



Predictors of response to spinal manipulative therapy, dry needling and exercise in patients with cervicogenic headache

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ABSTRACT

Background and purpose: Spinal manipulative therapy, dry needling, and exercise have been found to reduce pain and disability in individuals with cervicogenic headache (CGH). The purpose of this study was to quantify the impact of several baseline, anthropometric, demographic, and treatment-related factors on the likelihood that patients with CGH would experience a successful outcome following these interventions.

Methods: A secondary analysis of data from 142 patients with CGH that received upper cervical spinal manipulative therapy, dry needling, and exercise in a multi-center randomized controlled trial. The primary outcome was headache intensity as measured by the Numeric Pain Rating Scale. Binary logistic regression was performed to assess the impact of nine baseline factors and one treatment-related factor on the likelihood that patients with CGH would experience a successful outcome (i.e., $\geq 50\%$ improvement from baseline to 3 months).

Results: Only two of the independent variables made a unique statistically significant contribution to the model: sex ($P = 0.018$) and baseline headache intensity ($P = 0.003$). The strongest predictor of experiencing a successful outcome was sex (odds ratio: 3.906, 95% CI: 1.263, 12.195). The second significant predictor of experiencing a successful outcome was baseline headache intensity (odds ratio: 1.708, 95% CI: 1.203, 2.424). Chronicity of headache symptoms ($P = 0.296$), headache frequency ($P = 0.094$), age ($P = 0.981$), body mass index ($P = 0.101$), pretreatment medication levels ($P = 0.661$), headache duration ($P = 0.387$), disability ($P = 0.637$), and number of treatment sessions ($P = 0.455$) did not predict outcome.

Conclusions: In patients with cervicogenic headache that received spinal manipulative therapy, dry needling, and exercise, the strongest predictors of experiencing a successful outcome were male sex and baseline headache intensity.

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1. Introduction

The International Classification of Headache Disorders defines cervicogenic headache (CGH) as, “headache caused by a disorder of the cervical spine and its component bony, disc, and/or soft tissue elements, usually but not invariably accompanied by neck pain.” (The International Classification of Headache, 2013) The pooled frequency of CGH in adults evaluated for headaches in clinic has been estimated to be 3.1% with approximately 80% being female (Robinson et al., 2025). Upper cervical spinal manipulative therapy, dry needling, and exercise have each been found effective in the management of CGH (Dunning et al., 2016, 2021; Bini et al., 2022; Xu and Ling, 2025; Koonalinthip et al., 2026; Jung et al., 2024). Furthermore, a recent systematic review and meta-analysis that included 41 randomized controlled trials involving 1922 patients concluded that spinal manipulative therapy combined with dry needling was the highest-ranked intervention for short-term (4-12 weeks) reductions in headache intensity and frequency for patients with CGH (Koonalinthip et al., 2026).

Several prior trials have investigated whether certain baseline patient characteristics can help identify which patients with CGH are more likely to respond to conservative interventions. A secondary analysis of a randomized controlled trial of 141 patients with CGH found that sex, absence of light headedness, and headache intensity were the strongest predictors of success at following manipulation/mobilization and exercise interventions (Jull and Stanton, 2005). In a retrospective chart review of 44 patients with CGH, increased patient age, provocation or relief of headache with movement, and gainful employment were all baseline patient characteristics that were found predictive of improved outcomes following spinal manipulation/mobilisation and exercise interventions (Fleming et al., 2007). In a retrospective cohort study of 82 patients with CGH, higher depression scores, limited cervical range of motion, and multiple prior treatments (>5), were identified as significant prognostic indicators of unresponsiveness to greater/third occipital nerve block treatments (Li et al., 2025).

In patients with CGH, the numeric pain rating scale (NPRS) and neck disability index (NDI) have been found to possess moderate and excellent reliability, respectively; furthermore, both instruments have exhibited adequate responsiveness and construct validity in this population (Young et al., 2019). Nevertheless, there still remains a paucity of evidence with respect to the prognostic value of baseline scores on these measures in patients with CGH, as well as other patient and demographic characteristics that may be able to predict the likelihood of a successful response to a particular intervention (Fleming et al., 2007; Li et al., 2025).

