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Effects of isometric training on the treatment of patients with neck pain

A meta-analysis

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Abstract

Background: The aim of this meta-analysis was to evaluate the effects of isometric training interventions on the treatment of patients with neck pain.

Methods: Electronic databases, including PubMed, The Cochrane Library, Web of Science, etc., were retrieved and screened by computer, and 18 articles with a total of 868 samples were included. Review Manager 5.4 software was used for the meta-analysis.

Results: The meta-analysis results showed that isometric training can reduce visual analogue scale scores of patients[weighted mean difference (95% confidence interval) = -0.80(-0.88, -0.73), $P < .00001$]; decrease patients neck disability index score, isometric training was better than the control group [weighted mean difference (95% confidence interval) = 5.55 (4.57, 6.53), $P < .0001$]; in improving patients' motion of the sagittal plane [weighted mean difference (95% confidence interval) = 1.53 (-0.40, 3.63), $P = .12$], coronal plane [weighted mean difference (95% confidence interval) = 2.12 (0.56, 3.68), $P = .008$], horizontal plane [weighted mean difference (95% confidence interval) = 3.58 (1.56, 5.59), $P = .0005$], isometric training was superior to the control group. More than 20 isometric training interventions had more significant effects on visual analogue scale and range of motion. And isometric training for more than 8 weeks had more significant effects on the visual analogue scale and neck disability index scores.

Conclusion: Isometric training has significant effects on relieving neck pain, improving neck dysfunction, and improving joint mobility. However, the two indicators of visual analogue scale and neck disability index had more influential factors; the sample size of most studies was relatively small, and the intervention measures in the control group were relatively simple. It is expected that more abundant research will expand and deepen in the future, laying the foundation for meta-analysis.

Abbreviations: CI = confidence interval, NDI = neck disability index, RCT = randomized controlled trial, ROM = range of motion, WMD = weighted mean difference, VAS = visual analogue scale.

Keywords: dysfunction, isometric training, meta-analysis, neck pain, randomized controlled trial, range of motion

1. Introduction

Neck pain is a common symptom affecting people in their daily lives.[1] Due to their unhealthy lifestyle, stress, and poor posture in work and study, people are in a posture with their heads bent forward and their heads bowed at their desks, which causes relaxation and strain of the neck muscle and ligament, cervical spine stability disorder, cervical nerve compression, slow blood flow, and carotid artery stimulation. Patients with severe disease will suffer from cervical degeneration, developmental cervical spinal stenosis, and other symptoms, which will affect their study and work.[2,3] According to statistics, the incidence of neck pain disease is about 71%,[4] and unhealthy ways such as long-term sitting at the desk have become increasingly common. The disease is growing rapidly and tends to be younger.[5] Therefore, the positive impact of exercise on health and its important role in disease prevention are gradually gaining importance.[6,7]

Studies have shown that neck pain is closely related to lesions in the musculature around the cervical spine. Numerous studies and guidelines have confirmed the efficacy of exercise therapy for improving neck pain.[8] Compared with passive therapies such as acupuncture and massage, it has long-term effects and low recurrence rates.[9] Isometric training refers to increasing muscle tension to fight against a fixed resistance exercise, and is simple, safe, noninvasive, time-saving, and effective.[10] Neck isometric training improves the strength of neck muscles and the tension of surrounding soft tissues through slight or no

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

This study is a secondary collection of data, therefore doesn't require ethical approval.

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movement of the cones and enhances the stability of the core muscles and the whole neck of the patients, thereby improving cervical dysfunction.[11]

Therefore, this study will systematically evaluate the effects of randomized controlled trials (RCT) collected on isometric training in the treatment of neck pain through a meta-analysis to provide a reference for the selection of appropriate treatment options for patients with neck pain in clinical practice.

2. Data resource and methods

Document inclusion, exclusion, retrieval, and screening criteria were developed in accordance with the PRISMA statement.[12]

2.1. Literature inclusion criteria

1) The study type was a RCT.
2) This study was conducted in a population of patients aged ≥ 18 years with neck pain symptoms.
3) The experimental group used isometric exercises for training intervention, whereas the control group used non-isometric exercises or no training intervention. (blank controls).
4) Outcome indicators included one of the following:

VAS
NDI
ROM

2.2. Literature exclusion criteria

1) Articles of meta, systematic evaluation and reviews;
2) Full text of articles not available;
3) Zoopery;
4) Literature that did not match the research content;
5) Repetitive literature.

2.3. Literature retrieval strategy

Relevant literature that met the inclusion and exclusion criteria of this study were searched through a computer in the electronic databases of PubMed, The Cochrane Library, Web of Science, Embase, CNKI, WanFang Data, CBM, and VIP, with the retrieval time from the database established to February 2022.

The search terms were “Neck Pain”, “Neck Pains”, “Neck Ache”, “Isometric contraction”, “Contraction, Isometric”, “Isometric Contractions”, “randomized controlled trial”, “RCT”, “randomized controlled trial,” and so on.

2.4. Literature screening and data extraction

The researchers screened the literature independently and in a double-blinded manner. Literature was extracted according to the literature search and the inclusion and exclusion criteria. The author information, publication year, country, sample size, sex, intervention measures, intervention content, data before and after intervention, and sample size were checked, and those with consistent results were included in the study.

2.5. Risk of bias assessment of the included literature

The risk of bias assessment was carried out according to the requirements of the Cochrane guidelines for systematic evaluation,[7] which has three evaluation results, namely “yes (low risk) ”, “no (high risk) ”, “unclear (unclear bias situation) ”, and its total points are 6, meaning that the risk of bias is discussed from six aspects. Higher scores indicated lower risk and higher quality. High quality: total score ≥ 5; medium quality:3 ≤ total score ≤ 5; low quality: total score ≤ 2.

2.6. Statistical method

Meta-analysis of the data was performed using Review Manager software (RevMan v. 5.4.1) in this study. The outcome index of this study was a continuous variable, and the combined effect size was expressed by the WMD, with a 95%CI, $P < .05$, indicating statistical significance. Heterogeneity was assessed using the X^2 and I^2 tests. When the heterogeneity was small ($P < .1$, $I^2 < 50\%$), the fixed-effects model was used; if the heterogeneity was large ($P > .1$, $I^2 > 50\%$), the random-effects model was used, and the heterogeneity source was analyzed by sensitivity analysis and meta-regression. According to the reference standard of effect size proposed by Cohen, the absolute value of the effect size less than or equal to 0.2 is a small effect; 0.2 to 0.8 is a medium effect; and greater than or equal to 0.8 is a large effect.[13] Risk of publication bias was assessed by using an adjusted comparison funnel plot.

3. Results

3.1. Literature screening results

Using the established search strategy, 211 related articles were identified. A total of 98 documents were included after screening repeated literature using EndNote X9 literature management software, and after reading the titles, abstracts, and full texts by two researchers (YJQ & YM). Finally, 18 articles were included after screening based on the intervention measures, outcome variables, experimental design, and research content by two researchers (YJQ & YM) (as shown in Fig. 1).

3.2. Basic characteristics of the included literature

Basic characteristics of the included literature as shown in Table 1.

3.3. Quality assessment of included literature

The quality of the included studies was assessed according to Cochrane version 5.1.08, and the assessment results are shown in Figures 2 and 3.

3.4. Meta-analytic results

3.4.1. Effect of isometric training on the visual analog scale in patients with neck pain. 16 studies used the VAS to assess the severity of neck pain in patients.[14,16,18–31] There was no obvious heterogeneity among the included studies (X^2=22.78, $P = .09$, I^2=34%), and it was analyzed using a fixed-effects model. The results of meta-analysis showed that isometric training can improve neck pain in patients [*WMD* (95%*CI*) = -0.81 (-0.88,-0.73), $P < .00001$], as shown in Figure 4.

To further prove the robustness of the results, meta-regression analysis was performed in terms of publication year, intervention time, intervention frequency, average age, sample size, and article quality. To avoid false-positive results, at least ten studies were included for each covariate. Therefore, a univariate meta-regression analysis was used to demonstrate the robustness of the results. As shown in Table 2, the publication year, intervention time, intervention frequency, average age, sample size, and article quality ($P > .05$) indicate that the results are relatively robust and statistically significant.

