Changes in Vertebral Artery Hemodynamics Associated With McKenzie Therapeutic Cervical Movements: An Exploration Using Duplex Ultrasound Imaging

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Abstract

Objective: The purpose of this study was to explore vertebral artery hemodynamic changes associated with McKenzie therapeutic cervical movements in healthy individuals.

Methods: A single-group repeated-measure design was used to examine 20 healthy participants aged 22.05 (1.69) years, mean (standard deviation). Vertebral artery volume flow, diameter, resistive index, time-averaged maximum velocity, and pulsatility index were measured using Duplex ultrasound. Vertebral artery hemodynamics were measured at cervical neutral positions then compared against vertebral artery hemodynamics measured during end-range loading and after repeated McKenzie therapeutic movements. Wilcoxon signed rank tests were used for comparisons, and standardized mean differences (SMDs) were calculated to quantify the changes in size.

Results: Repeated retraction with extension in a sitting position and end-range retraction with extension in supine position were significantly associated with an increase in vertebral artery volume flow, $P \leq .01$, and the SMD suggests small-medium changes in size. Statistical significant vertebral artery dilation was observed in the sitting position with protraction, combined retraction with extension, and flexion, $P \leq .01$, yet the SMD suggested small changes in size. End-range flexion was significantly associated with a reduction in vertebral artery pulsatility index, and the SMD suggested large changes in size. Repeated retraction with extension in supine position was significantly associated with an increase in vertebral artery time-averaged maximum velocity, yet the SMD revealed no clinically important difference.

Conclusion: For the healthy participants in this study, McKenzie cervical movements were mostly associated with an increase in vertebral artery hemodynamics. (J Manipulative Physiol Ther 2019;42:66-74)

Key Indexing Terms: *Spine; Cervical Vertebrae; Rehabilitation; Vertebral Artery*

Introduction

Neck pain and related dysfunctions and pathologies are common health issues that may have biobehavioral and socioeconomic consequences.[1-3] The multidimensional impact of neck pain and its biomechanical complexity poses challenges to health care management. Various neuromuscular impairments are associated with neck pain, which may restrict total neck mobility in the activities of daily living and further increases neck pain.[4,5] The etiology of neck pain is mostly nonpathologic in nature, but may be related to mechanical overloading resulting from faulty postures and repeated stressful neck movements.[6,7] The activities of daily living require the cervical spine to play a complex role in providing multidirectional and combined movements while maintaining head stability.[8] Cervical spine complexity extends to vertebral biomechanics in that both vertebral extension and flexion occur at different vertebral levels of the cervical spine during a single cervical movement.[9,10] However, designing management programs for cervical related disorders might be difficult owing to the anatomical and biomechanical complexity of the cervical spine.

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The vertebral artery (VA) has an anatomical relationship with the cervical spine, as it branches from the subclavian arteries, typically entering the transverse foramen at the sixth cervical vertebrae and then ascending through the transverse foramen of each cervical vertebrae to enter the foramen magnum.[11] The VA supplies the spinal cord, brainstem, cerebellum, and posterior part of the brain.[11,12] The brain receives 15% of cardiac output, and the VA system is responsible for 25% of the global cerebral blood flow supplying the posterior cerebral circulation.[12] The VA can be divided into 5 segments: (1) the preforaminal segment extending from the subclavian artery to the sixth cervical vertebrae, (2) the foraminal segment extending from the sixth to the second cervical vertebrae, (3) the extraspinal segment arising from the second cervical vertebra to the dura, (4) the intracranial segment arising from the dura to create the basilar artery, and (5) the muscular and spinal segments.[13] The hemodynamics of the VA are associated with cervical movement and positioning.[11] Movement occurring at the cervical spine might change the hemodynamics of the VA because of its position in relation to the vertebrae.[14] Various conditions are related to deficiencies in the VA. Headache is one problem that has an impact on quality of life and physical functioning, which may result from VA insufficiency and vertebral malalignment.[14-19] Dizziness and vertigo are 2 of the most common causes of seeking medical consultation, which also could be caused by VA insufficiency.[20-22] The VA is a pain sensitive structure and can cause occipital pain when affected by spontaneous dissection, compression, or irritation of the sympathetic plexus.[23]

