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Original Article

Neural and visceral manipulation in infants with congenital muscular torticollis: a feasibility study

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Abstract. [Purpose] As an alternative to manual stretching, the aim of this study was to investigate the feasibility of using neural/visceral manipulation as a safe and effective intervention to increase neck range of motion of infants with congenital muscular torticollis. [Participants and Methods] Ten 4-month old infants with congenital muscular torticollis received eight sessions of neural/visceral manipulation administered for 30–50 minutes without observed pain. Specific palpation techniques addressed restricted tissue areas of neck, head, trunk and extremities. Neck rotation and lateral flexion were assessed by still photography and a computer program calculating ROM angles before, immediately following, and 4 months post intervention. Motor development and social competence were monitored over time using the Alberta Infant Motor Scale and Bayley-III Social Emotional Scale. [Results] Results of analysis of variances revealed significant improvements in passive and active neck rotation and lateral flexion. Significant increases were also found on the Alberta Infant Motor Scale and Bayley-III Social-Emotional scale. [Conclusion] Neural/visceral manipulation can be used safely in infants with congenital muscular torticollis to improve neck range of motion.

Key words: Visceral manipulation, Neural manipulation, Congenital muscular torticollis

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INTRODUCTION

Congenital muscular torticollis (CMT) is a condition diagnosed shortly after birth characterized by unilateral shortening/tightness of the sternocleidomastoid (SCM) muscle[1–3)] causing the head to tilt toward and the chin to rotate away from the affected SCM[2, 4, 5)]. CMT affects 0.3% to 2% of infants[2, 4)] with the incidence as high as 16%[6)]. The etiology of CMT remains unknown; however, the most widely cited theories are intrauterine fetal constraint and birth trauma[1, 6, 7)]. Lee and colleagues assessed infants' SCMs with ultrasound to determine the degree of SCM fibrosis[8)]. Thirty nine percent of 67 infants with CMT had type 3 SCM fibrosis; 34% of the babies had a history of breech position, and 91% of infants in the breech position were delivered by cesarean section. Thus, Lee et al. suggest that type 3 fibrosis torticollis is due to intrauterine fetal constraint and malposition, rather than delivery trauma[8)]. Other possible causes of CMT include ischemia, infections[10)], vascular injury, heredity and compartment syndrome[9)].

Associated with CMT are asymmetries such as plagiocephaly, ipsilateral mandibular asymmetry, ear displacement, scoliosis, hip dysplasia, pelvic asymmetry, congenital hip and foot deformity[3, 6)]. Postural asymmetry and plagiocephaly may

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begin with growth constraint in-utero and is further perpetuated by the back to sleep program as the baby preferentially lies on the flattened skull side[11, 12]. In a study of 7,609 infants across the Netherlands, Boere-Boonekamp and van der Linden Kuiper found that 8.2% of infants had positional preference (head turned to one side most of the time), with nearly 10% of the infants having flattening of the occiput on the head-turned side[11]. Sheu and colleagues found a 21.2% per year increase in plagiocephaly in Texas from 1999 to 2007[13]. Also, delays in early motor milestones are documented in infants with CMT which appear to be associated with limited time in prone during waking hours[14].

Researchers typically divide CMT into three subtypes: 1) postural torticollis having "positional preference" with no muscular or passive range of motion (PROM) restrictions 2) muscular torticollis with SCM tightening and PROM limitations and 3) SCM pseudotumor with a discrete palpable mass, and PROM limitations[2, 11].

Early diagnosis and treatment are recommended for best outcomes[3, 15, 16]. Results of a study of 980 children with CMT concluded that therapy initiated before one month of life resulted in a 98% success rate, declining to 85% at 3–4 months, and proportionally lower at later months of the first year[17]. Another study found that range of motion and thickness of the SCM were significantly better for the infants who began treatment before six weeks than infants receiving later treatment[18]. Current CMT Clinical Practice Guidelines by the American Physical Therapy Association (APTA) are based on the both the severity (range of motion (ROM) and muscular limitations) and infant's age of referral[19].

