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Review article

Can baseline features predict a reduction in pain and disability following neck-specific exercise in people with chronic non-specific neck pain?: A systematic review

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ABSTRACT

Background: Neck-specific exercises are effective for chronic non-specific neck pain, though responses vary considerably.
Objectives: Identify baseline features that predict a reduction in neck disability, pain and better global change following neck-specific exercise interventions.
Design: Systematic review of prospective cohort studies and secondary analyses of randomised controlled trials.
Methods: Six databases were searched until June 2025. Studies investigating baseline demographic and clinical characteristics, as well as physical and psychological features, with the outcome of pain and disability, or global changes were included. Methodological quality was assessed with the Quality in Prognosis Studies tool, and the Grading of Recommendations Assessment, Development and Evaluation (GRADE) tool was used to assess the certainty of evidence.
Results: Four studies (318 participants) were included. Older age (OR = 5.52) and being male (OR = 5.52) predicted pain reduction. Catastrophising predicted higher levels of disability (OR = 2.91) post exercise. Higher cervical movement velocity (OR = 3.68) and lower accuracy (OR = 5.99) at baseline both predicted less disability and pain. Shorter pain duration (LR+:3.21; LR-:0.36) and lower baseline disability (LR+:2.29; LR-:0.52) predicted a successful global response. The certainty of evidence for these findings is very low.
Conclusions: Baseline characteristics such as older age, male sex, lower movement accuracy, higher movement velocity, shorter pain duration, and lower baseline disability may predict favourable outcomes following neck-specific exercises, while catastrophising may predict poorer disability outcomes. However, given the very low certainty of evidence, these results should be interpreted cautiously.
Trial registration: PROSPERO (Registration number CRD42023408332)

1. Introduction

Chronic non-specific neck pain is a highly prevalent musculoskeletal condition (Côté et al., 2016). Although neck pain is often mild and not agonising, neck pain can significantly affect patient's daily life by depriving sleeping quality (Van Looveren et al., 2021) and increasing psychological stress (Stephen et al., 2022). Clinical guidelines recommend neck exercise within a multi-modal physiotherapy programme including psychological support for the management of chronic neck pain (Blanpied et al., 2017). Exercise for the management of chronic neck pain is supported by evidence from systematic reviews and meta-analyses, which indicate that neck exercise programmes are not only well accepted by individuals with chronic neck pain (Blomgren et al., 2018), but also serve as a fundamental part of rehabilitation for improving neuromuscular and sensory function, reducing disability and relieving pain (Aguayo-Alves et al., 2024; Dirito et al., 2024; Hayden

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et al., 2005; Osborne et al., 2024; Villanueva-Ruiz et al., 2022).

Compared to general physical activity, neck-specific exercises aim to enhance neck neuromuscular control and have demonstrated effectiveness for treating various neuromuscular impairments (Blomgren et al., 2018; Dirito et al., 2024) in addition to reducing neck pain and disability (Peterson and Peolsson, 2023; Villanueva-Ruiz et al., 2025). Neck-specific exercise interventions include exercises such as neck muscle strengthening and endurance training (Chiu et al., 2005; O'Leary et al., 2012), motor control training (Falla et al., 2013; Gallego Izquierdo et al., 2016; Villanueva-Ruiz et al., 2025), and neck proprioceptive training (Gallego Izquierdo et al., 2016). Whilst recognised as being effective overall at improving neuromuscular coordination (Blomgren et al., 2018), decreasing sternocleidomastoid activity (Dirito et al., 2024) and decreasing neck pain and disability (Peterson and Peolsson, 2023; Villanueva-Ruiz et al., 2025), the changes in neck pain and disability following neck exercise vary among individuals with some people having excellent results and others very little change. This may be due to the heterogeneity in the population including differences in baseline demographic features, clinical characteristics, physical and psychological features (Bohman et al., 2019; Villanueva-Ruiz et al., 2022).

It is postulated that a comprehensive evidence synthesis of baseline features that predict more favourable outcomes with neck-specific exercise interventions will optimise recommendations for specific treatment selection for the management of people with chronic neck pain (Childs et al., 2008). Therefore, the aim of this systematic review is to synthesise current evidence in order to identify which baseline features can predict a reduction in neck disability and pain intensity, or better global change following neck-specific exercise interventions for people with chronic neck pain.

2. Methods

This systematic review adhered to a predetermined, published protocol (Chen et al., 2023) which was prospectively registered on PROSPERO (CRD42023408332) and is reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines (Page et al., 2021).

2.1. Eligibility criteria

The eligibility criteria for included studies were informed by the participants, interventions, comparators, outcomes, and study design (PICOS) framework (Chen et al., 2023).

2.1.1. Population

Studies were considered eligible if they involved individuals aged 18 or above who had experienced chronic neck pain lasting for a minimum of three months. Studies including participants with specific causes of neck pain and diagnoses such as fracture, nerve root compression, neurological diseases, or whiplash associated disorders were excluded (Domingues et al., 2018).

2.1.2. Intervention

Interventions were required to consist of only neck-specific exercises which could include any exercises that specifically targeted the neck region.

2.1.3. Comparators

Comparators of intervention were not applicable, as this study focuses solely on neck-specific exercises and the prediction of its treatment effectiveness from baseline features.

