Review / Обзорная статья
DOI: https://doi.org/10.38025/2078-1962-2025-24-4-130-140

Safety and Therapeutic Outcomes of Cervical High-Velocity Low-Amplitude Manipulation in Clinical Practice: a Review

Rahmat Nugraha[1,*], Rizky Wulandari Ramli[1], Latifa Insani Nurhalim[1], Sitti Rahma[1], Sri G. Fahriana[2]

[1] *Health Polytechnic of Ministry of Health Indonesian Republic Makassar, Makassar, Indonesia*
[2] *Pembangunan Nasional Veteran Jakarta University, Jakarta, Indonesia*

ABSTRACT

INTRODUCTION. High-velocity low-amplitude (HVLA) manipulation of the cervical spine is commonly used in clinical practice to manage various musculoskeletal conditions. This review discusses the safety profile and therapeutic outcomes of cervical HVLA manipulation, highlighting its role in optimizing patient care while minimizing potential risks.

AIM. To review scientific evidence on the safety and effectiveness of HVLA manipulation therapy on the cervical spine and evaluate its impact on patients' clinical improvement. Through this analysis, it is expected to provide guidance for practitioners in assessing the risks and benefits of using HVLA techniques in physiotherapy practice.

MATERIALS AND METHODS. This study employed a literature review approach by collecting articles from the PubMed (49 publications), ScienceDirect (198 publications), PEDro (2 publications), and EBSCO (21 publications) databases, published between 2014 and 2024. The initial search identified a total of 270 articles related to HVLA manipulation for cervical musculoskeletal disorders. Following the selection process, 62 articles were removed due to duplication, 158 articles were deemed irrelevant at the title review stage, and 26 articles were evaluated based on their abstracts. The final selection included 15 articles that met the inclusion criteria for analysis. The selected articles comprised randomized controlled trials and meta-analyses assessing the effectiveness of HVLA on pain, mobility, and function. The selection process was conducted systematically to ensure data validity and relevance.

RESULTS AND DISCUSSION. The study findings indicate that the application of HVLA manipulation on the cervical spine is effective in reducing pain, increasing range of motion (ROM), and improving function in patients with musculoskeletal neck disorders, including mechanical neck pain and tension headache. HVLA influences joint biomechanics, releases restrictions, and reduces muscle tension, contributing to enhanced mobility and pain reduction. Additionally, this technique provides pain modulation effects and long-term benefits for patients' functional activities. However, implementing HVLA requires a comprehensive risk assessment to identify suitable patients and minimize potential complications, including the risk of vertebral artery injury. These findings highlight the importance of an evidence-based approach and caution in clinical practice to ensure optimal and safe therapeutic outcomes.

CONCLUSION. HVLA manual therapy on the cervical spine is effective and safe, particularly for neck pain relief and functional improvement, although certain risks must be considered. Practitioners should conduct a thorough risk assessment and take patient conditions into account for optimal outcomes. The impact of HVLA on blood flow, blood pressure, handgrip strength, and cervical spine muscle strength is not significant, making it unsuitable as a primary intervention.

KEYWORDS: high-velocity low-amplitude (HVLA), musculoskeletal manipulation, therapy safety, neck pain, range of motion

For citation: Nugraha R., Ramli R.W., Nurhalim L.I., Rahma S., Fahriana S.G. Safety and Therapeutic Outcomes of Cervical High-Velocity Low-Amplitude Manipulation in Clinical Practice: a Review. Bulletin of Rehabilitation Medicine. 2024; 24(4):130–140. https://doi.org/10.38025/2078-1962-2025-24-4-130-140

* **For correspondence:** Rahmat Nugraha, E-mail: rahmatnugraha@poltekkes-mks.ac.id

Received: 26.02.2025
Accepted: 16.06.2025
Published: 16.08.2025

Безопасность и терапевтические результаты манипуляций на шейном отделе позвоночника высокоскоростной низкоамплитудной манипуляции в клинической практике: обзор

Нуграха Р.[1,*], Рамли Р.В.[1], Нурхалим Л.И.[1], Рахма С.[1], Фахриана Ш.Г.[2]

[1] *Политехнический институт Министерства здравоохранения Индонезийской Республики Макассар, Макассар, Индонезия*

[2] *Ветеран Национального университета развития Джакарты, Джакарта, Индонезия*

РЕЗЮМЕ

ВВЕДЕНИЕ. Высокоскоростная низкоамплитудная техника (HVLA) на шейном отделе позвоночника обычно используется в клинической практике для лечения различных заболеваний опорно-двигательного аппарата. В этом обзоре обсуждаются профиль безопасности и терапевтические результаты шейной HVLA-манипуляции, подчеркивая ее роль в оптимизации ухода за пациентами при минимизации потенциальных рисков.

ЦЕЛЬ. Рассмотреть научные данные о безопасности и эффективности терапии манипуляцией HVLA на шейном отделе позвоночника и оценить ее влияние на клиническое улучшение состояния пациентов. Ожидается, что с помощью этого анализа будут предоставлены рекомендации для практикующих врачей по оценке рисков и преимуществ использования методов HVLA в физиотерапевтической практике.

МАТЕРИАЛЫ И МЕТОДЫ. В этом исследовании использовался подход обзора литературы путем сбора статей из баз данных PubMed (49 публикаций), ScienceDirect (198 публикаций), PEDro (2 публикации) и EBSCO (21 публикация), опубликованных за 2014–2024 годы. Первоначальный поиск выявил в общей сложности 270 статей, связанных с HVLA при шейных мышечно-скелетных расстройствах. После отбора 62 статьи были удалены из-за дублирования, 158 статей были признаны нерелевантными на этапе рассмотрения заголовка, а 26 статей были оценены на основе их рефератов. Окончательный выбор включал 15 статей, которые соответствовали критериям включения для анализа. Выбранные статьи включали рандомизированные контролируемые испытания и метаанализы, оценивающие эффективность HVLA в отношении боли, подвижности и функции. Процесс отбора проводился систематически, чтобы гарантировать достоверность и релевантность данных.

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ. Результаты исследования показывают, что применение HVLA на шейном отделе позвоночника эффективно для уменьшения боли, увеличения диапазона движений (ROM) и улучшения функции у пациентов с мышечно-скелетными заболеваниями шеи, включая механическую боль в шее и головную боль напряжения. HVLA влияет на биомеханику суставов, снимает ограничения и снижает мышечное напряжение, способствуя повышению подвижности и уменьшению боли. Кроме того, эта техника обеспечивает эффекты модуляции боли и долгосрочные преимущества для функциональной активности пациентов. Однако внедрение HVLA требует комплексной оценки риска для выявления подходящих пациентов и минимизации потенциальных осложнений, включая риск повреждения позвоночной артерии. Эти результаты подчеркивают важность подхода, основанного на доказательствах, и осторожности в клинической практике для обеспечения оптимальных и безопасных терапевтических результатов.

