European Journal of Physical and Rehabilitation Medicine
EDIZIONI MINERVA MEDICA

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European Journal of Physical and Rehabilitation Medicine 2021 Oct 12
DOI: 10.23736/S1973-9087.21.07293-2

Article type: Systematic reviews and meta-analyses

Article first published online: October 12,2021
Manuscript accepted: October 7, 2021
Manuscript received: September 25, 2021

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TITLE

Effects of Exercise on Balance in Patients with Non-Specific Low Back Pain: a Systematic Review and Meta-Analysis

RUNNING TITLE

Non-Specific Low Back Pain and Balance

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ABSTRACT

Introduction. Non-specific low back pain (NS-LBP) is one of the most common musculoskeletal conditions related to medical expenses and disability. Evidence suggests that changes in motion patterns could induce trunk instability and impaired postural control. Therefore, this systematic review investigated the effects of exercise on balance in patients with NS-LBP.

Evidence acquisition. A systematic review and meta-analysis were conducted. Findings were reported following the 2020 PRISMA statement and the main databases were searched for RCTs. Studies were independently screened through a standardized form and their internal validity assessed by using the Cochrane risk of bias (RoB) tool. Pooled effects were calculated at post-treatment and quality of evidence was assessed through the GRADE framework.

Evidence synthesis. Twelve articles were included in the review, eight in the meta-analysis. None of the studies were judged at low RoB. There is very low quality evidence that exercise is effective in reducing Centre of Pressure (CoP) displacement [-16.99 (-27.29, -6.68); p=0.001] and in improving single-leg stance test performance [-28.7 (-48.84, -8.67); p=0.005] and dynamic balance [-4.74 (-8.02, -1.46); p=0.005]. Conversely, no significant results were observed in “ellipse area” and in “limits of stability” indexes. Other results were summarized in a qualitative synthesis.

Conclusions. Exercise could be effective in improving both static and dynamic balance in patients with NS-LBP over a short-term period. However, quality of evidence was estimated as very low, hence further double-blinded, high-quality RCTs are needed to address clinical practice and research.

Keywords: Low Back Pain; Exercise; Postural Balance; Physical Therapy Modalities; Systematic Review.

INTRODUCTION

Low back pain (LBP) is the most common musculoskeletal condition, frequently related to medical expenses and disability[1,2]. It is considered the main cause of limitation in everyday activities and work absence in most countries, representing an important economic burden globally[3,4].

Despite its high prevalence, LBP frequently has a favorable prognosis. Although a specific cause of pain can seldom be identified, in most cases no pathology is present and the prevalent form consists of mechanical, non-specific LBP (NS-LBP)[5]. Pain typically improves consistently within 6 weeks, even if many subjects - estimates varying from 2% to 34% - still experience pain after 3 months and later, turning this condition into a chronic state[6].

Up to now, several hypotheses have been made about the mechanisms underlying the onset of NS-LBP. Many authors have suggested that changes in motion patterns and impairments in spine stability could play a role in spinal disorders[7,8]. Indeed, different studies have focused on the activity of the deep muscles of the trunk, typically showing delayed activation, diminished resistance and weakness, especially during episodes of pain[9].

In this context, evidence suggests that these changes probably induce postural instability as well as impaired postural control; in fact, there is evidence that NS-LBP subjects show an increase in center of pressure (CoP) displacement and velocity[10-12] and proprioceptive deficits, probably as a consequence of pain[13]. Interestingly, a recent systematic review highlighted how balance is significantly impaired in individuals with chronic LBP, thus suggesting clinicians should carry out a proper balance assessment; this evaluation should be used to monitor and guide the treatment period[14]. As a consequence, different instruments and motor-task tests have been adopted over the years, showing overall acceptable values of reliability and validity[15-17].

To date, several randomized controlled trials (RCTs) have already investigated the effects of therapeutic exercise on pain and disability in patients with NS-LBP with conflicting results. Specifically, exercise seems to be slightly effective in improving pain levels and functional status in chronic LBP, while there is no evidence of its efficacy in the case of acute pain[18]. However, no systematic reviews to date have established the effectiveness of exercise on balance outcomes[19] in patients with NS-LBP, so a synthesis of evidence is still missing.

Based on the above line of reasoning, this systematic review aimed to investigate the effects of exercise on balance in patients with NS-LBP. Secondly, we explored which modality of exercise appeared to be superior to others and lastly, if effects are still present over a medium- or a long-term period.

EVIDENCE ACQUISITION

Protocol registration

The reporting of the current review followed the “2020 Preferred Reporting Items for Systematic Reviews and Meta-Analysis” (PRISMA 2020 checklist)[20]. A “PICO” strategy was used to state the research question (P: non-specific low back pain; I: therapeutic exercise; C: all the other therapies routinely applied; O: balance performance). The protocol was regularly approved and published in an international prospective register of systematic reviews (PROSPERO, https://www.crd.york.ac.uk/prospero/ , registration ID: CRD42021236669).

Search strategy

A search process was carried out to assess the effects of exercise on balance performance in NS-LBP subjects. PubMed, Embase, Cochrane CENTRAL, Scopus and PEDro databases were consulted up to April 2021. To be thorough, we performed cross-referencing to retrieve any possible missing study and gray literature was also considered through Google web searching and ClinicalTrials.gov. Different search terms and keywords were used, such as “low back pain”, “non-specific low back pain”, “chronic low back pain”, “exercise”, “training”, “physical therapy”, “physiotherapy”, “balance”, “proprioception”, “equilibrium” and “posture”. These words were combined differently according to database functioning; details are provided in the Appendix.

Eligibility criteria

Inclusion criteria for this review were the following: randomized, or quasi-randomized controlled clinical trials (RCTs or quasi-RCTs) also including feasibility or pilot studies; trials assessing the effects of active exercise on any balance performance indicator, both instrumental and motor-task tests, and studies which compared any other kind of control interventions, conducted in subjects presenting NS-LBP. Further considered criteria were adult population (18-70 years old) and papers written in English. Due to the intrinsic variability of exercise therapies, no restriction in terms of dosage was applied. Similarly, we did not apply any limitations regarding control groups, except for the exclusion of trials comparing two (or more) different types of exercise; control therapies included usual care, instrumental therapies, passive applications (e.g. manual/manipulative treatments, massage, hot and/or cold packs), waiting lists and educational/informative counselling. Although gait can be considered an indicator of balance performance, we opted to exclude studies focusing on gait analysis due to its complexity and peculiarities.

Study selection and data collection

Records obtained from databases were managed using “Rayyan, Intelligent Systematic Review” (www.rayyan.ai)[21]. Title, abstract and full texts were screened independently by three reviewers (MA, MC, EP) to identify eligible studies. Discrepancies were resolved through a discussion with another reviewer (FDF). Details of the study selection process are provided in the PRISMA 2020 flow diagram (Fig. 1). Main characteristics of included studies were extracted in a standardized form and summarized in a table (Tab. I) reporting first author name, main objective, outcomes, sample size, participants’ allocation and information regarding the intervention in terms of dosage. Another table (Tab. II) detailed the characteristics of compared interventions and results. As before, the same reviewers independently screened the included studies and resolved any disagreement with a consensus.

In case of missing data, investigators were contacted via e-mail.

Outcomes

The primary outcome of the current review was balance improvement, measured at post-intervention and/or at medium- or long-term follow-up.

We considered any possible indicator of balance performance such as posturography, static and dynamic stabilometry and all types of measurement coming from a motor-task test.

Secondary outcome measures were changes in physical parameters (e.g. endurance, muscular strength, motor-task performances) and self-reported questionnaires related to psychological attitude such as fear-avoidance beliefs, pain-related fear and catastrophizing. Furthermore, patient care satisfaction was taken into account.

Risk of bias assessment

The updated version of the Cochrane Risk of Bias (RoB) tool in RCTs[22] (13 items' version) was used to assess the methodological quality of the included studies. Three blinded reviewers (MA, MC, EP) independently made their evaluation by reading full-text articles and a final discussion with two other reviewers (FDF, MM) resolved each discrepancy. This tool included six domains (selection bias, performance bias, attrition bias, detection bias, reporting bias, other sources of bias) made up of 13 criteria. Reviewers could make their judgement considering a three-point scale: low, unclear and high RoB.

Measures and synthesis of results

As measurements of treatment effect, we reported results and differences among groups in a descriptive way, by using mean +/- standard deviation (SD) and mean and 95% confidence interval (CI). In the case of data presented as median and interquartile range (IQR), median was assimilated to mean and SD was obtained considering a 1.35:1 ratio.