The 16 studies were divided into two subgroups according to the total frequency of interventions. Among them, 7

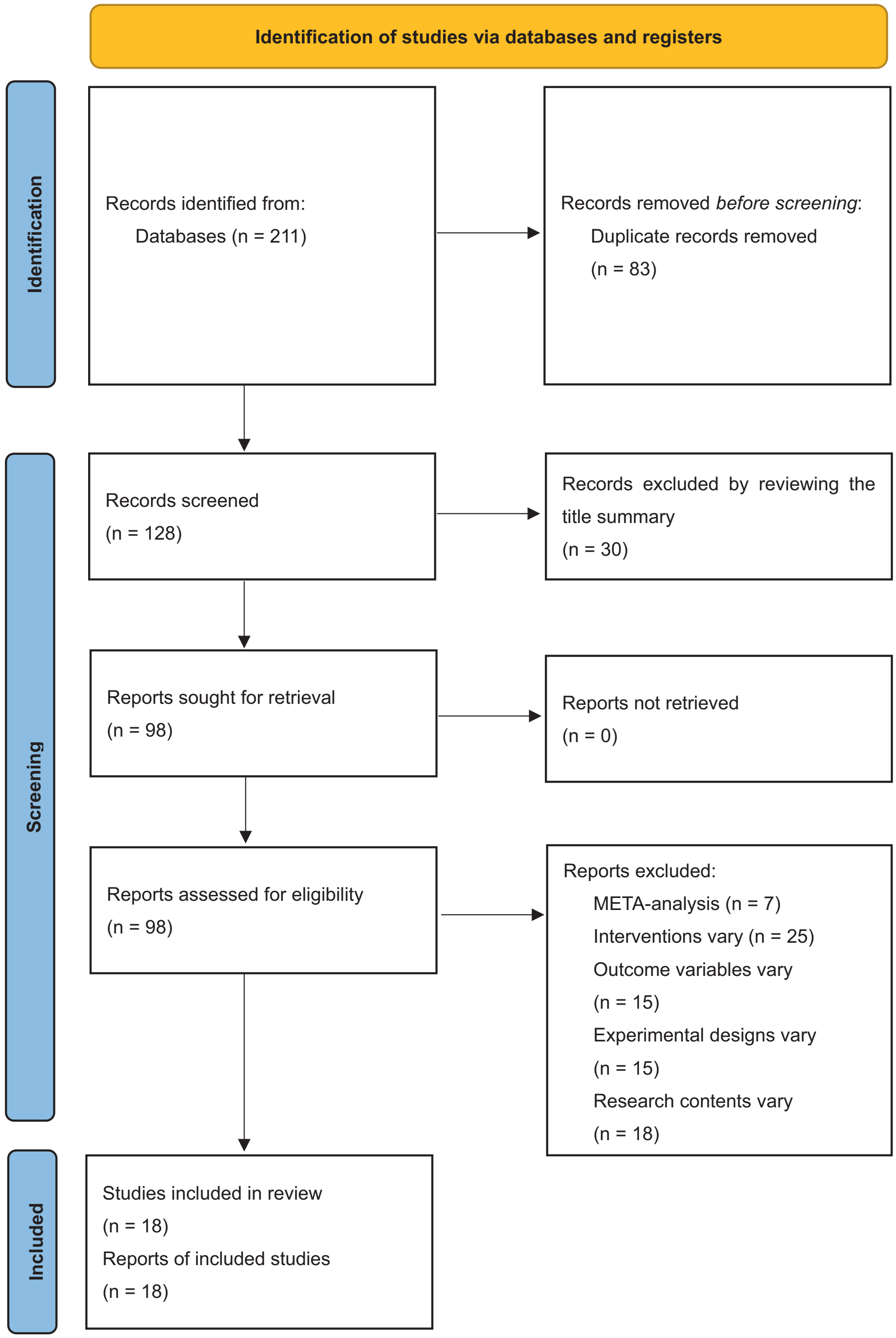

Figure 1. Literature screening process.

studies[18,19,21,22,28–30] had more than 20 isometric training interventions, with a sample size of 1223 cases, including 629 cases in the experimental group and 594 cases in the control group. There was no significant heterogeneity among the included studies (X^2=9.10, P = .10, I^2=40%). Analyzed by the fixed-effects model, the two groups were statistically significant [WMD = -0.79, 95%CI (-0.88, -0.70), P < .001]. The frequency of isometric training interventions in nine studies[14,17,20,23–27,31] was less than 20, with a sample size of 558 cases, including 277 cases in the experimental group and 281 cases in the control group. There was no significant heterogeneity between the included studies (X^2=13.39, P = .10, I^2=40%). Analyzed using the fixed-effects model, the results showed that the difference between the two groups was statistically significant [WMD = -0.84, 95%CI (-0.97, -0.71), P < .001], as shown in Figure 5.

This study divided the 16 studies into 2 subgroups according to the total intervention period. Among them, six studies[18,19,21,28,29] had an isometric training intervention period of more than eight weeks, with a sample size of 1133 cases, including 584 cases in the experimental group and 549 cases in the control group. There was no significant heterogeneity among the included studies (X^2=1.99, P = .85, I^2=0%), Analyzed by fixed effects model, the results showed that the two groups

Table 1

Basic characteristics of the included literature.

Author (yr)	Area	Sample size (T/C)	Average age (T/C yrs)	Major interventions (wk)		Intervention frequency	Outcome index	Symptom
				T	C			
Chiu TT, 2005[14]	America	67/78	40.4 ± 6.7/40.7 ± 8.4	Isometric Exercise (6 Weeks)	Nneuro-regulation (6 Weeks)	18 Times	①	Chronic Neck Pain
Falla D, 2013[15]	Denmark	23/23	39.1 ± 8.7/38.6 ± 9.0	Isometric Exercise (8 Weeks)	Blank	16 Times	②	Chronic Neck Pain
Galindez X, 2018[[16]	Spain	13/14	32.15 ± 1.87/34.3 ± 1.71	Isometric Exercise (3 Weeks)	Neuro-regulation (3 Weeks)	12 Times	①②③	Chronic Neck Pain
Kashfi P, 2019[17]	Iran	32/32	20.50 ± 0.13/20.33 ± 0.12	Isometric Exercise (8 Weeks)	Exercise Therapy (8 Weeks)	24 Times	③	Chronic Neck Pain
Lidegaard M, 2013[18]	Denmark	15/15	41.7 ± 10.8/40.5 ± 7.27	Isometric Exercise (10 Weeks)	Health Lecture (10 Weeks)	20 Times	①	Chronic Neck Pain
Muhammad K, 2014[19]	Pakista	34/34	34.43 ± 2.7	Isometric Exercise (12 Weeks)	Exercise Therapy (12 Weeks)	24 Times	①	Chronic Neck Pain
Griffiths C, 2009[20]	U.K	37/37	51.1 ± 14.0/51.5 ± 13.6	Isometric Exercise (6 Weeks)	Exercise Therapy (6 Weeks)	18 Times	①②	Neck Disease
Cao XL, 2021[21]	China	45/45	45.6 ± 7.1/46.2 ± 7.3	Isometric Exercise (6 Weeks)	Conventional Therapy (6 Weeks)	24 Times	①②	Chronic Neck Pain
Chen BL, 2009[22]	China	55/40	32.8/32.6	Isometric Exercise (12 Weeks)	TCM Therapy (12 Weeks)	24 Times	①	Cervical Spondylosis
Chen YM, 2014[23]	China	30/30	41.3 ± 1.9/43.4 ± 2.4	Isometric Exercise (2 Weeks)	TCM Therapy (2 Weeks)	6 Times	①	Chronic Neck Pain
Duan YC, 2015[24]	China	15/15	23.13 ± 3.11/24.53 ± 3.96	Isometric Exercise (6 Weeks)	TCM Therapy (6 Weeks)	12 Times	①②③	Dysfunction
Guo HP, 2020[25]	China	20/20	43.7 ± 2.8/44.6 ± 2.1	Isometric Exercise (4 Weeks)	Exercise Therapy (4 Weeks)	12 Times	①②	Chronic Neck Pain
Li YF, 2018[26]	China	34/34	58.5 ± 4.2/58.8 ± 4.8	Isometric Exercise (4 Weeks)	TCM Therapy (4 Weeks)	12 Times	①②	Chronic Neck Pain
Liu SZ, 2015[27]	China	22/22	26.95 ± 1.8/25.95 ± 2.9	Isometric Exercise (6 Weeks)	Exercise Therapy (6 weeks)	18 Times	①③	Neck Pain
Ning FP, 2008[28]	China	55/40	32.82 ± 8.6/31.58 ± 7.5	Isometric Exercise (12 Weeks)	TCM Therapy (12 Weeks)	36 Times	①	Cervical Spondylosis
Wei Q, 2021[29]	China	405/400	16.38 ± 0.74/16.34 ± 0.85	Isometric Exercise (12 Weeks)	Exercise Therapy (12 Weeks)	24 Times	①②	Cervical Spondylosis
Xie ZR, 2018[30]	China	20/20	19.95 ± 0.24/19.90 ± 0.24	Isometric Exercise (12 Weeks)	TCM Therapy (12 Weeks)	24 Times	①②③	Neck Discomfort
Zhu YR, 2015[31]	China	39/31	56.8 ± 10.31/58.02 ± 12.09	Isometric Exercise (12 Weeks)	TCM Therapy (2 Weeks)	6 Times	①②③	Cervical Spondylosis