The McKenzie approach is an evaluative and therapeutic strategy in musculoskeletal physiotherapy practice for managing pain and restoring the function of the cervical spine.[24-26] This approach aims to control cervical disability when used in the early stages, such as for postural correction and increasing the flexibility of the adjacent musculotendinous structures. It aims to categorize mechanically induced spinal pain into postural, dysfunctional, and derangement syndromes to centralize and reduce spinal pain.[25,26] Patient cervical self-management techniques used by McKenzie specialists have been shown to be effective for nonspecific neck pain.[27,28] The objective of the assessment of patients with cervical-related disorders is to select self-management techniques as directional preference movements, which should be repeated to reduce the pain and symptoms.[25,26] McKenzie cervical movements aim to induce vertebral movement, affecting neck structures such as ligaments, facet joints, and blood vessels.[24-26] Neck movements and positioning could alter the VA's hemodynamics. For example, neck rotation, extension, and loss of cervical lordosis can cause luminal narrowing and reduce the VA blood flow, which might lead to a mechanical occlusion to the VA. It has been suggested that[29,30] neck rotation can compress to the VA through the dynamic stretching to the facet that can stretch the VA, where axial rotation of the cervical spine places the VA under high strain force.[31] In contrast, another study found minimal effects from head and neck positions on the VA blood flow.[32]

The McKenzie cervical approach has been shown to be an effective management strategy for cervical spine impairments for reducing pain, disability, and frequency of seeking medical care.[27,28,33] Vertebral artery hemodynamics have been studied previously during neck rotation manipulation, and some studies have found a reduction in contralateral VA blood flow during combined neck extension and rotation,[11,34,35] and other studies have reported no changes.[36,37] The effect of static end-range and repeated cervical movements used in the McKenzie approach on VA hemodynamics has not been determined. The VA hemodynamic normative changes associated with McKenzie cervical movements need to be explored and understood in healthy individuals to understand the VA response in symptomatic or older individuals for future studies. Therefore, the objective of the current study was to measure the changes in the VA hemodynamics associated with McKenzie cervical movements in healthy adults.

Methods

Design and Participants

An experimental single-group repeated-measure design was employed. Vertebral artery hemodynamics were obtained at baseline, at static end-range posture, and immediately after repeated movement using the McKenzie cervical movement approach.[27,28] Sample size calculation was based on the study where a significant difference in vertebral artery volume flow post-exercise was reported.[38] An appropriate sample size was estimated to be at least 19 participants at (α) 0.05, with a power (1 − β) of 80%. Sample size was calculated using the effect size of 0.85, where the mean (standard deviation) for the VA volume flow was 90 (12) mL/min before exercise and increased to 129 (12) mL/min post-exercise.[38]

A total of 20 participants were randomly recruited from among Kuwait University students via an advertising email. They were contacted by the researcher (N.F.A.) by telephone to answer any participants' questions, check the general inclusion and exclusion criteria, and arrange an appointment for the examination. The general inclusion and exclusion criteria were checked initially via telephone to reduce the burden from participants attending the research site without being able to take part in the study; however, each participant was interviewed by the researcher (A.M.A.), who is a vascular specialist, to confirm the eligibility criteria.

Inclusion and Exclusion Criteria. Men and women were included in the study if they considered themselves healthy and were aged ≥18 years. Participants were excluded from the study if they had a history of pain in the cervical spine, cervical spine injuries or trauma, cervical disc disease, chronic headache, or cardiovascular disorders that were self-declared by the participants; were taking medication at the time of the study; or had other previous medical history that might affect the normative VA baseline hemodynamics based on the clinical decision of the investigator (A.M.A.).