ЗАКЛЮЧЕНИЕ. HVLA на шейном отделе позвоночника эффективна и безопасна, особенно для облегчения боли в шее и улучшения функций, хотя необходимо учитывать определенные риски. Практикующие врачи должны проводить тщательную оценку риска и учитывать состояние пациента для достижения оптимальных результатов. Влияние HVLA на кровоток, артериальное давление, силу рукопожатия и силу мышц шейного отдела позвоночника не является значительным, что делает его непригодным в качестве первичного вмешательства.

КЛЮЧЕВЫЕ СЛОВА: высокоскоростная низкоамплитудная техника (HVLA), мышечно-скелетные манипуляции, безопасность терапии, боль в шее, диапазон движений

Для цитирования: Nugraha R., Ramli R.W., Nurhalim L.I., Rahma S., Fahriana S.G. Safety and Therapeutic Outcomes of Cervical High-Velocity Low-Amplitude Manipulation in Clinical Practice: a Review. Bulletin of Rehabilitation Medicine. 2024; 24(4):130–140. https://doi.org/10.38025/2078-1962-2025-24-4-130-140

* **Для корреспонденции:** Rahmat Nugraha, E-mail: rahmatnugraha@poltekkes-mks.ac.id

Статья получена: 26.02.2025
Статья принята к печати: 16.06.2025
Статья опубликована: 16.08.2025

INTRODUCTION

High-velocity low-amplitude (HVLA) manipulation is a manual technique commonly used in physiotherapy and chiropractic care to address various musculoskeletal disorders. In HVLA, manipulation is performed rapidly but with relatively low force to influence joint mobility and reduce tension in the surrounding tissues. This technique aims to restore joint range of motion, alleviate pain, and enhance function in areas experiencing restriction or dysfunction, particularly in the cervical spine (neck) segment [1]. Cervical HVLA manipulation can help manage mechanical neck pain and other related musculoskeletal disorders, such as tension headaches and shoulder pain, which are closely linked to postural conditions and muscle imbalances around the cervical region [2, 3].

In clinical practice, the HVLA technique for the cervical spine is often considered due to its potential benefits in managing both chronic and acute neck pain. This technique is believed to provide rapid and significant results for certain conditions and is frequently used alongside other therapeutic modalities, such as strengthening exercises and stretching, to achieve more optimal treatment outcomes [4]. Although cervical HVLA manipulation has the potential to yield positive results, it requires a comprehensive understanding of anatomy, biomechanics, and patient risk assessment to minimize the likelihood of serious adverse effects, such as vertebral artery injury [5].

HVLA manipulation therapy for the cervical spine has been proven to provide significant benefits in reducing pain, improving mobility, and enhancing function in patients with various musculoskeletal disorders of the neck. Several studies have shown that this technique is effective in reducing the intensity of mechanical neck pain and increasing cervical joint range of motion, thereby contributing to postural recovery and improvement in functional activities [4].

HVLA manipulation also has a positive impact on patients' quality of life, particularly for individuals experiencing limitations in daily activities due to chronic neck pain. A study by Puentedura E.J. et al. (2012) found that patients receiving cervical HVLA manipulation showed significant improvements in pain parameters and quality of life compared to those undergoing therapy without manipulation [6]. Additionally, this therapy serves as a safe, non-surgical option that can be integrated with other interventions, such as strengthening exercises and mobilization, to achieve better outcomes in managing neck disorders, reduce the need for pharmacological treatments, and lower the risk of long-term complications [7].

Although cervical HVLA manipulation offers potential benefits, it also raises concerns regarding the risk of injury, particularly to the vertebral artery and neural structures surrounding the cervical spine. Vertebral artery injury, although rare, can lead to serious consequences such as ischemic stroke induced by thrombosis or embolism following cervical manipulation [5]. Additionally, there is a risk of nerve damage due to excessive pressure or stretching of cervical neural structures, which may result in radicular pain or other neurological symptoms [8]. These risks are influenced by various factors, including the manipulation technique used, the patient's health condition, and the practitioner's experience or skill level. Research suggests that practitioners with proper training and sufficient experience are more likely to minimize these risks through comprehensive risk assessment and cautious technique application [2]. Specific conditions such as a history of vascular disease or cervical spine disorders should also be considered in clinical decision-making to avoid unwanted complications.

There is a lack of consensus among practitioners regarding the safety limits and appropriate procedural standards for cervical HVLA techniques, leading to variations in clinical practice and potential risks for patients. Existing guidelines and recommendations are often inconsistent, making it challenging for practitioners to determine the best approach to implementing this technique [9]. In this context, a comprehensive review is essential to compile and analyze the latest scientific evidence on the safety and effectiveness of cervical HVLA therapy. By integrating findings from various studies, this review aims to provide clearer, evidence-based guidance for practitioners, thereby improving care standards and minimizing risks for patients. The results of this review are expected to serve as a valuable reference in clinical practice, assisting in better decision-making regarding the application of cervical HVLA manipulation and promoting safe and effective physiotherapy practices.

AIM

To review the scientific evidence regarding the safety and effectiveness of HVLA manipulation therapy on the cervical spine and to evaluate its impact on patients' clinical improvement. Through this analysis, the study aims to provide guidance for practitioners in assessing the risks and benefits of using HVLA techniques in physiotherapy practice.

MATERIALS AND METHODS

Publications on this topic were collected and analyzed from the PubMed, ScienceDirect, PEDro, and EBSCO databases, covering studies published from 2014 to 2024. The search algorithm was developed in accordance with the requirements and guidelines for reporting systematic reviews and meta-analyses (PRISMA) [10]. The search strategy included studies using specific search terms and keywords (including MeSH). Keywords used in the database search: ("HVLA Thrust" OR "High-Velocity Low-Amplitude" OR "Cervical Manipulation") AND "Cervical". The final search was conducted on 03.11.2024.

RESULTS AND DISCUSSION

Introduction to High-Velocity Low-Amplitude (HVLA) Technique

HVLA manipulation is a manual therapy technique commonly used in physiotherapy and chiropractic practice to address various musculoskeletal disorders. In HVLA, manipulation is performed rapidly while applying relatively low force to influence joint mobility and reduce surrounding tissue tension. HVLA involves the application of a quick force within a short duration, distance, and/or rotational area within the anatomical range of motion of a joint. This technique targets restrictive barriers across one or multiple planes of movement to achieve the release of restrictions [25].