Note: T is the experimental group, and C is the outcome index of the control group.
① VAS = visual analog pain index, ② NDI = neck disability index, and ③ ROM = range motion.

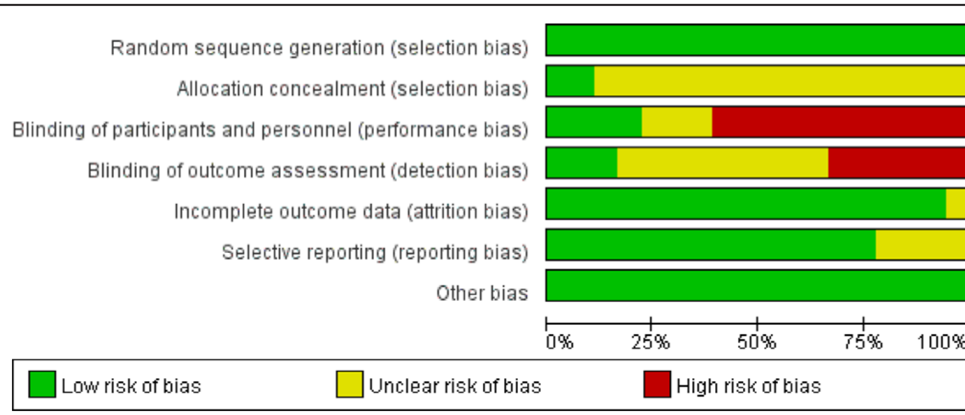

Figure 2. Assessment of the overall risk of bias of the included literature.

being statistically significant [*WMD* = -0.75, 95%*CI* (-0.85, -0.66), $P < .00001$]. The other 10 studies[14,16,20,21,23–27,31] had isometric training intervention periods of less than eight weeks, with a total sample size of 648 cases, including 322 cases in the experimental group and 326 cases in the control group. There was no significant heterogeneity among the included studies (X^2=17.41, $P = .04$, I^2=48%). Analyzed by the fixed-effects model, the results showed that the two groups were statistically

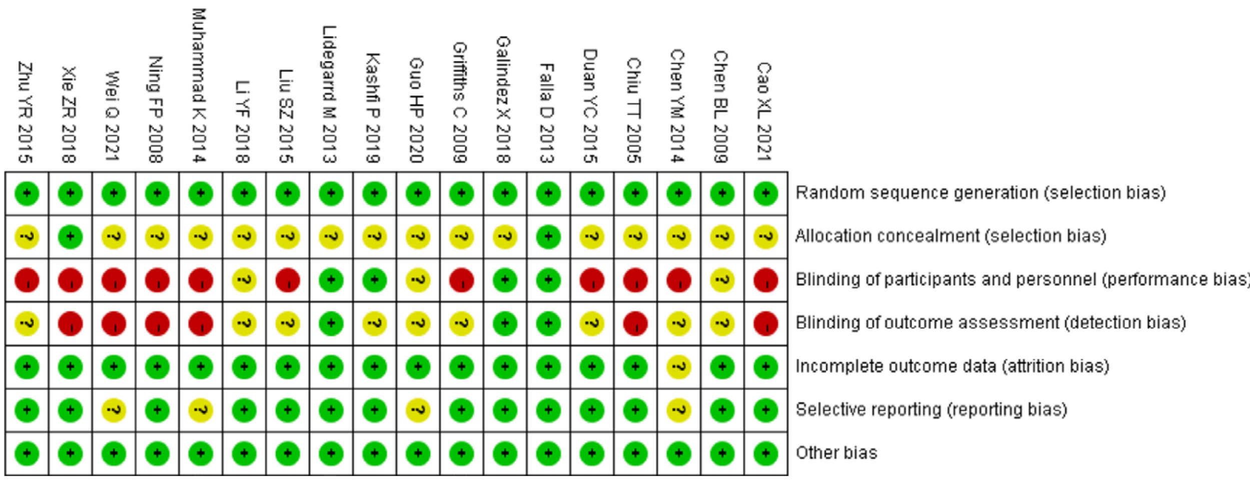

Figure 3. Details of the bias assessment of the included literature.

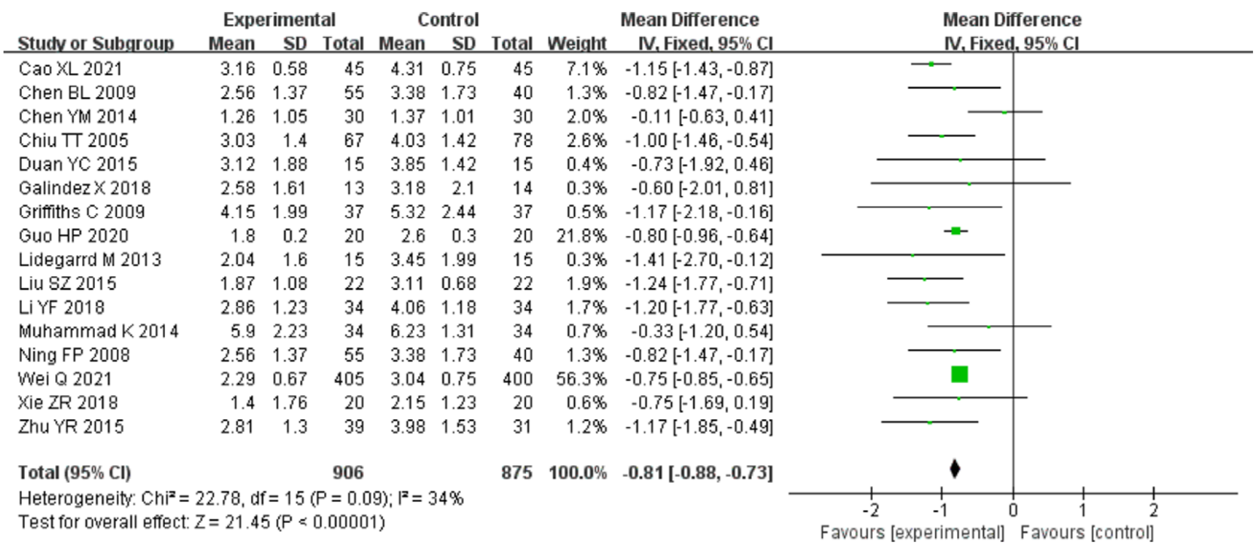

Figure 4. Forest plot of VAS meta-analysis. VAS = visual analogue scale.

Table 2

Results of meta-regression analysis of VAS effect size.

