

SUBOCCIPITAL MYOFASCIAL TREATMENT AND ATLAS ALIGNMENT: A PROSPECTIVE RADIOLOGICAL STUDY

TRATAMENTO MIOFASCIAL SUBOCCIPITAL E ALINHAMENTO DO ATLAS: ESTUDO RADIOLÓGICO PROSPECTIVO

TRATAMIENTO MIOFASCIAL SUBOCCIPITAL Y ALINEACIÓN DEL ATLAS: ESTUDIO RADIOLÓGICO PROSPECTIVO

ORLANDO ANGULO¹ , LLUIS MANENT² , NOEMÍ LAGUNA³ , JOSÉ GABRIEL LEÓN-HIGUERA² , ANDRÉS GALINDO⁴ 

1. Universidad Cooperativa de Colombia, Facultad de Medicina, Sede Villavicencio, Villavicencio, Colombia.

2. Foundation University of Health Sciences, Bogotá, Cundinamarca, Colombia.

3. AO Helige Clinic, Morelos, Mexico.

4. Center for Research and Popular Education (CINEP), Department of General Information System, Bogotá DC, Colombia.

ABSTRACT

Objective: To determine and evaluate radiological changes in the asymmetry of the lateral atlantodental interval and atlas tilt after the application of the Atlasprofilax intervention. **Methods:** A radiological prospective study was conducted on patients who underwent the Atlasprofilax Method in Mexico. A total of 258 patients provided informed consent and were enrolled in the study. Group A (n=79) underwent the intervention, while Group B (n=179) served as the control group. Anteroposterior transoral radiographs were obtained for both groups. The open-mouth anteroposterior projection was selected for clear visualization of relevant structures. **Results:** Both groups had a very similar distribution of lateral atlantodental interval prior to the intervention. Both groups exhibited positive lateral atlantodental interval asymmetry with most values ranging from 1 mm to 2.9 mm. After the intervention in Group A, a highly significant and clear improvement was observed, with a reduction in lateral atlantodental interval asymmetry trending toward zero and enhanced orthogonality of the C1-C2 complex. Atlas tilt and the alignment of the C2 spinous process did also significantly improve. **Conclusions:** The Atlasprofilax intervention yielded significant improvements by decreasing lateral atlantodental interval asymmetry, correcting atlas tilt, and aligning the C2 spinous process in the treated group, both in comparison to the control group and when evaluating pre- and post-intervention changes. These results contribute valuable data to the ongoing debate regarding the clinical significance of lateral atlantodental interval asymmetries and underscore the need for further research to better understand their implications. **Level of Evidence II; Prospective comparative therapeutic (radiological) study.**

Keywords: Cervical Atlas; Atlanto-Axial Joint; Odontoid Process; Rotation; Radiography.

RESUMO

Objetivo: Determinar e avaliar as alterações radiológicas na assimetria do intervalo atlantodental lateral e na inclinação do atlas após a aplicação da intervenção Atlasprofilax. **Métodos:** Foi conduzido um estudo radiológico prospectivo em pacientes submetidos ao Método Atlasprofilax no México. Um total de 258 pacientes forneceu consentimento informado e foi incluído no estudo. O Grupo A (n=79) foi submetido à intervenção, enquanto o Grupo B (n=179) serviu como grupo controle. Radiografias transorais anteroposteriores foram obtidas para ambos os grupos. A projeção anteroposterior com a boca aberta foi selecionada para uma visualização clara das estruturas relevantes. **Resultados:** Ambos os grupos apresentaram uma distribuição muito semelhante do intervalo atlantodental lateral antes da intervenção. Ambos os grupos exibiram assimetria positiva do intervalo atlantodental lateral, com a maioria dos valores variando de 1 mm a 2,9 mm. Após a intervenção no Grupo A, foi observada uma melhora altamente significativa e clara, com redução da assimetria do intervalo atlantodental lateral tendendo a zero e maior ortogonalidade do complexo C1-C2. A inclinação do atlas e o alinhamento do processo espinhoso de C2 também melhoraram significativamente. **Conclusões:** A intervenção Atlasprofilax resultou em melhorias significativas, reduzindo a assimetria do intervalo atlantodental lateral, corrigindo a inclinação do atlas e alinhando o processo espinhoso de C2 no grupo tratado, tanto em comparação com o grupo controle quanto na avaliação das mudanças pré e pós-intervenção. Esses resultados contribuem com dados valiosos para o debate em curso sobre a significância clínica das assimetrias do intervalo atlantodental lateral e destacam a necessidade de mais pesquisas para compreender melhor suas implicações. **Nível de Evidência II; Estudo terapêutico comparativo prospectivo (radiológico).**

Descritores: Atlas Cervical; Articulação Atlantoaxial; Processo Odontoide; Rotação; Radiografia.

RESUMEN

Objetivo: Determinar y evaluar los cambios radiológicos en la asimetría del intervalo atlantodental lateral y la inclinación del atlas después de la aplicación de la intervención Atlasprofilax. **Métodos:** Se realizó un estudio radiológico prospectivo con grupo de control en pacientes que se sometieron al Método Atlasprofilax en México. Un total de 258 pacientes proporcionaron consentimiento informado y fueron incluidos en el estudio. El Grupo A (n=79) recibió la intervención, mientras que el Grupo B (n=179) sirvió como grupo control. Se

Study conducted by the AO Helige Clinic, Morelos, Mexico.

Correspondence: Orlando Angulo. Universidad Cooperativa de Colombia, campus Villavicencio, Facultad de Medicina, Carrera 22 No. 7-06, barrio La Rosita, Villavicencio, Colombia. orlando.angulo@campusucc.edu.co



obtuvieron radiografías transorales anteroposteriores para ambos grupos. Se seleccionó la proyección anteroposterior con la boca abierta para una visualización clara de las estructuras relevantes. Resultados: Ambos grupos mostraron una distribución muy similar del intervalo atlantodental lateral antes de la intervención. Ambos grupos exhibieron asimetría positiva del intervalo atlantodental lateral, con la mayoría de los valores en el rango de 1 mm a 2,9 mm. Después de la intervención en el Grupo A, se observó una mejora altamente significativa y clara, con una reducción de la asimetría del intervalo atlantodental lateral tendiendo a cero y una mayor ortogonalidad del complejo C1-C2. La inclinación del atlas y la alineación del proceso espinoso de C2 también mejoraron significativamente. Conclusiones: La intervención Atlasprofilax produjo mejoras significativas al reducir la asimetría del intervalo atlantodental lateral, corregir la inclinación del atlas y alinear el proceso espinoso de C2 en el grupo tratado, tanto en comparación con el grupo control como al evaluar los cambios antes y después de la intervención. Estos resultados aportan datos valiosos al debate en curso sobre la importancia clínica de las asimetrías del intervalo atlantodental lateral y subrayan la necesidad de más investigación para comprender mejor sus implicaciones. **Nivel de Evidencia II; Estudio terapéutico comparativo prospectivo (radiológico).**

Descriptor: Atlas Cervical; Articulación Atlantoaxial; Apófisis Odontoides; Rotación; Radiografía.