It remains unknown if baseline patient characteristics and treatment-related factors can identify which patients with CGH are more likely to experience a successful response following spinal manipulative therapy, dry needling, and exercise. Therefore, the purpose of this secondary analysis of a prior randomized controlled trial (Dunning et al., 2021) was to identify predictors of response to spinal manipulative therapy, dry needling, and exercise by quantifying the impact of several baseline, anthropometric, demographic, and treatment-related factors on the likelihood that patients with CGH ($n = 142$) would experience a successful outcome (i.e., $\geq 50\%$ improvement in the NPRS from baseline to 3 months) at the 3-month follow-up.

2. Methods

2.1. Overview of original trial

This study is a secondary analysis of a previously published randomized controlled trial of 142 patients with CGH (Dunning et al., 2021). The trial was a randomized, single-blinded, multi-center, parallel-group trial compared two treatment protocols for the management of CGH: thrust spinal manipulation and dry needling vs. nonthrust spinal mobilization and exercise (Dunning et al., 2021). For patients to

be eligible, they had to present with a diagnosis of CGH according to the revised diagnostic criteria (Sjaastad et al., 1998) developed by the Cervicogenic Headache International Study Group (CHISG). (Sjaastad et al., 1998; Sjaastad and Fredriksen, 2000; Vincent and Luna, 1999).

Between February 2015 and February 2018, 312 consecutive patients with CGH were screened for eligibility, of whom 142 patients were included from 10 different U.S. states. In the trial (Dunning et al., 2021), all patients received up to eight treatment sessions at a frequency of once or twice per week over a 4-week period. Both groups received an impairment-based manual therapy approach using either high-velocity low-amplitude thrust manipulation or nonthrust mobilization directed primarily to the upper cervical (C1-2) and upper thoracic (T1-2) articulations as described in the previous trial (Dunning et al., 2021). The nonthrust mobilization group also received a program of craniocervical flexion exercises (Falla et al., 2003, 2004; Jull, 2000) and peri-scapular progressive resistance exercises (Jull et al., 2002), whereas, the thrust spinal manipulation group received up to 8 sessions of electrical dry needling for 20-min durations at a frequency of 1-2 times per week for 4 weeks using a semistandardized protocol of 8-12 needles.

The primary outcome was headache intensity as measured by the Numeric Pain Rating Scale (NPRS). Secondary outcomes included headache frequency and duration, disability as measured by the Neck Disability Index (NDI), medication intake (the number of times the patient had taken prescription or over-the-counter analgesic or anti-inflammatory medication for their headaches during the past week), and the Global Rating of Change (GROC). The original trial (Dunning et al., 2021) that this secondary analysis is based upon was conducted following the Consolidated Standards of Reporting Trials (CONSORT) extension for pragmatic clinical trials (Zwarenstein et al., 2008). It was approved by the ethics committee at Universidad Rey Juan Carlos (URJC-DPTO 31-2014) and the previously published trial (Dunning et al., 2021) was prospectively registered. All participants signed an informed consent prior to their participation in the study.

2.2. Secondary analysis design

To identify and quantify predictors of response to spinal manipulative therapy, dry needling, and exercise in patients with CGH, the primary outcome (NPRS) was recoded into a dichotomous categorical variable with two groups: responders (treatment success, i.e., $\geq 50\%$ improvement in headache intensity as measured by the NPRS from baseline to 3 months) and non-responders (treatment failure, i.e., $< 50\%$ improvement headache intensity as measured by the NPRS from baseline to 3 months). Responders from both intervention groups were included in the analysis. Notably, although the International Headache Society has historically considered a $\geq 50\%$ reduction in headache frequency as a standard for defining a successful outcome, this benchmark was explicitly designed for controlled trials of preventive treatments for patients with migraine (primary headaches), not patients with CGH (secondary headaches) (Tassorelli et al., 2018). Furthermore, a $\geq 50\%$ improvement threshold in pain intensity was used to define a successful outcome because this standard benchmark has historically been recommended for chronic pain clinical trials and is considered to constitute a clinically meaningful response (Dworkin et al., 2008). Additionally, the diagnosis of CGH in the original trial (Dunning et al., 2021) was made according to the revised diagnostic criteria developed by the Cervicogenic Headache International Study Group (CHISG). (Sjaastad et al., 1998; Sjaastad and Fredriksen, 2000; Vincent and Luna, 1999).

In this analysis, we hypothesized that several baseline, anthropometric, demographic, and treatment-related factors may be associated with the response to treatment in patients with CGH. The following factors were included in the analysis: (1) age, (2) sex, (3) body mass index, (4) duration of headache symptoms, (5) baseline headache intensity, (6) baseline headache frequency, (7) baseline headache duration, (8) baseline medication intake, (9) baseline neck disability, and (10) number of completed treatment sessions in the initial 4-week

regimen.