2.1.4. Exposure and outcome measures

2.1.4.1. Baseline features (predictors). All baseline features included in this study are classified into three distinct categories: (1) demographic and clinical characteristics, (2) physical features, and (3) psychological features.

2.1.4.2. Outcome measures. Post-exercise intervention neck pain intensity, disability and global response are the outcomes to assess the effectiveness of neck exercises. The measurement could take place immediately after the intervention or during follow-up periods. Pain and disability could be measured individually or, in combination, with a certain threshold of change specified, as a dichotomous positive or negative response after neck exercises. Examples of measurements of neck pain intensity are Visual Analog Scale (VAS) (Aitken, 1969) and Numeric Rating Scale (NRS) (Jensen et al., 1986). Example of disability measurements are the Neck Disability Index (NDI) (Vernon and Mior, 1991), Northwick Park Questionnaire (NPQ) (Leak et al., 1994) and Northern American Spine Society questionnaire (NASS) (Daltroy et al., 1996). An example of global outcomes which combine pain intensity and/or disability with other variables is the global rate of change scale (GROC) (Daher and Dar, 2024).

2.1.5. Study design

This systematic review included studies of prognostic factor research (Riley et al., 2013). This involves the secondary analysis of randomised controlled trials (RCTs) of neck-specific exercises and non-RCTs (prospective cohort studies) which identify individual features associated with subsequent outcome at various timepoints of follow-up from a population that received a neck-specific exercise intervention. The studies included were conducted in either primary care settings or secondary care settings.

2.1.6. Exclusion criteria

Exclusion criteria were as follows: (1) Studies that failed to specify baseline features; (2) Studies not including pain intensity or disability outcomes; (3) Secondary analysis of RCTs which reported the follow-up outcomes of a population combining the group receiving neck exercise with other groups (control or other interventions); (4) Prognostic model studies which involved a formal combination of multiple predictors from which outcomes of a specific endpoint can be calculated for individual patients (Steyerberg et al., 2013); (5) Articles published in languages other than English.

2.2. Information sources

The main reviewer (GY) conducted thorough searches in the following databases from inception to June 2025: MEDLINE (OVID Interface), Embase (OVID Interface), Web of Science (All Databases), Scopus, CINAHL (EBSCO interface), and PubMed. Furthermore, the reference lists were searched manually to ensure comprehensive coverage. Forward citation tracking was conducted to identify additional relevant studies. Key papers identified in the initial search were entered into PubMed, Scopus, Web of Science, Google Scholar and all citing articles published were screened for eligibility using the same inclusion and exclusion criteria applied to the primary search.

2.3. Search strategy

The search strategy was developed in collaboration with a librarian. The original strategy was developed in MEDLINE and incorporated both medical subject heading (MeSH) terms and keywords combinations. The final strategy was adapted to all databases as outlined in Supplementary File 1.

2.4. Data management

The first reviewer (GY) retrieved articles and exported them into EndNote software (Version 9, Clarivate Analytics, United States) to remove duplicates.

2.5. Study selection

Titles and abstracts were screened by the first and second reviewers (GY and ZC). Full text articles were screened for studies that met the inclusion criteria or if it was uncertain based on their abstract or title classification. When consensus could not be reached, a third reviewer (DF) was consulted to make the final decision. The inter-rater agreement of the study selection process was calculated with Kappa statistics using IBM SPSS Statistics V.29.0 (2023).

2.6. Data extraction

Data extraction was conducted by two reviewers (GY, ZC) independently using a designated data extraction form. The items included: 1) authors and year of publication, 2) study design, 3) sample size and participant characteristics, 4) baseline features (potential predictors) of interest, 5) intervention, duration and follow-up period, 6) methods for statistical analysis, 7) results with intervention on neck pain/disability and 8) significant association of baseline features with the interested outcome. The data extraction form was tested on two selected articles before implementation.

2.7. Risk of bias

The Quality in Prognosis Studies tool (QUIPS) (Hayden et al., 2013) was used to assess risk of bias of included studies with a standardised assessment form for each selected article (Supplementary File 2). QUIPS has been adapted for assessing risk of bias in prognostic studies (Hayden et al., 2006) and has acceptable inter-rater reliability (Hayden et al., 2013). There are six key assessment domains in QUIPS: 1) study participation, 2) study attrition, 3) prognostic factor measurement, 4) confounding measurement and account, 5) outcome measurement and 6) analysis and reporting (Hayden et al., 2006). Each domain investigates a specific set of information, and the report of each of these sets of information was categorised as 'yes', 'no', 'partial' or 'unsure'. Then, the risk of bias of each domain was classified as 'high,' 'moderate,' or 'low'. A domain was rated to have high risk if any rating of reporting was 'no' and low risk if all ratings of reporting were 'yes', whereas other combination of 'yes' with 'partial' or 'unsure' was rated moderate. A study was rated to have an overall high risk of bias if one or more domains were rated as high risk. In contrast, a study was identified to have a low overall risk of bias if all six domains were evaluated as low risk. Two reviewers (GY, ZC) first independently assessed the risk of bias. Then the rating was confirmed with reference to the agreement of the two reviewers (GY, ZC) (Hayden et al., 2013) and any disagreement was mediated through discussion with the third reviewer (DF).

2.8. Data synthesis

Due to heterogeneity of post-exercise outcomes and time assessment-point, a meta-analysis was not feasible. Studies were included for descriptive and quantitative synthesis using structured tabulation and forest plots without meta-analysis. Descriptive findings from studies were grouped based on the domain of baseline features and the domain of post-exercise outcome investigated.