INTRODUCTION

Asymmetry of the lateral atlantodental interval (LADI) has been a subject of considerable debate among radiologists.¹⁻⁴ While some authors regard LADI asymmetry as a common normal variant without pathological significance^{1,2}, others suggest it may indicate pathological C1-C2 rotation, potentially reflecting an atlantoaxial rotatory subluxation (ARS)^{3,4}. Although ARS is often associated with traumatic atlantoaxial injuries⁵ and increased LADI asymmetry, radiographic evidence has shown LADI asymmetries in patients who are asymptomatic, raising questions about the clinical importance of radiological diagnosis in these cases. Nevertheless, significant differences in LADI have been observed between patients with clinical symptoms, such as cervical tenderness and torticollis, and asymptomatic individuals, particularly among pediatric subjects. A study involving 70 children, both injured and non-injured, investigated LADI asymmetry and its association with clinical symptoms⁶. The mean LADI asymmetry in the non-injured group was 1.4 ± 0.7 mm, which was significantly different from the injured group's mean LADI asymmetry of 3.8 ± 2.2 mm ($P < .001$). This data highlighted a clear distinction between the groups, with the non-injured cohort displaying a maximum LADI of 2.7 mm and the injured group presenting a minimum LADI of 2.5 mm. Furthermore, cervical tenderness exhibited a positive correlation with LADI asymmetry. The mean LADI asymmetry of 3.8 mm in injured children exceeded the normal range for adults, as defined by Wolansky et al., where an LADI greater than 3 mm is deemed abnormal⁷.

In children, the lateral atlantodental interval (LADI) is generally smaller than in adults, with research by Mendenhall et al. showing frequent asymmetry in asymptomatic children, regardless of age or sex, with a mean difference of 0.09 ± 1.23 mm (range: -6.05 to 4.87 mm)⁸. While diagnostic imaging like X-rays and CT scans is commonly used to assess atlantoaxial rotatory subluxation (ARS), MRI is not universally recommended for cervical spine injury diagnosis⁹.

A study using anteroposterior open-mouth radiographs found LADI asymmetry in 54% of subjects², highlighting the importance of maintaining a straight head position to minimize bias and false positives in ARS and LADI evaluation. Previous studies have demonstrated the efficacy of the Atlasprofilax intervention in reducing LADI asymmetry¹⁰⁻¹³. This intervention involves non-invasive, device-mediated stimulation of the suboccipital myofascia using mechanotransductive vibropercussion¹⁴.

Numerous studies have investigated links between neurological disorders, such as Arnold-Chiari malformation¹⁵⁻¹⁸, and benign pain syndromes like headaches, with abnormalities in the suboccipital myofascia and related structures, including the myodural bridge and suboccipital muscles¹⁹⁻²⁴. Despite their importance, biomechanical and metabolic changes in the suboccipital myofascia and craniocervical junction anatomy are often overlooked, with only 6% of functional spinal disorder cases showing symmetrical positioning of the occiput, atlas, and axis, as most patients exhibit left-sided laterality of the atlas and axis²⁵. A RCT on the LADI improvement through the same method showed a significant radiological and clinical results¹³.

Additionally, it remains uncertain whether these subclinical alterations could contribute to joint dysfunction at the C0-C1-C2 level, resulting in increased LADI asymmetries that may be mistakenly categorized as within the normal range. Given the ongoing debate surrounding the clinical significance and acceptable thresholds of LADI asymmetry in radiological evaluations, alongside promising results from small-sample studies highlighting the positive impact of the Atlasprofilax method on reducing LADI asymmetry and Atlas tilt, a larger prospective study was undertaken, encompassing 258 patients.

METHODS

Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

- Ethics committee approval:
Approved: No. BIO359

The above, within the framework of resolution 8430 of October 4th, 1993 of the Ministry of Health of the Republic of Colombia, which establishes the scientific, technical and administrative standards for health research, according to Chapter 1 Art. 5-16 and in accordance with international requirements: Declarations of Helsinki, Finland, latest version year 2000, international ethical guidelines for biomedical research and experimentation in human beings, prepared by the Council of International Organizations of Medical Sciences (CIOMS) in collaboration with the World Health Organization (WHO), Geneva 1993 and 2002.

Funding statement

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

Study design

A Prospective comparative therapeutic radiological study was conducted on patients who underwent the Atlasprofilax Method between August 2013, and January 2017, in Mexico and in Colombia. The study strictly adhered to the official Mexican Medical *Lex Artis* guidelines for radiological examination and followed good medical practices. A total of 258 patients provided informed consent and were enrolled in the study.

Group A consisted of the active intervened group, comprising 79 patients who underwent the intervention. Before the intervention and at the one-month follow-up appointment post-intervention, anteroposterior transoral radiographs were obtained for these patients. On the other hand, Group B, the non-intervened control group, included 179 subjects who did not receive the intervention but were enrolled in the study. Anteroposterior transoral radiographs were obtained for this group as well. Flowchart in the Figure 1 below.

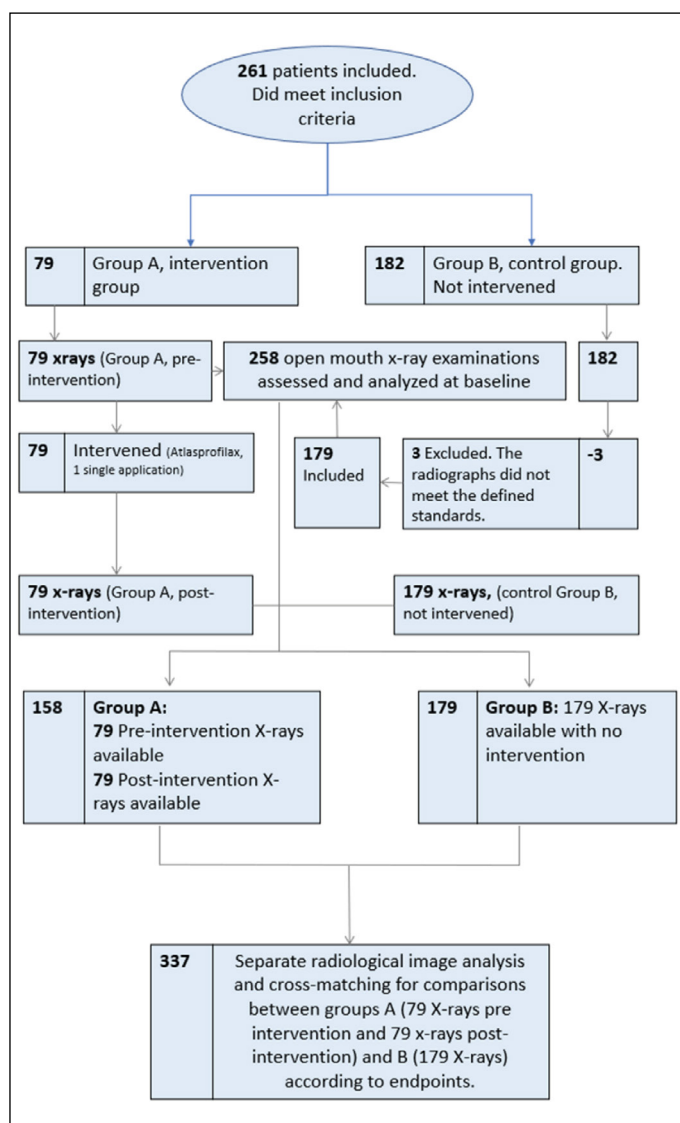


Figure 1. Illustrates the study flowchart, outlining the sequence of events and participant allocation.