HVLA techniques involve the application of a rapid force within a short duration, distance, and/or rotational area within the anatomical range of motion of a joint. This approach is used to engage restrictive barriers across one or multiple planes of movement to achieve the release of restrictions. HVLA manipulation utilizes high velocity and low amplitude thrusts to manipulate the joint effectively. According to LaPelusa A. and Bordoni B. [26]. Dr. Kirkaldy-Willis was the first to conceptualize and publish the theory of the Biomechanics and Biology of the Spinal Degenerative Cascade. He defined HVLA as "a skilled, passive therapeutic maneuver in which a synovial joint is taken beyond its normal physiological range of motion (toward the restrictive barrier) without exceeding anatomical integrity limits".

HVLA therapy is a specialized manual therapy technique that applies a rapid and short-duration force within a small range of motion in the joint's anatomical movement. This method engages restrictive barriers to achieve the release of restrictions. HVLA treatment is commonly associated with an audible and palpable release, often perceived as a "pop", which occurs due to cavitation within the spinal intervertebral joint, followed by subsequent release [27].

Table 1. Data of Selected Review Articles

No	Study	Aim	Method	Results and Conclusion
1	**García-Pérez-Juana D., et al. [11]**	To examine the effects of cervical thrust manipulation or sham manipulation on cervicocephalic kinesthetic sense, pain intensity, pain-related disability, and pressure pain sensitivity in patients with chronic mechanical neck pain	Fifty-four individuals with mechanical neck pain were randomly assigned to receive either cervical thrust manipulation (right or left) or sham manipulation. Immediate outcomes included cervical kinesthetic sense assessed by JPSE and PPT. Additionally, neck pain intensity (numerical pain rating scale) and neck pain-related disability (NDI) were collected in the first week	The study found that cervical thrust manipulation improved JPSE, PPT, and NDI in participants with chronic mechanical neck pain. The changes in JPSE and NDI were significant, exceeding the minimal detectable change. The effect size for PPT was moderate, with only the C5-C6 zygapophyseal joint surpassing the minimal detectable threshold. Neck pain intensity remained unchanged one week post-intervention
2	**Shackleton E., et al. [12]**	To determine whether positive and negative communication before HVLA manipulation at the C7-T1 spinal segment, within an osteopathic consultation setting, respectively increase or decrease PPT to create contextual placebo and nocebo effects. Study design: Pretest-posttest randomized controlled design	35 asymptomatic participants were recruited and randomly assigned to three separate condition arms using a repeated-measures crossover design: negative communication (NegC), neutral communication (NeuC), or positive communication (PosC). Each condition included spinal manipulation (HVLA thrust) at the C7-T1 segment. PPT was measured using an algometer at the C7 spinous process before and after each condition setting	There was a significant effect of communication style on PPT across all three conditions. Post-hoc analysis showed that positive communication had a significant effect on PPT (i.e., a placebo effect), while negative communication did not produce a significant effect (i.e., no nocebo effect). These findings are discussed in the context of communication styles used during osteopathic clinical consultations, highlighting their potential to enhance health outcomes in National Health Service and other clinical settings
3	**Whalen W., et al. [13]**	To develop best practice recommendations for chiropractic management in adults with neck pain	A steering committee of chiropractic experts developed recommendations based on the latest clinical guidelines. Additional literature was identified through targeted searches. A national panel of 56 chiropractic experts assessed 50 statements using a modified Delphi process. Consensus was reached on all statements within three rounds from August to November 2018	The statements covered various aspects of clinical encounters, including consent, diagnosis, assessment, treatment planning, execution, and referral for adults with neck pain. The best practice recommendations were based on the best available scientific evidence. For uncomplicated neck pain, including cases with headaches or radicular symptoms, chiropractic manipulation and multimodal care were recommended
4	**Casanova-Méndez A., et al. [14]**	To compare the short-term effects of two thoracic spinal manipulation maneuvers in subjects with chronic non-specific neck pain	Sixty participants were randomly divided into two groups: one received the Dog technique in a supine position, and the other underwent the Toggle-Recoil technique in a prone position, both targeting T4. Evaluations included neck pain (VAS), cervical range of motion, and pressure pain threshold at C4, T4, and upper trapezius tense bands. Measurements were taken before, immediately after, and 20 minutes post-intervention	Both maneuvers improved neck mobility, mechanosensitivity, and short-term pain reduction, with no significant clinical differences between groups. However, the Toggle-Recoil group showed slightly better outcomes in cervical extension ($p = 0.009$), right lateral flexion ($p = 0.004$), and left rotation ($p < 0.05$)

Table 1 Continued

No	Study	Aim	Method	Results and Conclusion
5	**Corum M., et al. [15]**	To evaluate the effects of two manual therapy techniques on pain, disability, and PPT in patients with TTH and neck pain	Forty-five TTH patients were randomly assigned to three groups, each receiving eight treatment sessions: manipulation and exercise (manipulation group), suboccipital inhibition and exercise (myofascial release group), or exercise alone (control group). Headache frequency, pain severity (VAS-headache, VAS-neck pain), and disability (HIT-6, NDI) were assessed at baseline, post-treatment, and at a three-month follow-up. PPT was also evaluated in the temporalis muscle	The manipulation group showed significantly greater improvements than the myofascial release group in headache frequency, pain severity, and PPT scores. Additionally, the manipulation group demonstrated statistically significant improvements in all outcome measures compared to the control group. Manipulation combined with exercise, alongside pharmacological treatment, appears to be a promising approach for TTH patients with cervical dysfunction
6	**Giacalone A., et al. [16]**	To explain how cervical manipulation affects musculoskeletal disorders	A systematic search was conducted in PubMed from January to March 2020. Two independent reviewers screened articles using the PRISMA diagram. Inclusion criteria included RCTs published in peer-reviewed journals from 2005 to 2020, involving participants of all ages. The intervention examined was thrust manipulation or HVLA directed at the cervical spine. After reviewing the literature, 21 out of 74 articles were deemed relevant	HVLA techniques in musculoskeletal disorders influence pain modulation, mobility, and strength locally and remotely. Cervical manipulation is effective for managing cervicalgia, epicondylalgia, temporomandibular disorders, and shoulder pain. However, its effect on strength in healthy individuals remains inconclusive. While complications from vertebral manipulation are rare, improper application poses risks, and patient tolerance or contraindications may limit its use. The optimal number of manipulations and long-term benefits are still unclear
8	**Dunning J., et al. [17]**	To determine the cavitation side during C1–2 rotational HVLA thrust manipulation and to calculate the number of cavitations, the duration of upper cervical manipulation, and the duration of a single cavitation	Nineteen asymptomatic participants received two upper cervical thrust manipulations targeting the right and left C1-C2 articulation. Skin-mounted microphones on bilateral C1 transverse processes recorded sound waves. Cavitation side, duration, and number were analyzed using spectrogram analysis and audio feedback via custom Matlab software	Bilateral cavitation was detected in 91.9 % of manipulations, while unilateral cavitation occurred in only 8.1 % ($p < 0.001$). Of 132 total cavitations, 72 were ipsilateral and 60 contralateral to the targeted C1–2 articulation, with no significant side preference ($p = 0.294$). The average number of cavitations per C1–2 HVLA thrust was 3.57, and per subject, it was 6.95. The mean cavitation duration was 5.66 ms, while the mean manipulation duration was 96.95 ms. Upper cervical HVLA thrust manipulations are significantly more likely to produce bilateral than unilateral cavitations, with multiple cavitations per thrust. This challenges the traditional manual therapy approach of targeting a single ipsilateral or contralateral facet joint in the upper cervical spine