Summary statistics: The relationship between the predictor and non-dichotomous outcome measures including neck disability, neck pain intensity and global change of symptoms are presented as β-coefficient (Georgopoulos et al., 2019). The positive or negative response to neck exercise in terms of passing a certain threshold of change in pain and disability is a dichotomous outcome and the result is expressed as an odds ratio (OR). All extracted OR values and the corresponding 95 % confidence intervals (95 %CIs) were then log-transformed to β-coefficients (Bonett, 2007). The predictive capability of baseline features on GROC were reported by positive likelihood ratio (LR+) and negative likelihood ratio (LR-) with 95 %CIs (Daher and Dar, 2024).

Synthesis method: In addition to the descriptive report, to illustrate the direction and magnitude of predictive strength, forest plots without meta-analysis were constructed with reference to β-coefficients or likelihood ratios with corresponding 95 %CIs. When stepwise or backward regression was used and the effect size of the predictor with non-significant association was not reported, the result is reported descriptively only.

2.9. Certainty of evidence

The certainty of evidence was evaluated with the Grading of Recommendations Assessment, Development and Evaluation (GRADE) tool (Guyatt et al., 2008) when a predictive factor was investigated in more than one study. The tool consists of two factors which increase the certainty of evidence: 'moderate or large effect size' and 'exposure-response gradient' (Huguet et al., 2013). There are six factors that can downgrade the certainty of evidence: 1) phase of investigation, 2) study limitations, 3) inconsistency, 4) indirectness, 5) imprecision and 6) publication bias. With reference to the GRADE Handbook (Schünemann et al., 2013), the evaluation started with the phase of investigation. When the studies reporting a predictor consisted mainly of phase 1 exploratory studies that identify potential prognostic factors which are particularly vulnerable to type I errors (false positive results), the certainty of evidence was downgraded from high to moderate. Prognostic studies in phases 2 and 3 of investigation are considered with high certainty of evidence in which a phase 2 study aims to confirm independent associations between a prognostic factor and the outcome with a developed hypothesis and a phase 3 study aims to understand a prognostic pathway (Huguet et al., 2013). Subsequently, the certainty of evidence was upgraded or downgraded for other factors with reference to the GRADE Handbook.

2.10. Deviations from protocol

Some deviations from the registered PROSPERO protocol (CRD42023408332) were made: 1) age of inclusion was changed from 18 to 55 to above 18 to improve the generalisability of the review; 2) global change was included in the outcomes in addition to neck pain and disability; 3) prognostic model studies were excluded in the new design for the review to focus on prediction from individual baseline features to better align with our original study aim; 4) the risk of bias appraisal tool was changed from the risk-of-bias tool for non-randomised studies of interventions (ROBINS-I) to QUIPS which is more specific for prognostic studies (Hayden et al., 2013).

3. Results

3.1. Study identification and selection

Procedures of the selection process, along with reasons for exclusion at each step, are provided in Fig. 1 with the reason of exclusion during full-text screening and corresponding full references documented in Supplementary File 3. Four studies were selected for data extraction (Table 1). The agreement for abstract and title screening between the two reviewers was almost perfect at $k = 0.96$. The agreement for full text screening between the two reviewers was almost perfect at $k = 0.97$.