Inclusion criteria

The study included subjects who provided informed consent to participate. For Control group B (n=179), subjects were required to provide a transoral radiograph and were not intervened. For the intervention group (Group A), subjects were also required to provide a transoral radiograph before and after undergoing the Atlasprofilax Method in a specialized medical clinic.

Exclusion criteria

Patients who did not provide consent to participate in the study were excluded. Additionally, subjects who did not have a maximum of one-month pre- or post-therapy transoral x-ray examination were excluded. Pregnant individuals were also excluded from the study. In cases where the radiological technique prevented clear visualization of the atlas (2 cases), and in one case where the x-ray examination was performed in a decubitus position, these individuals were excluded from the sample.

Participants

The final study population consisted of 258 subjects (172 women and 86 men) who participated in the study divided in 2 groups: Group A, active group, intervened (n=79); Group B, control group, not intervened (n=179).

Intervention

Radiological intervention

Patients were positioned in an anteroposterior stance with shoulders equidistant from the image receptor, head facing forward, mouth wide open, and lower incisors perpendicular to the receptor to ensure a clear anterior-posterior projection of the odontoid process. X-rays with positional errors, such as superimposition of teeth or the skull base on the dens, were excluded, leading to the removal of three cases from the analysis.

Clinical Intervention

The intervention consisted of a non-invasive neurostimulation, called the Atlasprofilax Method¹⁴, applied to several key points of the suboccipital area to stimulate certain muscle and fascial receptors applied by a medical doctor by means of a special device. This device uses controlled mechanotransductive vibropressure at specific frequency which was applied during an average of eight minutes. The purpose was to attain a deep mechanotransduction effect on the suboccipital myofascia and suboccipital muscles which regulate atlas-axis position and head movement²⁶.

Demographics, samples and collected data

The following demographic and other data for measurement and endpoints determining purposes were collected: gender, age, left and right LADI measured in the x-ray before or after the intervention, or both, Atlas tilt, and deviation of the C2 spinous process from a cranio-caudal centerline prior and/or after the therapy.

A total of 337 transoral radiographs were examined, of which 258 were taken without having received the Atlasprofilax intervention (179 control group B; 79 group A before the intervention) and 79 were taken after the application of the Atlasprofilax (for the active group A). Mean average age was 58 years. 33.33% were males.

Methods, measurements, and endpoints

The measurements were performed using a pencil, protractor, scalimeter, and negatoscope to ensure standardized line-drawing and distance assessments across all radiographs. Calibration of radiograph scales and standardized procedures maintained accuracy, consistency, and reliability in the measurement process.

Measurements: measurements prior to endpoints

- **LADI measurement:** The determination of left/right (a)symmetry of the LADI was performed by measuring the distance in millimeters between two vertical lines on each lateral mass of the atlas (lines A and B) and their proximity to the odontoid neck (Figure 2). To measure LADI, a vertical line (line A) was drawn at the medial point of each lateral mass of the atlas where it was closest to the odontoid. Another vertical line (line B) was drawn at the odontoid neck. It is important to note that due to anatomical variations in the shape of the odontoid process, the space to be measured is the one located at the neck of the odontoid process, specifically along the line joining the narrowest edges of both lateral masses (line B). (Figure 2)
- **Atlas Tilt Measurement in Degrees:** The tilt angle of the atlas was determined by measuring the angle, in degrees, between the horizontal baseline (line D) and another line joining the lower facets of the atlas (line C) that was subtracted from line F (mastoid tilt line) for neutralizing possible head tilt bias. (Figure 2)
- **C2 Spinous Process Deviation in Millimeters:** The alignment or deviation of the C2 spinous process was assessed by comparing a vertical line dividing equal parts of the odontoid (line F) with another vertical line in the center of the spinous process of C2 (line E). This comparison helped determine any improvement in alignment after the intervention (Figure 2). This comparison helped determine any improvement in alignment after the intervention. These measurements were essential in evaluating the LADI, atlas tilt, and C2 spinous process deviation, providing objective data for assessing the effectiveness of the intervention. (Figure 2)

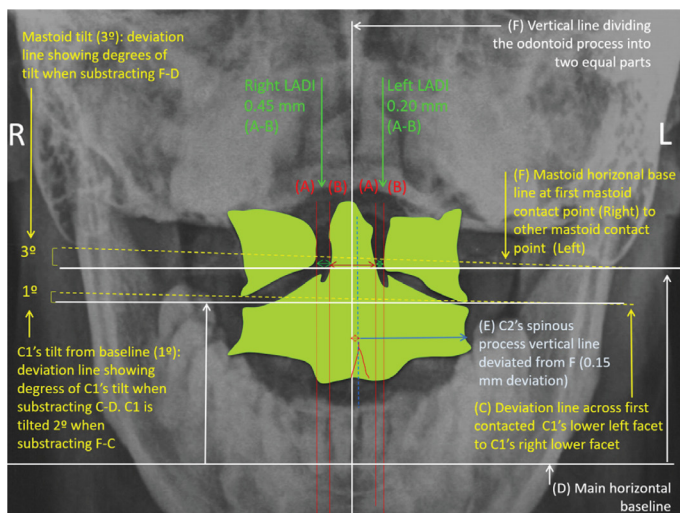


Figure 2. Lines drawn to determine LADI (lines A & B), C1 tilt (lines F minus C) and C2 spinous process deviation (lines F minus E).

Statistical analysis

Statistical tests were conducted using R (v4.4.2) and LMEM Trees for some endpoints²⁷. Endpoints 1 and 4 are descriptive. For endpoints 2, 6, and 7, comparative tests were performed between control group B and group A, using either Student's t-test or Mann-Whitney U test after validating normality and variance homogeneity. For endpoints 3 and 5, McNemar's test for paired data was used to evaluate changes in LADI symmetry and inclination post-intervention in group A.

RESULTS

Endpoint 1 assessed the quantification of the difference between right and left LADI in the control group (Group B). A descriptive analysis showed a positive asymmetry in LADI, deviating from the value of "0", which would indicate total symmetry. This observation is illustrated in Figure 3.

Endpoint 2 compared the right-left LADI difference between the control group (B) and the pre-intervention group (A) using coded range values for statistical analysis. The Shapiro-Wilk test confirmed a normal distribution with no significant deviations, and Figure 4 illustrates the comparability between groups.

The normality hypothesis was rejected, so the non-parametric Mann-Whitney U test was used, eliminating the need for variance homogeneity testing. The p-value of 0.439 and 95% confidence interval (-2.54, 3.71) indicated no significant difference between groups, confirming their comparability.