The study was approved by the Human Research and Ethics Committee at Kuwait University Health Sciences Centre and Kuwait Ministry of Health (ref: 2017/570). All participants acknowledged their understanding of the study procedures and signed the consent form in accordance with the Declaration of Helsinki of 1975. Voluntary participation was clearly explained, and confidentiality and privacy were maintained.

Instrumentation

Duplex ultrasound (LOGIQ S7 Expert, General Electric, New York, New York) was used to assess the extracranial part of the vertebral artery using a linear array transducer (linear prime 20-5 MHz). The Duplex ultrasound is a noninvasive ultrasound-based system usually used to measure the sufficiency of vertebral artery blood flow.[11,39] The Duplex ultrasound is a valid and reliable tool for measuring the hemodynamics of the VA.[40-42] In this study, the dominant (left) vertebral artery was examined. However, a previous study found that there were no significant differences in blood flow between the right and left vertebral arteries.[43]

Data Collection Procedures

Data collection procedures were conducted at the ultrasound laboratory at Kuwait University. All participants were assessed in a temperature-controlled (22 ± 2°C) environment using a Duplex ultrasound. Initially, participants were seated for 10 minutes before the ultrasound scanning to stabilize the vertebral artery baseline hemodynamics. The examination procedures consisted of 2 positions: upright sitting and supine position. At the beginning of each position, baseline VA hemodynamics were obtained, including flow volume, VA diameter, resistive index (RI), time-averaged of maximum velocity (TMAX), and pulsatility index (PI). The VA diameter was measured using B-mode ultrasound during quiet respiration. The preset ultrasound protocol for vascular imaging was selected on low-flow setting (low range of pulse repetition frequency and medium-low wall filter) as specified on the machine preset protocol for vascular imaging of the VA with proper color gain. A low-range pulse repetition frequency setting was used to detect flow with color and with pulsed Doppler flow. A sample volume of 2 mm was positioned at the center of the VA. The Doppler angle was checked to ensure it was less than 60° and parallel to the vessel wall to avoid velocity recording error. The luminal diameter of the VA was determined as the distance between the external layers of the parallel walls during quiet respiration in longitudinal view, using the electronic calipers incorporated into the ultrasound machine software. Minimal pressure was used to guarantee satisfactory vessel imaging. In measuring vessel diameter, the axis parallel to the skin was preferred because it depends on the flattening of the vessel. Once a satisfactory position was found, the investigator requested that the participant maintain the position throughout each ultrasound examination. Diameter was determined when the walls were best visualized while ignoring luminal irregularities. Specifically, the transducer was placed on the mid-neck side at the foraminal segment of the left VA between 2 successive transverse processes at the level of C4-C5 equivalent to the level of angle of the mandible (Fig 1).[13] The angle-corrected TMAX was determined as the integral of the mean flow velocities of all moving particles passing sample volume over 3 to 5 complete cardiac cycles. An expert sonographer with >20 years of experience in the field of vascular imaging performed all ultrasound measurements.

After recording the VA hemodynamics at a neutral neck position during upright sitting, the ultrasound testing procedures were repeated twice for each McKenzie sagittal plane movement: during end range loading, and at neutral neck position after repeated movement of 10 repetitions for retraction, protraction, retraction with extension, and flexion.[25-26] Specifically, VA hemodynamics were measured for the following movements with the participants seated in an upright position in an unarmed chair: (1) neutral head position, (2) end-range retraction, (3) repeated retraction for 10×, (4) end-range protraction, (5) repeated protraction for 10×, (6) retraction with extension, (7) repeated retraction with extension for 10×, (8) flexion, and (9) repeated flexion for 10×.[25-26] Therefore, the VA hemodynamics attained for each McKenzie movement could be compared against the VA hemodynamics measured at a neutral neck position. One-minute rest was provided after each movement to restabilize the VA hemodynamics.