3.2. Characteristics of included studies

Characteristics of the included studies and findings are summarised

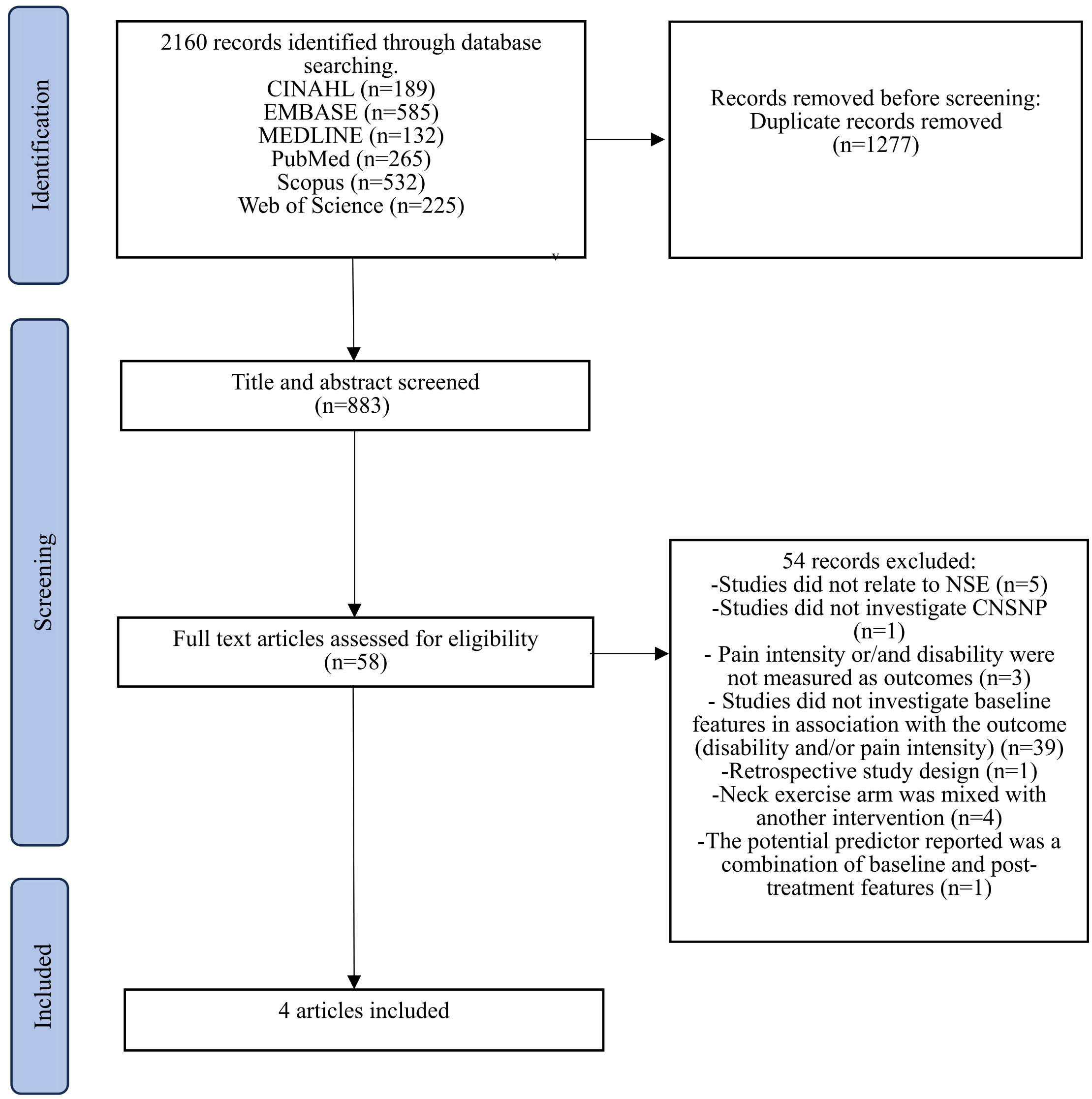

Fig. 1. Flow diagram of search and selection of studies.

in Table 1. Three secondary analyses of RCTs (Daher and Dar, 2024; Sarig Bahat et al., 2020; Thompson and Woby, 2018), and one cohort study (Cecchi et al., 2011) were included. A total of 318 people with chronic neck pain were investigated in the included studies.

3.3. Risk of bias assessment

The risk of bias assessment was performed using QUIPS tool (Table 2). Overall, the included studies had moderate to high risk of bias. All studies had low risk of bias in the domains of 'outcome measurement' and 'analysis and reporting'. For the two studies rated to have high overall risk of bias (Sarig Bahat et al., 2020; Thompson and Woby, 2018), high risk of bias for 'study attrition' was noted as the characteristics of the dropouts and reason of missing follow-ups were not reported. One study had high risk of bias for 'study confounding' which reflects the lack of adjustment with key confounding factors in the regression analyses (Thompson and Woby, 2018).

3.4. Data synthesis

Forest plots without meta-analysis (Fig. 2) were constructed with reference to β-coefficients from statistical conversion (Cecchi et al., 2011; Sarig Bahat et al., 2020) and likelihood ratios (Daher and Dar, 2024) to illustrate the direction and magnitude of predictive strength from an individual baseline feature on a specific outcome for the included studies, with the exception of Thompson & Woby (2018) as the 95 %CI was not available.

3.5. Prediction of post-exercise disability from baseline psychological features

Three studies investigated the association of baseline psychological features and post-exercise pain and disability (Cecchi et al., 2011; Sarig Bahat et al., 2020; Thompson and Woby, 2018). These features were measured by life satisfaction, mood and catastrophising items from 36-item Short Form Questionnaire (SF-36), the Chronic pain Self-Efficacy Scale-Physical Function Sub-Scale (CPSES-PFSS), Fear-Avoidance Beliefs Questionnaire (FABQ), Fear-Avoidance Beliefs Questionnaire-Physical Activity (FABQ-PA), Pain Catastrophising Scale (PCS), and Tampa Scale for Kinesiophobia (TSK). Supported by a single study (Cecchi et al., 2011), catastrophising was found to be associated with higher post-exercise disability at a 1-year follow-up (OR = 2.91, 95 % CI: 0.83; 1.20). Based on the GRADE analysis (Table 3), the overall certainty of evidence on predicting greater disability post-exercise with greater catastrophising is very low as the result comes from only one study. All other psychological features were not reported to have

Table 1
Overview of key characteristics from the included studies.