Endpoint 3 assessed the right-left LADI difference in Group A before and after the intervention, showing a significant shift toward symmetry (Figure 5). Post-intervention, 69 of 79 participants in Group A had "0" LADI values, compared to only 2 of 179 in the non-intervened Group B. (Figure 5)

Given the importance of determining the effectiveness of the treatment, which is measured by achieving a value of zero in the difference between right LADI and left LADI, the data were reorganized accordingly. See Table 1 below.

A McNemar test with continuity correction showed a p-value < 0.001 (95% CI: 0.0, 0.058), rejecting the null hypothesis and confirming the effectiveness of the Atlasprofilax method in improving LADI asymmetry in Group A. Endpoint 4 analyzed right and left LADI distributions separately, with Figure 6 illustrating marked asymmetry in Group B versus near-symmetrical alignment in Group A post-intervention. (Figure 6)

Endpoint 5 addressed the comparison of LADI minus C2 spinous process (in mm) measurement pre- and post-intervention in Group A. As it can be seen in Figure 7 (below), the distribution of Group B (in blue) is very dispersed while the tendency in group A (intervened) tends significantly to the "0" which means symmetry.

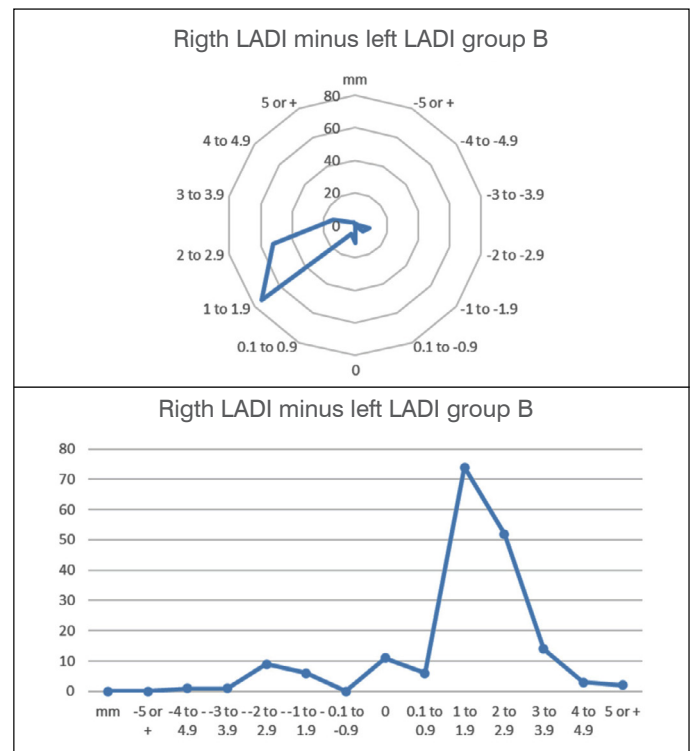


Figure 3. Displays the distribution of LADI's L/R difference, showing a tendency toward positive asymmetry in the ranges of 1 to 1.9 and 2 to 2.9, deviating from the "0" value (which represents expected symmetry). Above: Spider diagram; Below: Line chart.

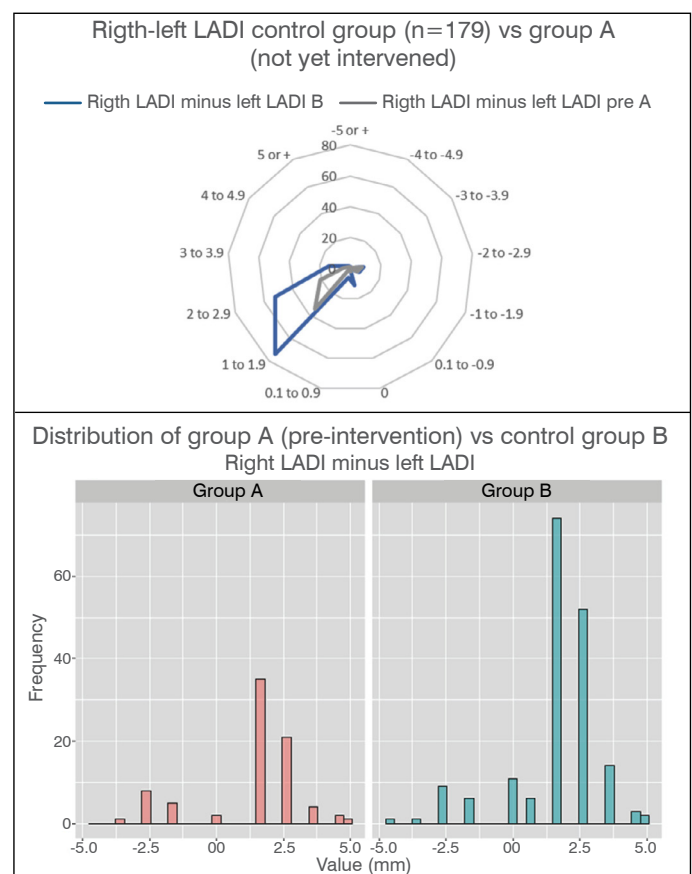


Figure 4. LADI distribution comparison between Group B (Control, in blue) and Group A (not yet intervened, in gray). Spider chart, in ranges (Above). Histogram with the ranges transformed into continuous variables (Below).

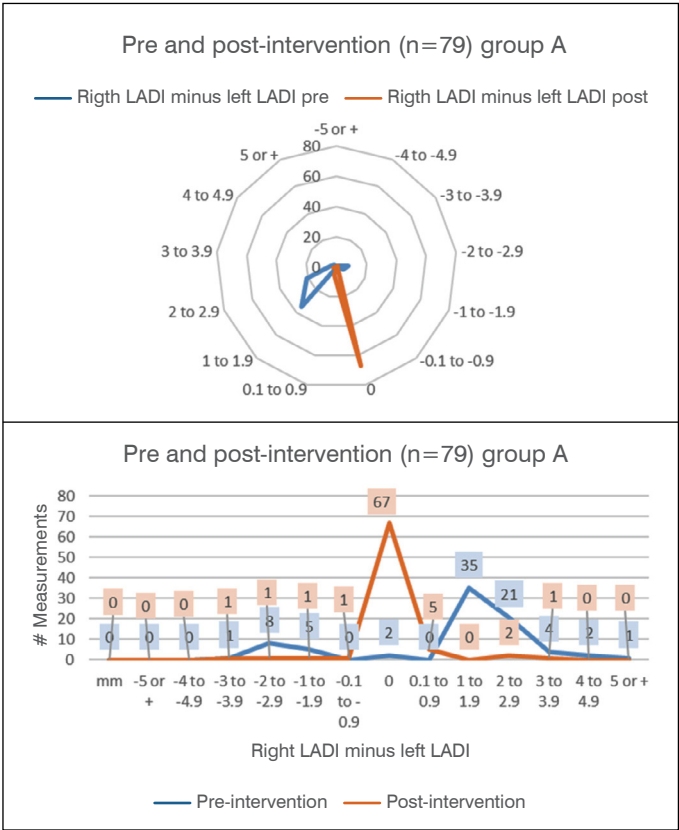


Figure 5. Spider diagram and line plot for ranges before transformation into continuous values for endpoint 3.

Table 1. Contingency table pre- versus post-intervention.