2.3. Statistical analysis

Statistical analysis was performed using SPSS software, version 29.0 (Chicago, IL, USA). Univariable comparisons of baseline and treatment-related factors between the response and non-response groups were performed. Means, standard deviations, and 95% confidence intervals were calculated for the within-group change scores for the response and non-response groups. After recoding the primary outcome variable (NPRS) into a categorical variable with two groups (responders and non-responders), binary logistic regression was performed using a Forced Entry Method (i.e., all predictor variables were tested in one block to assess their predictive ability while controlling for the effects of other predictors in the model) to assess the impact of several baseline, anthropometric, demographic, and treatment-related factors on the likelihood that patients with CGH ($n = 142$) would experience a successful outcome following a standardized 4-week intervention of physical therapy (i.e., either spinal manipulation plus dry needling or spinal mobilization and exercise). Independent variables were classified as making a unique statistically significant contribution to the model if their respective P-value was $<.05$. The Hosmer and Lemeshow test was used to determine if the model fit the data. The Cox & Snell R-squared test and Nagelkerke R-squared test were used to quantify the percentage of the variance in the outcome status that is explained by the total model. In addition, a classification table with a probability threshold of .5 was used to calculate the sensitivity of the model in predicting those patients who experienced a successful outcome and the specificity of the model in predicting those who had an unsuccessful outcome.

3. Results

A total of 142 participants were analyzed, of whom 50 (35.2%) were classified as responders and 92 (64.8%) were classified as non-responders. Baseline characteristics and treatment-related factors for the response and non-response groups are shown in Table 1. Within-group means and change scores for responders and non-responders are shown in Table 2.

Binary logistic regression was performed to assess the impact of several baseline, anthropometric, demographic, and treatment-related factors on the likelihood that patients with CGH ($n = 142$) would experience a successful outcome (i.e., $\geq 50\%$ improvement in headache intensity as measured by the NPRS from baseline to 3 months) following a standardized 4-week intervention of either upper cervical and upper thoracic spinal manipulation plus electrical dry needling ($n = 74$) or upper cervical and upper thoracic spinal mobilization plus exercise ($n = 68$). The model contained 10 independent variables: age, sex, body mass index (BMI), duration of headache symptoms, baseline headache intensity, baseline headache frequency, baseline headache duration, baseline medication intake, baseline disability, and number of completed treatment sessions.

The full model containing all predictors was statistically significant ($X^2 = 43.236$; $P < 0.001$; $df = 10$; $n = 142$), indicating that the model was able to distinguish between patients who experienced a successful outcome and those who did not. The total model explained between 26.2% (Cox and Snell R-squared) and 36.1% (Nagelkerke R-squared) of the variance in outcome status and correctly classified 71.8% of cases. Furthermore, the model was a good fit (Hosmer and Lemeshow, $X^2 = 5.801$, $df = 8$, $P = 0.670$). The sensitivity of the model in predicting those patients who experienced a successful outcome was 85.9%; however, the specificity in predicting those who had an unsuccessful outcome was 46.0%.

As shown in Table 3, only two of the independent variables made a unique statistically significant contribution to the model: sex ($P = 0.018$) and baseline headache intensity ($P = 0.003$). The strongest predictor of experiencing a successful outcome was sex, recording an

Table 1

Baseline characteristics and treatment-related factors.