Author, year & study design	Sample size and participant characteristics (mean and SD)	Baseline features	Intervention	Results of regression analysis of baseline features
Cecchi et al. (2011); Prospective cohort study	N = 162 Age: 65 (12.5) 75 % female Disability: (NPQ global score): 40.7 (17.1)	**Demographics and clinical characteristics:** Age Female BMI NPQ **Psychological features:** Life satisfaction (from the SF-36) Mood (from the SF-36) Catastrophising (question from the PCS)	Intervention: isometric, dynamic and stretching exercises for neck and shoulder Duration: 5 supervised sessions in 8 days, then home exercise for 1 year Follow-up: 1year	OR for poor outcome (less than 30 % improvement of NPQ global score): **At the end of treatment:** Age: OR (0.98), 95 %CI (0.94–1.02) Female: OR (1.75), 95 %CI (0.62–4.97) BMI: OR (0.94), 95 %CI (0.82–1.07) Life satisfaction, Y/N: OR (3.09), 95 %CI (0.95–10.07) Mood (1–6, 6 best): OR (0.95), 95 %CI (0.64–1.40) Catastrophising, Y/N: OR (1.28), 95 %CI (0.57–2.89) Time from onset-years: OR (1.03), 95 %CI (0.99–1.07) NPQ (0–100): OR (0.92), 95 %CI (0.76–1.11) **1 year after treatment:** Age: OR (1.02), 95 %CI (0.98–1.06) Female: OR (0.59), 95 %CI (0.21–1.67) BMI: OR (0.98), 95 %CI (0.85–1.13) Life satisfaction, Y/N: OR (1.50), 95 %CI (0.50–4.50) Mood (1–6, 6 best): OR (1.03), 95 %CI (0.70–1.52) Catastrophising, Y/N: OR (2.91), 95 %CI (1.31–6.48)[a] Neck pain duration, months: OR (1.02), 95 %CI (0.98–1.07) NPQ (0–100): OR (1.00), 95 %CI (0.83–1.20)
Daher and Dar (2024); Secondary analysis of an RCT	N = 60 Age: 54.47 (10.76) Gender ratio not given Baseline NDI: 17.07 (4.48) Baseline VAS (0–10): 6.65 (1.67)	**Demographics and clinical characteristics:** Age BMI Duration since onset NDI VAS **Physical features:** Neck flexor endurance AROM **Psychological features:** FABQ	Intervention: Aerobic exercise with neck exercises or neck exercises alone (neck stretching and strengthening) Duration: 6 weeks Follow-up: 6 weeks	Likelihood ratios (LR) for treatment success (global rate of change = +5/15 or above) at 6 weeks: Duration since onset, ≤180 days: LR+ (95 %CI): 3.21 (1.61, 6.39)[a] LR- (95 %CI): 0.36 (0.19, 0.66) NDI score≤17 at baseline: LR+ (95 %CI): 2.29 (1.16, 4.56)[a] LR- (95 %CI): 0.52 (0.33, 0.83) FABQ-PA score≤13: LR+ (95 %CI): 1.62 (0.94, 2.76) LR- (95 %CI): 0.64 (0.38, 1.06)
Sarig Bahat et al. (2020); Secondary analysis of an RCT	N = 79 Age: 48.3 (13.5) 65.8 % female Baseline VAS: 46.2 (21.7)	**Demographics and clinical characteristics:** Age Gender NDI VAS **Physical features:** Global accuracy (°) Global mean velocity (°/s) Global peak velocity (°/s) **Psychological features:** TSK	Intervention: Home kinematic training with VR system or head-laser beam with poster Duration: 4 weeks. Follow-up: 3 months	Effective predictors of treatment response (≥50 % reduction in VAS, or ≥7 % reduction in NDI, or a global perceived effect of 3–5 of 5 and ≥ 40 % improvement in global mean velocity) at post-intervention and follow-up: **Post-intervention:** Gender (male vs female): OR (5.52), 95 % CI (1.25–24.32)[a], β(1.71) NDI at baseline ≥20 % vs ≤ 20 %: OR (4.90), 95 % CI (1.23–19.52)[a], β (1.59) VAS at baseline ≥50 % vs ≤ 50 %: OR (2.30), 95 % CI (0.62–8.50), β (0.83) Global accuracy≥16° vs ≤ 16: OR (5.99), 95 % CI (1.05–34.2)[a], β (1.79) Global mean velocity ≥65°/s vs ≤ 65°/s: OR (3.68), 95 % CI (1.06–12.75)[a], β (1.30) **3-month follow-up:** Age: OR (5.52), 95 % CI (1.009–1.31)[a], β (0.07) NDI at baseline ≥20 % vs ≤ 20 %: OR (4.90), 95 % CI (1.53–62.0)[a], β (2.28)
Thompson and Woby (2018); Secondary analysis of an RCT	N = 17 Age: 51 (14) 53 % female Baseline NRS: 5.4 (2.1) Baseline NPQ: 39 (14)	**Demographics and clinical characteristics:** Age Gender Pain duration NRS **Psychological features:** PCS TSK CPSES-PFSS	Intervention: neck stretching and strengthening exercises Duration: 4 weeks Follow-up: 6 months	The association between changes in disability and baseline features: -NRS: R^2 (0.33), β (0.57), $P < 0.05$[a] Age, sex, pain duration, PCS, TSK and CPSES-PFSS were not significantly correlated with changes in disability (P > 0.05)

AROM: Active Range of Motion; BMI: Body Mass Index; CI: Confidence Interval; CPSES-PFSS: Chronic pain Self-Efficacy Scale-Physical Function Sub-Scale; FABQ: Fear-Avoidance Beliefs Questionnaire; FABQ-PA: Fear-Avoidance Beliefs Questionnaire-Physical Activity; LR+: Positive Likelihood Ratio; LR-: Negative Likelihood Ratio; NDI: Neck Disability Index; NPQ: Northwick Park Questionnaire; NRS: Numeric Pain Rating Scale; OR: Odds Ratio; PCS: Pain Catastrophizing Scale; RCT: Randomized

Controlled Trial; ROC: Receiver Operating Characteristic; SF-36: 36-item Short Form Questionnaire; SD: Standard Deviation; TSK: Tampa Scale for Kinesiophobia; VAS: Visual Analogue Scale; VR: Virtual Reality; Y/N: Yes/No.
[a] Statistically significant result.