Table 1 Continued

No	Study	Aim	Method	Results and Conclusion
9	**Sparks C.L., et al. [18]**	To compare the short-term effects of HVLA thrust manipulation on the upper cervical and upper thoracic regions versus non-thrust mobilization in patients with neck pain	A study evaluated the effects of HVLA thrust manipulation and non-thrust mobilization in patients with mechanical neck pain. Various tests and measurements were conducted before and after treatment. Results showed that patients receiving combined HVLA thrust manipulation on the upper cervical and thoracic spines had greater reductions in pain and disability than those receiving non-thrust mobilization. They also exhibited greater improvements in passive C1-2 rotation range of motion and deep cervical flexor motor performance. The number needed for a successful outcome was 1.8 and 2.3 at the 48-hour follow-up	The combination of HVLA thrust manipulation on the upper cervical and upper thoracic spines is significantly more effective in the short term than non-thrust mobilization in patients with mechanical neck pain
10.	**Malich P., et al. [19]**	This study aims to assess the effects of HVLA manipulations on force distribution, pressure, and balance in individuals with atlanto-occipital blockage, with a focus on post-treatment improvements	Diagnostic tests (cervical spine compression, Spurling, de Kleyn) and pedobarography (using EPS/R2 mat and BIOMECH STUDIO software) were used to assess functionality and postural parameters before and after HVLA therapy	Initial diagnosis showed significant balance, force distribution, and gait impairments. After HVLA therapy, improvements included better weight distribution, reduced left-side pressure, enhanced body oscillation control, normalized right foot abduction, and slight increases in foot vault index and average foot pressure during gait
11.	**Galindez-Ibarben-goetxea X., et al. [20]**	To evaluate the effects of indiscriminate manipulation at C5, MT, and ST on cervical ROM, isometric flexion peak force, SCM muscle EMG activation during CCFT, and biceps at rest	A randomized controlled pilot study with intention-to-treat analysis was conducted on 36 asymptomatic subjects (18 males, mean age 30), divided into three groups: AMC5 (n = 12), MT (n = 12), and ST (n = 12). Outcomes were measured pre- and post-intervention	Significant changes ($p < 0.1$) were found in cervical flexion isometric peak force (-13.15 %, d = 0.52). The MT group showed significant improvements in extension (10.44 %) and left rotation ROM (12.25 %), while no significant changes were observed during CCFT. The study suggests a trend of decreased cervical flexion strength in the MT group, with notable gains in extension and left rotation ROM
12.	**Haas M., et al. [21]**	To identify the dose-response relationship of SMT visits and evaluate its effectiveness compared to light massage control	RCT on 256 chronic CGH patients, randomized to 4 SMT dose levels (0, 6, 12, 18 sessions) over 18 visits in 6 weeks. Light massage was given when SMT was not applied. Dose-response and control comparisons were assessed at weeks 6, 12, 24, 39, and 52	A linear dose-response was observed across all follow-ups, with 1-day CGH reduction per 4 weeks for every 6 additional SMT visits ($p < 0.05$). The most effective dose (18 SMT visits) reduced CGH days from ~16 to 8 per month, showing a -3.3 ($p = 0.004$) and -2.9 ($p = 0.017$) difference vs. control at key endpoints. Other SMT doses had smaller, non-significant effects ($p > 0.05$). CGH intensity remained unchanged across doses. SMT showed a linear dose-response effect, with 18 visits halving CGH days and providing — 3 more days of relief per month vs. light massage

Table 1 End

No	Study	Aim	Method	Results and Conclusion
13	**Metcalfe S., et al. [22]**	To evaluate changes in anterolateral neck flexor strength after upper cervical manipulation	A total of 67 participants with mechanical neck pain or cervicogenic headache were divided into two groups. The treatment group received manipulation at dysfunctional upper (C0–C2) and lower (C2–C7) cervical segments, while the control group received manipulation only at lower cervical segments. Anterolateral neck flexor strength was measured using a hand-held dynamometer	After upper and lower cervical manipulation, the treatment group showed greater strength improvement on the weaker side. In the control group, a similar trend was observed but to a lesser extent. These findings suggest that manipulation has a neurological effect that immediately enhances muscle strength
14	**Pires P.F., et al. [23]**	To assess the immediate and short-term effects of upper thoracic manipulation on pain intensity and sternocleidomastoid muscle activity in young women with chronic neck pain	A randomized clinical trial with 32 women with chronic neck pain divided into an experimental group receiving upper thoracic manipulation below T1 using a pistol grip and a placebo group with an open-hand stabilization. Evaluations were conducted at baseline, immediately post-intervention, and 48-72 hours post-intervention. Sternocleidomastoid myoelectric activity was assessed at rest and during isometric cervical flexion and shoulder elevation. Neck pain intensity was measured using the VAS. Data were analyzed using two-way repeated measures ANOVA with Bonferroni correction ($p < 0.5$)	Moderate effects on sternocleidomastoid myoelectric activity during isometric shoulder elevation were observed in the experimental group only at the short-term evaluation ($d > 0.40$). No significant differences were found between groups across evaluation time points ($p > 0.5$). Both intra- and inter-group analyses showed no significant changes in cervical muscle activity or neck pain intensity at immediate or short-term follow-ups
15	**Quesnele J.J., et al. [24]**	To analyze the cerebrovascular hemodynamic response of the VA during cervical rotation and manipulation in vivo using MRI	A pilot study with 10 healthy male participants (ages 24-30) measured VA blood flow and velocity at C1-2 using MRI after three head positions and upper cervical manipulation. Thirty phase-contrast flow-encoded images were collected per cardiac cycle across four conditions to assess blood flow profiles. Differences in flow (mL/s) and velocity (cm/s) were analyzed using repeated measures ANOVA	No significant side-to-side differences were found in VA blood velocity ($p = 0.14$) or flow ($p = 0.19$) across conditions. No interactions or trends indicated changes in flow or velocity. The study concludes that head positions and cervical manipulation do not significantly affect VA hemodynamics in healthy young males, with no evidence of cerebrovascular hemodynamic impact from mechanical interaction with the VA during head movement