Baseline Variable	All ($n = 142$)	Response group ($n = 50$)	Non-response group ($n = 92$)
Gender (male/ female)	33/109	15/35	18/74
Age (years)	40.2 $\pm$ 13.6	40.5 $\pm$ 13.7	39.9 $\pm$ 13.7
Body Mass Index (kg/ m ²)	25.6 $\pm$ 3.9	24.7 $\pm$ 3.5	26.0 $\pm$ 4.1
Duration of symptoms (years)	4.5 $\pm$ 5.4	4.8 $\pm$ 6.5	4.3 $\pm$ 4.8
Medication intake n (%)			
Not at all	11 (7.7%)	0 (0.0%)	11 (12.0%)
Once a week	18 (12.7%)	6 (12.0%)	12 (13.0%)
Once every couple of days	46 (32.4%)	18 (36.0%)	28 (30.4%)
Once or twice a day	51 (35.9%)	20 (40.0%)	31 (33.7%)
Three or more times a day	16 (11.3%)	6 (12.0%)	10 (10.9%)
Number of treatment sessions	7.3 $\pm$ 1.2	7.5 $\pm$ 1.2	7.2 $\pm$ 1.2
Headache intensity (NPRS, 0-10)	6.1 $\pm$ 1.6	6.7 $\pm$ 1.1	5.8 $\pm$ 1.7
Disability (NDI, 0-50)	21.1 $\pm$ 8.6	23.1 $\pm$ 8.4	19.9 $\pm$ 8.6
Headache frequency (0-7 days)	4.6 $\pm$ 1.7	5.1 $\pm$ 1.7	4.4 $\pm$ 1.7
Headache duration n (%)			
0-5 h	7 (4.9%)	2 (4.0%)	5 (5.4%)
6-10 h	23 (16.2%)	4 (8.0%)	19 (20.7%)
11-15 h	28 (19.7%)	15 (30.0%)	13 (14.1%)
16-20 h	31 (21.8%)	11 (22.0%)	20 (21.7%)
21-25 h	23 (16.2%)	9 (18.0%)	14 (15.2%)
26 or more hours	30 (21.1%)	9 (18.0%)	21 (22.8%)

Data are mean (SD) except for gender and medication intake. NPRS= Numeric Pain Rating Scale, 0-10, lower scores indicate less pain; NDI= Neck Disability Index, 0-50, lower scores indicate greater function; Headache frequency= number of headache days in the last week, 0-7, higher scores indicate worsening; Headache duration= total headache hours in the last week, higher scores indicate worsening; Medication intake= the number of times the patient had taken prescription or over-the-counter analgesic or anti-inflammatory medication in the past week for their headaches.

Table 2

Within-group mean and change scores for responders and non-responders.

Outcome	Timeline Scores: Mean $\pm$ SD (95% CI)	
	Within-Group Change Scores: Mean (95% CI)	
	Response group ($n = 50$)	Non-response group ($n = 92$)
Numeric Pain Rating Scale – Headache Intensity (0-10)		
Baseline	6.7 $\pm$ 1.1 (6.4, 7.1)	5.8 $\pm$ 1.7 (5.4, 6.1)
1 week	4.2 $\pm$ 2.1 (3.6, 4.8)	4.7 $\pm$ 2.0 (4.3, 5.1)
Change baseline $\rightarrow$ 1 week	-2.6 (-3.1, -2.0)	-1.1 (-1.4, -0.7); $P < 0.001$
4 weeks	1.9 $\pm$ 1.7 (1.4, 2.4)	3.6 $\pm$ 2.0 (3.2, 4.1)
Change baseline $\rightarrow$ 4 weeks	-4.8 (-5.4, -4.2)	-2.1 (-2.5, -1.8); $P < 0.001$
3 months	0.8 $\pm$ 1.0 (0.5, 1.0)	3.6 $\pm$ 2.0 (3.2, 4.0)
Change baseline $\rightarrow$ 3 months	-6.0 (-6.3, -5.7)	-2.2 (-2.5, -1.8); $P < 0.001$

Headache intensity as measured by the Numeric Pain Rating Scale (NPRS), 0-10, lower scores indicate less pain.

odds ratio of 3.906 (95% CI: 1.263, 12.195); that is, males with CGH were almost 4 times more likely to achieve a successful outcome at 3 months than females with CGH. The second significant predictor of experiencing a successful outcome was baseline headache intensity, with an odds ratio of 1.708 (95% CI: 1.203, 2.424). That is, for every 1-point increase in baseline headache intensity on the NPRS (0-10), patients with CGH were 1.7 times more likely to achieve a successful outcome at 3 months.

Table 3

Binary logistic regression for predicting the likelihood of a successful outcome (i.e., $\geq 50\%$ improvement in headache intensity from baseline to 3 months) in patients with cervicogenic headache ($n = 142$) receiving spinal manipulation, perineural electrical dry needling, and exercise.