Study characteristics	Regression coefficient (β)	95%CI	*t* value	*P* value
publication year	0.063	−0.039 ~ 0.166	1.39	.198
intervention time	0.030	−0.146 ~ 0.207	0.39	.708
intervention frequency	−0.008	−0.097 ~ 0.080	−0.22	.832
average age	−0.020	−0.066 ~ 0.024	−1.04	.327
sample size	−0.001	−0.003 ~ 0.001	−1.38	.202
article quality	−0.100	−0.573 ~ 0.372	−0.48	.641

CI = confidence interval, VAS = visual analog pain index.

significant [*WMD* = -0.89, 95%*CI* (-1.01-0.78), *P* < .00001], as shown in Figure 6.

3.4.2. Effects of isometric training on neck disability index in patients with neck pain 10 studies used the NDI to assess cervical dysfunction in patients with neck pain.[15,16,20–26,29–31] According to the results of the forest plot in Figure 6, heterogeneity was observed among the included studies (X^2=59.60, *P* < .00001, I^2=85%). Analyzed using the random-effects model, the meta-analysis results showed that isometric training can effectively improve cervical spine function [*WMD* (95%*CI*) = 5.55 (4.57, 6.53), *P* < .00001], as shown in Figure 7. The points in Figure 8 were relatively symmetrically distributed from left to right, indicating that there was no publication bias in the literature. Therefore, isometric training had a significant impact on the NDI of patients with neck pain.

To explore the source of heterogeneity, sensitivity analysis was used to exclude the included studies individually from the

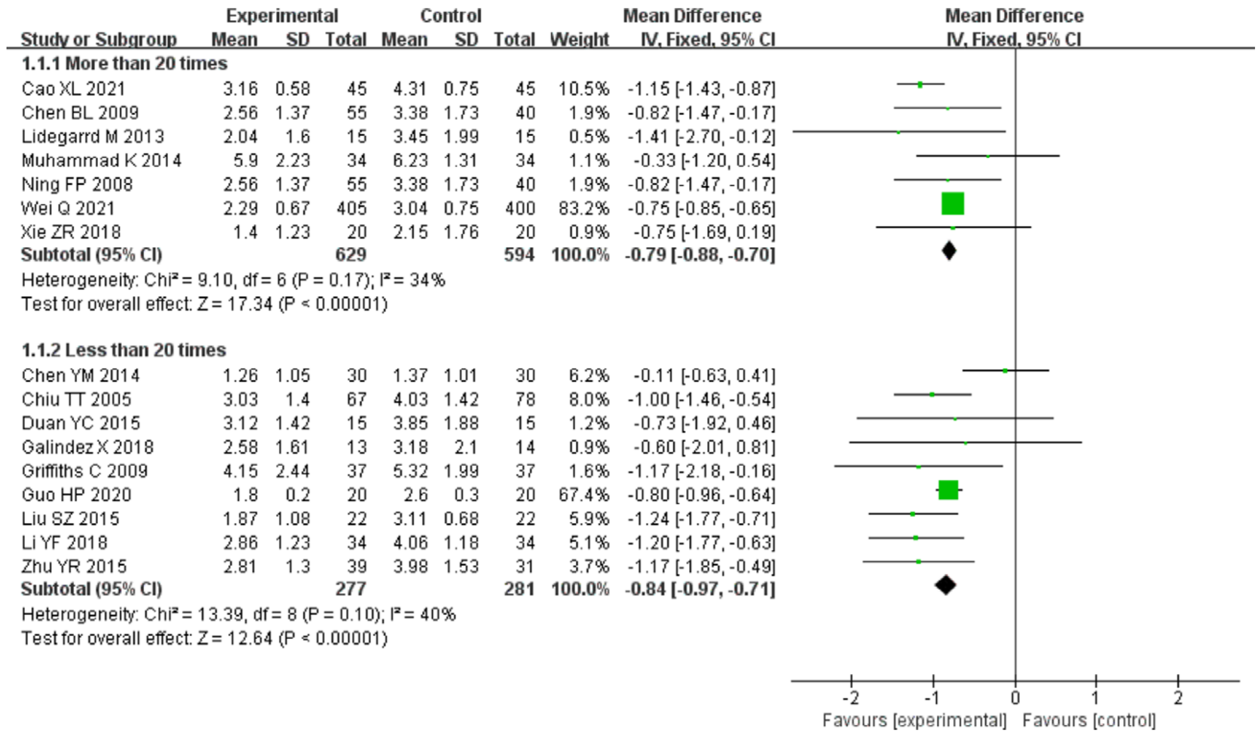

Figure 5. Subgroup analysis of neck pain severity with different intervention frequencies (VAS). VAS = visual analogue scale.

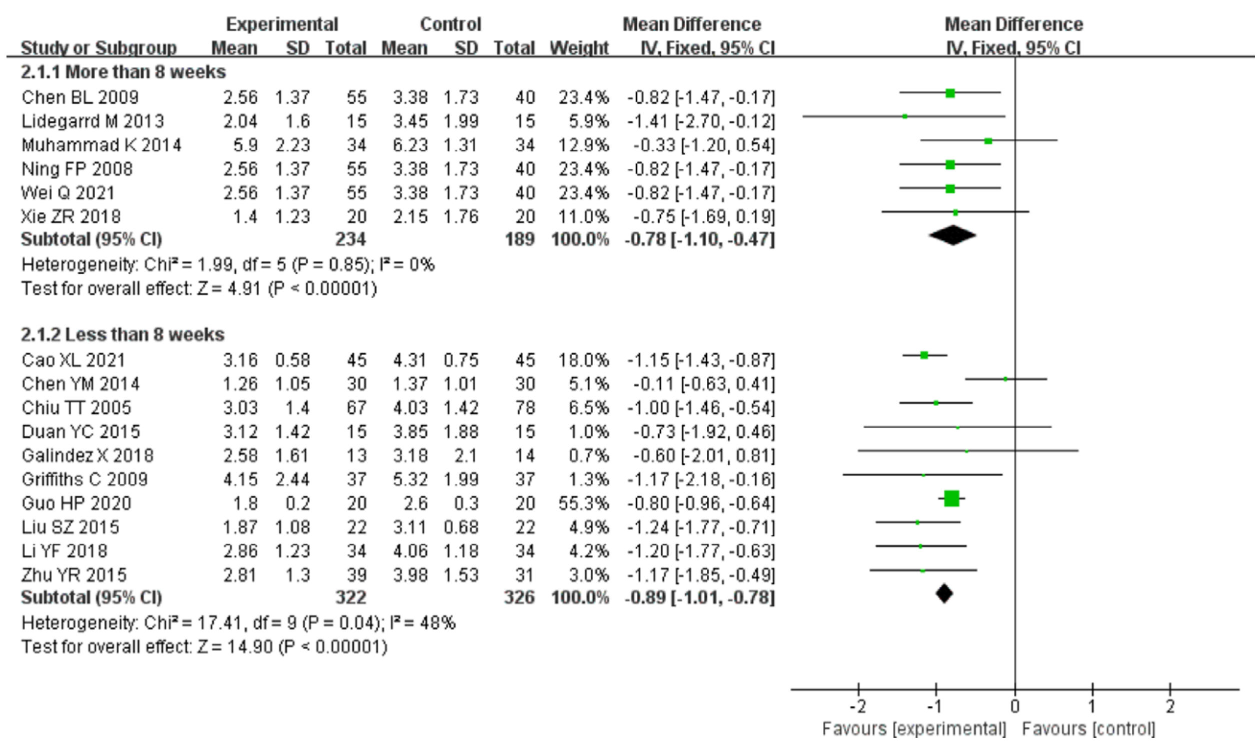

Figure 6. Subgroup analysis of neck pain severity with different intervention period (VAS). VAS = visual analogue scale.

overall study. The heterogeneity of the remaining research literature reduced only after the exclusion of Wei,[29] I^2=23%, 95%CI = 5.95 [5.39, 6.52], P < .0001, and there was heterogeneity among studies. After performing sensitivity analysis, the source of heterogeneity was found to believe that the NDI studied by Wei in 2021 had potential bias factors related to the selection of sample size. Therefore, this study was considered less sensitive and had relatively stable results, as shown in Table 3.