Note: *HVLA — high-velocity low-amplitude; JPSE — joint position sense error; PPT — pressure pain thresholds; NDI — neck disability Index; TTH — tension-type headache; VAS — visual analogue scale; RCTs — randomised controlled trials; MT — targeted manipulation; ROM — range of motion; ST — sham intervention; SMT — spinal manipulative therapy; CGH — comparative genomic hybridization; VA — vertebral artery; MRI — magnetic resonance Imaging; SCM — sternocleidomastoid.*

HVLA cervical manipulation techniques offer an alternative approach for patients with cervical neck dysfunction beyond traditional medical pathways. This technique aims to restore joint range of motion, reduce pain, and improve function in areas experiencing restriction or dysfunction, particularly in the cervical spine segment [1]. HVLA manipulation of the cervical region can help manage mechanical neck pain and other related musculoskeletal disorders, such as tension headaches and shoulder pain, which are closely linked to postural conditions and muscle imbalances around the cervical area [2, 3].

The cervical region (neck) consists of vascular, musculoskeletal, and neural pathways between the skull and the thorax. It is an area prone to injury and somatic dysfunction, leading to pain and loss of mobility. The use of HVLA techniques on the cervical spine, while potentially providing positive outcomes, requires a thorough understanding of anatomy, biomechanics, and patient risk assessment to reduce the likelihood of serious side effects, such as vertebral artery injury [5].

In clinical practice, HVLA techniques on the cervical spine are often considered for their potential benefits in addressing both chronic and acute neck pain. These techniques are believed to produce rapid and significant results in certain conditions and are frequently combined with other therapeutic modalities, such as strengthening exercises and stretching, to achieve more optimal therapeutic outcomes. HVLA manipulation therapy for the cervical spine has been shown to provide significant benefits in reducing pain, improving mobility, and enhancing function in patients with various musculoskeletal neck disorders. Several studies indicate that this technique is effective in reducing the intensity of mechanical neck pain and increasing the range of motion in cervical joints, thereby contributing to postural recovery and improvements in functional activities [4].

Research indicates that HVLA therapy can result in significant improvements in reducing neck pain and enhancing functionality. This therapy method is often found to be more effective than other conservative treatments or pharmacological interventions. Recent approaches to risk management recommend thorough risk assessment and precise clinical decision-making to minimize potential complications. Practitioners are advised to conduct a comprehensive evaluation of patients before initiating therapy [28].

Although HVLA manipulation on the cervical spine has potential benefits, this technique also raises concerns regarding the risk of injury, particularly to the vertebral arteries and neural structures surrounding the cervical spine. The application of HVLA techniques to the cervical region requires a comprehensive examination beforehand to ensure that patients meet safety criteria. This assessment includes evaluating medical history, physical condition, and the potential presence of contraindications, such as vascular disorders or structural issues in the neck, which may increase the risk of injury [29]. A thorough assessment can help identify suitable patients, allowing this technique to be applied effectively without compromising patient safety.

HVLA therapy works by facilitating joint mobilization and reducing muscle tension, contributing to pain reduction and improved mobility. Patients undergoing HVLA therapy often report an improved quality of life and enhanced ability to perform daily activities. These positive effects can persist after therapy sessions, providing long-term benefits for patients.

HVLA on Pain and Range of Motion (ROM)

Intervertebral joint dysfunction is characterized by reduced spinal segment mobility, and spinal manipulation has the potential to influence joint mobility, leading to changes in spinal kinematic behavior. It has been found that HVLA is more effective in reducing neck pain at rest and in improving active cervical range of motion compared to control mobilization procedures in subjects suffering from mechanical neck pain [28].

Proper spinal manipulation procedures will affect the mobility of non-moving joints and lead to increased range of motion in specific segments. However, Clements et al. found that HVLA manipulation of the atlantoaxial joint resulted in significant immediate improvements in passive asymmetric atlantoaxial rotation, regardless of whether the HVLA technique was applied unilaterally — either toward or away from the restricted rotation — or bilaterally. Additionally, it was found that the increase in cervical ROM after the manipulative procedure was not dependent on the side of manipulation. Therefore, it is possible that the HVLA thrust possesses an inherent quality that can alter cervical biomechanics, regardless of the direction or side of the thrust. HVLA thrust also contributes to an increase in range of motion. Thus, there is a possibility that pain modulation effects, rather than direct range of motion effects, may cause changes in active range of motion [30].

Previous studies have shown that spinal manipulation is effective in reducing pressure pain thresholds and increasing cervical range of motion in patients with mechanical neck pain. Other research has reported that no long-term changes in passive cervical range of motion occur following spinal manipulation. Cassidy J.D. et al. compared the immediate effects of spinal manipulative therapy with the muscle energy technique as a mobilization procedure on pain and range of motion in the cervical spine [5].

Safety of HVLA Related to Blood Flow

Vertebrobasilar Artery (VBA) stroke can occur for a number of reasons. In cases of traumatic events, the theoretical focus is on mechanical forces associated with head movement that cause irritation or damage to the intimallayer, leadingtovasospasmortearingoftheVertebral Artery (VA), which alters blood flow. Based on Bernoulli's principle, an increase in blood flow velocity occurs at and/or immediately after a point of vascular narrowing due to stretching or compression. This can result in turbulent and jetting flow immediately downstream of the distorted area, potentially triggering a local thrombogenic response that leads to VBA stroke.

A common hypothesis suggests that head rotation, including Cervical Spine Manipulation (CSM), can cause stretching and compression of the VA, leading to a reduction in the cross-sectional area of the blood vessel. Considering cervical kinematics during rotation, mechanical changes to the VA are possible. However, in cadaveric studies, Symons B.M. et al., 2002, and Wuest S. et al., 2010, measured the axial forces sustained by the VA during the range of motion, injury testing, and various CSM techniques using paired piezoelectric crystals sewn into the arterial wall. Cervical spinal manipulation produced strain values lower than those observed during physiological neck rotation [31, 32].

Arterial flow never exceeded half of the end-diastolic flow seen in stenosis cases confirmed by Yurdakul M. and Tola M., 2011, and remained entirely within the reference range after all head positions and CSM procedures. The most significant changes were observed during contralateral rotation, where VA velocity after CSM was 8 % lower than in the neutral position and 9 % lower than in the mid-position for peak velocity measurements. When examining VA flow, the greatest change was 7 %, observed in the contralateral VA after CSM. These blood flow changes were relatively small and, according to Licht et al., not considered clinically significant [33].

Approximately 50 % of total cervical rotation occurs at the atlantoaxial region. During rotation, it is proposed that the artery contralateral to the rotation side is stretched, while the ipsilateral artery is compressed against bony landmarks in that area. Cervical spinal manipulation is hypothesized to be a mechanism for vertebral artery injury due to rotational forces applied during many cervical spinal manipulation techniques.