The second set of ultrasound examinations was performed in a supine position, which started with 5 minutes of rest to restabilize the VA hemodynamics. After rest, the VA hemodynamics were measured using the Duplex ultrasound following the same ultrasound procedures conducted in the sitting position. The VA hemodynamics were established at a neutral neck position to provide a comparative standard. Then the VA hemodynamics were measured twice for each McKenzie movement: at end range, and at neutral cervical position, after repeated movements 10 times for retraction, protraction, and retraction with extension.[25-26] The participants were instructed to position themselves so that their head and neck lay over the table and the edge of the table at the level of the spinous process of the third thoracic vertebra, with one hand placed behind the occiput to support the head (Fig 1). Vertebral artery hemodynamics were measured for (1) neutral head position, (2) end-range retraction, (3) repeated retraction for 10×, (4) end-range retraction with extension, and (5) repeated retraction with extension for 10×. During supine movements, the head was

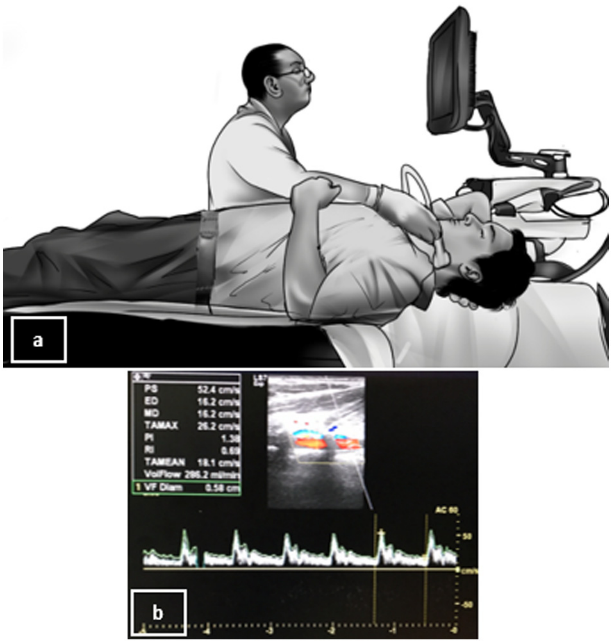

Fig 1. *(A) Showing the experimental setup for Duplex Ultrasound imaging. The participant was positioned in supine with neutral neck posture after repeated retraction with extension to measure the hemodynamics of the vertebral artery. Following the McKenzie principle, the participant was positioned so the edge of the table was at the level of the spinous process of the third thoracic vertebra with the right hand placed behind the occiput to support the head. (B) Illustrating the Duplex ultrasound imaging between 2 successive transverse processes at the C4-C5 level.*

continuously supported by the hand throughout the whole range of movement. Similarly, 1-minute rest was given after each movement to recover baseline hemodynamics.

All the examined movements in sitting and sitting positions were standardized following the guidelines of the McKenzie approach.[25-26] No randomization was applied to the order of the McKenzie movements examined to increase the practicality of the examination procedures and to have control of the variable under exploration: VA hemodynamics. Changing the order of the movements examined might have required changing the position from sitting to supine and vice versa, which could have caused an external uncontrollable factor to change VA hemodynamics, and might have required longer rest periods to restabilize the VA hemodynamics. Order effect was eliminated by providing rest periods after each movement as explained. One-minute rest was provided after each McKenzie movement, which was considered a sufficient time to stabilize the hemodynamics of the VA. There is no specific study on the VA that could be used to estimate the time needed for hemodynamic stabilization; however, skeletal muscles' perfusion signals appear to decay on the order of 1 minute after exercise.[44] The perfusion signals explored previously were for lower limb muscles with a higher-intensity exercise of 10 to 20 lb when compared to the current study intensity.[44] In addition, the ultrasound examination after each McKenzie movement lasted for an average of 1 minute, extending the average actual time interval between each McKenzie movement to 2 minutes, which is equivalent to the hemodynamic restabilization period used with a previous investigation.[44] Five minutes was provided between the sitting and supine positions to restabilize the VA hemodynamics, which can be considered a sufficient restabilization period. Although a 2-minute time interval might seem sufficient post-McKenzie movement, as explained earlier, a longer time interval of 5 minutes was provided to restabilize the position changing effect from sitting to supine. Specifically, 5 minutes is sufficient to restore arterial resting diameter.[45] Less than a 5-minute time interval was used previously with the higher-intensity exercise of cycling.[38] The sitting position involved 8 McKenzie movements, but because each movement was followed on average by 1 minute of ultrasound examination and an additional 1-minute rest, and the intensity of the movement can be considered relatively low intensity, the 5 minutes provided can be considered sufficient between sitting and supine positions.