This study divided the 10 studies into 2 subgroups according to the total intervention frequency. Three studies[21,29,30] conducted isometric training interventions over 20 times with a sample size of 935 cases, including 470 cases in the experimental group and 465 cases in the control group. There was no

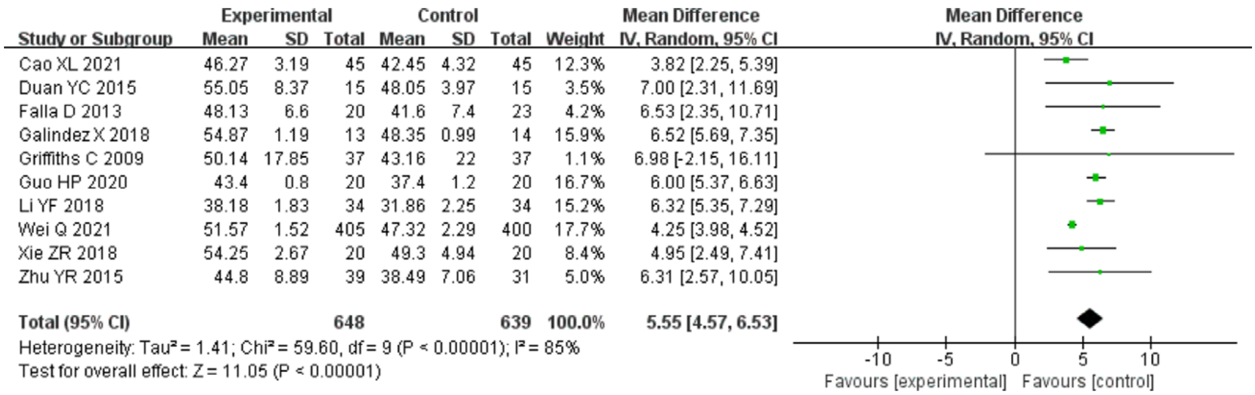

Figure 7. Forest plot of NDI meta-analysis. NDI = neck disability index.

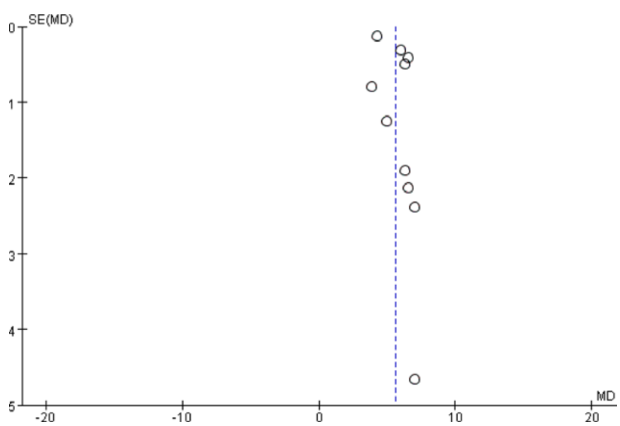

Figure 8. Funnel plot of the NDI meta-analysis. NDI = neck disability index.

Table 3

Quantitative data of NDI sensitivity analysis

	I^2	Z	Effect size 95%CI
All Literature	85%	11.05 (P < .0001)	5.55[4.57,6.53]
Falla D, 2013[15]	86%	10.67 (P < .0001)	5.51[4.49,6.52]
Galindez X, 2018[16]	81%	10.36 (P < .0001)	5.35[4.34,6.36]
Griffiths C, 2009[20]	87%	10.89 (P < .0001)	5.53[4.54,6.53]
Cao XL, 2021[21]	86%	10.57 (P < .0001)	5.80[4.72,6.87]
Duan YC, 2015[24]	86%	10.71 (P < .0001)	5.50[4.49,6.50]
Guo HP, 2020[25]	81%	9.51 (P < .0001)	5.47[4.34,6.60]
Li YF, 2018[26]	84%	9.98 (P < .0001)	5.41[4.35,6.47]
Wei Q, 2021[29]	23%	20.69 (P < .0001)	5.95[5.39,6.52]
Xie ZR, 2018[30]	87%	10.49 (P < .0001)	5.61[4.56,6.66]
Zhu YR, 2015[31]	86%	10.62 (P < .0001)	5.51[4.49,6.53]

CI = confidence interval, NDI = neck disability index.

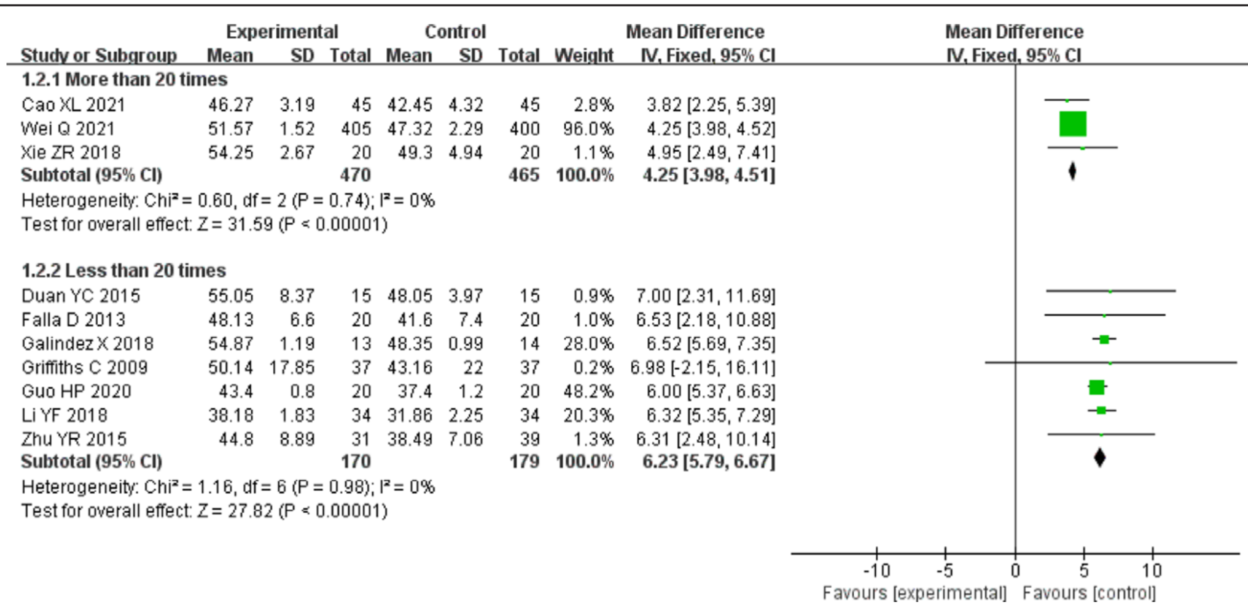

Figure 9. Subgroup analysis of the effects of different intervention frequency on cervical dysfunction (NDI). NDI = neck disability index.

heterogeneity between the included studies (X^2=0.60, P = .74, I^2=0%), analyzed by the fixed-effects model, with the difference between the two groups being statistically significant [WMD = 4.25, 95%CI(3.98,4.51), P < .001]. Seven of the studies[15,16,20,24–26,31] conducted isometric training interventions fewer than 20 times, with a total sample size of 349 cases, including 170 cases in the experimental group and 179 cases in the control group. There was no heterogeneity among the included studies (X^2=1.16, P = .98, I^2=0%). Analyzed using the fixed-effects model, the results showed that the difference between the two groups was statistically significant [WMD = 6.23, 95%CI (5.79, 6.67), P < .001], as shown in Figure 9.

Ten studies were divided into two subgroups depending on the total intervention period. Three of the studies[15,29,30] with isometric training intervention periods over 8 weeks had a sample size of 885 cases, including 445 cases in the experimental group and 440 cases in the control group. There was no heterogeneity between the included studies (X^2=1.35, P = .51, I^2=0%); therefore, a fixed-effects model analysis was used. The two groups were statistically significant [WMD = 4.27, 95%CI (4.00,4.53), P = .51]. Seven studies[16,20,21,24–26,31] had an isometric training intervention period of less than 8 weeks with a sample size of 399 cases, including 195 cases in the experimental group and 204 cases in the control group. There was no significant heterogeneity between the included studies (X^2=9.53, P = .15, I^2=37%); therefore, a fixed-effects model analysis was used. The two groups were statistically significant [WMD = 6.05, 95%CI (5.63,6.48), P = 9.53], as shown in Figure 10.