		Post-intervention		
		0	Non-zero	Total
Pre-intervention	0	2	0	2
Pre-intervention	Non-zero	65	12	77
	Total	67	12	79

A similar process to that of endpoint 3 was conducted, involving a reorganization of the data to compare the inclination between LADI and the C2 spinous process in group A (post-intervention). (Figure 7 and Table 2)

A McNemar test with continuity correction ($p < 0.001$, 95% CI: 0.0, 0.114) rejected the null hypothesis, confirming the effectiveness of the Atlasprofilax method in Group A. Endpoint 6 compared LADI minus the C2 spinous process between control Group B and post-intervention Group A, showing significant differences in the Shapiro-Wilk test, with Group A trending toward symmetry (0 value), unlike Group B. (Table 3, Figure 8)

The normality hypothesis was rejected, and a Mann-Whitney U test ($p = 0.002$, 95% CI: 0.499, 2.499) confirmed a significant difference between post-intervention Group A and control Group B, providing strong evidence that the Atlasprofilax intervention positively influenced the distance between LADI and the C2 spinous process.

Endpoint 7 assessed the presence and distribution of Atlas tilt in the control group B as it can be seen in the Figure 9 below.

The Figure 9 above demonstrates a clear improvement, with group A (post-intervention) showing an enhanced horizontal position of the Atlas and minimal to no tilt. In contrast, group B displays a much more pronounced deviation from the 0° value, which represents no tilt or complete horizontality.

Endpoint 7.1 compared Atlas tilt (in degrees) between control Group B and post-intervention Group A using a similar statistical approach as in Endpoints 2 and 6, with Shapiro-Wilk normality tests conducted on the coded ranges.

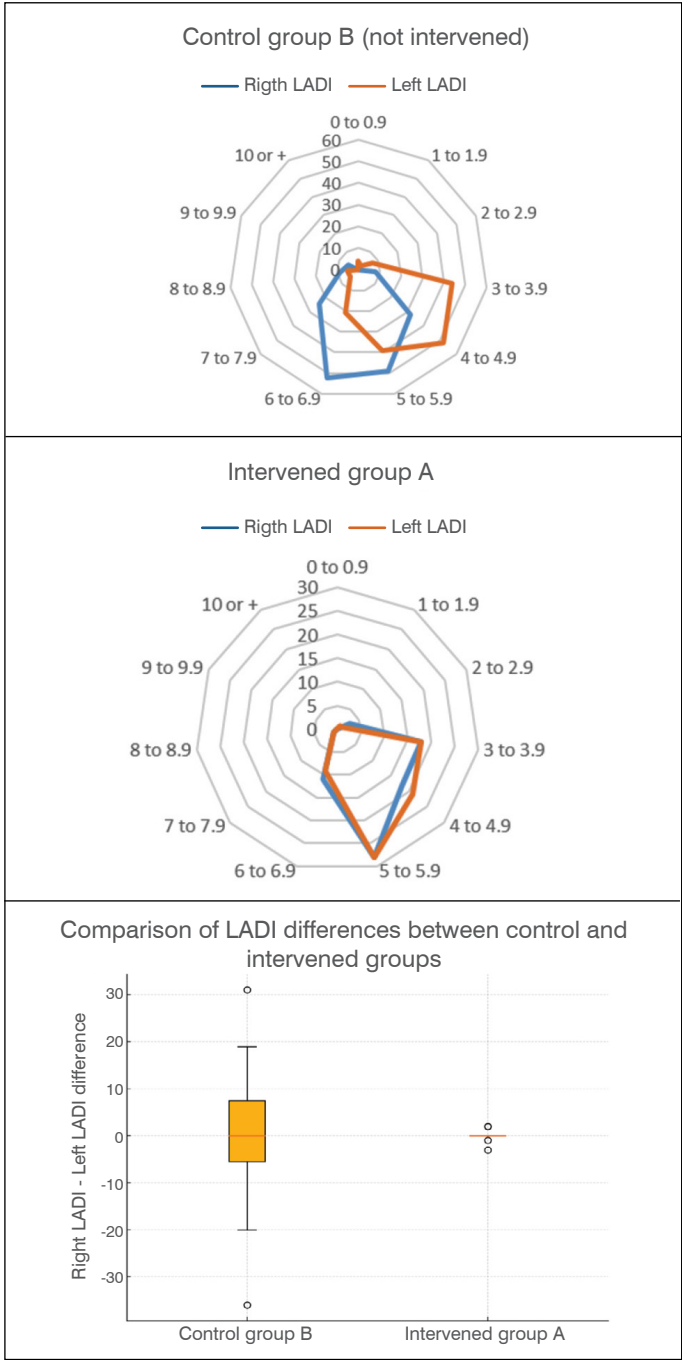


Figure 6. Spider diagram (top) and boxplots (bottom) illustrating a pronounced asymmetry between left and right LADI for Group B (left), contrasted with near symmetry for Group A after the intervention (right).

For the Atlas tilt (Figure 10) the normality hypothesis was rejected, prompting the use of a Mann-Whitney U test with the asymptotic method, conducted via the "exactRankTest" library due to the sample size. The analysis yielded a p-value of < 0.001 , with a 95% confidence interval of (0.1, 2.0), demonstrating a significant difference between group A (post-intervention) and control group B. These results provide strong evidence that the Atlasprofilax intervention effectively improved Atlas tilt, guiding it toward a more horizontal, balanced position.

DISCUSSION

The LADI asymmetry ranges for Group A (pre-intervention) and Group B (non-intervened) were similar in distribution, means, and

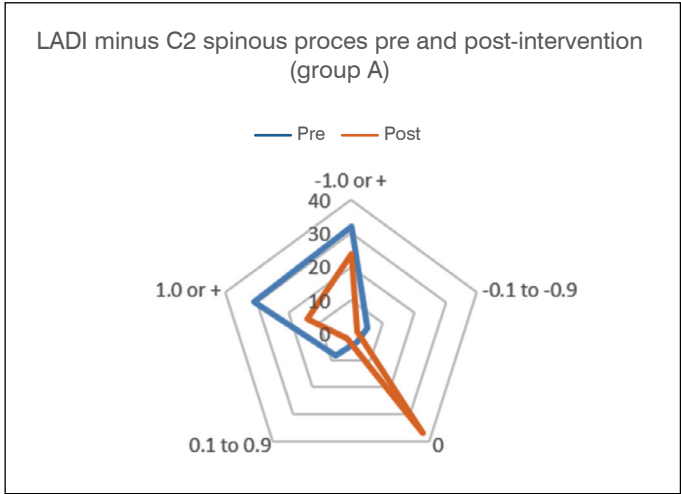


Figure 7. Spider diagram depicting the trend toward zero (full symmetry) in group A (orange) and the dispersion away from zero in control group B (blue).

Table 2. Contingency table pre- vs. post-intervention on C2 spinous process.