Predictor of response (independent variable)	B	S.E.	Wald	P-value	Exp(B) Odds Ratio	95% C.I. for Odds Ratio
Gender (male/female)	1.364	.577	5.589	.018	3.906	1.263 12.195
Age (years)	.000	.017	.001	.981	1.000	.968 1.034
BMI (kg/m^2)	-.104	.063	2.688	.101	.902	.797 1.020
Duration of headache symptoms (years)	.044	.042	1.093	.296	1.045	.962 1.135
Baseline headache intensity (NPRS, 0-10)	.535	.179	8.978	.003	1.708	1.203 2.424
Baseline headache frequency (0-7 days)	.269	.161	2.797	.094	1.308	.955 1.792
Baseline headache duration (hours)	-.130	.151	.747	.387	.878	.653 1.180
Baseline medication intake	.098	.223	.193	.661	1.103	.713 1.706
Baseline disability (NDI, 0-50)	.014	.030	.223	.637	1.014	.957 1.075
Number of treatment sessions	.136	.182	.559	.455	1.146	.802 1.636

NPRS= Numeric Pain Rating Scale, 0-10, lower scores indicate less headache pain intensity; NDI= Neck Disability Index, 0-50, lower scores indicate greater function; Headache frequency = number of headache days in the last week, 0-7, higher scores indicate worsening; Headache duration = total headache hours in the last week, higher scores indicate worsening; Medication intake = the number of times the patient had taken prescription or over-the-counter analgesic or anti-inflammatory medication in the past week for their headaches; BMI = body mass index, kg/m^2 , higher numbers indicate greater body fat or excess weight for height; B = *b*-weight or log-odds coefficient, the change in the log odds associated with a one-unit change in the independent variable with the other variables held constant; SE = standard error; Wald = Wald statistic following the Wald chi-squared test of significance to confirm whether each independent variable in the model is significant or not; df = degrees of freedom; P-value = indicates level of significance; Exp(B) = the exponential value of B or odds ratio, the predicted change in odds for a unit increase in the predictor; CI = confidence interval.

Of the 10 independent variables, headache frequency recorded the third largest odds ratio (OR: 1.308; 95% CI: .955, 1.792); nevertheless, it failed to make a significant contribution ($P = 0.094$) to the model. Likewise, age ($P = 0.981$), BMI ($P = 0.101$), baseline medication intake ($P = 0.661$), baseline headache duration ($P = 0.387$), baseline disability ($P = 0.637$), length of history with headache symptoms ($P = 0.296$), and number of treatment sessions ($P = 0.455$) did not predict outcome.

4. Discussion

In the current study, the strongest predictors of experiencing a successful outcome in individuals with CGH were baseline headache intensity and male sex. In individuals with CGH, patient characteristics including age, chronicity of headache symptoms, pretreatment medication levels, baseline headache frequency, BMI, baseline headache duration, baseline disability, and the number of treatment sessions did not make a significant or meaningful contribution to predicting treatment response to spinal manipulative therapy, dry needling, and exercise.

4.1. Sex and baseline headache intensity

In the present study, males represented 23.2% (33 out of 142 subjects) of the sample; however, 30.0% of those who experienced a successful outcome (i.e., 15 of 50 subjects) were male versus 19.6% of those who experienced an unsuccessful outcome (i.e., 18 of 92 subjects) were male. More specifically, males had a better odds than females (OR: 3.906; 95% CI: 1.263, 12.195) of experiencing a successful outcome following treatment with spinal manipulative therapy, dry needling, and exercise. Nevertheless, given that only 33 of the 142 patients in the trial were male and the wide confidence interval for the odds ratio with the lower bound approximating the value of 1, sex as a meaningful predictor of response to treatment in patients with CGH should be interpreted cautiously. Notwithstanding, Jull and Stanton reported females had better odds (OR = 6.19) of experiencing a successful response (i.e., 80-100% reduction in headache frequency) following manual therapy and exercise at the 1-year follow-up (Jull and Stanton, 2005); however, Flemming et al. found sex was not a predictor of success for headache pain, frequency, or function (Fleming et al., 2007). The disparity between studies regarding the predictive value of sex on outcome in patients with CGH may be multidimensional; that is, in lieu of sex-specific physiology, baseline outcome floor/ceiling effects, biopsychosocial factors, and/or treatment preference may be contributing factors.

Similar to the findings of our study, Jull and Stanton (2005) found

baseline pain intensity played a role in predicting outcome of patients with CGH that received manual therapy and exercise. More specifically, Jull and Stanton found higher baseline headache intensity resulted in significantly better odds of having a 80-100% reduction in headache frequency at the short term follow-up (7 weeks) (Jull and Stanton, 2005). Furthermore, higher baseline pain intensity during palpation of the upper cervical articulations provided a higher odds ratio for success (OR = 2.45) at 1-year (Jull and Stanton, 2005).