3. 4.3 Effect of isometric training on neck range of motion in patients with neck pain. Six of the 19 studies reported the effect of isometric training intervention on the sagittal, coronal, and ROM of the neck in patients with neck pain.[16,19,24,27,30,31]

(1) Range of motion in the sagittal plane of the neck

According to the meta-analysis of the changes in the range of motion in the sagittal plane of the neck of the patients by isometric training intervention, there was no obvious heterogeneity among the included studies (X^2=6.11, P = .30, I^2=18%); therefore, a fixed-effects model analysis was used. Meta-analysis results showed that isometric training can improve sagittal range of motion [WMD (95%CI) = 1.53 (-0.40, 3.63), P = .12], as shown in Figure 11.

Six studies were divided into two subgroups according to the total intervention frequency. Two studies[19,30] conducted isometric training interventions over 20 times, with a total sample size of 108 cases, including 54 cases in the experimental group and 54 cases in the control group. There was no heterogeneity among the included studies (X^2=0.29, P = .59, I^2=0%). Analyzed using the fixed-effects model. The results of the meta-analysis showed that the difference between the two groups was statistically significant [WMD = 1.43, 95%CI (-1.65, 4.52), P = .36]. The other 4 studies[16,24,27,31] had isometric training interventions fewer than 20 times, with a total sample size of 171 cases, including 89 cases in the experimental group and 82 cases in the control group. There was no significant heterogeneity among the included studies (X^2=5.81, P = .12, I^2=48%), and the fixed-effects model was used for analysis. The results showed that the difference between the two groups was statistically significant [WMD = 1.90, 95%CI (-1.73, 5.52), P = .31], as shown in Figure 12.

(2) Range of motion in the coronal plane of the neck

According to the meta-analysis of the changes in the range of motion in the coronal plane of the neck of the patients by isometric training intervention, there was no heterogeneity among the included studies (X^2=1.20, P = .95, I^2=0%).

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
2.2.1 More than 8 weeks								
Falla D 2013	48.13	6.6	20	41.6	7.4	20	0.4%	6.53 [2.18, 10.88]
Wei Q 2021	51.57	1.52	405	47.32	2.29	400	98.4%	4.25 [3.98, 4.52]
Xie ZR 2018	54.25	2.67	20	49.3	4.94	20	1.2%	4.95 [2.49, 7.41]
Subtotal (95% CI)			**445**			**440**	**100.0%**	**4.27 [4.00, 4.53]**
Heterogeneity: Chi² = 1.35, df = 2 (P = 0.51); I² = 0%								
Test for overall effect: Z = 31.35 (P < 0.00001)								
2.2.2 Less than 8 weeks								
Cao XL 2021	46.27	3.19	45	42.45	4.32	45	7.3%	3.82 [2.25, 5.39]
Duan YC 2015	55.05	8.37	15	48.05	3.97	15	0.8%	7.00 [2.31, 11.69]
Galindez X 2018	54.87	1.19	13	48.35	0.99	14	26.3%	6.52 [5.69, 7.35]
Griffiths C 2009	50.14	17.85	37	43.16	22	37	0.2%	6.98 [-2.15, 16.11]
Guo HP 2020	43.4	0.8	20	37.4	1.2	20	45.2%	6.00 [5.37, 6.63]
Li YF 2018	38.18	1.83	34	31.86	2.25	34	19.0%	6.32 [5.35, 7.29]
Zhu YR 2015	44.8	8.89	31	38.49	7.06	39	1.2%	6.31 [2.48, 10.14]
Subtotal (95% CI)			**195**			**204**	**100.0%**	**6.05 [5.63, 6.48]**
Heterogeneity: Chi² = 9.53, df = 6 (P = 0.15); I² = 37%								
Test for overall effect: Z = 27.92 (P < 0.00001)								

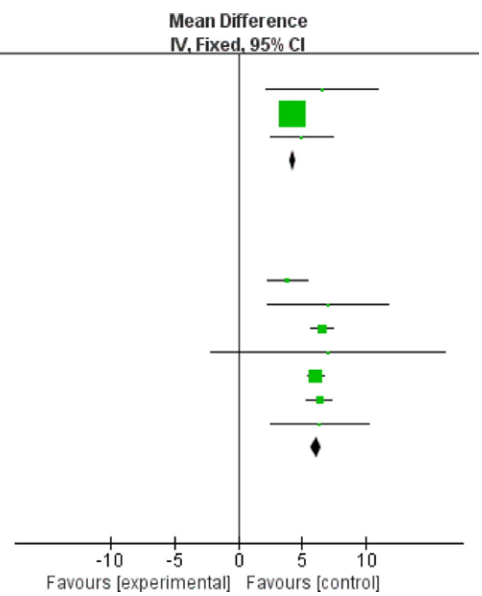

Figure 10. Subgroup analysis of the effects of different intervention period on cervical dysfunction (NDI). NDI = neck disability index.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
Duan YC 2015	113.45	14.7	15	107.94	12.1	15	4.0%	5.51 [-4.13, 15.15]
Galindez X 2018	107.99	5.18	13	108.37	5.72	14	22.0%	-0.38 [-4.49, 3.73]
Kashfi P 2019	78.33	6.4	34	76.52	7.7	34	32.9%	1.81 [-1.56, 5.18]
Liu SZ 2015	100.23	8.01	22	101.11	7.48	22	17.8%	-0.88 [-5.46, 3.70]
Xie ZR 2018	98	11.85	20	98.5	12.8	20	6.4%	-0.50 [-8.14, 7.14]
Zhu YR 2015	79.22	8.73	39	73.36	10.84	31	16.9%	5.86 [1.16, 10.56]
Total (95% CI)			**143**			**136**	**100.0%**	**1.53 [-0.40, 3.46]**
Heterogeneity: Chi² = 6.11, df = 5 (P = 0.30); I² = 18%								
Test for overall effect: Z = 1.56 (P = 0.12)								

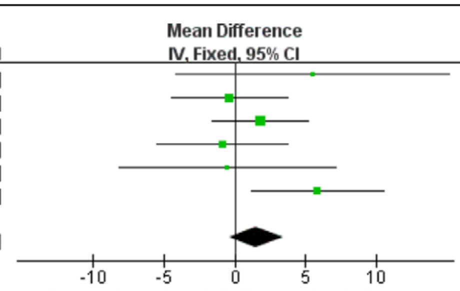

Figure 11. Forest plot of sagittal ROM meta-analysis. ROM = range of motion.

Analyzed using the fixed-effects model, the results of the meta-analysis showed that isometric training can effectively improve the range of motion in the coronal plane [*WMD* (95%*CI*) = 2.12 (0.56, 3.68), *P* = .008], as shown in Figure 13.

Six studies were divided into two subgroups according to the total intervention frequency. Two studies[19,30] had isometric training interventions over 20 times, with a total sample size of 108 cases, including 54 cases in the experimental group and 54 cases in the control group. There was no heterogeneity between the included studies (X^2=0.00, P = 1.00, I^2=0%); therefore, the fixed-effects model analysis was used, and the difference between the two groups was statistically significant [*WMD* = 1.69, 95%*CI* (-1.40,4.78), *P* = .28]. The other four studies[16,24,27,31] had isometric training interventions fewer than 20 times, with a total sample size of 171 cases, including 89 cases in the experimental group and 82 patients in the control group. There was no heterogeneity among the included studies (X^2=1.10, P = .78, I^2=0%), and the fixed-effects model was used for analysis. The results showed that the difference between the two groups was statistically significant [*WMD* = 2.27, 95%*CI* (0.46, 4.07), *P* = .01], as shown in Figure 14.