Spinal manipulation interventions stretch the vertebral arteries well within the normal physiological range of neck movement, making it unlikely that spinal manipulation thrusts in the cervical region mechanically compromise the vertebral artery. Manipulation occurs within the normal physiological limits of cervical rotation and, therefore, is unlikely to alter or affect the hemodynamics of blood flow through the ipsilateral vertebral artery. Without pre-existing risk factors, hemodynamic measurements of the V3 segment of the vertebral artery indicate no significant differences in blood flow or blood velocity in the suboccipital part (V3) of the VA following head rotation or high-velocity low-amplitude manipulation procedures.

HVLA on Blood Pressure

Spinal Manipulative Therapy (SMT) on the upper cervical region can enhance parasympathetic dominance, while SMT on the lower cervical region increases sympathetic activity in healthy individuals. However, parasympathetic dominance has been observed in patients with neck pain who received both upper and lower cervical SMT. Upper cervical SMT has been shown to lower blood pressure in healthy individuals, whereas the effects of upper and lower cervical SMT on patient groups remain unclear. Nevertheless, a strong increase in vagal tone has been suggested to counteract sympathetic tone and stress-related effects or contribute to pain reduction.

Other underlying mechanisms for blood pressure reduction may include cervicosympathetic reflex stimulation, modulation of muscle tone, and the elimination of pressor reflex effects. Welch A. and Boone R., 2001, reported a significant reduction in blood pressure and pulse pressure but found no changes in heart rate following manipulation. Welch hypothesized that if the upper cervical segments are manipulated, a parasympathetic response would be triggered due to their proximity to the brainstem, where the motor nuclei of cranial nerves III, VII, IX, X, and XI are located. Conversely, manipulation of the upper thoracic or lower cervical segments would elicit a sympathetic response due to the involvement of the stellate ganglion, which stimulates the sympathetic chain ganglia [34].

Another theory suggests that the reduction in systolic blood pressure following upper cervical SMT may be attributed to the activation of the cervical sympathetic reflex, which responds to signals from muscle spindles or Golgi tendon organs in the suboccipital spine to counteract the vestibulosympathetic reflex [20].

HVLA in Enhancing Handgrip Strength

Spinal manipulation can influence how the central nervous system responds to functional tasks. Cervical thrust techniques increase the resting electromyographic activity of the biceps brachii muscle, which enhances elbow flexor strength and may affect grip strength [35, 36]. However, the observed changes in grip strength only represented a 5 % increase from the baseline score, which is below the clinically significant threshold reported for this outcome measure [37]. Therefore, it was concluded that low-cervical and upper-thoracic thrust manipulation is no more effective than a placebo in inducing grip strength in patients with chronic, non-specific mechanical neck pain.

A lower pressure pain threshold, compared to healthy controls, has been observed in patients with chronic non-specific neck pain both locally at the cervical spine and along peripheral nerve trunks (median, radial, and ulnar nerves). Upper limb neurodynamic tests are used to detect increased mechanosensitivity of the brachial plexus nerve trunks and report their reliability levels [22].

In randomized controlled trials, the overall findings indicate that cervical or thoracic thrust manipulation has similar effects on improving the mechanosensitivity of upper limb nerve trunks and grip strength in patients with chronic, non-specific mechanical neck pain. However, all these changes were small and below the threshold considered clinically relevant [38].

Regarding free pain grip strength, it is concluded that spinal manipulation can influence how the central nervous system responds to functional tasks. Cervical thrust techniques increase the resting electromyographic activity of the biceps brachii muscle, which may enhance elbow flexor strength and affect grip strength. Immediate changes in grip strength have been observed following spinal manipulation in healthy individuals and in patients with lateral epicondylalgia, with improvements ranging from 10 % to 40 % of baseline values. Contrary to the findings of Bautista-Aguirre F. et al., changes in this study only represented a 5 % increase from the initial score, which was below the clinically significant threshold reported for this outcome measure. Therefore, it can be concluded that HVLA is not effective in improving neural mechanosensitivity or free pain grip strength in patients with chronic, non-specific mechanical neck pain [38].

HVLA in Enhancing Cervical Spine Muscle Strength

Adequate joint proprioception is crucial for muscle function, as dysfunctional spinal joints can alter mechanoreceptor input, affecting neural control of strength and tone. Poor sensory integration may lead to movement dysfunction or strength impairment, which can be addressed through manipulation. Segmental spinal dysfunction alters neurological input, reducing local muscle tone and weakening neck muscles, particularly in those with neck pain. Treating upper and lower cervical dysfunction has shown positive effects on anterolateral neck flexor strength, including muscles like the longus colli, rectus capitis, scalenes, platysma, and sternocleidomastoid. The predicted weaker side demonstrated greater strength gains, leading to bilateral balance in clinical assessments. This suggests a link between atlas misalignment and asymmetric muscle strength, highlighting the role of segmental dysfunction in neural inhibition [22].

Previous studies on manipulation have only reported temporary treatment effects. The strength gains observed in the present study may also be temporary. Further research is needed to determine the duration of the positive effects of manipulation. The presence of strength enhancement following passive techniques highlights the potential role of neurological inhibition in weak muscles during examination. Although long-term strength gains are best achieved through therapeutic exercises, reducing inhibitory afferent input may optimize and accelerate recovery [22].

Manipulation benefits neurological function by inducing changes in afferent excitation levels from sensory impulses originating from spinal segments. Altered afferent input ultimately results in rapid changes in muscle strength. Treatment of segmental dysfunctions in the upper and lower cervical spine through manipulation produces greater improvements in neck strength on the weaker side compared to the stronger side. This effect is more pronounced than treatment limited to lower cervical spine manipulations alone, suggesting that manipulation has neurological effects that result in immediate changes in muscle strength. This study also provides strong support for the necessity of segment-specific and direction-specific manipulative interventions in patients with mechanical neck pain [22].

CONCLUSION

HVLA manual therapy applied to the cervical spine shows promising potential in terms of both safety and effectiveness. Although certain risks must be considered, the clinical benefits of this therapy can be substantial, particularly in managing neck pain and improving functional capacity. Practitioners should consistently conduct thorough risk assessments and consider individual patient conditions to optimize treatment outcomes. The impact of HVLA on factors such as blood flow, blood pressure, handgrip strength, and cervical muscle strength has not been found to be significant, supporting its safety considerations. Despite its therapeutic effects, HVLA should not be considered a primary intervention in patient management.