		Post-intervention		Total
		0	Non-zero	
Pre-intervention	0	3	0	3
Pre-intervention	Non-zero	34	42	76
	Total	37	42	79

SD (Group A: mean 1.17, SD 0.50; Group B: mean 1.15, SD 0.49; $p=0.697$), aligning with literature values (0.99 ± 1.05 mm) where 95% of patients had asymmetry ≤ 3 mm, with a maximum of 5 mm. LADI asymmetry may indicate ligamentous injury or atlantoaxial rotatory subluxation, making it difficult to distinguish normal variation from pathology⁸. The absence of consensus on standardized "normal" asymmetric values leads to a subclinical range where LADI asymmetry may reflect a pathological condition, potentially involving craniovertebral junction soft tissues (e.g., posterior atlanto-occipital membrane, myodural bridge, suboccipital muscles, deep cervical fascia). Studies have shown a link between chronic neck/head pain and the suboccipital muscles, which play a key role in the mechanics of the craniovertebral junction (CCJ). Additionally, these muscles show a higher prevalence of anatomical abnormalities compared to others in the suboccipital region, often exhibiting undesired morphological changes. Chronic alterations in the suboccipital muscles can disrupt CCJ biomechanics and interfere with the reciprocal tension between the dura mater and specific fibers located on the posterior atlanto-occipital membrane²³. Such disturbances may contribute to subclinical LADI asymmetry and related dysfunctions.

Chronic alterations in the suboccipital muscles can disrupt craniovertebral junction (CCJ) biomechanics and interfere with the reciprocal tension between the dura mater and specific fibers located on the posterior atlanto-occipital membrane²³. The rectus capitis minor (RCPm), densely populated with muscle spindles and connected to the myodural bridge²⁸, may contribute to nociception, proprioception, and balance mechanisms²⁹. Such disturbances can impact CCJ functionality and stability, and subclinical LADI asymmetry may reflect these issues.

Case studies, case series and one RCT have shown substantial improvements in LADI asymmetry and radiographic Atlas tilt following the use of the Atlasprofilax method¹⁰⁻¹³, along with clinical enhancements in specific pathologies³⁰⁻³². Discussion around CCJ abnormalities, particularly related to suboccipital myofascial alterations and their link to chronic pain pathologies, remains an area of ongoing research. The Atlasprofilax method, a non-invasive intervention employing mechano-transductive vibro-percussion on the suboccipital fascia, has shown promising potential¹⁴. Given evidence

Table 3. Shapiro-Wilk normality tests for both groups A and B.

Group	n	W	p-value
B (Control)	179	0.93	<0.001
A (post-intervention)	79	0.88	<0.001

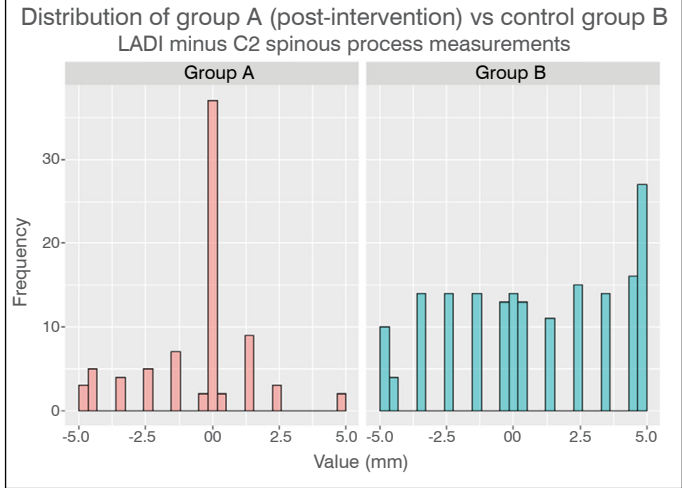
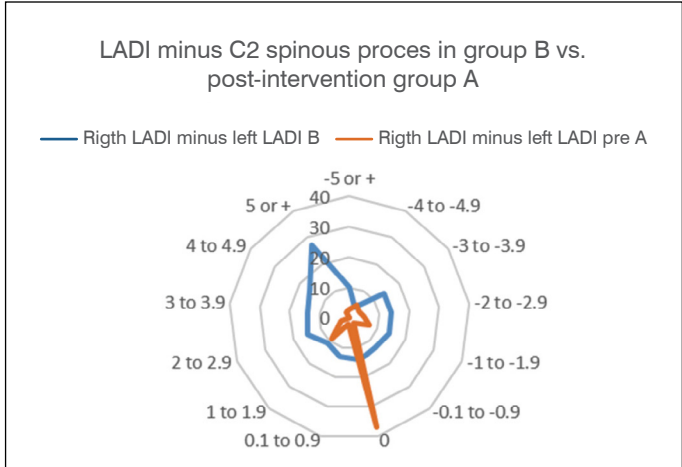


Figure 8. (Above) Spider diagram illustrating in ranges the alignment trend of the C2 spinous process toward zero (total or near-total symmetry) in group A (in orange) versus a more widely dispersed and asymmetric alignment (in blue) for control group B. (Below) Same but in values and using a histogram.

that suboccipital muscles can contract in isolation, influencing Atlas positioning³³, it is plausible that the vibropercussive forces of the Atlasprofilax method positively impact suboccipital muscle function via a specific biomechanical mechanism, enhancing C0-C1-C2 orthogonality and promoting greater LADI symmetry.

The significant impact on C1 and C2 joint symmetry may have important clinical implications, warranting further exploration of correlations with LADI asymmetries in conditions like tension headache, migraine, and chronic cervical pain, which are linked to suboccipital muscle abnormalities^{18,20,21}, while Atlasprofilax aims to optimize metabolic and biomechanical properties in the suboccipital myofascia through mechanotransductive stimuli, addressing fascial armoring, Arnold's nerve compression, and myodural bridge tensions.

CONCLUSIONS

The observed improvements in LADI, Atlas tilt, and C2 alignment may result from favorable biomechanical changes in the C0-C1-C2 soft tissues, including enhanced orthogonality and joint symmetry, with potential clinical relevance for conditions like

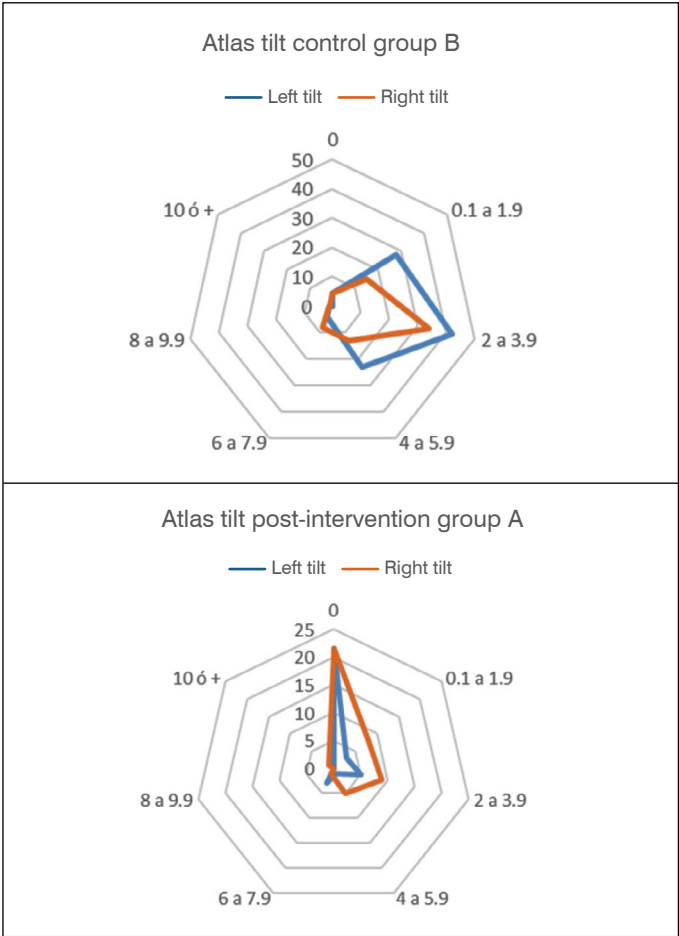


Figure 9. (Above) Atlas tilt (left in blue, right in orange) of the Control Group tending to 2 - 3.9 degrees of tilt. (Below) Atlas tilt (left in blue, right in orange) of the intervened Group A to 0 degrees of tilt.