A meta-analysis was performed using "Review Manager v 5.3.5" (The Nordic Cochrane Centre, http://ims.cochrane.org/revman) and alpha level was set at 0.05 to test for overall effect.

For continuous variables, mean difference (MD or *Cohen's "d"*) or standardized mean difference (SMD or *Hedges' "g"*) with 95% CI were calculated using a random effects model, to acknowledge the possible clinical and methodological diversity among included studies.

An effect size (ES) ranging from 0.2 to 0.49 was considered "small", from 0.5 to 0.79 "moderate", and a value of 0.8 or above "large". Heterogeneity was measured through I^2 statistics which explained how much of the variation between studies was due to heterogeneity rather than to chance. Values ranging from 0% to 40% suggest "not important" heterogeneity, from 30% to 60% indicate "moderate" levels, from 50% to 90% represent "substantial", and from 75% to 100% "considerable" heterogeneity[23].

The quality of evidence was assessed through the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) method, as suggested by the Updated Cochrane Back Review Group method guidelines[24]. Using this approach, it is possible to downgrade the quality of evidence from "high" to "moderate", "low" or "very low" on the basis of 5 key-domains: risk of bias, inconsistency, indirectness, imprecision and publication bias.

EVIDENCE SYNTHESIS

Selection of the Studies

The search strategies led us to identify a total of 2262 studies, 478 of which were detected as duplicates and consequently removed. In a second stage, 1784 records were screened by reading title and abstract and 1758 were excluded since they were not pertinent. Finally, a total of 26 articles were assessed by reading the full text and 14 were subsequently excluded. As a consequence, 12 studies completely met the criteria we stated for the current review and were included in the final synthesis; 9 of these RCTs were also considered for meta-analysis. Further details of the study selection process are reported in the PRISMA 2020 flow-chart (Fig. 1).

Please, insert Figure 1 approximately here

Description of the studies

All the included studies (n=12)[25-36] were RCTs. Interventions presented differences across studies, since four trials[25,29,30,34] investigated the effects of a Pilates training, two studies[32,35] focused on stability training and two others[28,36] on whole vibration therapy; functional resistance exercises, diaphragmatic training, therapeutic exercise and sensorimotor training were investigated by the other included studies[26,27,31,33]. Regarding control groups, most of the studies[25,26,28-32,34,36] opted for "no intervention", only suggesting daily normal activities; two trials[27,35] compared exercise to instrumental therapies such as TENS, ultrasounds and laser-therapy. Ghasemi and colleagues[33] performed a three-arm trial, so that a comparison was possible with two different types of manual therapy (cranio-sacral treatment and muscle-energy techniques).

The overall sample size was 521 (mean: 43.41, SD: 17.74), with a mean age of 38.77 +/- 10.04 years. The period of treatment varied from a minimum of 1 day (single session in Lopes' study[29]), to a maximum of 14 weeks[30], resulting in a mean of 8.9 +/- 3.9 weeks. Frequency of treatments greatly varied (mean: 2.27 +/- 1.19), since Lopes[29] investigated a single session and Karimi[35] assessed a program of ten consecutive sessions performed on a daily basis. Treatments had an average duration of 34.11 +/- 20.08 minutes, although studies[28,36] investigating the whole-body vibration therapy had shorter duration (8 and 15 min.) with respect to the other exercise programs (range: 20 – 60 min.).

All the included studies considered assessments at post treatment, while only two RCTs[31,33] reported evaluations over a medium- or long-term period; specifically, Ghasemi[33] considered 2-month and Kuukkanen and Mälkiä[31] 6- and 12-month follow-up assessment. The main characteristics of the included RCTs are reported in Table I.

Outcomes

Although all the included trials investigated at least one outcome related to balance, only two of them[29,30] considered these as a primary outcome.

All the trials assessed static balance, whereas in two studies[27,29] dynamic balance was considered. The static balance performances were explored through different modalities: six studies[29-33,36] measured postural sway by using posturography, four trials[25-27,34] adopted different motor-task tests such as stork stand test[25], blind flamingo test[26], unilateral hip bridge endurance test[27] and single limb stance test[34]; finally, two RCTs[28,35] considered stability indices through the "Biodex Balance System". In both the studies[27,29] assessing dynamic balance, the "star excursion balance test" was used.

Other considered outcome measures were related to physical parameters. Two studies[25,34] detected lumbar mobility, two others[28,36] investigated trunk muscle performances and another[26] measured the physical fitness levels of the subjects.

Please, insert Table I approximately here

Please, insert Table II approximately here

Risk of bias

The RoB was evaluated for all twelve included studies and specific details are reported in Figures 2 and 3. None of these studies reported a low risk for all the items. Since the trials dealt with physical therapy modalities, a high RoB was attributed to "blinding of personnel" criterion; furthermore, none of the studies declared that the subjects were masked, so blinding of participants was also considered to be at high risk of bias. In addition, some issues were detected for selection bias: seven RCTs[25-28,31,33,35] were judged at high risk for allocation concealment, and one of these[31] did not perform a proper random sequence generation. Other six studies[25,27,32,33,35,36] did not detail the randomization procedure sufficiently, so the risk was judged as unclear. Five[26,31-33,35] out of twelve studies were considered at high RoB for detection bias, since assessors were not blinded; another one[27] was considered at unclear risk for this point.

Three studies[32,33,35] were evaluated at high risk of attrition bias, and for another three trials some details were missing (unclear RoB). Baseline comparability was not guaranteed in three RCTs[25,31,36] and co-interventions management was not considered sufficiently performed in six studies[27,28,31,33,35,36]; in three of these works[28,31,35], the risk was judged as high.

Please, insert Figure 2 approximately here

Please, insert Figure 3 approximately here

Description of results

The overall effect of exercise on balance in NSLBP subjects was estimated through a qualitative synthesis; in addition, a meta-analysis was performed for some end-points, by including the studies[25,27-31,33-35] which adopted comparable outcome measures.

Among RCTs investigating balance performance during a motor-task test, four studies[25-27,34] reported results in favor of exercise; however, only Cortell-Tormo[26] and Otadi[27] found a between-group significance (+ 58%, p ≤0.05 during "blind flamingo test" and +65%, p≤0.05 during the "unilateral hip bridge endurance test).

Concerning postural sway variables, results were different across the studies; only Keading[36] did not find any significant difference in a pre-post comparison, neither in a "within-group" nor in a between-groups analysis. Rather, three trials reported effects of exercise for most of the assessed variables: Lopes[29] and Patti[30] found an overall reduction of postural sway registered in CoP displacements (-44,7 cm, p<0.001; -94,9 mm, p<0.001 respectively); Rhee[32] observed a reduction in anterior-posterior sway (p=0.04), but not in medium-lateral sway (p=0.86). Kuukkanen and Mälkiä[31] did not find any significant differences in displacements, although some pre-post changes were detected in CoP velocity (+ 1.5 mm/s, p=0.03). Ghasemi[33] observed an overall improvement in posturographic parameters for all the groups of intervention, even if the most relevant changes were detected in the "craniosacral therapy group", especially during a single-leg standing test with closed eyes ($p<0.001$ at post treatment, p=0.03 at follow-up). Considering the large number of variables used to evaluate postural sway, a consultation of Tab. I and II is advised.

Two studies[28,35] considered limits of stability to evaluate balance performance; Karimi[35] reported the overall stability index improving from 9.78±1.87 to 8.22±2.27, $p\leq0.05$; Del Pozo Cruz[28] found a significant improvement of 20.37% (–0.11°, p=0.031) over the anterior-posterior axis, but not over the medium-lateral one. However, no differences between groups were registered.

Regarding the two studies[27,29] investigating dynamic balance through SEBT, both found improvements in the exercise groups in the different directions ($p\leq0.05$), however only Otadi[27] reported significant changes between groups ($p\leq0.05$).

Only two studies[31,33] considered follow-up assessments; Ghasemi[33] reported mean CoP velocity and ellipse area improvements in the exercise group at 2 months after the end of the treatment period (-0.0002, $p\leq0.05$ and -0.002, $p\leq0.05$), Kuukkanen and Mälkiä[31] found improvements only in the "home based exercise" group both at 6 and at 12 months follow-up (+ 1.0 and +1.6, p=0.01 and p=0.002, respectively).

Concerning secondary outcomes, two studies[25,34] reported superiority of exercise in increasing flexibility (Fingertip-to-floor test: +8.45, p=0.032 and +2.2 cm $p\leq0.05$, respectively).