ADDITIONAL INFORMATION

Rahmat Nugraha, Bachelor of Physiotherapy, Magister of Sports Physiology Concentration in Physiotherapy, Lecture, Health Polytechnic of Ministry of Health Indonesian Republic Makassar.
E-mail: rahmatnugraha@poltekkes-mks.ac.id;
ORCID: https://orcid.org/0009-0003-9342-8785
Rizky Wulandari Ramli, Student, Health Polytechnic of Ministry of Health Indonesian Republic Makassar.
Latifa Insani Nurhalim, Student, Health Polytechnic of Ministry of Health Indonesian Republic Makassar.
Sitti Rahma, Physiotherapist, Health Polytechnic of Ministry of Health Indonesian Republic Makassar.
Sri G Fahriana, Lecture, Pembangunan Nasional Veteran Jakarta University.

Author Contributions. All authors confirm their authorship according to the international ICMJE criteria (all authors contributed significantly to the conception, study design and preparation of the article, read and approved the final version before publication). Special contributions: Nugraha R. — conceptualization, writing — original draft, writing — review & editing; Ramli R.W. — writing — original draft; Nurhalim L.I. — writing — original draft; Rahma S. — supervision; Fahriana S.G. — supervision.
Funding. This clinical study did not receive any external funding.
Disclosure. The authors declare no apparent or potential conflicts of interest related to the publication of this article.
Data Access Statement. The data that support the findings of this study are available on reasonable request from the corresponding author.

References

1. Giacalone A., Febbi M., Magnifica F., Ruberti E. The Effect of High Velocity Low Amplitude Cervical Manipulations on the Musculoskeletal System: Literature Review. Cureus. 2020; 12(4): e7682. https://doi.org/10.7759/cureus.7682
2. Hurwitz E.L., Carragee E.J., van der Velde G., et al. Treatment of Neck Pain: Noninvasive Interventions. Spine, 2002; 33(4 Suppl): S123–S 52. https://doi.org/10.1097/brs.0b013e3181644b1d
3. Fernandez-de-Las-Penas C., Alonso-Blanco C., Cuadrado M.L., Pareja J.A.. Myofascial trigger points in the suboccipital and upper trapezius muscles in episodic tension-type headache. Headache: The Journal of Head and Face Pain. 2007; 47(3): 312–322. https://doi.org/10.1016/j.math.2006.07.003
4. Gross A.R., Hoving J.L., Haines T., et al. Manipulation and Mobilization for Mechanical Neck Disorders. Cochrane Database of Systematic Reviews. 2015; 2015(9): CD004249. https://doi.org/10.1002/14651858.CD004249.pub4
5. Cassidy J.D., Boyle, E., Côté P., et al. Risk of Vertebrobasilar Stroke and Chiropractic Care: Results of a Population-Based Case-Control and Case-Crossover Study. Spine. 2008; 33(4 Suppl): S176–S183. https://doi.org/10.1097/BRS.0b013e3181644600
6. Puentedura E.J., Cleland J.A., Landers M.R., et al. Thoracic spine thrust manipulation for the management of patients with neck pain: a randomized clinical trial. Journal of Orthopaedic & Sports Physical Therapy. 2012; 42(2): 66–75. https://doi.org/10.2519/jospt.2012.3894
7. Roșu D., Rusu R., Radu P., Popescu A., Man C., Fleancu J., Tomuș A., Muntean R., Ursu V., Ștefănică V. The Impact of HVLA Manipulations and Therapeutic Massage in Increasing the Mobility of the Lateral Flexion of the Neck. BRAIN. Broad Research in Artificial Intelligence and Neuroscience. 2023; 14(4): 266–291. https://doi.org/10.18662/brain/14.4/505
8. DiFabio R.P. Manipulation of the cervical spine: risks and benefits. Physical Therapy. 1999; 79(1): 50–65. https://doi.org/10.1093/ptj/79.1.50
9. Giacalone A., Febbi M., Magnifica F., Ruberti E. The Effect of High Velocity Low Amplitude Cervical Manipulations on the Musculoskeletal System: Literature Review. Cureus. 2020; 12(4): e7682. https://doi.org/10.7759/cureus.7682