Table 4. Shapiro-Wilk Normality Tests for Groups A and B.

Group	n	W	p-value
B (control)	179	0.85	<0.001
A (post-intervention)	79	0.63	<0.001

tension headache, migraine, and chronic cervical pain, while this study contributes new data to refine differential diagnoses by re-evaluating the subclinical and pathophysiological implications of normal LADI asymmetry ranges.

The findings highlight the need to reassess normal LADI

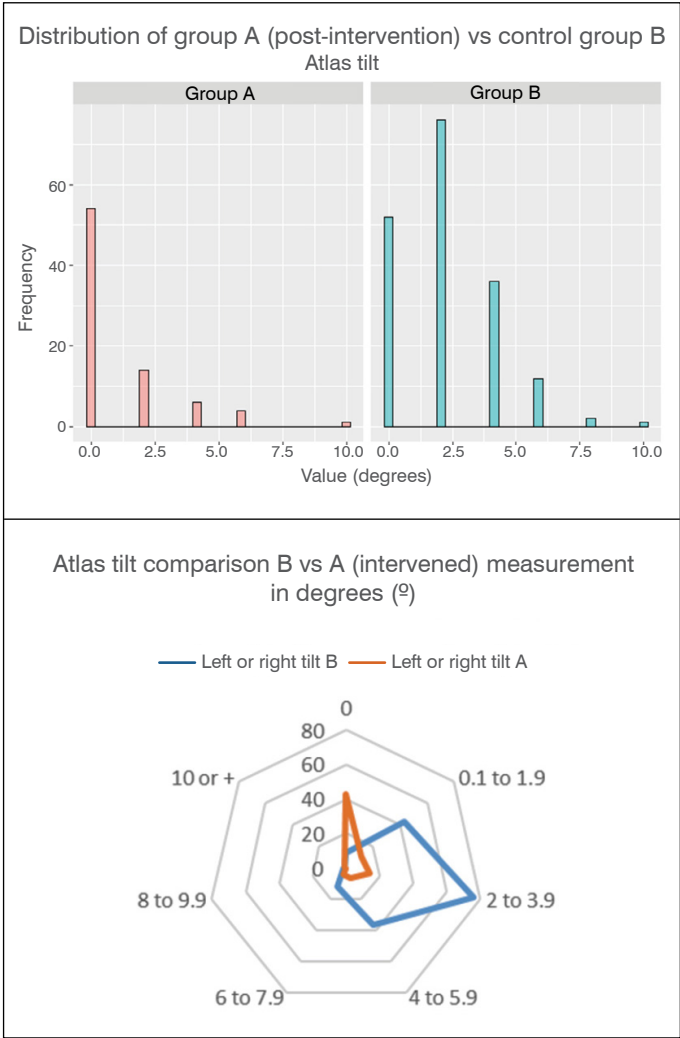


Figure 10. Endpoint 7.1 (figure below): (Above) Histogram comparing the presence of Atlas tilt (measured in degrees) between control group B and the radiological outcomes of post-intervention group A patients. (Below) Spider diagram showing the trend to 0° in the Group A and the dispersion away from 0° in the control Group B.

asymmetry, challenging existing norms and exploring subclinical ranges to refine diagnostics, improve understanding of physiopathological processes, and optimize patient care, while further investigation into LADI asymmetries and the potential of Atlasprofilax for craniocervical and myofascial disorders is warranted.

CONFLICT OF INTEREST

All authors declare no potential conflict of interest related to this article.

CONTRIBUTIONS OF THE AUTHORS

Each author contributed individually and significantly to the development of this article. JGL: Conceptualization, Supervision; LM: Writing – original draft, Writing – review & editing, Supervision; AMGE: Methodology, Formal analysis; NLH: Methodology, Conceptualization, Writing – original draft, Investigation; OAC: Investigation, Methodology, Supervision, Writing – review & editing.

DATA AVAILABILITY DECLARATION

After publication, the data will be available on demand from the authors, a condition justified in the manuscript.

REFERENCES

1. Chen Y, Zhuang Z, Qi W, Yang H, Chen Z, Wang X, et al. A three-dimensional study of the atlantodental interval in a normal Chinese population using reformatted computed tomography. *Surg Radiol Anat.* 2011;33(9):801-6. doi: 10.1007/s00276-011-0817-7.

2. Lee S, Joyce S, Seeger J. Asymmetry of the odontoid-lateral mass interspaces: A radiographic finding of questionable clinical significance. *Ann Emerg Med.* 1986;15(10):1173-6. doi: 10.1016/S0196-0644(86)80860-5.

3. Wortzman G, Dewar FP. Rotary fixation of the atlantoaxial joint: Rotational atlantoaxial subluxation. *Radiology.* 1968;90(3):479-87. doi: 10.1148/90.3.479.