Cortell-Tormo[26] considered a group of motor-task tests to assess physical fitness, finding improvements in all of these attributable to exercise intervention ($p\leq0.01$). Del Pozo Cruz[28] assessed lifting capacity through the PILE test, finding a significant improvement of 16.58% (p=0.008); however, the same author did not find the same results in walking endurance. In addition, Keading[36] reported a positive trend in favor of intervention (p=0.056) concerning the isokinetic performance of trunk muscles.

Finally, no studies investigated psychological attitudes or levels of care satisfaction.

Effects of exercise on balance

Single leg stance test

Two trials[25,34] were included in the analysis, with a total sample size of 88 subjects. The forest plot in Fig. 4 shows how exercise significantly improves time of resistance in the single leg stance test in both of the trials included. As a consequence, the overall effect was in favor of exercise [MD: -28.7 (-48.84, -8.67); p=0.005]. Heterogeneity was not important (I^2=2%) and not significant (p= 0.31). Quality of evidence was rated as "very low" (Tab. III).

Please, insert Figure 4 approximately here

Postural sway

Centre of pressure total displacement

Two studies[29,30] were included in the analysis (Fig. 5), with an aggregate sample of 84 subjects. Both of the studies reported significant results in favor of exercise in reducing the CoP total displacement, as illustrated in Fig. 4. The pooled MD was of -16.99 (-27.29, - 6.68), p=0.001; heterogeneity was absent (I^2=0%) and not significant (p=0.42). Quality of evidence was judged as "very low" (Tab. III).

Please, insert Figure 5 approximately here

Ellipse Area

Three RCTs[29,30,33] were included in the meta-analysis (Fig. 6), with a total sample of 114 subjects; one study reported significant results in favor of exercise, one study found no significant effects in favor of exercise and another one no significant results in favor of the control group. The overall effect on the ellipse surface area was not significant in favor of exercise, resulting in a pooled effect size (SMD) of -0.28 (-0.97, 0.41), p=0.42. Heterogeneity was substantial (I^2=70%) and significant (p=0.04). Quality of evidence was rated as "very low" (Tab. III).

Please, insert Figure 6 approximately here

Limits of stability

Anterior-posterior index

Two studies[28,35] were included in the analysis (Fig. 7), with an overall sample size of 87. One trial reported a non-significant effect of the control group compared to exercise group and the other one found a non-significant effect of exercise in improving antero-posterior stability index. The overall effect of exercise was indifferent, with a pooled effect (MD) of -0.00 (-0.38, 0.38), p=1.00. Heterogeneity was not important (I^2=26%) and not significant (p=0.25). Quality of evidence was rated as "very low" (Tab. III).

Please, insert Figure 7 approximately here

Medium-lateral index

Two studies[28,35] were considered for meta-analysis (Fig. 8), with an average sample of 87 subjects. One trial reported a non-significant effect on the control group and the other a non-significant effect of exercise in improving medium-lateral stability index. The overall effect was not significantly in favor of control interventions, resulting in a pooled effect (MD) of 0.03 (-0.41, 0.48), p=0.89; heterogeneity was considerable (I^2=81%) and significant (p=0.02). Quality of evidence was "very low" (Tab. III).

Please, insert Figure 8 approximately here

Dynamic balance (SEBT)

Two studies[27,29] assessing dynamic balance through SEBT were considered for meta-analysis (Fig. 9), with a total sample size of 70. Both trials reported effects in favor of exercise, in one case not-significantly. The overall effect was significantly in favor of exercise, with a mean difference of -4.74 (-8.02, -1.46), p=0.005. Heterogeneity was absent (I^2=0%) and not significant (p=0.86). Quality of evidence was judged as “very low” (Tab. III).

Please, insert Figure 9 approximately here

Please, insert Table III approximately here

CONCLUSIONS

Summary of evidence

To the best of our knowledge, this is the first systematic review investigating the effects of exercise on balance in patients with NS-LBP. In our opinion this aspect should be considered of particular importance since to date, several studies[37-39] have demonstrated how balance could frequently be affected in NS-LBP; moreover, previous reviews invited clinicians to take into consideration a balance assessment in the context of NS-LBP[12,14]. However, an SR on the topic was missing.

Results of the current review highlighted that exercise seems to improve balance performance in NS-LBP individuals, since qualitative and quantitative synthesis showed how postural sway, motor-task tests and dynamic balance are positively influenced following a period of exercise training. Specifically, the most affected variables seem to be total CoP displacement, performance obtained during a single-leg stance test and dynamic balance, assessed through SEBT. However, conflicting results emerged in some parameters related to postural sway, such as total ellipse area, CoP velocity and limits of stability, in which only a positive trend (without any significant result) was observed. These findings are detectable at the end of the period of treatment, since most of the included studies only reported data concerning a "pre-post" evaluation; nevertheless, some positive cues are present in those trials which considered an evaluation over a medium-term period[31,33].

Results also gave some indication that balance improvements could be accompanied by some modifications of physical parameters such as lumbar flexibility, fitness levels, lifting capacity and the isokinetic performance of trunk muscles. This last aspect should be considered of particular importance if confirmed by additional evidence, since changes in physical function (especially regarding the performance of trunk muscles) may explain the improvements obtained in balance; unfortunately, the included studies (2) which explored such variables were very limited. Moreover, these outcomes were assessed by different modalities, so that conclusions should be drawn with care.

Clinical implications

In light of the abovementioned findings, some considerations are necessary. Firstly, the highlighted efficacy of exercise can probably confirm some theories underlying balance impairment in NS-LBP; indeed, the most acknowledged mechanism seems to be the altered proprioceptive function deriving from faulty muscular responses and leading to deficit in trunk repositioning, postural control and balance[40-43]. Moreover, it is largely known that multiple sensory information is involved in the organization of postural control, so that in addition to visual and vestibular cues, somatosensory information arising from the musculoskeletal system has an important role in posture[44.] In this context, exercise could act on different physical parameters and mechanisms such as muscle endurance, functional stabilization, proprioception, coordination and flexibility, thus ensuring an improved postural control both in static and in dynamic conditions. Evidence suggests how this is possible through a continuous sensorial re-weighting coming from the integration of somatosensory information, processed by the central nervous system[45-47]. This point can also explain the reason why different types of exercise (e.g. functional resistance training, Pilates, sensorimotor training, active vibration therapy) all appeared to be effective in improving balance.

Secondly, due to the huge variability of the methods applied in the RCTs, a subgroup analysis for type of exercise was not possible. Despite this, the studies investigating exercises targeted on stabilization[25,29,30,32,34,35] (e.g. core stability, Pilates, spinal stabilization) were definitely prevailing (50%) compared to other trials: more specifically, these trials reported improvements in at least one of the static balance parameters and in three studies those changes were significantly greater in the intervention group. Moreover, Lopes *et al* also found a significant change in the dynamic balance assessment. Concerning the remaining studies, results were overall in favor of exercise as well. However, it is important to point out that three[26,27,31] of these studies included, in their intervention, a number of exercises oriented towards stabilization mechanisms or, at least, movements involving the activation of the spinal core. Conversely, these improvements were not observed in the other two trials[28,36], where whole-body vibration and sensorimotor training were considered. We can hypothesize that exercise, when specifically targeted to stability mechanisms, could lead to larger effects in improving balance. Furthermore, our assumption seems to be in line with previous literature, reporting positive effects on balance and a reduction in falls in healthy people and in the elderly following a Pilates training[48-51].

Despite the above-mentioned importance of a proper balance assessment in NS-LBP, some issues emerge if we consider the clinical relevance of the measures employed in the different studies. Although posturography is to be considered a reliable method to evaluate balance in NS-LBP[52,53], this examination is strictly addressed to a static performance and it does not provide any information concerning the dynamic skills of the people[54,55]; moreover, this assessment is not performed in an ecological environment with respect to the activities of daily living[53,56]. The same reasoning should be done for the single leg stance test, in which many confounding factors can affect the validity of this test[57]. On the other hand, both the studies that used the SEBT, a more dynamic reliable test[58,59], reported clinical significant changes after the exercise therapy. As a consequence, this fact represents, once again, indirect proof that balance is impaired in NS-LBP, thus leading to a worsening of dynamic performances. Besides, exercise training can positively influence such aspects, presumably through proper proprioceptive stimulation and improvement in the stability of trunk muscles.

Implications for research and healthcare policies

Methods applied in the included studies appeared to be characterized by a certain degree of heterogeneity. This aspect is mostly related to the interventions. Exercise is *de facto* a kind of active therapy for the patient; however, the manner in which different modalities can imply different forms of physical stimulation should be considered[60-62]. Moreover, not all the protocols were described following the proper checklist suggested for exercise trials[63], with subsequent issues in terms of reproducibility.