10. Moher D., Liberati A., Tetzlaff J., et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: the PRISMA statement. PLoS Med. 2009; 6(7): e1000097. https://doi.org/10.1371/journal.pmed.1000097
11. García-Pérez-Juana D., Fernández-de-las-Peñas C., Arias-Buría J.L., et al. Changes in Cervicocephalic Kinesthetic Sensibility, Widespread Pressure Pain Sensitivity, and Neck Pain After Cervical Thrust Manipulation in Patients with Chronic Mechanical Neck Pain: A Randomized Clinical Trial. Journal of Manipulative and Physiological Therapeutics. 2018; 41(7): 551–560. https://doi.org/10.1016/j.jmpt.2018.02.004
12. Shackleton E., Toutt C., Edwards D.J. Psychological context effects of participant expectation on pain pressure thresholds as an adjunct to cervicothoracic HVLA thrust manipulation: A randomised controlled trial. International Journal of Osteopathic Medicine. 2020; 35: 5–12. https://doi.org/10.1016/j.ijosm.2019.11.003
13. Whalen W., Farabaugh R.J., Hawk C., et al. Best-Practice Recommendations for Chiropractic Management of Patients with Neck Pain. Journal of Manipulative and Physiological Therapeutics. 2019; 42(9): 635–650. https://doi.org/10.1016/j.jmpt.2019.08.001
14. Casanova-Méndez A., Oliva-Pascual-Vaca Á., Rodriguez-Blanco C., et al. Comparative short-term effects of two thoracic spinal manipulation techniques in subjects with chronic mechanical neck pain: A randomized controlled trial. Manual Therapy. 2014; 19(4): 331–337. https://doi.org/10.1016/j.math.2014.03.002
15. Corum M., Aydin T., Medin Ceylan C., Kesiktas F.N. The comparative effects of spinal manipulation, myofascial release and exercise in tension-type headache patients with neck pain: A randomized controlled trial. Complementary Therapies in Clinical Practice. 2021; 43: 101319. https://doi.org/10.1016/j.ctcp.2021.101319
16. Giacalone A., Febbi M., Magnifica F., Ruberti E. The Effect of High Velocity Low Amplitude Cervical Manipulations on the Musculoskeletal System: Literature Review. Cureus. 2020; 12(4): e7682. https://doi.org/10.7759/cureus.7682
17. Dunning J., Mourad F., Barbero M., et al. Bilateral and multiple cavitation sounds during upper cervical thrust manipulation. BMC Musculoskeletal Disorder. 2013. Available at: http://www.biomedcentral.com/1471-2474/14/24 (Accessed 01.02.2025).
18. Sparks C.L., Liu W.C., Cleland J.A., et al. Functional Magnetic Resonance Imaging of Cerebral Hemodynamic Responses to Pain Following Thoracic Thrust Manipulation in Individuals With Neck Pain: A Randomized Trial. Journal of Manipulative and Physiological Therapeutics. 2017; 40(9): 625–634. https://doi.org/10.1016/j.jmpt.2017.07.010
19. Malich P., Bitenc-Jasieńko A., Pasternak A., et al. The effect of HVLA manipulation on static and dynamic postural parameters — a case study of a patient with a blocked atlantooccipital transition. Fizjoterapi Polska. 2024; 24(1): 215–225. https://doi.org/10.56984/8ZG2EF8t5I
20. Galindez-Ibarbengoetxea X., Setuain I., González-Izal M., et al. Randomised controlled pilot trial of high-velocity, low-amplitude manipulation on cervical and upper thoracic spine levels in asymptomatic subjects. International Journal of Osteopathic Medicine. 2017; 25: 6–14. https://doi.org/10.1016/j.ijosm.2016.11.004
21. Haas M., Bronfort G., Evans R., et al. Dose-response and efficacy of spinal manipulation for care of cervicogenic headache: a dual-center randomized controlled trial. Spine Journal. 2018; 18(10): 1741–1754. https://doi.org/10.1016/j.spinee.2018.02.019
22. Metcalfe S., Reese H., Sydenham R. Effect of high-velocity low-amplitude manipulation on cervical spine muscle strength: A randomized clinical trial. Journal of Manual and Manipulative Therapy. 2006; 14(3): 152–158. https://doi.org/10.1179/106698106790835687
23. Pires P.F., Packer A.C., Dibai-Filho A.V., Rodrigues-Bigaton D. Immediate and Short-Term Effects of Upper Thoracic Manipulation on Myoelectric Activity of Sternocleidomastoid Muscles in Young Women with Chronic Neck Pain: A Randomized Blind Clinical Trial. Journal of Manipulative and Physiological Therapeutics. 2015; 38(8): 555–563. https://doi.org/10.1016/j.jmpt.2015.06.016
24. Quesnele J.J., Triano J.J., Noseworthy M.D., Wells G.D. Changes in vertebral artery blood flow following various head positions and cervical spine manipulation. Journal of Manipulative and Physiological Therapeutics. 2014; 37(1): 22–31. https://doi.org/10.1016/j.jmpt.2013.07.008
25. Wirth B., Gassner A., de Bruin E.D., et al. Neurophysiological Effects of High Velocity and Low Amplitude Spinal Manipulation in Symptomatic and Asymptomatic Humans: A Systematic Literature Review. Spine (Phila Pa 1976). 2019; 44(15): E914–E926. https://doi.org/10.1097/brs.0000000000003013
26. LaPelusa A., Bordoni B. High-Velocity Low-Amplitude Manipulation Techniques [Internet]. Treasure Island (FL): StatPearls Publishing. 2025 Jan. [updated 2023 Jun 4; cited 2025 Jun 15]. Available at: https://www.ncbi.nlm.nih.gov/books/NBK574527/ (Accessed 01.02.2025).
27. Elder B., Tishkowski K. Osteopathic Manipulative Treatment: HVLA Procedure - Cervical Vertebrae. Treasure Island (FL): StatPearls. 2022. Available at: https://www.ncbi.nlm.nih.gov/books/NBK565847/ (Accessed 01.02.2025).
28. Martínez-Segura R., Fernández-de-las-Peñas C., Ruiz-Sáez M., et al. Immediate Effects on Neck Pain and Active Range of Motion After a Single Cervical High-Velocity Low-Amplitude Manipulation in Subjects Presenting with Mechanical Neck Pain: A Randomized Controlled Trial. Journal of Manipulative and Physiological Therapeutics. 2006; 29(7): 511–517. https://doi.org/10.1016/j.jmpt.2006.06.022
29. Carlesso L.C., Gross A.R., Santaguida P.L., Burnie S.J. Adverse Events Associated With Spinal Manipulation Therapy (SMT) for the Treatment of Neck and/or Low Back Pain: A Systematic Review. Manual Therapy. 2011; 16(5): 490–497. https://doi.org/10.1016/j.math.2011.02.005
30. Clements B., Gibbons P., Mclaughlin P. The amelioration of atlanto-axial rotation asymmetry using high velocity low amplitude manipulation" Is the direction of thrust important? In Journal of Osteopathic Medicine. 2001; 4(1): 8–14. https://doi.org/10.1016/S1443–8461(01)80038-1
31. Symons B.M, Leonard T., Herzog W. Internal forces sustained by the vertebral artery during spinal manipulative therapy. Journal of Manipulative and Physiological Therapeutics. 2020; 25(8): 504–510. https://doi.org/10.1067/mmt.2002.127076
32. Wuest S., Symons B., Leonard T., Herzog W. Preliminary Report: Biomechanics of Vertebral Artery Segments C1-C6 During Cervical Spinal Manipulation. Journal of Manipulative and Physiological Therapeutics. 2010; 33(4): 273–278. https://doi.org/10.1016/j.jmpt.2010.03.007
33. Yurdakul M., Tola M. Doppler criteria for identifying proximal vertebral artery stenosis of 50 % or more. Journal of ultrasound in medicine: official journal of the American Institute of Ultrasound in Medicine. 2011; 30(2): 163–168. https://doi.org/10.7863/jum.2011.30.2.163
34. Welch A., Boone R. Sympathetic and parasympathetic responses to specific diversified adjustments to chiropractic vertebral subluxations of the cervical and thoracic spine. Journal of chiropractic medicine. 2008; 7(3): 86–93. https://doi.org/10.1016/j.jcm.2008.04.001
35. Dunning J., Rushton A. The effects of cervical high-velocity low-amplitude thrust manipulation on resting electromyographic activity of the biceps brachii muscle. Manual Therapy. 2009; 14(5): 508–513. https://doi.org/10.1016/j.math.2008.09.003
36. Suter E., Mcmorland G. Brief report Decrease in elbow flexor inhibition after cervical spine manipulation in patients with chronic neck pain. 2002; 17(7): 541–544. https://doi.org/10.1016/s0268-0033(02)00025-6
37. Kim J.K., Park M.G., Shin S.J. What is the minimum clinically important difference in grip strength? Clinical Orthopaedics and Related Research. 2014; 472(8): 2536–2541. https://doi.org/10.1007/s11999-014–3666-y
38. Bautista-Aguirre F., Oliva-Pascual-Vaca Á., Heredia-Rizo A. M., et al. Effect of cervical vs. thoracic spinal manipulation on peripheral neural features and grip strength in subjects with chronic mechanical neck pain: A randomized controlled trial. European Journal of Physical and Rehabilitation Medicine. 2017; 53(3): 333–341. https://doi.org/10.23736/S1973-9087.17.04431-8