4.2. Age and chronicity of symptoms

Unlike the prognosis and trajectories of many other chronic musculoskeletal pain conditions (Aili et al., 2021; Burgess et al., 2020; Mallen et al., 2007; Green et al., 2018), in the present study, age and chronicity of symptoms were not predictors of outcome in patients with CGH receiving physical therapy interventions. More specifically, for practicing clinicians and potential patients considering interventions for CGH, age and duration of symptoms that did not make the regression model as significant predictors of outcome. That is, based on the results of the binary logistic regression model of this secondary analysis, since length of history with headache symptoms and age are not predictors of response, and all other predictive variables in the model being held constant, it is likely that a 50-year-old patient presenting with a 30-year history of CGH has a similar chance of a successful response to upper cervical spinal manipulation, perineural electrical dry needling, and/or exercise for CGH as a 20-year-old patient with a 1-year history of CGH.

Similar to the findings of Jull and Stanton (2005), the current study did not find age to be a predictor of responsiveness to physiotherapy management of CGH; however, in contrast to the findings of the current study, one prior study found older age to significantly predict a poor response to treatment in relation to physical function, headache intensity, and headache frequency (Fleming et al., 2007). Nevertheless, in that analysis, the sample was small ($n = 44$), with a mean age of 49 years, and without a specific age range for further discussion.

4.3. Disability, headache duration, and headache frequency

The current analysis did not find baseline disability or headache duration to be significant predictors of outcome, which is consistent with prior analyses (Fleming et al., 2007; Li et al., 2025). However, higher baseline disability scores on the Northwick Park Neck Pain Questionnaire (NPQ) have previously been found to significantly lower the odds of success (i.e., 80-100% reduction in headache frequency at 7 weeks) (Jull and Stanton, 2005). Notably, baseline headache duration

and headache frequency were not predictors of response in the present study, and this appears to agree with prior studies (Jull and Stanton, 2005; Fleming et al., 2007; Li et al., 2025).

4.4. Number of completed treatment sessions

The goal of prognostic studies is to “forecast future outcomes, not identify what causes the outcomes” (Kamper, 2026); therefore, given the design and statistical methods employed in the present study, we cannot be certain why the number of completed treatment sessions in the initial 4-week regimen did not predict outcome in patients with CGH receiving spinal manipulative therapy, dry needling, and exercise. Nevertheless, the mean number of completed treatment sessions for the 50 responders (7.5, SD 1.2) was not significantly different ($P = 0.157$) from the 92 non-responders (7.2, SD 1.2); that is, this small between-group difference (i.e., 0.3 treatment sessions) likely has little clinical impact on the primary outcome at 3 months. Moreover, this may in part explain why the number of completed treatment sessions ($P = 0.455$) did not predict outcome in the present study.

4.5. Limitations

The purpose of this secondary analysis was not to evaluate treatment effectiveness of one intervention compared with another, but rather to identify and quantify predictors of outcome in patients with CGH receiving physical therapy interventions. Therefore, we included all responders (i.e., $\geq 50\%$ improvement in the primary outcome from baseline to endpoint) irrespective of group assignment within the binary logistic regression model. Notably, several prior secondary analyses of randomized clinical trials with chronic musculoskeletal pain conditions have pooled responders from two or more active treatment arms in the regression model to more robustly quantify predictors of outcome (Jull and Stanton, 2005; Cao et al., 2024; Zieger et al., 2022; Wright et al., 2011); nevertheless, this may be viewed as a design limitation to the statistical analysis employed in the present study.

5. Conclusion

In patients with CGH, the strongest predictors of experiencing a successful outcome were male sex and baseline headache intensity. Chronicity of headache symptoms, age, pretreatment medication levels, baseline headache frequency, BMI, baseline headache duration, baseline disability, and the number of completed treatment sessions were not predictive of outcome following treatment with spinal manipulative therapy, exercise and dry needling.

CRedit authorship contribution statement

James Dunning: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ian Young:** Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Joshua Prall:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Firas Mourad:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Paul Bliton:** Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Roger Kerry:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **James Escaloni:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Filippo Maselli:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **César Fernández-de-las-Peñas:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Formal

analysis, Conceptualization.

Trial registration

The trial was prospectively registered at ClinicalTrials.gov: NCT02373605. <https://clinicaltrials.gov/study/NCT02373605>.