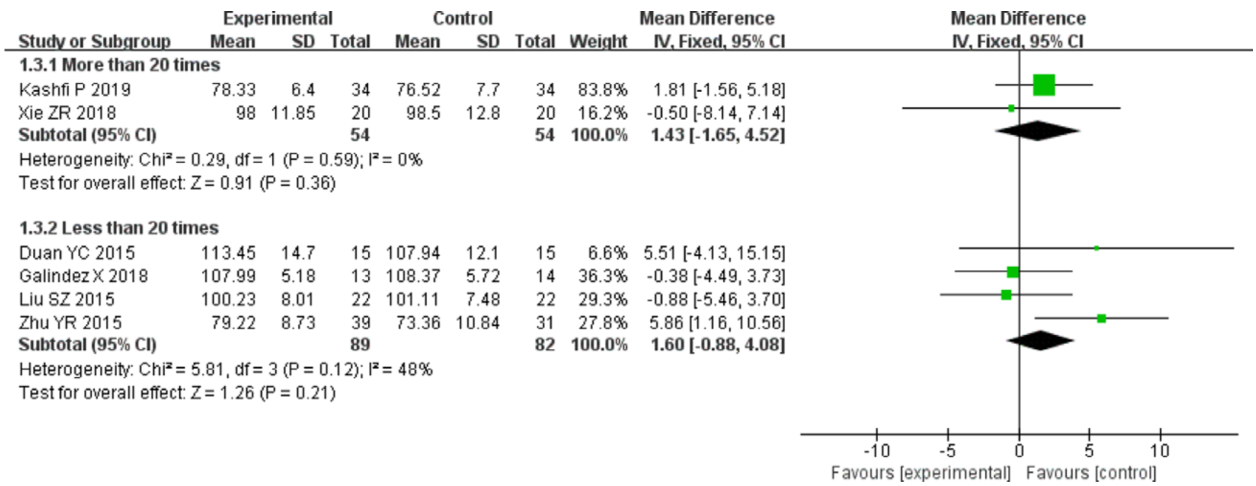

Figure 12. Effect of isometric training on sagittal activity (ROM). ROM = range of motion.

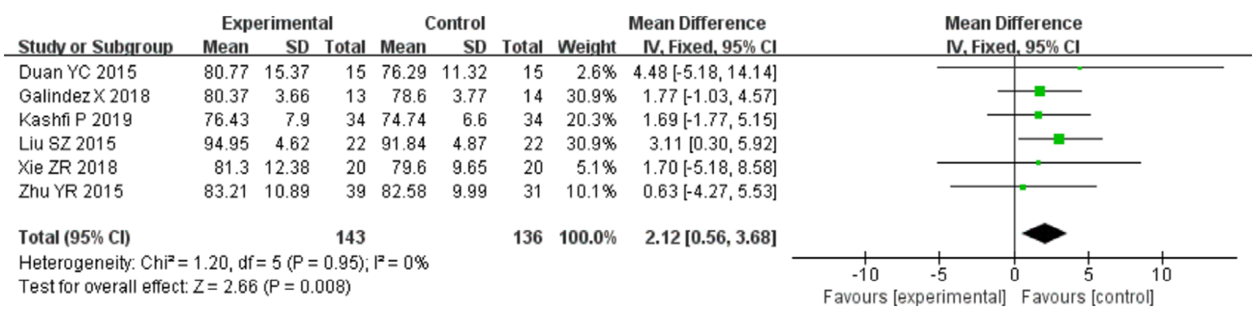

Figure 13. Forest plot of coronal ROM meta-analysis. ROM = range of motion.

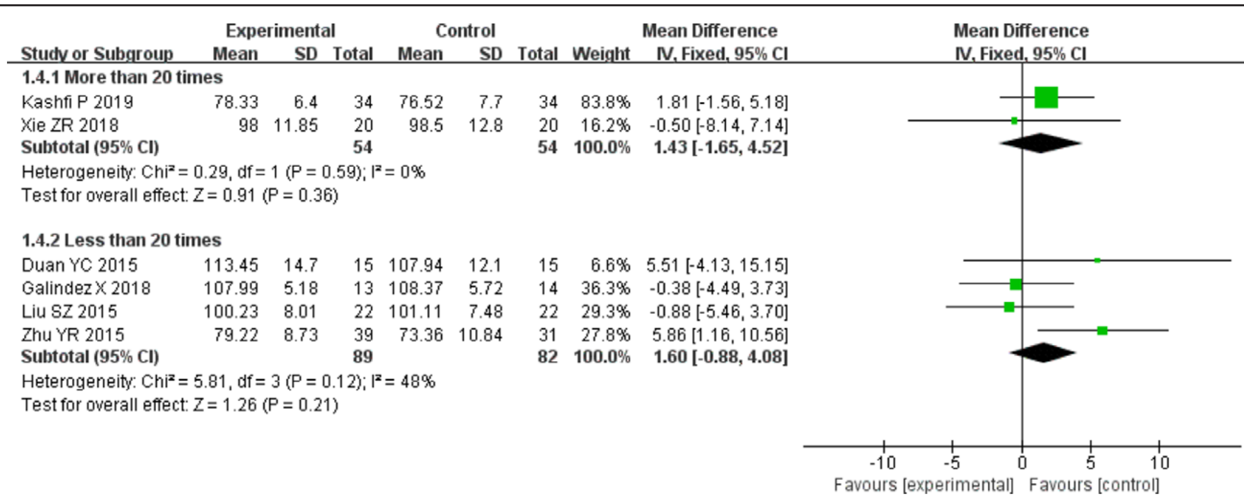

Figure 14. Effect of isometric training on coronal activity (ROM). ROM = range of motion.

(3) Range of motion in the horizontal plane of the neck

According to the meta-analysis of the changes in the range of motion in the horizontal plane of the neck of the patients by isometric training intervention, there was no heterogeneity among the included studies (X^2=6.34, P = .27, I^2=21%); therefore, the fixed-effects model was used for analysis. The meta-analysis results showed that isometric training can improve horizontal mobility [*WMD* (95%*CI*) = 3.58 (1.56, 5.59), P = .0005], as shown in Figure 15.

The six studies were divided into two subgroups based on the total frequency of interventions. Two studies[19,30] conducted isometric training interventions more than 20 times, with a sample size of 108 cases, including 54 cases in the experimental group and 54 cases in the control group. There was no significant heterogeneity among the included studies (X^2=1.26, P = .26, I^2=20%). Analyzed by the fixed-effects model, the results showed that the difference between the two groups was statistically significant [*WMD* = 2.82, 95%*CI* (-0.33, 5.96), P = .08]. The other four studies[16,24,27,31] had isometric training interventions fewer than 20 times, with a sample size of 171 cases, including 89 cases in the experimental group and 82 cases in the control group. There was no significant heterogeneity among the included studies (X^2=4.70, P = .20, I^2=36%), and the fixed-effects model was used for the analysis. The results showed that the difference between the two groups was statistically significant [*WMD* = 4.11, 95%*CI* (1.48, 6.74), P = .002], as shown in Figure 16.

4. Discussion

Numerous studies have shown that isometric training relieves neck pain and improves neck function and its range of motion.[3,32] The study investigated the effect of isometric training on the improvement of neck pain through meta-analysis, and systematically evaluated the effect of isometric training on the degree of neck pain (VAS), neck dysfunction (NDI) and the range of motion (ROM) in the sagittal, coronal and horizontal plane of the neck. Through subgroup analysis, the improvement effect of isometric training on various indicators of patients was analyzed from the level of isometric intervention frequency, which provided the basis for the application and promotion of isometric training.

A total of 18 articles were included in this study, including 1891 patients. All 18 studies were RCTs, 2 studies[15,30] were randomized by lottery and applied allocation concealment, and the other 16 studies[14,16–29,31] were described only as randomized grouping, and no specific randomization scheme was described. In five studies,[15–19] the study subjects or interventionists were blinded, 11 studies[14,20,21,27–31] were unblinded, and the remaining three studies[22,25,26] were not described as blinded. All study outcomes were complete with no selective reporting.

The VAS is a commonly used pain assessment method in clinical practice at home and abroad,[33] which showed that among the VAS outcome indicators, isometric training had a statistically significant effect on the improvement of neck pain in patients (P < .05).