Traditional treatment for infants with CMT includes passive stretching of the shortened SCM muscle, strengthening of the contralateral SCM muscle, active ROM, handling and positioning to improve postural alignment[2, 20, 21]. Manual stretching is the most researched treatment of choice[22, 23]. Although prolonged stretching is an effective treatment approach[24], some clinicians report snapping of the SCM[26] as well as infants crying/resisting this form of therapy[16, 20, 25].

Neural manipulation (NM) and visceral manipulation (VM) are alternative forms of physical therapy thought to cause less discomfort or tissue damage[27–30]. (Please note, the term "manipulation" usually connotes direct, aggressive techniques, but in France, where these techniques were developed, "manipulation" implies gentle and non-aggressive manual therapy.) The difference between NM and VM is the structures that are palpated and treated. Neural manipulation (NM) is a manual therapy that assesses and treats neural and dural restrictions of the cranium, vertebral column, upper and lower limbs[27]. Visceral manipulation (VM) addresses normal mobility/tissue motion of the organs and their connective tissues which potentially contribute to these musculoskeletal asymmetries[28]. With torticollis, NM assists in the release of entrapped nerves (which innervate muscles and joints), so that the tension in the infant's neck muscles release. VM releases the organs and their associated connective tissue in the neck, thorax and abdomen which can be compressed and restricted due to the atypical, prolonged position of the infant in the uterus prior to birth[11, 12].

Although NM and VM are utilized worldwide to treat children and adults, one case studies series[31] describes this work with children; however, no peer reviewed articles have been published determining its feasibility for use with infants. Some researchers have found manual therapy and osteopathy to improve postural asymmetry and plagiocephaly in infants[12, 32, 33]. Neural mobilization research has mainly focused on the effectiveness of neural sliding and gliding exercises to decrease pain and improve range of motion in adults. Basson et al. undertook a meta-analysis of 40 studies (1,759 participants) which showed that neural mobilization positively affected cervical pain, back pain, plantar heel pain, and tarsal tunnel syndrome[34]. Neto et al. analyzed 45 studies looking at the effects on neural mobilization on the lower body[35]. Ten of the 45 studies met the meta-analysis criteria and showed moderate effects on flexibility in healthy individuals and large effects on pain and disability in people with low back pain. Barral's and Croibier's neural manipulation differs from other neural mobilization techniques, as the adhesions around the nerve are specifically palpated and manually released prior to specific elongation of the nerve[27].

The aim of this feasibility study was to determine if PT using a NM/VM approach was tolerated and beneficial for infants with CMT. This was accomplished by assessing: 1) infant responses to NM/VM during therapy sessions and by parent report, 2) the usage of photography with computer analysis as a feasible measure of cervical ROM, 3) changes in active and passive cervical range of motion (ROM) with gross motor and social emotional development of infants being monitored over the six months of the study.

PARTICIPANTS AND METHODS

A convenience sample of ten infants with CMT (six males, four females; 4.4 months ± 2.3) were recruited through a local hospital, community agencies and pediatricians. The general characteristics of the participants are shown in Table 1. According to the Clinical Practice Guidelines for CMT[19], all ten of the infants were considered to have muscular torticollis with SCM tightening and PROM limitations. Inclusion criteria were infants 0–12 months of age with CMT and families agreeing to participate for a 6-month window of time. Exclusion criteria were infants with acquired muscular torticollis and/or those with additional neurological, orthopedic diagnoses or with significant developmental delays unrelated to CMT. The study was approved through the University of New Mexico Human Research Protection Office (HRPO 09-271). Caregivers gave informed consent for the research, photography and publication of the results.