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Declaration of competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: James Dunning, PhD, DPT, MSc reports a relationship with American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy that includes: employment. J.D. is the director of the American Academy of Manipulative Therapy Fellowship in Orthopaedic Manual Physical Therapy. The American Academy of Manipulative Therapy is an accredited post-doctoral fellowship program that provides postgraduate training in musculoskeletal sonography, vestibular rehabilitation, spinal manipulation/mobilisation, dry needling, extremity manipulation/mobilisation, exercise prescription, and differential diagnosis to licensed physical therapists and medical physicians. J.D., I. Y., J.P., P.B., and J.E. are senior faculty of the American Academy of Manipulative Therapy Fellowship. The other authors declare that they have no competing interests. None of the authors received any funding for this study. 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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References

- Aili, K., Campbell, P., Michaleff, Z.A., et al., 2021. Long-term trajectories of chronic musculoskeletal pain: a 21-year prospective cohort latent class analysis. *Pain* 162 (5), 1511–1520. <https://doi.org/10.1097/j.pain.0000000000002137>.
- Bini, P., Hohenschurz-Schmidt, D., Masullo, V., Pitt, D., Draper-Rodi, J., 2022. The effectiveness of manual and exercise therapy on headache intensity and frequency among patients with cervicogenic headache: a systematic review and meta-analysis. *Chiropr. Man. Ther.* 30 (1), 49. <https://doi.org/10.1186/s12998-022-00459-9>.
- Burgess, R., Mansell, G., Bishop, A., Lewis, M., Hill, J., 2020. Predictors of functional outcome in musculoskeletal healthcare: an umbrella review. *Eur. J. Pain* 24 (1), 51–70. <https://doi.org/10.1002/ejp.1483>.
- Cao, W., Wang, L., Hou, T.H., et al., 2024. Disease-related factors associated with acupuncture response in patients with chronic tension-type headache: a secondary analysis of A randomized controlled trial. *Chin. J. Integr. Med.* 30 (8), 684–691. <https://doi.org/10.1007/s11655-023-3615-2>.
- Dunning, J., Butts, R., Zacharko, N., et al., 2021. Spinal manipulation and perineural electrical dry needling in patients with cervicogenic headache: a multicenter randomized clinical trial. *Spine J.* 21 (2), 284–295. <https://doi.org/10.1016/j.spinee.2020.10.008>.
- Dunning, J.R., Butts, R., Mourad, F., et al., 2016. Upper cervical and upper thoracic manipulation versus mobilization and exercise in patients with cervicogenic headache: a multi-center randomized clinical trial. *BMC Musculoskelet. Disord.* 17, 64. <https://doi.org/10.1186/s12891-016-0912-3>.
- Dworkin, R.H., Turk, D.C., Wyrwich, K.W., et al., 2008. Interpreting the clinical importance of treatment outcomes in chronic pain clinical trials: IMMPACT recommendations. *J. Pain* 9 (2), 105–121. <https://doi.org/10.1016/j.jpain.2007.09.005>.
- Falla, D., Bilenkij, G., Jull, G., 2004. Patients with chronic neck pain demonstrate altered patterns of muscle activation during performance of a functional upper limb task. *Comparative Study Research Support, Non-U.S. Gov't. Spine (Phila Pa 1976)* 29 (13), 1436–1440.
- Falla, D., Jull, G., Dall'Alba, P., Rainoldi, A., Merletti, R., 2003. An electromyographic analysis of the deep cervical flexor muscles in performance of craniocervical flexion. *Research Support, Non-U.S. gov't. Phys. Ther.* 83 (10), 899–906.
- Fleming, R., Forsythe, S., Cook, C., 2007. Influential variables associated with outcomes in patients with cervicogenic headache. *J. Man. Manip. Ther.* 15 (3), 155–164. <https://doi.org/10.1179/106698107790819846>.