In the outcome indicator, the subgroup analysis showed that isometric training had a statistically significant difference in the improvement of the neck pain index (P < .05), whether the intervention frequency was more than 20 times or less than 20 times, and isometric training intervention with more than 20 times had a more significant effect. Meanwhile, the subgroup analysis showed that isometric training had a statistically significant difference in the neck pain index

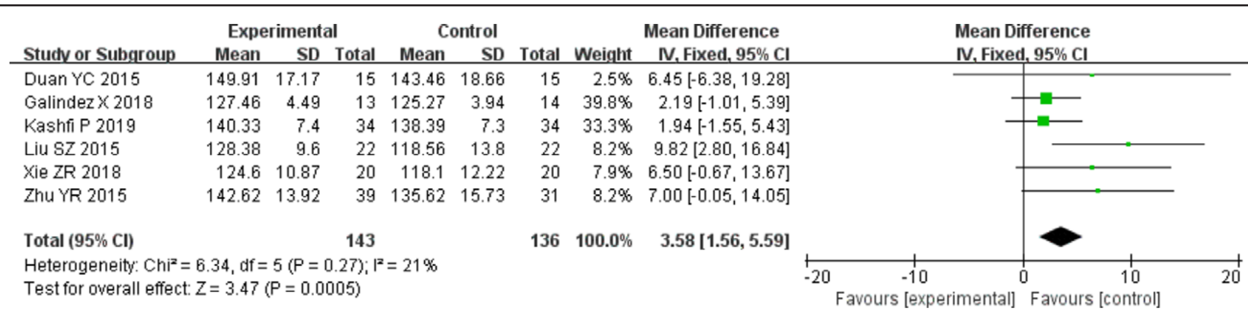

Figure 15. Forest plot of horizontal ROM meta-analysis. ROM = range of motion.

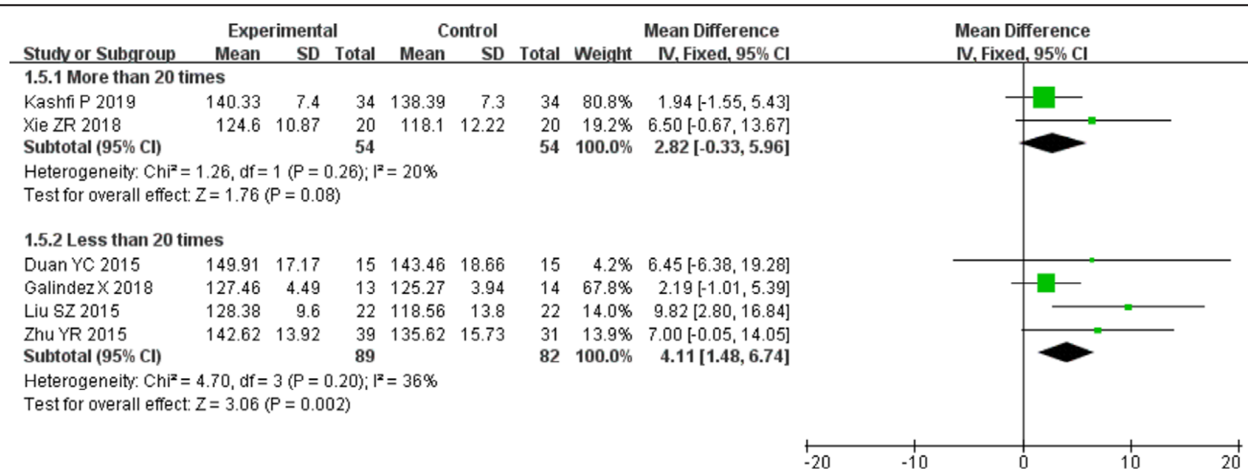

Figure 16. Effect of isometric training on horizontal activity (ROM). ROM = range of motion.

of patients ($P < .05$) regardless of whether the intervention period was more than 8 weeks or less, and isometric training intervention with more than 8 weeks had a more significant effect. Previous studies have confirmed[34–36] that isometric training can enhance isometric muscle strength of cervical flexion, posterior extension, and rotation in patients with chronic neck pain. At the same time, it can promote blood circulation in the neck, increase the strength and endurance of the neck muscles, and strengthen the coordination of muscle movements, thereby relieving neck pain.

The NDI emphasizes neck dysfunction due to neck pain[37] In this outcome indicator, the results of meta-analysis showed that isometric training intervention could improve cervical spine dysfunction ($P < .05$) Moreover, the research showed that the isometric training with a total intervention frequency of both more than 20 times and less than 20 times had a positive effect on the neck dysfunction of patients, and the results were statistically significant ($P < .05$), indicating that isometric training was a kind of safe and effective exercise training method for improving neck dysfunction of patients. The results of the subgroup analysis showed the significant differences between isometric intervention periods of more than 8 weeks and less than 8 weeks ($P < .05$), and the effect was more significant with intervention of more than 8 weeks.

The ROM measurement is one of the indicators used to evaluate the range and degree of joint motor function impairment, which can determine whether joint movement is limited, the degree of limitation and etc. This study showed that isometric training had a positive effect on improving the sagittal, coronal, and horizontal planes of the patients' neck range of motion ($P < .05$). Among the three outcome indicators, the meta-analysis results showed that an intervention frequency of both more than 20 times and fewer than 20 times could improve range of motion of the sagittal, coronal, and horizontal plane of the neck joints ($P < .05$). With the intervention frequency more than 20 times, the effect of isometric training was more significant in the sagittal and horizontal range of motion.

The results of this study showed that the subgroup analysis method reduced the heterogeneity of the corresponding results, improved the reliability of the research results, and strengthened the guiding role of the research conclusions for practical application. However, dividing the subgroups reduced the number of included articles; therefore, a sensitivity analysis was needed to judge the stability of the results. Through the analysis, it was found that the existence of heterogeneity in this study may be caused by the large number of intervention populations in related studies[29] Sensitivity analysis showed that after eliminating studies one by one or more, although the heterogeneity of some study results changed, the results of each study did not change substantially. It can be seen that the analysis results in this study were relatively reliable and had certain guidance role. In conclusion, isometric training can be used as the first choice for pain relief, neck function improvement, and joint range of motion in patients with neck pain, which have relatively good effects among various interventions. Nonetheless, when formulating a specific exercise program, it is necessary to consider the time, period, and frequency of the exercise intervention according to the degree of neck pain and symptoms to achieve the best effect.

The meta-analysis was conducted strictly in accordance with the PRISMA statement list,[12] but there were still some limitations: 1) The patients included in this study had certain clinical heterogeneity in sex, age, course of disease, disease condition, etc. 2) The intervention time included in this study was inconsistent, ranging from 2 weeks to 12 weeks. 3) The VAS and NDI indicators were greatly influenced by subjective factors, which might have biased the results. 4) This study only discussed the intervention frequency by subgroup analysis, failing to discuss and analyze the time, population, and period. 5) In the ROM indicator, the subgroup analysis data of the intervention period was the same as the data of intervention frequency, and the subgroup analysis of the intervention period was not carried out. 6) There number of included articles was relatively small in some subgroups, and it was expected that more relevant studies would be conducted to expand the results of the meta-analysis to provide a variety of rehabilitation recommendations for patients with neck pain in the future.

5. Conclusion

Isometric training can help improve neck pain symptoms in patients with neck pain, reduce the degree of neck pain, and improve neck dysfunction and joint range of motion in three planes. The frequency of exercise intervention of both more than 20 times and less than 20 times can improve each index of patients, and an intervention frequency of more than 20 times had more significant improvement effects on the degree of neck pain and sagittal and horizontal range of motion. In addition, an exercise intervention period of more than 8 weeks and less than 8 weeks can improve the VAS and NDI indices of patients, and the effect of isometric training with an intervention period of more than 8 weeks was more significant.

Author contributions

Jiaqi Yang, Min Yang, and Qinqin Lin: study design, definition of intellectual content, data analysis, manuscript preparation, and editing. Jiaqi Yang and Min Yang: potential studies search and screening, data extraction, and the risk of bias assessment. Qinqin Lin and Rui Xi: arbitration of any disagreements during the review. All authors critically reviewed, revised, and approved the final version of this manuscript.
Conceptualization: Jiaqi Yang, Qinqin Lin, Rui Xi, Min Yang.
Methodology: Jie Fu, Min Yang.
Software: Jiaqi Yang, Jie Fu.
Writing – original draft: Jiaqi Yang.
Writing – revision & editing: Min Yang.

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