Measurements were taken within a 2-week window of time in each study phase: a) baseline: prior to therapy, b) post: after 8 sessions of therapy, and c) post 4 months: 4 months following last therapy session. Three measures of cervical range of motion (active and passive cervical rotation, passive lateral cervical flexion) were assessed by still photography as

Table 1. Demographics of infant participants with Congenital Muscular Torticollis (CMT)

Infant	Gender	Ethnicity	Adjusted age at referral	Birth history (CMT Classification)
1	Male	Caucasian	3 mos.	Preterm/NICU; Right>Left CMT; plagocephaly; reflux; respiratory distress; (Grade 2)
2	Female	Caucasian	7 mos.	Preterm/NICU; drug exposed; Left CMT; plagocephaly; reflux; (Grade 6)
3	Male	Hispanic	5 mos.	Preterm/NICU; R CMT; plagocephaly; respiratory distress; (Grade 2)
4	Female	African American	8 mos.	Preterm Twin/NICU; drug exposed; Left CMT; plagocephaly; reflux; (Grade 6)
5	Male	Hispanic	7 mos.	Full term; Left CMT; plagocephaly; (Grade 6)
6	Male	Asian American	3 mos.	Preterm Twin/NICU; Breech delivery; Left CMT; plagocephaly; (Grade 3)
7	Female	Caucasian	4 mos.	Full term; Right CMT; plagocephaly; (Grade 2)
8	Male	Hispanic	2 mos.	Full term Twin; Right CMT; plagocephaly; (Grade 3)
9	Female	Caucasian	1 mos.	Full term Twin; Left CMT; (Grade 3)
10	Male	Caucasian	4 mos.	Full term; Right CMT; plagocephaly; (Grade 3)

NICU: Neonatal Intensive Care Unit; CMT: congenital muscular torticollis; mos.: months; Classification: American Physical Therapy Association Clinical Practice Guidelines.

shown in Figs. 1 and 2. Two secondary measures were administered to monitor the stability of the infants' development over the 6-month window of time: a) Alberta Infant Motor Scales (AIMS), a standardized assessment for infants 0–18 months of age used to measure motor development with reported high inter-rater reliability (r=0.95–0.99), test-retest reliability (r=0.86–0.99) and concurrent validity (r=0.84–0.97)[36] and b) Bayley Scales of Infant Development III Social Emotional Scale, a standardized subtest measuring the infant's sensitivity to visual, auditory and touch stimuli and the infant's ability to attend, to respond and self-calm[37]. The scale has high reliability and construct validity[37]. Inter-rater reliability of 90% or greater agreement between research team members was established for these secondary measures.

Range of Motion (ROM) measurement methodology was developed over the course of one year prior to use in the study. Still photography was used as suggested by Rahlin and her colleague[38] who reliably documented habitual head deviation from midline of 30 infants with CMT while lying in supine. Using still photographs of the infants and a protractor, the investigators measured the angle formed from a line between the acromion processes and a line between both eyes to document head tilt. In our study, a similar supine resting posture (neutral) was photographed; however rather than measuring the head position at rest, we measured active and passive cervical rotation, as well as passive lateral flexion. Active ROM (AROM) was measured first to avoid influence of passive ROM (PROM) on this measure.

Still photography methodology similar to Christensen et al.[39] was used to document active and passive cervical rotation. Two dots 1 cm in diameter were placed on the top of the infant's head as landmarks to measure head rotation and accommodate the variety of head shapes. Lying supine on a measuring board atop a massage table, the infant's shoulders were stabilized with the head in a neutral flexion/extension position (Fig. 2). With the camera stabilized on a fixed tripod 24" cephalad from the top of the head, a photo was first taken in the starting position. A toy or examiner's face was slowly moved three times to the right and three times to the left side to facilitate the infant's head turning for active cervical rotation ROM measures. A photo was taken at the endpoint for each trial (Fig. 1). The same procedure was used for passive cervical rotation ROM measures with a researcher turning the infant's head passively and a photo was taken at the endpoint. In our measures of cervical rotation, the measuring board limited the rotation to 95°, as the infant's head was at, but not off the edge of the measuring board. Ohman[4] positioned the infants' heads so they were slightly off the edge of the measuring board. Thus, "normal" rotation in our study was 95°, instead of 110°[2, 4].

