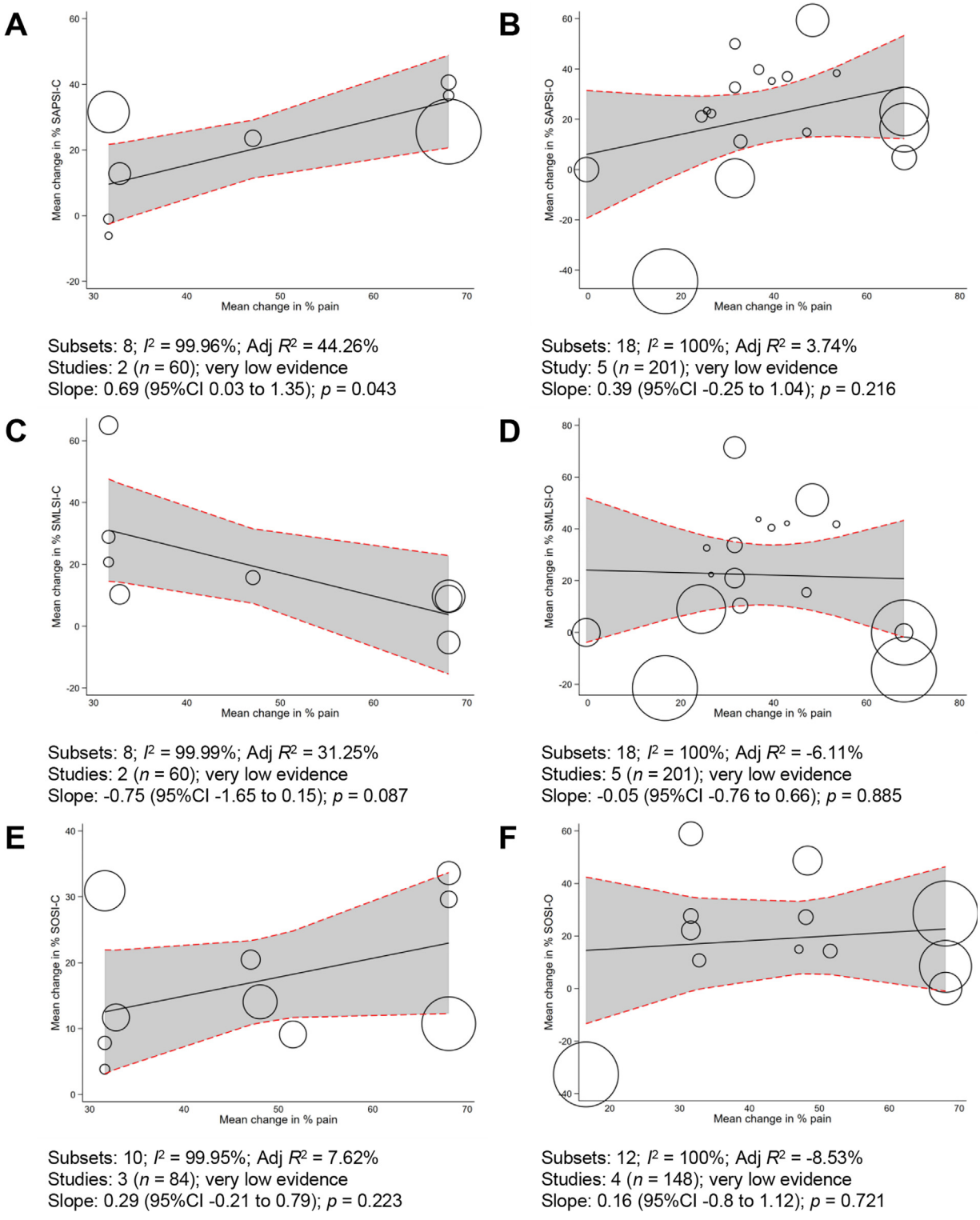


Fig. 5. Meta-regression of relationship between the mean change in pain intensity and the mean change in static stability index. (A) Pain intensity *vs.* SAPSI-C; (B) pain intensity *vs.* SAPSI-O; (C) pain intensity *vs.* SMLSI-C; (D) pain intensity *vs.* SMLSI-O; (E) pain intensity *vs.* SOSI-C; (F) pain intensity *vs.* SOSI-O. Individual data circles represent results from study subsets. The size of each circle reflects the precision of the mean change in balance outcomes, with larger circles signifying greater precision (i.e., the reciprocal of the squared standard error). 95%CI = 95% confidence interval; SAPSI-C = static anteroposterior stability index with eyes closed; SAPSI-O = static anteroposterior stability index with eyes open; SMLSI-C = static mediolateral stability index with eyes closed; SMLSI-O = static mediolateral stability index with eyes open; SOSI-C = static overall stability index with eyes closed; SOSI-O = static overall stability index with eyes open.