Table 2
Risk of bias assessment with the Quality in Prognosis Studies tool.

Study	Study participation	Study attrition	Prognostic factor measurement	Outcome measurement	Study confounding	Analysis and reporting	Overall risk of bias
Cecchi et al. (2011)	Low	Low	Moderate	Low	Moderate	Low	**Moderate**
Daher and Dar (2024)	Low	Low	Moderate	Low	Moderate	Low	**Moderate**
Sarig Bahat et al. (2020)	Moderate	High	Moderate	Low	Moderate	Low	**High**
Thompson and Woby (2018)	Moderate	High	Moderate	Low	High	Low	**High**

significant association with post-exercise disability.

3.6. Prediction of post-exercise disability from baseline pain and disability

Two studies investigated the association of baseline disability and post-exercise disability based on the NDI or NPQ (Cecchi et al., 2011; Sarig Bahat et al., 2020) and two studies investigated the association of baseline pain intensity and post-exercise disability using either the NRS and VAS (Sarig Bahat et al., 2020; Thompson and Woby, 2018).

Sarig Bahat et al. (2020) reported that higher baseline NDI post-intervention (OR = 4.90, 95 % CI: 1.23; 19.52) and 3 months after intervention (OR = 4.90, 95 %CI: 1.53; 62.0) had positive associations with positive recovery of disability while a greater baseline VAS score had no significant association with recovery of disability (OR = 2.3, 95 %CI: 0.62; 8.50). Thompson and Woby (2018) reported that baseline NRS score was positively associated with improvement of disability after the intervention ($\beta = 0.57$, $P < 0.05$). Cecchi et al. (2011) reported that baseline global NPQ score was not associated with a poor outcome of NPQ immediately after or one year after the exercise intervention (OR = 0.92 to 1.00).

Overall, there is very low certainty of evidence on the prediction of disability following neck exercise from baseline neck pain intensity and disability (Table 3). This was limited by the phase of study, study limitation as reflected by at least moderate risk of bias and inconsistency.

3.7. Prediction of post-exercise disability from age and sex

Three studies investigated the association of age or sex with post-exercise disability (Cecchi et al., 2011; Sarig Bahat et al., 2020; Thompson and Woby, 2018). One study reported an association of older age (OR = 5.52, 95 % CI: 1.009; 1.31) and male sex (OR = 5.52, 95 % CI: 1.25; 24.32) with reduction of disability (Sarig Bahat et al., 2018). Cecchi et al. (2011) reported no association of older age (OR = 0.98 to 1.02) or female sex with the outcome of disability (OR = 0.59 to 1.75) immediately after and one year after the exercise intervention. One study did not report the effect size with age and sex as an association to post-exercise pain and disability was not present (Thompson and Woby, 2018). Overall, there is very low certainty of evidence on the prediction of disability following neck exercise from age or sex (Table 3). This was limited by the phase of study, study limitation as reflected by at least moderate risk of bias and inconsistency.

3.8. Prediction of post-exercise pain intensity from baseline psychological features

One study investigated the association of baseline TSK score with post-exercise pain intensity (Sarig Bahat et al., 2020) and found no significant association.

3.9. Prediction of post-exercise pain intensity from baseline pain and disability

One study investigated the association of baseline pain intensity and disability and post-exercise pain intensity (Sarig Bahat et al., 2020) and reported that pain reduction is associated with both greater baseline pain intensity (OR = 2.30, 95 % CI: 0.62; 8.50) and greater baseline NDI score (OR = 4.90, 95 % CI: 1.23; 19.52). Overall, there is very low certainty of evidence on the prediction of pain intensity following neck exercise from baseline pain intensity and disability as there are no corroborating studies.

3.10. Prediction of post-exercise pain intensity from age and sex

One study reported a positive association of older age (OR = 5.52, 95 % CI: 1.009; 1.31) and male sex (OR = 5.52, 95 % CI: 1.25; 24.32) with improvement in pain intensity (Sarig Bahat et al., 2020). The certainty of evidence is very low for predicting improvement in pain intensity from age and sex.

3.11. Prediction from physical features

Baseline cervical range of motion, velocity and movement accuracy were grouped as 'kinematic features'; Sarig Bahat et al. (2020) reported that higher global mean velocity of neck movement is associated with better recovery of disability and pain (OR = 3.68, 95 % CI: 1.06; 12.75). In addition, in the same study, less global movement accuracy was associated with better recovery of disability and pain intensity (OR = 5.99, 95 % CI: 1.05; 34.2). The certainty of evidence for the prediction of post-exercise pain and disability from cervical movement velocity and accuracy are both very low.

3.12. Prediction of post-exercise global response

One study reported the outcome following exercise based on the GROC, with the treatment regarded as successful when the score of GROC increased by > 5 out of 15 (Daher and Dar, 2024). A shorter duration of neck pain since onset and lower baseline neck disability (NDI) predicted a better likelihood of a positive treatment outcome. As these results were only supported by one study, the certainty of evidence is very low for predicting a better likelihood of a positive treatment outcome from shorter duration of neck pain since onset and lower baseline neck disability.