Expectation bias was minimized, where the scans were obtained without the operator's knowledge of the maneuvers. Specifically, the operator (A.M.A.) is a sonography specialist and does not have a solid background in the McKenzie approach. However, N.F.A. is a senior physiotherapy specialist and supervised the accurate performance of all McKenzie maneuvers during the data collection stage, and she was concealed from the sonography results during the examination. End-range protraction, repeated protraction, end-range flexion, and repeated flexion were only examined in sitting position and were not examined during supine because cervical protection and flexion are frequently prescribed to be performed during sitting. Moreover, during the piloting stage it was difficult for the participants to maintain the antigravity positions during the ultrasound examination. Therefore, these positions were only examined in the sitting position to increase the clinical relevance and the practicality of the research.

Statistical Analysis

Statistical Package for the Social Sciences version 23 was used for data analysis (IBM Corp, Armonk, New York). Descriptive statistics, including median (interquartile range), were used to describe the demographic data and the results. The RI, TMAX, and PI were automatically calculated using the Duplex ultrasound. The RI is peak systolic velocity (lowest diastolic velocity/peak systolic velocity), and PI is peak systolic velocity (minimum diastolic velocity/mean velocity). Shapiro-Wilk tests were used to assess the normal distribution of the data. The data for several variables were not normally distributed; therefore, nonparametric Wilcoxon signed rank tests were administrated to compare VA hemodynamics attained at neutral position against each

McKenzie movement.[46] Owing to multiple comparisons, the level of statistical significance was set at $P \leq .01$. Standardized mean differences (SMDs) were calculated to estimate the size of the changes—small, medium, or large—to suggest clinically important differences.[47,48]

Results

Twenty participants were examined: 10 men and 10 women, aged 22.05 (1.69) years, height 167.13 (11.73) cm, weight 68.09 (19.20) kg, and body mass index 24.13 (4.73) presented in mean (standard deviation).

No reduction in VA volume flow was demonstrated with McKenzie cervical movements, except for a slight reduction during end-range flexion (Table 1). Two statistically significant differences were identified in volume flow during McKenzie cervical movements: repeated retraction with extension in the sitting position and end-range retraction with extension in the supine position ($P \leq .01$) (Table 1). The SMD suggests medium-size changes in VA volume flow in supine position during end-range retraction with extension and after repeated retraction with extension (SMD $\geq$ 0.5) (Table 1). For VA diameter, statistically significant dilation was identified in the sitting position in repeated protraction, retraction with extension, end-range loading and repeated movement, and repeated flexion ($P \leq .01$) (Table 1). The SMD suggest medium-size changes in VA diameter in the supine position during end-range retraction with extension and after repeated retraction with extension (SMD $\geq$ .5) (Table 1).

No statistically significant differences in VA RI were found with McKenzie cervical movement (Table 2). The SMD suggested medium-size VA RI reduction during end-range flexion in the sitting position (SMD $\geq$ 0.5) (Table 2). Moreover, TMAX significantly increased after repeated retraction with extension in the supine position ($P \leq .01$) (Table 2), yet the SMD suggests no clinically important change (SMD < 0.2) (Table 2). The PI was significantly reduced during end-range loading of flexion ($P \leq .01$), and the SMD suggest a large-size difference (SMD $\geq$ 0.8) (Table 2).