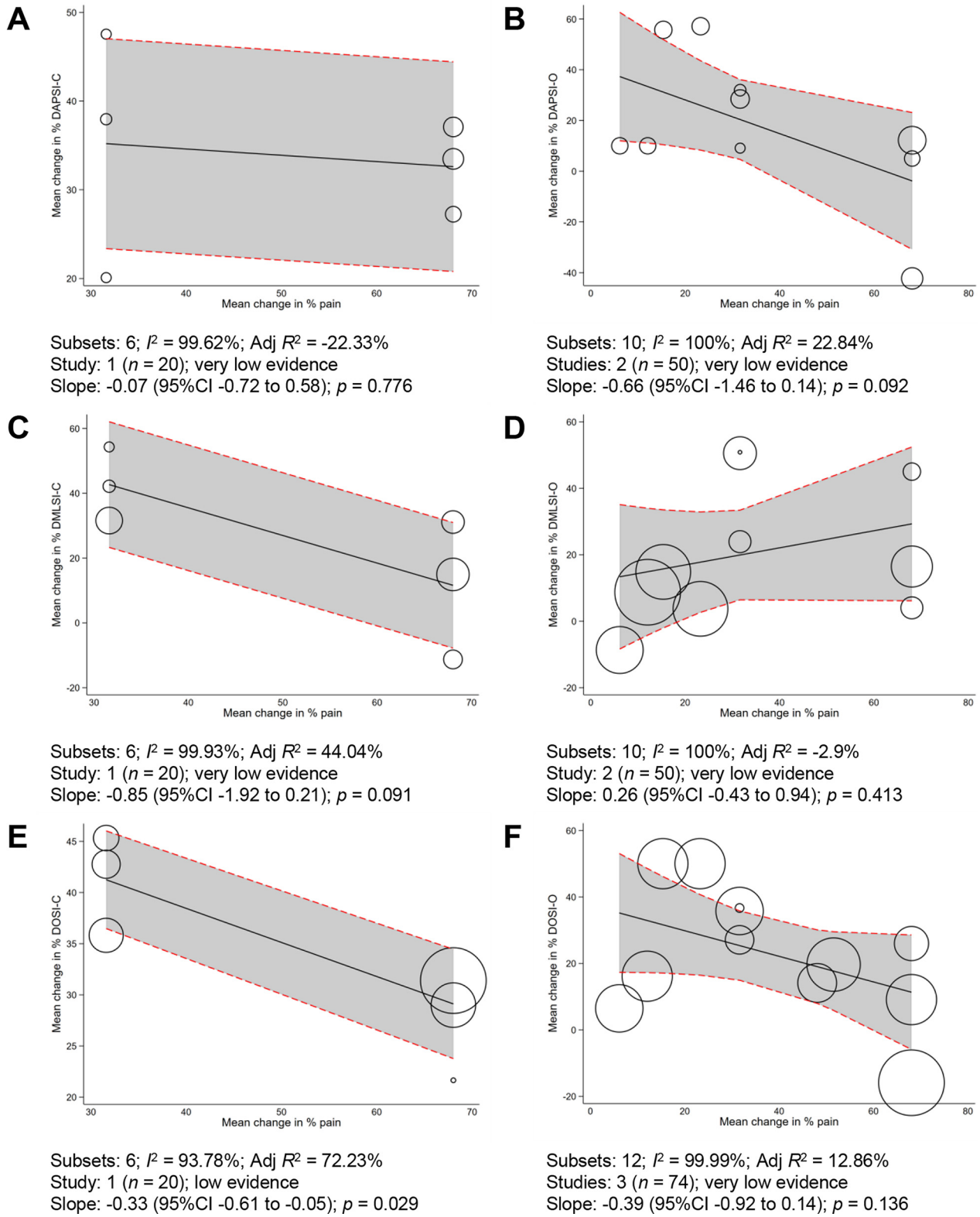


Fig. 6. Meta-regression of relationship between the mean change in pain intensity and the mean change in dynamic stability indices. (A) Pain intensity *vs.* DAPSI-C; (B) pain intensity *vs.* DAPSI-O; (C) pain intensity *vs.* DMLSI-C; (D) pain intensity *vs.* DMLSI-O; (E) pain intensity *vs.* DOSI-C; (F) pain intensity *vs.* DOSI-O. Individual data circles represent results from study subsets. The size of each circle reflects the precision of the mean change in balance outcomes, with larger circles signifying greater precision (i.e., the reciprocal of the squared standard error). 95%CI = 95% confidence interval; DAPSI-C = dynamic anteroposterior stability index with eyes closed; DAPSI-O = dynamic anteroposterior stability index with eyes open; DMLSI-C = dynamic mediolateral stability index with eyes closed; DMLSI-O = dynamic mediolateral stability index with eyes open; DOSI-C = dynamic overall stability index with eyes closed; DOSI-O = dynamic overall stability index with eyes open.