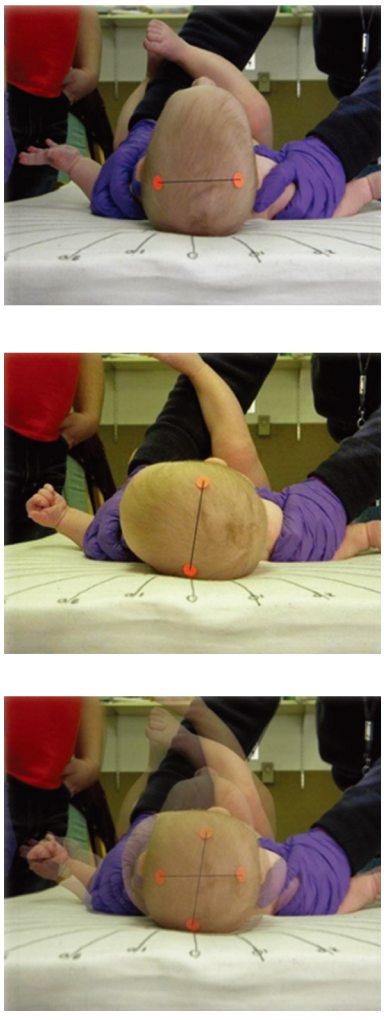

Fig. 1. Active cervical ROM measurement.

Beginning with the accepted approach of using an arthroidal protractor[4] to measure passive cervical flexion range of motion, a cushioned measuring board with an embedded protractor was created. With the infant lying supine on the measuring

board (Fig. 2), one researcher stabilized the infant's shoulders. With the camera positioned 30" directly anterior to the infant's nose, photos were taken for baseline (neutral) position. The infant's head was gently moved passively from neutral to lateral flexion to the infant's resistance barrier, three times to right and left each side, and photos were taken (Fig. 2).

The pediatric physical therapist who administered the intervention was blinded to results of study measures. Participants received eight sessions of physical therapy (PT) using a NM/VM approach lasting 30–50 minutes, every two weeks as tolerated by the infant. The NM/VM approach is based upon the work of Barral and associates[27, 28]. With both manipulation approaches, the therapist palpated the infant's body to determine the location of the tissue restrictions. Once the restrictions were located, the therapist gently mobilized the identified tissue manually, not imposing a direct stretch on the neural, fascial, or vascular tissue, until these tissues were ready to elongate. Techniques were modified if the babies fussed, to avoid crying during the sessions. With the exception of positioning alternatives during sleep and "tummy time", the parents were not instructed in any home exercises.

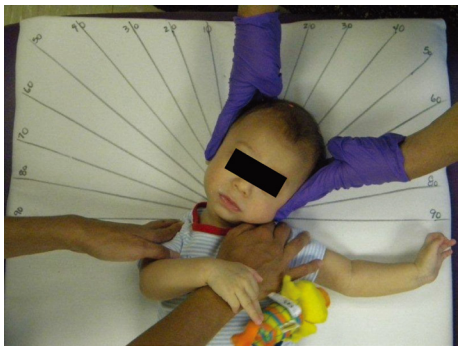

Fig. 2. Lateral cervical flexion PROM measurement.

Examiners inspected the data collected from the ROM measures and identified the best photo for analysis by consensus. Individual infants' photos for active and passive cervical rotation as well as passive lateral cervical flexion were imported into a computer program with graphical user interface specifically created to measure head angles in infants. Measurements were compared as pairs of images, the first of which represented a reference position (neutral) and the second of which represented the endpoint (to the left or to the right) of passive lateral cervical flexion and active or passive rotation. As each image was displayed on the computer, the researcher selected the two reference points on the image to form a line. For rotational measurements, the lines were created by two dots on the top of the head. For lateral flexion measurements, the line was created between the pupils of the infants' eyes. The computer program then calculated the difference in rotation angles between each pair of images (neutral vs. endpoint) in a format that was imported into Microsoft Excel. To be able to calculate the angle of the line created by the two reference points in any given image, the following equation was used: $\text{atan2}((y2-y1)/(x2-x1)) \times 180/\pi$.