- Green, D.J., Lewis, M., Mansell, G., et al., 2018. Clinical course and prognostic factors across different musculoskeletal pain sites: a secondary analysis of individual patient data from randomised clinical trials. *Eur. J. Pain* 22 (6), 1057–1070. <https://doi.org/10.1002/ejp.1190>.
- Jull, G., 2000. Deep cervical flexor muscle dysfunction in whiplash. *J. Musculoskel. Pain* 8, 143–154.
- Jull, G., Trott, P., Potter, H., et al., 2002. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. *Clinical Trial Multicenter Study Randomized Controlled Trial Research Support, Non-U.S. Gov't. Spine (Phila Pa 1976)* 27 (17), 1835–1843. ; discussion 1843.
- Jull, G.A., Stanton, W.R., 2005. Predictors of responsiveness to physiotherapy management of cervicogenic headache. *Cephalalgia* 25 (2), 101–108. <https://doi.org/10.1111/j.1468-2982.2004.00811.x>.
- Jung, A., Carvalho, G.F., Szikszay, T.M., Pawlowsky, V., Gabler, T., Luedtke, K., 2024. Physical therapist interventions to reduce headache intensity, frequency, and duration in patients with cervicogenic headache: a systematic review and network meta-analysis. *Phys. Ther.* (2), 104. <https://doi.org/10.1093/ptj/pzad154>.
- Kamper, S.J., 2026. Evidence in practice - Prognosis and prediction. *J. Orthop. Sports Phys. Ther.* 56 (8), 563–565. <https://doi.org/10.2519/jospt.2026.0701>.
- Koonalintip, N., Koonalintip, P., Stonsaovapak, C., 2026. The comparative efficacy of treatments for cervicogenic headache: a systematic review and network meta-analysis of randomised controlled trials. *Eur. J. Pain* 30 (2), e70219. <https://doi.org/10.1002/ejp.70219>.
- Li, J., Wu, B., Wang, X., et al., 2025. Clinical features, risk factors, and a nomogram for predicting refractory cervicogenic headache: a retrospective multivariate analysis. *Front. Neurol.* 16, 1531180. <https://doi.org/10.3389/fneur.2025.1531180>.
- Mallen, C.D., Peat, G., Thomas, E., Dunn, K.M., Croft, P.R., 2007. Prognostic factors for musculoskeletal pain in primary care: a systematic review. *Br. J. Gen. Pract.* 57 (541), 655–661.
- Robinson, C.L., Christensen, R.H., Al-Khazali, H.M., et al., 2025. Prevalence and relative frequency of cervicogenic headache in population- and clinic-based studies: a systematic review and meta-analysis. *Cephalalgia* 45 (3), 03331024251322446. <https://doi.org/10.1177/03331024251322446>.
- Sjaastad, O., Fredriksen, T.A., 2000. Cervicogenic headache: criteria, classification and epidemiology. *Review. Clin. Exp. Rheumatol.* 18 (2 Suppl. 19), S3–S6.
- Sjaastad, O., Fredriksen, T.A., Pfaffenrath, V., 1998. Cervicogenic headache: diagnostic criteria. The cervicogenic headache international study group. *Headache* 38 (6), 442–445.
- Tassorelli, C., Diener, H.C., Dodick, D.W., et al., 2018. Guidelines of the International Headache Society for controlled trials of preventive treatment of chronic migraine in adults. *Cephalalgia* 38 (5), 815–832. <https://doi.org/10.1177/0333102418758283>.
- The international classification of headache disorders: 3rd edition. *Cephalalgia* 33 (9), 2013, 629–808.
- Vincent, M.B., Luna, R.A., 1999. Cervicogenic headache: a comparison with migraine and tension-type headache. *Comparative study. Cephalalgia* 19 (Suppl. 25), 11–16.
- Wright, A.A., Cook, C.E., Flynn, T.W., Baxter, G.D., Abbott, J.H., 2011. Predictors of response to physical therapy intervention in patients with primary hip osteoarthritis. *Phys. Ther.* 91 (4), 510–524. <https://doi.org/10.2522/ptj.20100171>.
- Xu, X., Ling, Y., 2025. Comparative safety and efficacy of manual therapy interventions for cervicogenic headache: a systematic review and network meta-analysis. *Front. Neurol.* 16, 1566764. <https://doi.org/10.3389/fneur.2025.1566764>.
- Young, I.A., Dunning, J., Butts, R., Cleland, J.A., Fernandez-de-Las-Penas, C., 2019. Psychometric properties of the numeric pain rating scale and neck disability index in patients with cervicogenic headache. *Cephalalgia* 39 (1), 44–51. <https://doi.org/10.1177/0333102418772584>.
- Zieger, A., Kern, A., Barth, J., Witt, C.M., 2022. Do patients' pre-treatment expectations about acupuncture effectiveness predict treatment outcome in patients with chronic low back pain? A secondary analysis of data from a randomised controlled clinical trial. *PLoS One* 17 (5), e0268646. <https://doi.org/10.1371/journal.pone.0268646>.
- Zwarenstein, M., Treweek, S., Gagnier, J.J., et al., 2008. Improving the reporting of pragmatic trials: an extension of the CONSORT statement. *Br. Med. J.* 337, a2390. <https://doi.org/10.1136/bmj.a2390>.