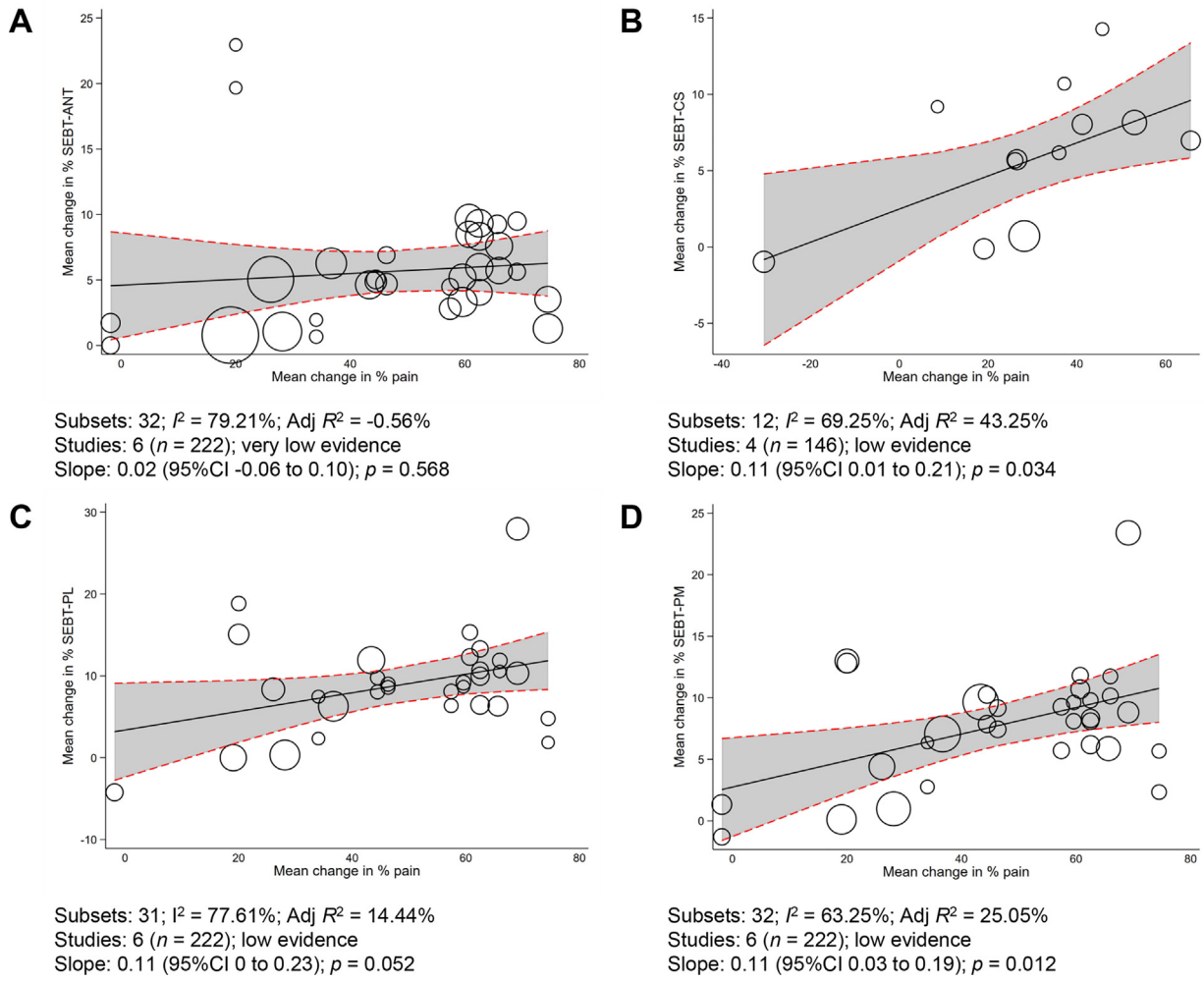


Fig. 7. Meta-regression of relationship between the mean change in pain intensity and the mean change in SEBT. (A) Pain intensity *vs.* SEBT-ANT; (B) pain intensity *vs.* SEBT-CS; (C) pain intensity *vs.* SEBT-PL; (D) pain intensity *vs.* SEBT-PM. Individual data circles represent results from study subsets. The size of each circle reflects the precision of the mean change in balance outcomes, with larger circles signifying greater precision (i.e., the reciprocal of the squared standard error). 95%CI = 95% confidence interval; SEBT = star-excursion balance test; SEBT-ANT = anterior score of star-excursion balance test; SEBT-CS = composite score of star-excursion balance test; SEBT-PL = posterolateral score of star-excursion balance test; SEBT-PM = posteromedial score of star-excursion balance test.

by only a few studies. This could potentially introduce small-study bias, particularly in the analyses of the DOSI-C. Further, due to limited data availability, there was insufficient data for subgroup analysis to compare findings between working-age and older adults. This limitation hinders our ability to establish a definitive conclusion regarding the impact of aging on the temporal association between changes in CNSLBP and balance control. Third, since the included studies did not report certain balance control outcomes, such as the number of falls, these aspects should be investigated in the future. Fourth, most of the included studies exhibited a high risk of bias and most of the pooled results demonstrated high heterogeneity. Therefore, more high-quality and homogeneous trials are needed to validate our findings and address these knowledge gaps.

5. Conclusion