4. Discussion

The key findings from this systematic review suggest that some demographic, psychological, and physical factors may influence response to neck-specific exercise, although the certainty of the evidence remains very low. The finding that individuals with lower cervical movement

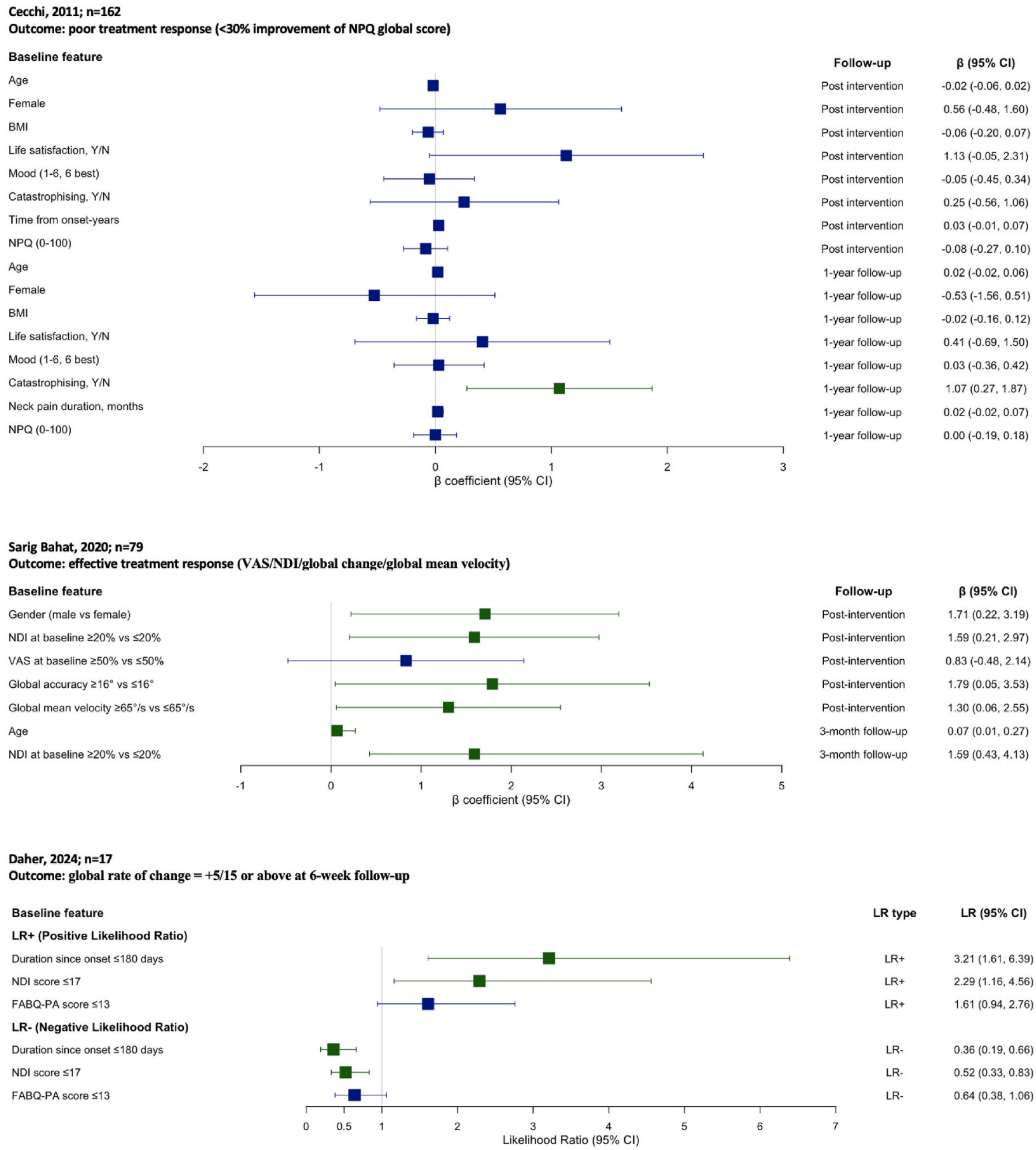

Fig. 2. Forest plots without meta-analysis illustrating predictive strength of baseline features from the included studies (green: significant association/likelihood ratio; blue: non-significant association/likelihood ratio)
BMI: Body Mass Index; CI: Confidence interval; FABQ-PA: Fear-Avoidance Beliefs Questionnaire-Physical Activity; LR: Likelihood Ratio; NDI: Neck Disability Index; NPQ: Northwick Park Questionnaire; VAS: Visual Analog Scale.

accuracy had better recovery in pain, disability and motor control with targeted proprioceptive and kinematic retraining (Sarig Bahat et al., 2020), is supported by the rule of specificity of exercise which states that exercise training must be relevant and matched to the specific demands of the sport or desired outcome to be effective. A similar observation has been found in relation to the management of people with low back pain with lumbar movement control impairment, where the improvement of lumbar movement control was greater when receiving specific motor skill training compared with general strengthening and flexibility training (Hooker et al., 2025).