Discussion

The present preliminary study describes the hemodynamic response of the VA during McKenzie cervical movements in healthy participants. Various end-range and repeated movements were significantly associated with an enhancement in VA hemodynamics. Cervical retraction with extension, both in sitting and supine positions, was associated with an increase in VA volume flow. The increase in VA volume flow identified during end-range retraction with extension in the supine position was associated with moderate change size, as suggested by the SMD. No statistically significant changes were observed in RI with McKenzie therapeutic cervical movements. Following repeated retraction with extension in the supine position, a significant increase in VA TMAX was identified, yet the SMD suggests that the observed change was not clinically important (SMD < 0.2). A statistically significant reduction in PI was shown during end-range cervical flexion with large change size.

End-range cervical flexion was slightly associated with a reduction in VA volume flow and diameter, and these observations were associated with a statistically significant reduction in VA RI, and PI. However, VA insufficiency is determined by the reduction in volume flow by 100 mL/min.[49] The findings of the current study mostly point toward an increase in volume flow. The slight reduction in volume flow associated with end-range cervical flexion was 8.80 mL/min, which is less than the cutoff point of VA insufficiency of 100 mL/min.[49] In contrast, after repeated cervical flexion, VA hemodynamics were improved for volume flow and diameter. It has been suggested previously that cervical flexion can be used to manage headaches, where cervical flexion is thought to mechanically stretch cervical muscles and ligaments and widen the intervertebral disc spaces of the upper cervical vertebra.[25-26] Vertebral artery hemodynamics were measured during end-range cervical flexion, which could explain the slight hemodynamic reduction, yet VA hemodynamics at cervical neutral position after repeated cervical flexion was associated with an increase in VA volume flow and diameter.

We hypothesize that McKenzie methods might influence the global cerebral blood flow by enriching the blood supply to the posterior cerebral circulation, which supplies the brainstem, cerebellum, and spinal cord.[15] McKenzie movements might enlarge the passing space of the VA at the transverse foramen of each cervical vertebrae, which might explain the increase in VA hemodynamics observed in the current exploration. It is possible that this is why the McKenzie cervical approach has been shown to be successful in managing mechanically induced pain and related symptoms.[28,29] The current study suggests that the McKenzie cervical approach could address conditions related to VA insufficiency. However, this is only a hypothesis because the current study only measured healthy participants. Prospective randomized studies with groups of individuals with VA insufficiency would be needed to explore this possibility.

Vertebral artery hemodynamics have been studied in relation to cervical positioning, such as during use of salon sinks and during surgeries. The cervical spine was studied in extension position in a salon sink, and no significant change VA blood flow was found,[50] and the findings of Foye et al disagree with the findings of the current study.[50] This contradiction could be related to elements of the cervical retraction movement accompanied with extension in the McKenzie approach, whereas the examination position of Foye et al was only cervical extension. During

Table 1. *The Hemodynamics of the Vertebral Artery for Male and Female Participants (n = 20) Measured in the Sitting and Supine Positions*