4. Adler DC, Jacobson G. Examination of the atlanto-axial joint following injury with particular. *Am J Roentgenol* 1956;76(6):1081-94.
5. Billmann F, Bokor-Billmann T, Burnett C, Kiffner E. Occurrence and significance of odontoid lateral mass interspace asymmetry in trauma patients. *World J Surg*. 2013;37(8):1988-95. doi: 10.1007/s00268-013-2048-z.
6. Eran A, Yousem DM, Izbudak I. Asymmetry of the odontoid lateral mass interval in pediatric trauma CT: Do we need to investigate further? *Am J Neuroradiol*. 2016;37(1):176-9. doi: 10.3174/ajnr.A4492.
7. Wolansky LJ, Rajaraman V, Seo C, Patel N, Kazmi K, Doddakashi S, et al. The lateral atlantodens interval: Normal range of asymmetry. *Emerg Radiol*. 1999;6(5):290-3. doi: 10.1007/s101400050070.
8. Mendenhall SK, Huh A, Pandya J, Alentado V, Balsara K, Ho C, et al. Evaluation of lateral atlantodental interval asymmetry in the pediatric age group: normative values. *J Neurosurg Pediatr*. 2018;22(2):195-9. doi: 10.3171/2018.2.PEDS17694.
9. Tomycz ND, Chew BG, Chang YF, Darby JM, Gunn SR, Nicholas DH, et al. MRI is unnecessary to clear the cervical spine in obtunded/comatose trauma patients: The four-year experience of a level I trauma center. *J Trauma*. 2008;64(5):1258-63. doi: 10.1097/TA.0b013e318166d2bd.
10. León JG, Laguna N, Manent L, Lewis K, Angulo O. Radiological Improvements in Symmetry of the Lateral Atlantodental Interval and in Atlas Tilt after the Application of the Atlasprofilax Method. A Case Series. *CPQ Orthop*. 2022;6(3):1-13. Available from: <https://www.cientpe-riodique.com/article/CPQOS/6/3/128>.
11. León J, Manent L, Lewis K, Angulo O. Clinical and Imaging Improvement After the Atlasprofilax Method in a Patient with Cervicobrachial Syndrome and Temporomandibular Joint Disorders. A Case Report. *Acta Sci Orthop*. 2021;4(10):92-102. doi: 10.31080/asor.2021.04.0381.
12. Manent L, Higuera JGL, Angulo O, Garcia-Morcote CA, Solano MEZ. Improvement in Cervical Spinal Misalignment After the Application of the Neuromuscular Atlasprofilax Method in One Single Session. A Case Report [Preprint]. 2022. doi: 10.32388/624SUX.2.
13. Yanpolskiy AS, Borsuk DAA, Galchenko MI, Gerasimenko MY. Results of indirect vibropercussion correction of the first cervical vertebra position in chronic subluxation. *Russ J Physiother Balneol Rehabil*. 2025;24(1):36-47. doi: 10.17816/rjpb642184.
14. Angulo O. The Mystery around Suboccipital Myofascial Alterations and their Correlated Ailments. Could the Atlasprofilax Method be a Therapeutic Option?. *EC Orthop*. 2023;14(3):1-5. doi: 10.31080/ecor.2023.14.01004.
15. Rosa S, Baird JW, Harshfield D, Chehrena M. Craniocervical Junction Syndrome: Anatomy of the Craniocervical and Atlantoaxial Junctions and the Effect of Misalignment on Cerebrospinal Fluid Flow. *Hydroceph - Water Brain*. 2018. doi: 10.5772/intechopen.72890.
16. Song X, Gong J, Yu SB, Yang H, Song Y, Zhang XH, et al. The relationship between compensatory hyperplasia of the myodural bridge complex and reduced compliance of the various structures within the craniocervical junction. *Anat Rec (Hoboken)*. 2023;306(2):401-8. doi: 10.1002/ar.25040.
17. Zheng N, Yuan XY, Li YF, Chi YY, Gao HB, Zhao X, et al. Definition of the to be named ligament and vertebroductal ligament and their possible effects on the circulation of CSF. *PLoS One*. 2014;9(8):e103451. doi: 10.1371/journal.pone.0103451.
18. Labuda R, Nwotchouang BST, Ibrahimy A, Allen PA, Oshinski JN, Klinge P, et al. A new hypothesis for the pathophysiology of symptomatic adult Chiari malformation Type I. *Med Hypotheses*. 2022;158:110740. doi: 10.1016/j.mehy.2021.110740.
19. Alonso-Blanco C, de-la-Llave AI, Fernández-de-las-Peñas C. Muscle trigger point therapy in tension-type headache. *Expert Rev Neurother*. 2012;12(3):315-22. doi: 10.1586/ern.11.138.
20. Fernández-De-Las-Peñas C, Bueno A, Ferrando J, Elliott JM, Cuadrado ML, Pareja JA. Magnetic resonance imaging study of the morphometry of cervical extensor muscles in chronic tension-type headache. *Cephalalgia*. 2007;27(4):355-62. doi: 10.1111/j.1468-2982.2007.01293.x.
21. Fernández-De-Las-Peñas C, Cuadrado ML, Arendt-Nielsen L, Ge HY, Pareja JA. Association of cross-sectional area of the rectus capitis posterior minor muscle with active trigger points in chronic tension-type headache: A pilot study. *Am J Phys Med Rehabil*. 2008;87(3):197-203. doi: 10.1097/PHM.0b013e3181619766.
22. Scalfi F, Pontell ME, Enix DE. Proprioceptive neurons in the cervical myodural bridge: a feedback mechanism of dural tension monitoring. Presented at: 12th Biennial WFC Congress; 2013 Apr 10-13; Durban, South Africa.
23. Li C, Yue C, Liu ZC, Gong J, Wei XS, Yang H, et al. The relationship between myodural bridges, hyperplasia of the suboccipital musculature, and intracranial pressure. *PLoS One*. 2022;17(9):e0273193. doi: 10.1371/journal.pone.0273193.
24. Alix ME, Bates DK. A proposed etiology of cervicogenic headache: The neurophysiologic basis and anatomic relationship between the dura mater and the rectus posterior capitis minor muscle. *J Manipulative Physiol Ther*. 1999;22(8):534-9. doi: 10.1016/S0161-4754(99)70006-0.
25. Dörhage K, Knopf H, Graumann-Brunt S, Koch LE. Asymmetrie der Kopfgelenke. *Man Med-izin*. 2004;42(2):122-8. doi: 10.1007/s00337-004-0293-9.
26. George T, Tadi P. Anatomy, Head and Neck, Suboccipital Muscles. *StatPearls*. 2021. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/33620839>.
27. Fokkema M, Smits N, Zeileis A, Hothorn T, Kelderman H. Detecting treatment-subgroup interactions in clustered data with generalized linear mixed-effects model trees. *Behav Res Methods*. 2018;50(5):2016-34. doi: 10.3758/s13428-017-0971-x.
28. Enix DE, Scalfi F, Pontell ME. The cervical myodural bridge, a review of literature and clinical implications. *J Can Chiropr Assoc*. 2014;58(2):184-92.
29. Kulkarni V, Chandy MJ, Babu KS. Quantitative study of muscle spindles in suboccipital muscles of human fetuses. *Neurol India*. 2001;49(4):355-9.
30. Malagón J, Villaveces M, Manent L. A Therapeutic Alternative in the Management of Fibromyalgia. *Rev Cuarzo*. 2017;23(1):30-8. doi: 10.26752/cuarzo.v23.n1.221.
31. Gutiérrez Navas VE. EFECTO DE LA TERAPIA AtlasPROFILAX® SOBRE LOS SÍNTOMAS RELACIONADOS CON DISFUNCIÓN TEMPOROMANDIBULAR, BRUXISMO Y LA RELACIÓN DE LAS LÍNEAS MEDIAS DENTALES. *UstaSalud*. 2013;12(2):124-33. doi: 10.15332/us.v12i2.1216.
32. León JG, Manent L, Lewis K, Angulo O. Total Resorption of a Chronic L4-L5 Disc Extrusion After Application of the Atlasprofilax Method: A Case Report. *Am J Case Rep*. 2022;23:e935208-1–e935208-8. doi: 10.12659/ajcr.935208.
33. Sillevs R, Stockhausen D, Gerdt N, Hansen A. An isolated contraction of the Obliquus Capitis Inferior and Rectus Capitis Posterior Major demonstrated with Musculoskeletal Ultrasound Imaging. *Med Res Arch*. 2023;11(6). doi: 10.18103/mra.v11i6.4001.