Similarly, the comparison intervention also presented some differences, varying from usual care to instrumental therapies (e.g. electrotherapy). Furthermore, the authors adopted different outcome measures and, sometimes, various settings. Another point of interest should be the possible correlation between balance impairments and levels of pain or disability: so far, no studies have confirmed this aspect. Finally, only two of the included trials[29, 30] chose balance as the primary outcome.

For all these issues, it becomes hard to generalize our results, so that relative considerations should be taken carefully. Therefore, research should move in this direction by ensuring higher levels of uniformity in methods and better levels of consistency in results. In this way, it would be possible to properly inform clinicians and lead to updates in healthcare policies.

Quality of evidence

The quality of evidence ranged from "very low" to "low", according to GRADE criteria[24]. The reasons for downgrading were mostly similar for each considered outcome.

Primarily, we downgraded for risk of bias. Since the included studies dealt with exercise therapy, blinding of personnel was not possible at all and masking of participants was unlikely, so these criteria were judged at high RoB. Besides, most of the studies did not perform an allocation concealment[25-28, 31, 33, 35], thus a form of selection bias was possible. In some cases, the outcome assessor was not blinded either[26-27, 31-33, 35], and the "intention to treat" analysis was not always performed[26, 28, 31-33, 35]: consequently, detection and attrition biases were also suspected. Other potential sources of bias were related to an unsure baseline comparability (selection bias)[25, 31, 35] and to missing details concerning cointerventions (performance bias)[27, 28, 31, 33, 35, 36]; in addition, degrees or specializations of personnel (e.g. certified Pilates instructor) were sometimes not clearly specified (performance bias)[27, 28, 31, 33, 35, 36] (Fig. 2).

Another critical aspect was the imprecision of the assessments; indeed, all the data obtained from the analyses were characterized by wide confidence intervals and a small sample size.

Finally, two out of the six comparisons reported considerable levels of heterogeneity, leading us to downgrade for inconsistency.

Limitations

This research presents some limitations.

We performed a search including all the typologies of therapeutic exercise. On the one hand, this allowed us to consider, as a whole, all the active interventions frequently applied in the context of physical therapy. On the other hand, we had to summarize evidence considering an intrinsic degree of heterogeneity.

Only articles in English were admitted even if, according to our research, no studies written in other languages were found. Furthermore, our search strategy was performed on the main databases, aware that some studies of interest could have been overlooked.

As previously stated, we performed meta-analysis only when data were aggregable and assessment modalities were almost equivalent. In some cases, the procedures of evaluation were not fully described, or they presented some minimal differences. Hence, it is possible that such variability can affect the pooled effect size of some comparisons.

Finally, publication bias is another possible issue; as is known, there is no statistical tool able to accurately detect it [64].

Exercise could be effective in improving both static and dynamic balance in patients with NS-LBP over a short-term period. However, quality of evidence is very low and some methodological issues were detected in the included studies.

Further double-blinded, high-quality RCTs, comparing different subgroups of exercise and assessing balance through standardized and uniform modalities are needed. This could improve the quality of evidence and properly address clinicians and researchers in this field.

APPENDIX

Search strategy

"low back pain*"[Title/Abstract] OR "low back ache*"[Title/Abstract] OR "backache*"[Title/Abstract] OR "lumbar pain*"[Title/Abstract] OR "lumbar backache*"[Title/Abstract] OR "back pain*"[Title/Abstract] OR "lumbago"[Title/Abstract] OR "chronic pain*"[Title/Abstract] OR "chronic low back pain*"[Title/Abstract] OR "non specific low back pain*"[Title/Abstract] OR "non-specific low back pain*"[Title/Abstract] OR "aspecific low back pain*"[Title/Abstract] OR "chronic non specific low back pain*"[Title/Abstract] OR "chronic non-specific low back pain*"[Title/Abstract] OR "recurrent low back pain*"[Title/Abstract] OR "spinal pain*"[Title/Abstract]
AND
"exercise*"[Title/Abstract] OR "physical exercise*"[Title/Abstract] OR "rehabilitation*"[Title/Abstract] OR "physiotherap*"[Title/Abstract] OR "balance training*"[Title/Abstract] OR "training*"[Title/Abstract] OR "physical activit*"[Title/Abstract] OR "core stability"[Title/Abstract] OR "physical therap*"[Title/Abstract] OR "physical therapy modalities"[MeSH Terms] OR "motor control"[Title/Abstract]
AND
"balance"[Title/Abstract] OR "propriocept*"[Title/Abstract] OR "balance performance*"[Title/Abstract] OR "balance abilit*"[Title/Abstract] OR "stabilit*"[Title/Abstract] OR "postural stabilit*"[Title/Abstract] OR "postural control"[Title/Abstract] OR "equilibrium"[Title/Abstract] OR "postural balance"[Title/Abstract]

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NOTES

Submission: this research has not been published previously and it is not under consideration for publication elsewhere.

Funding: this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest: the authors declare that they have no conflict of interest.

Authors contributions: all the authors contributed to the study conception and design. Material preparation and data collection were performed by Fulvio Dal Farra, Federico Arippa, Mauro Arru, Martina Cocco and Elisa Porcu. Data analysis was developed by Fulvio Dal Farra, Federico Arippa, Marco Monticone and Marco Tramontano. The first draft of the manuscript was written by Fulvio Dal Farra, Marco Monticone and Marco Tramontano; all the authors commented on previous versions of the manuscript.

All the authors read and approved the final version of the manuscript.

Table I. Main characteristics of the included studies

Author/year	Objective	Outcomes	Population	Interventions	Comparison
Gladwell et al. (2005)[25]	To evaluate the effect of a Pilates program on active individuals with NS-CLBP.	1) Static Balance (Stork Stand test) 2) Pain (VAS) 3) Back Functional Status (ODI) 4) General Functional Status (SF-12) 5) Subjective Improvement 6) Sports Functioning 7) Flexibility	N=34 Male= 21% Age: 40.06 ± 9.7 years	Pilates (n=20) Description: 6 sessions; duration 1 hour each session over 6 weeks.	No intervention (n=14) Description: normal activities and pain relief.
Cortell-Tormo et al. (2017)[26]	To evaluate the effects of functional resistance training on health-related quality of life, disability, body pain, and physical fitness in CLBP females.	1) Physical fitness (balance, back endurance, abdominal and lower body muscular endurance) 2) Back pain (VAS) 3) Disability (ODI) 4) Quality of life (SF-36)	N=19 Male= 0% Age: 35.6 ± 8.44 years	Exercise group (n=11) Description: 24 sessions; duration 45-60 min each session, over 12 weeks.	Control Group (n=8) Description: daily activities, which did not include any form of physical exercise similar to those in the therapy.
Otadi et al. (2021)[27]	To explore the effects of combining diaphragm training with TENS on pain, function, static stability, and dynamic balance in athletes with NS-CLBP	1) Static stability (UHBE) 2) Dynamic balance (SEBT) 3) Pain (NRS)* 4) Function (COMI)	N=24 Male= 50% Age= 35.20 ± 9.73 years	Experimental Group (n=12) Description: 12 sessions of TENS, duration 30 min each session, plus 12 sessions diaphragm training, over 4 weeks.	Control Group (n=12) Description: 12 sessions of TENS, duration 30 min each session for 4 weeks.
Del Pozo-Cruz et al. (2011)[28]	Feasibility and effects of 12-week course of low-frequency vibrating board therapy for NS-CLBP.	1) Disability (RMDQ, ODI)* 2) Quality of life (EQ-5D-3L)* 3) Pain intensity (VAS)* 4) Postural stability (APSI, MLSI) 5) Walking endurance (6MWT) 6) Peripheral vibration sensibility; 7) Trunk strength and lifting capacity (PILE test)	N=50 Male= 27 % Age: 59,11 (±5)	Whole body vibration therapy(n=25) Description: 12 sessions; duration: 6 to 8 min each session over 3 months	No intervention (n=24) Description: normal daily activity
Lopes et al. (2017)[29]	Effects of Pilates exercises	1) Postural Sway* (posturographic assessment) 2) Dynamic balance	N=46 Male: 41% Age: 22,3 (±3,4)	Pilates exercises (n=23)	Control Group (n=80)