	Volume Flow (mL/min)				Diameter (cm)			
Examined Cervical Movement	Median (IQR)	Absolute Difference	*P* value	SMD	Median (IQR)	Absolute Difference	*P* value	SMD
Sitting position								
Neutral position	170.65 (72.28)	-	-	-	0.41 (0.07)	-	-	-
End-range retraction	185.60 (109.18)	14.95	.29	0.16	0.39 (0.08)	0.02	.43	0.27
Repeated retraction for 10×	182.20 (128.48)	11.55	.31	0.11	0.41 (0.09)	0.00	.19	0.00
End-range protraction	181.75 (101.02)	11.10	.41	0.13	0.41 (0.07)	0.00	.26	0.00
Repeated protraction for 10×	201.85 (87.60)	31.20	.21	0.39	0.42 (0.05)	0.01	.01 [a]	0.16
End-range retraction with extension	172.05 (79.03)	1.40	.88	0.02	0.42 (0.07)	0.01	.01 [a]	0.14
Repeated retraction with extension for 10×	189.50 (112.35)	18.85	.01 [a]	0.20	0.43 (0.05)	0.02	.01 [a]	0.33
End-range flexion	161.85 (110.58)	8.80	.99	0.09	0.39 (0.04)	0.02	.71	0.35
Repeated flexion for 10×	198.15 (91.03)	27.50	.29	0.33	0.42 (0.05)	0.01	.01 [a]	0.16
Supine position								
Neutral position	163.90 (58.12)	-	-	-	0.40 (0.05)	-	-	-
End-range retraction	160.55 (60.88)	3.35	.38	0.06	0.41 (0.04)	0.01	.82	0.22
Repeated retraction with 10×	178.50 (65.05)	14.60	.85	0.24	0.42 (0.05)	0.02	.52	0.40
End-range retraction with extension	238.80 (126.78)	74.90	.002 [a]	0.76	0.43 (0.06)	0.03	.02	0.54
Repeated retraction with extension for 10×	219.00 (80.93)	55.10	.02	0.78	0.42 (0.01)	0.02	.31	0.55

IQR, interquartile range; *SMD*, standardized mean difference.
At each cervical position, the vertebral artery hemodynamics were compared against the vertebral artery hemodynamics measured at neutral cervical position. SMD: 0.2 indicates small clinically important difference, 0.5 indicates medium clinically important difference, and 0.8 indicates large clinically important difference. Medium to large SMDs ≥ 0.5 were highlighted in bold.
[a] Indicates statistically significant difference; $P \leq .01$.

the McKenzie approach, the full range of cervical extension is reached, but in the salon sink position full cervical extension is not reached. However, Foye et al and the current study indicate that cervical extension did not compromise the VA hemodynamics. It has been suggested that during[50] surgery, sustained combined motion of neck hyperextension, rotation, and side flexion may cause an obstruction and stenosis to the VA, and improper neck positioning could lead to stroke and to position-related VA thromboses.[51-53] In contrast, no significant differences were found with various head and neck positions by Thiel et al.[33] The findings of the current study, along with the findings of previous studies, indicate that VA hemodynamics may be sensitive to neck positioning and movements. Some neck movements seem to compromise VA hemodynamics, and McKenzie cervical movements are associated with enhancement in VA hemodynamics.

Limitations

The current study had limitations. Order effect might have influenced the results, but this was minimized by providing a 1-minute rest after each movement. The sample size was based on VA volume flow, yet differences were noticed in other parameters, but the observed differences were not statistically significant, which could indicate a type II error. The observed differences could be confirmed with a larger sample size study. Thus, this study would have benefited from more participants. The participants in the current study were young, which limits the generalizability of the results to

Table 2. *The Hemodynamics of the Vertebral Artery for Male and Female Participants (N = 20) Measured in the Sitting and Supine Positions*