It is relevant to consider the fear-avoidance model of pain when interpreting the finding that catastrophising predicted greater disability following exercise; catastrophising can contribute to maladaptive beliefs, avoidance behaviour, and can reduce engagement with rehabilitation (Linton et al., 2000). Catastrophising can also amplify the perception of pain and has been consistently associated with poorer outcomes in chronic neck and back pain (Cresswell et al., 2020; Shimada et al., 2025; Wertli et al., 2014). Because neck-specific exercises primarily target motor and proprioceptive deficits, individuals with higher psychological traits may not experience comparable benefits unless combined with cognitive-behavioural approaches (Ploutarchou et al., 2024). For example, Overmeer et al. (2016) compared the effect of neck-specific exercise with or without a cognitive behavioural therapy (CBT) approach, measuring changes in neck pain and disability and pain catastrophising in a cohort of people with whiplash associated disorders. The results showed that neck-specific exercise with CBT provided a more

Table 3
Overall certainty of evidence - Predictors of neck disability after neck-specific exercise interventions.

Baseline feature for predicting post-exercise disability	Number of participants	Number of studies	Phase	GRADE factors Study limitations	inconsistency	indirectness	imprecision	publication bias	Moderate/large effect size	Exposure-response gradient	Overall certainty
Catastrophising[a]	162	1	1	–	–	–	–	–	–	–	+
Disability	241	2	1	X	X	✓	✓	✓	X	NA	+
Pain	96	2	1	X	X	✓	✓	✓	X	NA	+
Age	258	3	1	X	X	✓	✓	✓	X	NA	+
Sex	258	3	1	X	X	✓	✓	✓	X	NA	+
Cervical movement velocity[a]	79	1	1	–	–	–	–	–	–	–	+
Cervical movement accuracy[a]	79	1	1	–	–	–	–	–	–	–	+

Phase means phase of investigation. For GRADE factors: ✓, no serious limitations; ×, serious limitations (or 'not present' for moderate/large effect size, dose effect); NA, unable to rate item based on available information. For overall certainty of evidence: + very low; ++ low; +++ moderate; ++++ high. Only predictors investigated in more than one study or which showed statistical significance in at least one study are included in the table.

[a] For feature that is only reported in one study, the overall certainty is graded very low because of lack of corroboration from multiple studies.

sustained reduction in pain catastrophising which lasted for 24 months, and this effect was 12 months longer than that of neck-specific exercise alone.

Our findings align with previous findings that sex and age may modulate and recovery dynamics. For example, women not only experience higher rates of neck pain (Palacios-Ceña et al., 2021) and have higher pain sensitivity (Pieretti et al., 2016) but may also face greater challenges in achieving sustained pain relief due to lower treatment responsiveness (Fillingim et al., 2009). With respect to age, factors such as the low load characteristics of the exercise programs investigated or perhaps the more favourable expectations of older adults may have contributed to improved outcomes (Collado-Mateo et al., 2021), although this is speculative.

When interpreting the findings for the GROC, prolonged chronicity of pain can be associated with detrimental long-term changes both physically and psychologically, which potentially reduces the response to neck-specific exercise interventions. Prolonged pain can lead to central sensitization and maladaptive cortical reorganization, which could reduce responsiveness to physical interventions (Nijs et al., 2019), together with elevated psychological distress, such as anxiety and depression, further compounding disability (Newcomer et al., 2010) and potentially impacting on treatment response. Furthermore, when pain persists, changes in muscle structure become more extensive (Hodges and Danneels, 2019). It is therefore postulated that these time-dependent physical and psychological changes, can result in a less favourable treatment outcomes to neck-specific exercises.

4.1. Strengths and limitations

This is the first systematic review exploring baseline predictors of pain and disability outcomes following neck-specific exercises in people with chronic neck pain. The methodology was robust with preregistration of the systematic review on PROSPERO and the use of QUIPS for risk of bias assessment and GRADE for assessment of the certainty of evidence. However, the certainty of evidence of the findings is limited as all features showing significant predictive association were investigated in only one study each, and all studies included have at least moderate risk of bias with limitations in reporting of attrition and adjustment with confounding factors.

4.2. Clinical and research implications

Clinically, these findings suggest that neck-specific exercise may be particularly effective in specific subgroups, including older males, individuals with shorter pain duration, and those exhibiting higher neck movement velocity but reduced accuracy. Such stratification aligns with the movement toward precision rehabilitation, where exercise prescriptions are individualized based on phenotypic and psychosocial profiles (Falla and Hodges, 2017; O'Sullivan et al., 2018).

To minimise risk of bias, it is suggested that the reporting of future research investigating the effects of neck-specific exercise should include the characteristics and reasons for participant dropouts to reduce attrition bias. Moreover, confounding factors should be included in the regression analysis and the results adjusted accordingly. Additionally, future work should investigate potential interaction effects between physical and psychological predictors to understand how combined profiles influence exercise responsiveness.

5. Conclusion

In summary, baseline characteristics such as older age, male sex, lower movement accuracy, higher movement velocity, shorter pain duration, and lower baseline disability may predict favourable outcomes following neck-specific exercises, while higher catastrophising may predict poorer disability outcomes. However, given the very low certainty of evidence, these results should be interpreted cautiously.

CRediT authorship contribution statement

Cho Wai Geoffrey Yu: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Ziyan Chen:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Edith Elgueta-Cancino:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis. **Janet Deane:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Valter Devecchi:** Writing – review & editing, Methodology, Investigation. **Deborah Falla:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

Study registration

PROSPERO (Registration number CRD42023408332)

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Given her role as Editor-in-Chief of Musculoskeletal Science and Practice, Deborah Falla had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another journal editor. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2025.103473.

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