	on postural sway and dynamic balance in young individuals with NS-CLBP.	(SEBT)* 3) Pain intensity (VAS)		Description: a single session of 20 min	Description: 20 minute resting in sitting position
Patti et al. (2016)[30]	Effects of a program of Pilates exercises on pain perception and stabilometric parameters in patients with NS-LBP.	1) Disability (ODI)* 2) Balance (Posturographic assessment)*	N=38 Male: NA Age: 41,47 (±11,99)	Pilates exercises (n=19) Description: 3 times weekly, for 14 weeks duration: 50 min each session	Control group (n=19) Description: normal daily activity
Kuukkanen and Mälkiä (2000)[31]	Efficacy of progressive therapeutic exercise on postural sway in subjects with low back pain.	1) Functional disability (ODI) 2) Low back pain intensity (Borg scale).* 3) Postural sway (antero-posterior velocity; medio-lateral velocity; square side length).	N= 90 Male= 41 (46%). Age: 39,9 +/- 7,9 years.	1)Intensive training group (n=29). Description: twice per week (mean) guided exercises and 3 times per week (mean) home exercises for 3 months. 2) Home exercise group (n=29). Description: a mean of 3,5 times per week for three months.	Control group (n=28). Description: no intervention.
Sill Rhee et al. (2012)[32]	Effectiveness of spinal stabilization exercises (SSE) in improving the level of pain and balance sway in patients with recurrent LBP following treatment.	1) Patient pain (Million Visual Analogue Scale-MVAS). 2) Functional Disability (ODI). 3) Balance measurements (anterior-posterior (A/P) and medio-lateral (M/L) CoP).	N= 42. Male= 21 (50%). Age: 50,19 +/- 9,28 years.	SSE group (n= 21). Description: 20-minute exercise session in the lab 3 times per week for 4 weeks and 5 times per week at home.	Control group (n=21). Description: no specific intervention.
Ghasemi et al. (2020)[33]	Effectiveness of muscle energy techniques (MET), craniosacral therapy (CST) and sensorimotor training (SMT) on postural control in patients with NSLBP.	1)Postural control (posturographic assessment)	N= 45. Age: 20-40 years.	SMT group (n= 15). Description: 10 sessions over 5 weeks, 2 sessions per week, according to a global approach.	CST group (n= 15). Description: 10 sessions over 5 weeks, 2 sessions per week. MET group (n= 15). Description: 10 sessions over 5 weeks, 2 sessions per week.

Valenza et al. (2016)[34]	Effects of a Pilates exercise program in patients with NS-CLBP*.	1) Balance (Single-Limb Stance Test) 2) Disability (RMDQ* and ODI*) 3) Pain Intensity (VAS) 4) Lumbar Mobility (Modified Schober test) 5) Flexibility (Fingertip-to-Floor Test)	N=54 Male=23,5% (22% of Control Group and 25% of Experimental group). Age 38.95±11.20 years Experimental group: mean age of 37.62±12.14. Control group: mean age of 40.27±15.84.	Pilates exercise program (n=27) Description: twice a week for 8 consecutive weeks; duration: 45 min each session.	No intervention (n=27) Description: continued usual activities and received advice in the form of a leaflet.
Karimi et al. (2009)[35]	Effects of consecutive supervised stability training on postural balance in patients with CLBP.	1) Balance assessment: Overall Stability Indices (OSI) and Limits of Stability (LOS) 2) Time to Complete (TC) 3) Functional Performance (FP)	N= 38 Male NA Age 26.97±5.97 years CSST Group: 25.94 ± 5.7 years old. E group: 28.11±6.21 years old.	Concise supervised stability training (CSST) (n=20) Description: 10 consecutive days.	Electrotherapy (n=18) Description: Ultrasound (5 min), TENS (15 min), InfraRed (15 min) for 10 days consecutively.
Kaeding et al. (2017)[36]	To examine whether whole-body vibration (WBV) training is able to reduce back pain and physical disability in seated working office employees with CLBP.	1) Static posturography 2) RMDQ 3) ODI 4) Work-Ability-Index Questionnaire (WAI) 5) Quality of life questionnaire (SF-36) 6) Freiburger activity questionnaire 7) Isokinetic performance of the musculature of the trunk 8) Post-interventional sick leave	N=41 Male=31.7% Age 45.5 ± 9.1 years Intervention group: 46.4 ± 9.3 years old. Control group: 44.6 ± 9.1 years old.	Intervention group (n= 21) Description: WBV training 2.5 times a week; duration: 15 min each session (30-45 minutes per week), for 3 months.	Control group (n=20) Description: subjects did not take part in an intervention and were advised to continue their usual activities.

***:** primary outcome

Abbreviations. NS-CLBP: Nonspecific Chronic Low Back Pain; VAS: visual analogue scale; ODI: Oswestry Disability Index; CLBP: Chronic Low Back pain; SF-12: Short Form-12 Health Status Questionnaire; SF-36: Short-Form 36 Health Survey; TENS: Transcutaneous Electrical Nerve Stimulation; NRS: Numeric Rating Scale; COMI: Core Outcome Measures Index; UHBE: Unilateral Hip Bridge Endurance test; SEBT: Star Excursion Balance Test; RMDQ : Roland Morris Disability Questionnaire; 6MWT: 6 Minute Walking Test; PILE test: Progressive isoinertial lifting evaluation test; APSI: Anterior Posterior Stability Index; MLSI: Medio-Lateral Stability Index.

Table II. Description of interventions and main results.

Authors/Year	Description of Interventions	Main Results
Gladwell et al. (2005)[25]	*Pilates Group*: 10 Pilates exercises. Basic core exercises with additional exercises added during each session (side kickone, leg stretch, shoulder bridge, the hundred, swimming, swan dive, roll up, spine twist, arm stretch, one leg circle). Control Group: normal activities and pain relief.	Pilates Group reported increase in flexibility (+4.6 cm, P<0.05). and balance parameters (+16.1 s, P<0.05). Increase in general health (SF-12, +0.4, P<0.05) and sports functioning (+0.4, P<0.05), and significant decrease in pain (VAS, -0.5, P<0.05). Control Group: no significant differences from the baseline, apart from ODI (-6.0, P<0.05). Flexibility significantly increased in EG with respect to CG (+2.2 cm, P<0.05), while pain diary decreased (-0.5, P<0.05).
Cortell-Tormo et al. (2017)[26]	*Exercise Group*: upper- and lower-body resistance training exercises (4-point kneeling and lying positions, abdominal crunch, back extension, side plank, elbow bridge, squat, lunges, seat pull and row, single leg deadlift, anterior reach, stand row, pull squat, stand push). All exercises consisted of free weights (dumbbell), gym apparatus and body weight. *Control Group:* daily activities, which did not include any form of physical exercise similar to those in the therapy.	*After 12 weeks:* Exercise Group showed significant improvement in balance (-5.6 s, P<0.05), physical function (+8.6, P<0.05), body pain (-2.5, P<0.05), vitality (+16.2, P<0.05), physical component scale (+6.8, P<0.05), VAS (-2.5, P<0.01), ODI (-9.5, P<0.05), curl-up (+27 rep, P<0.01), squat (+8.7 rep, P<0.01), static back (+54.4 s, P<0.01), and side bridge (+26.7 s, P<0.01). Significant improvement in favor of EG attributable to the treatment was found in balance (58%, p<0.05), curl-up (83%, p<0.01), squat (22%, p<0.01), static back (67%, p<0.01), and side bridge (56%, p<0.01), physical function (10%, p<0.05), body pain (42%, p<0.05), vitality (31%, p<0.05), physical component scale (15%, p<0.05), VAS (62.5%, p<0.01), and ODI (61.3%, p<0.05).
Otadi et al. (2021)[27]	*Experimental Group:* 3 sessions per week of conventional TENS (30 min) plus diaphragm training for 12 sessions for 4 weeks. Exercises included supine breathing, crocodile breathing and 90/90/90 breathing with and without elastic band. *Control Group:* 3 sessions per week of conventional TENS (30 min) for 4 weeks. Both groups received TENS in a side-lying position with flexed hips and knees.	Improved function in both groups following the interventions (COMI -1.9 in CG and -2.6 EG, p<0.001). Significant improvements in static stability (UHBE +2.3 for CG and +13.2 for EG, p<0.001), dynamic balance (SEBT +3.8 in CG and +12.7 for EG, p<0.01), and pain (-1.6 for CG and -3.8 for EG p<0.001) in the experimental group compared to the control group. Larger improvement in the EG with respect to the CG in the static stability (UHBE >65%, p<0.05), dynamic balance (SEBT >70% p<0.05), and pain score (>58%, p<0.001),