	RI			TMAX (cm/s)			PI		
Examined Cervical Movement	Median (IQR)	*P* value	SMD	Mean (IQR)	*P* value	SMD	Mean (IQR)	*P* value	SMD
Sitting position									
Neutral position	0.73 (0.13)	-	-	30.40 (9.00)	-	-	1.76 (0.63)	-	-
End-range retraction	0.70 (0.11)	.14	0.25	32.60 (9.65)	.16	0.24	1.44 (0.75)	.06	0.46
Repeated retraction for 10×	0.70 (0.13)	.28	0.23	30.80 (9.10)	.20	0.04	1.59 (0.56)	.23	0.29
End-range protraction	0.69 (0.09)	.51	0.36	32.70 (7.43)	.19	0.28	1.47 (0.66)	.19	0.45
Repeated protraction for 10×	0.71 (0.11)	.56	0.17	31.65 (11.02)	.20	0.12	1.51 (1.09)	.75	0.28
End-range retraction with extension	0.74 (0.15)	.89	0.07	29.95 (9.90)	.55	0.05	1.55 (1.55)	.91	0.18
Repeated retraction with extension for 10×	0.68 (0.12)	.13	0.40	29.10 (14.03)	.57	0.11	1.35 (0.65)	.75	0.64
End-range flexion	0.65 (0.13)	.03	0.62	30.05 (9.88)	.70	0.04	1.32 (0.37)	.001 [a]	0.85
Repeated flexion for 10×	0.72 (0.14)	.50	0.07	29.30 (8.80)	.92	0.12	1.52 (0.54)	.19	0.41
Supine position									
Neutral position	0.71 (0.12)	-	-	33.30 (5.83)	-	-	1.55 (0.55)	-	-
End-range retraction	0.66 (0.15)	.76	0.37	32.75 (11.65)	.69	0.06	1.28 (0.60)	.69	0.47
Repeated retraction for 10×	0.69 (0.13)	.46	0.16	33.45 (10.42)	.91	0.02	1.56 (0.66)	.92	0.02
End-range retraction with extension	0.71 (0.13)	.62	0.00	37.25 (11.63)	.09	0.43	1.48 (0.61)	.88	0.12
Repeated retraction with extension for 10×	0.68 (0.05)	.46	0.33	34.25 (14.67)	.007 [a]	0.09	1.31 (0.34)	.28	0.52

IQR, interquartile range; *PI*, Pulsatility Index; *RI*, Resistive Index; *SMD*, standardized mean difference; *TMAX*, time-averaged maximum velocity.
At each cervical position, the vertebral artery hemodynamics were compared against the vertebral artery hemodynamics measured at neutral cervical position. SMD: 0.2 indicates small clinically important difference, 0.5 indicates medium clinically important difference, and 0.8 indicates large clinically important difference. Medium to large SMDs ≥ 0.5 were highlighted in bold.
RI = Peak Systolic Velocity – Lowest Diastolic Velocity / Peak Systolic Velocity.
PI = Peak Systolic Velocity – Minimum Diastolic Velocity / Mean Velocity.
[a] Indicates statistically significant difference; $P \leq .01$.

an older population. In addition, the exclusion of the VA normal variants was not performed and may have influenced the current study's hemodynamic data.

Future Studies

The current study explored the immediate change in the VA hemodynamics in association with McKenzie cervical movements in healthy individuals; however, the long-term change in the VA hemodynamics in relation to McKenzie cervical movements should be considered in future studies for symptomatic populations by implementing individualized McKenzie management. Specifically, the McKenzie approach is related to the individualized therapy provided based on the McKenzie diagnostic algorithm. Moreover, future research should consider the performance of additional measurements to explore the possible effect of other movements performed in the cervical spine on VA hemodynamic by a blinded assessor to enhance the reliability of the results. Future research should also consider the long-term effect of the movement explored at different time intervals.

Conclusion

The current study explored changes in VA hemodynamics in relation to McKenzie cervical movements in healthy individuals. The McKenzie cervical approach is significantly associated with a hemodynamics enhancement change, where VA hemodynamics were not compromised in healthy individuals.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): S.M.A., A.M.A., N.F.A.
Design (planned the methods to generate the results): S.M.A., A.M.A., N.F.A.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): S.M.A.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): S.M.A., A.M.A., N.F.A.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): S.M.A., A.M.A., N.F.A.
Literature search (performed the literature search): S.M.A., A.M.A., N.F.A.
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Practical Applications

- This preliminary study explored VA hemodynamic changes associated with McKenzie therapeutic cervical movements in healthy individuals.
- Statistically significant VA dilation was observed in the sitting position with protraction, combined retraction with extension, and flexion.
- Repeated retraction with extension in the supine position was significantly associated with an increase in VA time-averaged of maximum velocity, yet the standardized mean differences reveal no clinically important difference.

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