Pain relief following conservative interventions may be beneficial for balance improvement in individuals with CNSLBP. However, it is noteworthy that pain reduction alone could not comprehensively explain the improvements observed in balance control for these individuals. Other factors, such as cognitive or psychological factors, should be systematically evaluated to quantify their potential contributions to improving balance control in this population. Understanding the impact of these factors can ultimately lead to the development of more effective interventions for addressing balance impairments in individuals with CNSLBP.

Authors' contributions

DYKZ was responsible for the conceptualization, literature search, study selection, data extraction, risk-of-bias assessment, data analysis, and drafting of the manuscript; JQJL was involved in study selection, data extraction, and editing of the manuscript; JRC was involved in conceptualization and reviewed the manuscript; JCYN participated in the screening of studies and edited the manuscript; ZZ was responsible for

the conceptualization and manuscript revision; JW assessed the risk-of-bias assessment and edited the manuscript; CKCC assisted the screening of articles and manuscript writing; FFH helped edit the manuscript; SMP was involved in the conceptualization stage and review of the manuscript; DS participated in the drafting and editing of the manuscript; MLF was involved in the manuscript editing and review; KE: participated in the literature search and manuscript revision; SL and XW were involved in the manuscript editing; and AYLW was involved in the conceptualization, study screening, data analysis, manuscript editing, and overall project supervision. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests. The funding source has no competing interests and did not influence the preparation of this review.

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Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2024.100989.

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