Del Pozo-Cruz et al. (2011)[28]	**Whole body vibration therapy group*: The participants stood in standing position on a platform generating side-alternating oscillations of the whole body. *Control group*: normal pattern of daily activity for the 12-week duration of the study	*At post treatment:* The intervention group reported a statistically significant improvement of 20.37% (–0.11°, P=0.031) in the PSTAntPost; 25.15% (-20,28%, P=0.013) in the ODI; 9.31% in the RMDQ (-1,12 points, P=0.001); 8.57% (+0,06, P=0.042) in HRQoL, as measured by the EQ-5D-3L; 20.29% (–1.02 vu, P=0.002) in the sensibility test; 24.13% (-9,90 points, P=0.006) in VAS back and 16.58% (P=0.008) in the PILE test. No statistically significant improvement of PSTMedLat, 6MWT.
Lopes et al. (2017)[29]	**Pilates Exercise group*: the session included leg stretch, pelvic press, swimming and opposite arm and leg reach (bird dog) to enhance deep stabilizer muscles and hip extensors. Exercises were performed in the supine and prone position, where there is less impact on the joints to support the body, especially the spine. *Control group*: resting in the sitting position for the same period.	*At post treatment:* Significant improvement in SEBT values, except for the composite reach distance (p=0.059). SEBT in anterior direction increased by 3.3 % (P=0.019), the posterolateral by 5,6 % (P<0.001), the posteromedial by 5,0 % (P=0.03) Significant reduction of values of postural sway: CoPx -0,06 cm (P=0.019), CoPy -0,06 cm (P=0.002), Total CoP displacement -44,7 cm (P<0.001), CoP velocity -0.5cm/s (P<0.001), CoP area -1,8 cm^2 (P<0.001). Pain decreased after the Pilates exercises (VAS change: -29.5 ± 10.5%), while no changes were observed in the control group (VAS change: 3.0±16.4%).
Patti et al. (2016)[30]	**Pilates exercises*: diaphragmatic breathing exercise, pretraining and mobilization of pelvis and principal joints; retroversion, anterior tilt, and rotation of pelvis; mobilization of the spine and larger joints; the hundred; roll up; single leg circles with bent leg; spine stretch, rolling like a ball, single leg stretch, diaphragmatic breathing exercises. *Control Group*: daily activity and usual treatment, including NSAIDs.	*At post treatment:* In the Pilates exercises group, there was a significant improvement in all measured variables of posturography. Under the OE condition, there were significant decreases (paired t test) in sway path, (-94,9 mm, P<0.001), ellipse surface area (-40,4 cm^2, P<0.05), and y-mean (-6,21 mm, P <0.0001). Results were similar under CE conditions, with significant reduction in sway path, (-66mm, P<0.0001), ellipse surface area (-6,38 cm^2, P<0.001), and y-mean (-5,37 mm, P<0.0001). Greater reduction in ODI score for the experimental group.

Kuukkanen and Mälkiä (2000)[31]	*Intensive training Group (ITG):* Therapeutic exercise to increase the strength and endurance of trunk and lower extremity musculature, to improve body awareness, to promote dynamic stability and to control posture. The balance board was used with pulley exercises. Balance and coordination exercises were also included in the warm-up and cool-down portions of the program. In detail: strength exercises in 3–4 sets of 7–10 repetitions at 60–80% of 10RM; endurance exercises in 3–4 sets of 15–20 repetitions at 30–40% of 10RM. *Home exercise group (HEG):* same principles as the intensive training program, but performed without extra equipment *Control group*: Participants did not follow any prescribed training program.	Intensive training group reported increase in anterior-posterior sway velocity with open eyes between PI2 (15.0 +/- 2.9 mm/s) and PI3 (16,5+/- 3,5 mm/s): p= 0.03. Home exercise group reported increase in anterior-posterior sway velocity with eyes open between BM (14.9 +/- 4.5 mm/s) and PI1(17.0 +/- 5.6 mm/s): p=0.00; between BM and PI2 (15.9 +/- 3.0 mm/s): p= 0.014; between BM and PI3 (16.5 +/- 3.3 mm/s): p=0.02; no significance differences were reported in control group. Differences were observed in Anterior-posterior velocity at PI1 between HEG and CG with eyes open (3.17 mm/s, p= 0.05) and with eyes closed (4.36 mm/s, p= 0.01). Differences were observed in Medio-lateral velocity at PI1 between ITG and CG with eyes open (6.75 mm/s, p= 0.004) and between HEG and CG with eyes open (p= 0.01), and with eyes closed (4.34 mm/s, p= 0.02).
Sill Rhee et al. (2012)[32]	*Stabilization exercises group*: exercises to improve spinal stabilization through core muscle strengthening and to restore the stabilizing protective function of the spinal muscles around the spinal joints. Exercises to activate and train the isometric holding function of the spinal muscles at the affected vertebral segment (in co-contraction with the transversus abdominis muscle). *Control Group*: participants received a hard copy of medical management techniques, which included advice regarding bed rest, absence from work, prescription medications, and resuming normal activity as tolerated.	The SEE group reported significantly different changes in the A/P balance sway compared to the control group (p=0.04); the M/L sway displacement did not differ between groups (p=0.86). During the second perturbation, the A/P sway changes in the group following SSE decreased over time, especially in the A/P direction, compared to the control group; there were interactions in group X perturbation (p=0.01), and there was a significant difference following treatment (p<0.001) and repeated perturbations (p<0.001). For the M/L CoP sway displacement there was a significant difference following treatment (p<0.04) and repeated perturbations (p<0.001).
Ghasemi et al. (2020)[33]	*Sensory motor training (SMT) group*: patients experience different postures and bases of support and their center of gravity was challenged through three phases; static, dynamic, and functional. *Cranio-sacral therapy (CST) group*: each session comprised of four phases, namely, in prone position, in side-lying position in front of the therapist, in side-lying position behind the therapist, and in supine position; the therapist monitored the patient's cranial rhythm by releasing and relaxing his mind and paying close attention to the patient's cranial rhythm.	The results indicate that all three methods (CST, MET, and SMT) were effective on postural control in patients with NSCLBP, but CST influenced various balance factors, especially in SSLCE (SD-Ay): P0 (base time): p=0.001. P1 (post-treatment): p<0.001. P2 (follow-up): p=0.003. The effect of CST continued on most of the balance variables even after 2 months follow-up.

	Muscle-energy technique (MET) group: treatment of posterior or anterior rotation dysfunctions and correction of a sacroiliac joint up-slip.	
Valenza et al. (2016)[34]	*Pilates exercise program*: floor exercises with 55-cm ball on rubber mat, including spine stretches, saw, mermaid, one-leg stretch, double-leg stretch, crisscross, swan dive, swimming, spine twist, one-leg kick, double-leg kick, shoulder bridge, one-leg circle, side kick and 3 to 5 minutes of relaxation at the end with rubber roller. *No intervention*: usual activities and advice in the form of a leaflet, including information on postural care, physical activity, lifting weights, sedentary activities, sports, pain-free maximal physical activity level, behavioral advice, fear of movement, false beliefs and active lifestyle.	Post- treatment: significant improvements in the intervention group compared to the control group in balance (Single-Limb Stance Test - left: mean change ± standard deviation of 70.83±75.88 and 25.25±52.59 respectively and diff. btw gr 53.1±53.4; p=0.043), disability (RMDQ: mean change ± standard deviation of 5.31±3.37 and 2.40±6.78 respectively and diff. btw gr 3.2 ± 4.12, p=0.003; ODI: p<0.001), current pain (VAS: p=0.002), pain at its least (VAS: p=0.033), and flexibility (Fingertip-to-floor test: 8.45 ± 9.65; p=0.032). No significant changes between groups in balance (Single-Limb Stance Test - right: mean change ± standard deviation of 70.48±71.24 in the intervention group and 20.88±95.01 in the control group and diff. btw gr 51.2±42.1; p=0.055), lumbar mobility (Shober flexion: p=0.23, Shober extension: p= 0.245), pain on average (p=0.211) and pain at its worst (p=0.083). .
Karimi et al. (2009)[35]	*Concise supervised stability training (CSST):* Explanation of the importance of stability exercises; Isolation of muscular functions emphasizing the Transversus Abdominis Muscle (Tr A) and Multifidus by an expert physiotherapist using palpation and pressure biofeedback; Training tonic co-contractions of Tr A and Multifidus during single limb movements and then cross limb movements in different positions; Walking on treadmill with controlled speed and time (15 min). *Control group:* Ultrasound (1 MG, Continuous, 5 min), TENS (2 canal, 90 -110 Hz, 15 min), InfraRed (15 min).	Post stability training: The CSST group showed a significant difference (p<0.05) in the Overall Stability Index (from 9.78±1.87 to 8.22±2.27), in the Anterior–Posterior Stability Index (from 7.19±1.67 to 5.80±1.93) and in the Medial–Lateral Stability Index (from 6.73±2.14 to 5.92±1.79) during the Double Leg Eyes Closed condition. The CSST group also showed a significant difference (p<0.05) in: - Medial–Lateral Stability Index (from 3.42±1.93 to 2.14±0.81) during the Double Leg Eyes Open condition; - the Overall Stability Index (from 2.45±0.95 to 2.05±0.62) and in the Anterior–Posterior Stability Index

		(from 2.00±1 to 1.64±0.67) during the Single Leg Eyes Open condition; - Time to complete (from 184.55±52.5 to 124.5±20.2) and in Functional Performance (from 8.94±4.86 to 15.38±4.31). Control group showed a significant difference (p<0.05) in the Anterior–Posterior Stability Index (from 7.84±1.66 to 6.17±1.88) and in Medial–Lateral Stability Index (from 8.32±2.06 7.3±2.29) in the Double Leg Eyes Closed and in Functional Performance (from 12.93±4.16 to 16.31±7.04). Post stability training measures in the Single Leg Eyes Closed position showed no significant differences in either group.
Kaeding et al. (2017)[36]	*Intervention group:* WBV training 2.5 times a week for 3 months, with each training session lasting approximately 15 minutes and consisting of 5 sets of a duration of 60-120 seconds, a frequency of 10-30 hertz and an amplitude of 1.5-3.5 mm based on the used training program, with a progressive increase of the intensity and a constant variation of the training parameters frequency, amplitude and duration. *Control group:* did not take part in an intervention and were advised to continue their usual activities and not to start a new sports activity.	Post intervention: -Static posturography: no significant differences in the tests in any of the measured parameters between the groups; -the Intervention Group showed significant positive effects in the RMDQ (p=0.027), the ODI (p=0.002), the SF-36 (p=0.013), the Freiburger activity questionnaire (p=0.022), the post-interventional sick leave (p=0.008) and showed trends regarding a positive effect of the intervention on the muscular capacity of the muscles of the trunk in flexion.

Abbreviations. SF-12: Short Form-12 health status questionnaire; ODI: Oswestry Disability Index; VAS: Visual Analog Scale; TENS: Transcutaneous Electrical Nerve Stimulation; COMI: Core Outcome Measure Index, UHBE: Unilateral Hip Bridge Endurance test, SEBT: Star Excursion Balance Test; PSTAntPost: anterior posterior score from postural stability test; PSTMedLat: medial lateral score from postural stability test; CoP: center of pressure; HRQoL: Health related quality of life; RMDQ: Roland Morris Disability Questionnaire; 6MWT: 6 Minute Walking Test; PILE test: Progressive isoinertial lifting evaluation test; CoP: Centre of Pressure; CoPx, antero-posterior displacement of the CoP; CoPy: medio-lateral displacement of the CoP; OE: Open Eye; CE: Closed Eye; CG: Control Group; SSLCE: standing on single leg with closed eyes; WBV: whole-body vibration.

Table III. Quality of evidence assessed through GRADE framework [24]

Outcome	SMD (95% CI)	N. of subjects (Studies)	Comments	Quality of Evidence
CoP total displacement	-16,99 (-27.29, -6.68)	84 (2 RCT)	Downgraded by one level for risk of bias Downgraded by two levels for imprecision [a,b]	⊕⊖⊖⊖ Very low
Ellipse area	-0.28 (-0.97, 0.41)	114 (3 RCT)	Downgraded by one level for risk of bias Downgraded by one level for inconsistency (I^2=70%) Downgraded by one level for imprecision [a]	⊕⊖⊖⊖ Very Low
Limits of Stability (antero-posterior)	-0.00 (-0.38, 0.38)	87 (2 RCT)	Downgraded by one level for risk of bias Downgraded by two levels for imprecision [a,b]	⊕⊖⊖⊖ Very Low
Limits of Stability (medio-lateral)	0.03(-0.41, 0.48)	87 (2 RCT)	Downgraded by one level for risk of bias Downgraded by one level for inconsistency (I^2=81%) Downgraded by two levels for imprecision [a,b]	⊕⊖⊖⊖ Very low
Dynamic Balance (SEBT test)	-4.74(-8.02, -1.46)	70 (2 RCT)	Downgraded by one level for risk of bias Downgraded by two levels for imprecision [a,b]	⊕⊖⊖⊖ Very Low
Single-leg stance test	-28.7 (-48.84, -8.67)	88 (2 RCT)	Downgraded by one level for risk of bias Downgraded by two levels for imprecision [a b]	⊕⊖⊖⊖ Very Low

Imprecision: a =wide confidence interval, b= sample size <100.

GRADE criteria.

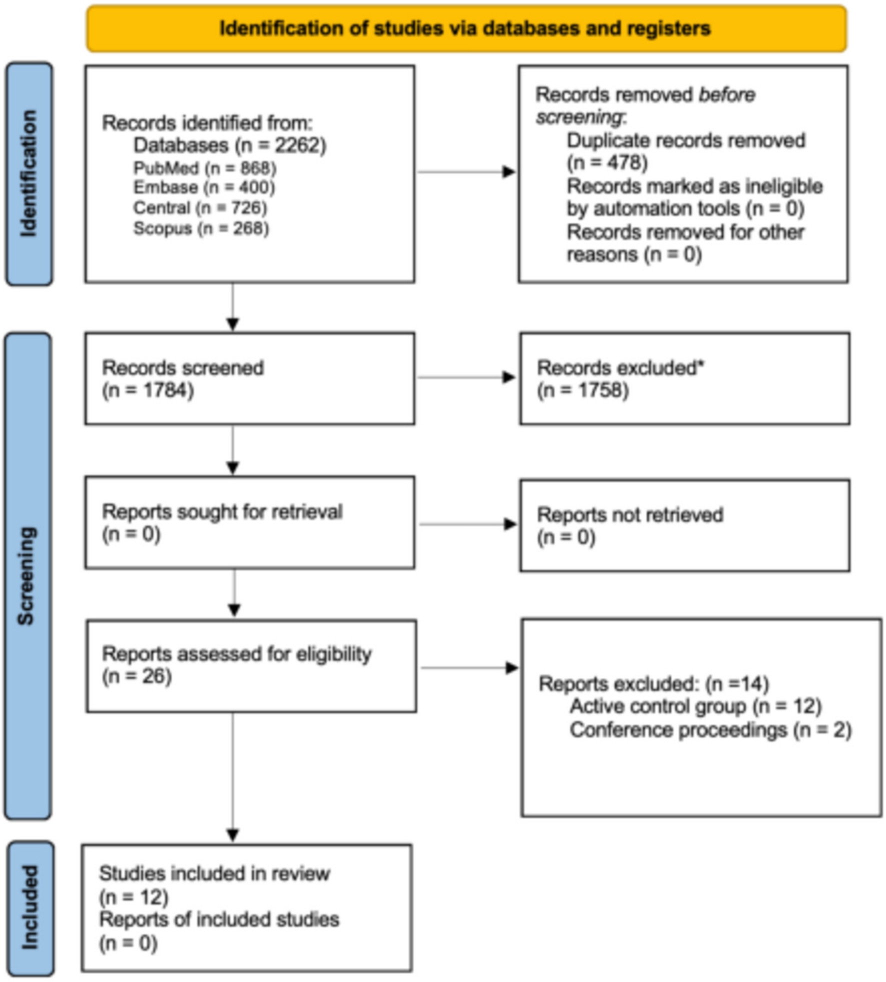
High Quality: We are very confident that the true effect lies close to that of the estimate of the effect.

Moderate quality: We are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different.

Low quality: Our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect.

Very low quality: We have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect.

Figure 1. Flow diagram based on PRISMA statement[20] (www.prisma-statement.org)



*All the excluded records were excluded by reviewers, without using any automation tool.

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for included study

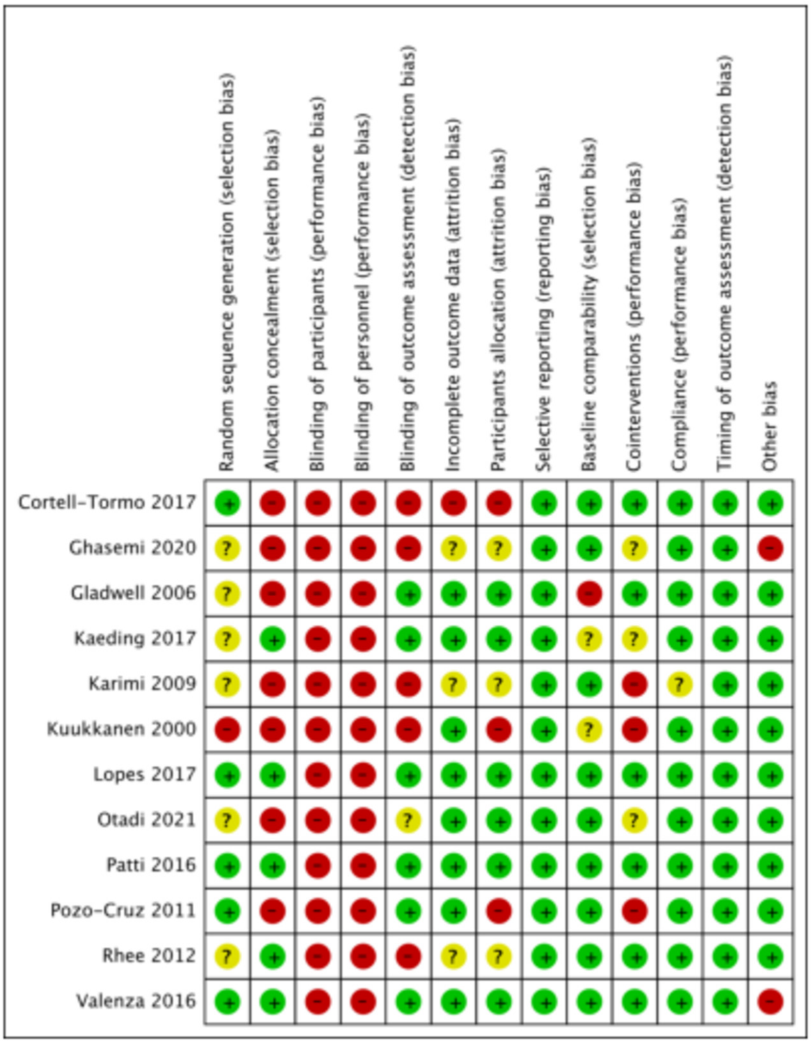


Figure 3. Risk of bias assessment graph for the included studies

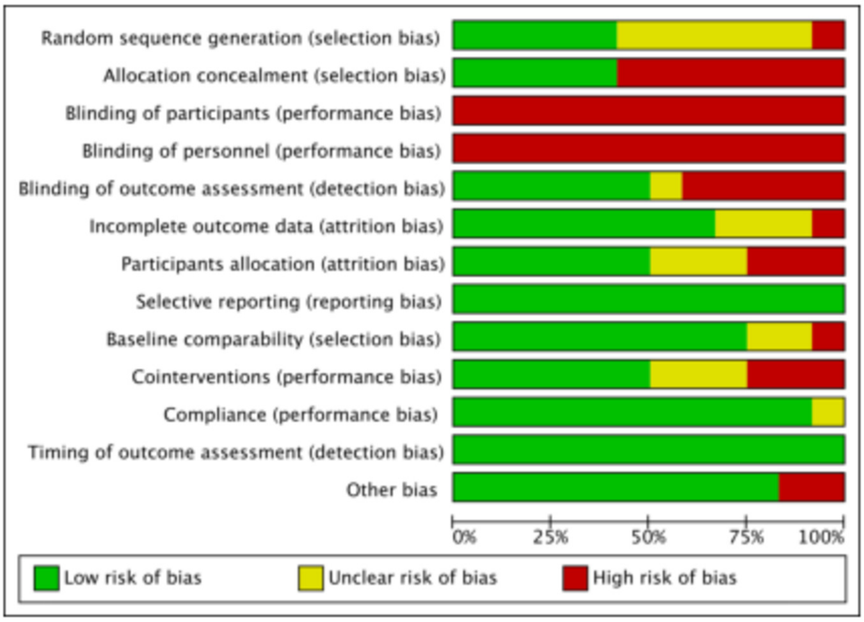


Figure 4 Forest plot of comparison: effect of exercise vs control interventions for balance in NS-LBP. Outcome: single-leg stance test. Abbreviations: CI, confidence interval; SD, Standard Deviation

	Exercise			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Gladwell 2006	−46.9	36.9	20	−23.1	27.7	14	81.1%	−23.80 [−45.53, −2.07]
Valenza 2016	−70.83	75.88	27	−20.88	95.01	27	18.9%	−49.95 [−95.81, −4.09]
Total (95% CI)			**47**			**41**	**100.0%**	**−28.75 [−48.84, −8.67]**

Heterogeneity: $Tau^2 = 6.68$; $Chi^2 = 1.02$, $df = 1$ ($P = 0.31$); $I^2 = 2\%$
Test for overall effect: $Z = 2.81$ ($P = 0.005$)

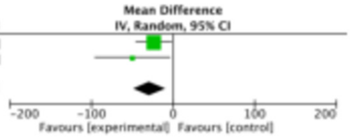


Figure 5. Forest plot of comparison: effect of exercise vs control interventions for balance in NS-LBP. Outcome: CoP displacement. Abbreviations: CI, confidence interval; SD, Standard Deviation

	Exercise			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Lopes 2017	210.5	42.7	23	237.3	47.2	23	15.7%	−26.80 [−52.81, −0.79]
Patti 2016	58.43	14.07	19	73.59	20.6	19	84.3%	−15.16 [−26.38, −3.94]
Total (95% CI)			**42**			**42**	**100.0%**	**−16.99 [−27.29, −6.68]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.65$, $df = 1$ ($P = 0.42$); $I^2 = 0\%$
Test for overall effect: $Z = 3.23$ ($P = 0.001$)

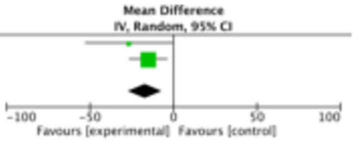


Figure 6. Forest plot of comparison: effect of exercise vs control interventions for balance in NS-LBP. Outcome: Ellipse area. Abbreviations: CI, confidence interval; SD, Standard Deviation

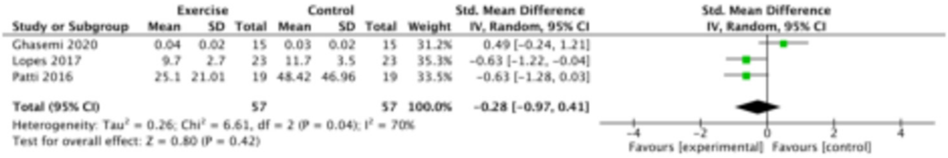


Figure 7. Forest plot of comparison: effect of exercise vs control interventions for balance in NS-LBP. Outcome: anterior-posterior index (limits of stability). Abbreviations: CI, confidence interval; SD, Standard Deviation

	Exercise			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Karimi 2009	1.87	0.93	18	1.64	0.67	20	40.9%	0.23 [−0.29, 0.75]
Pozo-Cruz 2011	0.41	0.95	25	0.57	0.4	24	59.1%	−0.16 [−0.57, 0.25]
Total (95% CI)			**43**			**44**	**100.0%**	**−0.00 [−0.38, 0.38]**

Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 1.34$, df = 1 (P = 0.25); $I^2 = 26\%$
Test for overall effect: Z = 0.00 (P = 1.00)

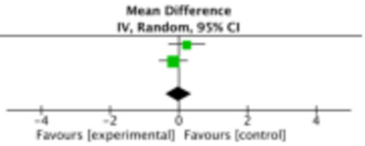


Figure 8. Forest plot of comparison: effect of exercise vs control interventions for balance in NS-LBP. Outcome: medium-lateral index (limits of stability). Abbreviations: CI, confidence interval; SD, Standard Deviation

	Exercise			Control				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Karimi 2009	1.73	0.61	18	1.44	0.49	20	44.0%	0.29 [−0.06, 0.64]
Pozo−Cruz 2011	0.3	0.21	25	0.47	0.37	24	56.0%	−0.17 [−0.34, −0.00]
Total (95% CI)			**43**			**44**	**100.0%**	**0.03 [−0.41, 0.48]**

Heterogeneity: $Tau^2 = 0.09$; $Chi^2 = 5.27$, df = 1 (P = 0.02); $I^2 = 81\%$
Test for overall effect: Z = 0.14 (P = 0.89)

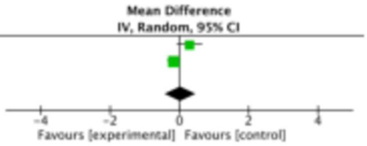


Figure 9. Forest plot of comparison: effect of exercise vs control interventions for balance in NS-LBP. Outcome: dynamic balance (SEBT). Abbreviations: CI, confidence interval; SD, Standard Deviation