Three angles were computed for each of the six ROM positions. Each infant's lowest ROM measures for active and passive cervical rotation and passive cervical lateral flexion were defined as the side used for analysis. Once the lowest baseline ROM (right or left) was established, only this side was used for the subsequent ROM measurements (baseline, after eight sessions, 4 months post intervention). In four of the 30 PROM measures recorded, the infants resisted passive head turning resulting in PROM values, which were less than AROM. For these measures, the infant's AROM value was used for PROM as it reflected the best performance of the infant.

Analysis of variance (ANOVA) using SPSS V25 documented changes in active cervical rotation, passive cervical rotation and lateral cervical flexion. Paired t-tests were used as post hoc analysis to the ANOVA and also used to compare the AIMS percentile score and Bayley Social Emotional Scale standard scores and the sensory sensitivity scores at baseline and 4 months after the last treatment.

RESULTS

ANOVA results showed significant improvements in active cervical rotation ($F=6.59$, $p<0.001$), passive cervical rotation ($F=7.78$, $p<0.001$) and passive lateral cervical flexion ($F=24.81$, $p<0.001$) as shown in Table 2. Post hoc tests indicated statistically significant changes (Table 2) in the infants' active cervical rotation immediately following intervention ($p=0.005$), at 4 months post intervention ($p<0.003$) as well as significant changes were found between the end of intervention (8 weeks) and 4 months post treatment ($p=0.04$). Range of motion measures for individual infants at baseline, post eight sessions and 4 months post intervention are displayed in Table 3. In general, all infants demonstrated changes with the exception of Infant 7 who showed decreased ROM in all cervical measures 4 months post intervention (Table 3). Infant 7 was later diagnosed with mild hemiparesis, which may have affected her cervical ROM.

Significant improvements for infants' passive cervical rotation were found between baseline and after the eighth treatment session ($p=0.002$) and 4 months post intervention ($p=0.001$) (Table 2). No significant changes were found between the end of intervention and 4 months post intervention. Passive lateral cervical flexion was significantly improved (Table 2) after intervention ($p=0.001$) at 4 months post treatment ($p=0.001$), but no significant differences were noted between the end of intervention (8 weeks) and 4 months post treatment.

Analysis using a paired t-test of the mean AIMS % score at baseline and at 4 months post intervention revealed significant gross motor difference for the group ($p=0.04$) as shown in Table 2. Table 4 displays the development of the individual infant participants over the course of the study. All infants maintained or increased their percentile ranking on the AIMS over the course of the study with the exception of Infant 1.

Table 2. Group changes on clinical measures across study (n=10)

Measure	Study timepoint		
	Baseline	8 Sessions	4 months
Neck rotation PROM (deg)			
Mean (SD)	58.8 (7.2)	72.7 (4.4)*1	76.7 (13.5)*2
Neck rotation AROM (deg)			
Mean (SD)	46.6 (11.8)	62.4 (10.1)*1	63.2 (12.4)*2
Lateral cervical flexion PROM (deg)			
Mean (SD)	25.1 (8.8)	41.0 (7.2)*1	48.4 (6.6)*2
AIMS			
Mean (SD)	23.3 (22.8)		54.7 (35.3)*2
BSID Social emotional scale			
Mean (SD)	89.5 (7.2)		108 (20.56)*2
Sensory sdcore			
Mean (SD)	29.0 (4.03)		36.1 (4.3)*2

8 sessions: end of intervention; PROM: passive range of motion; AROM: active range of motion; deg: degrees; SD: standard deviation; AIMS: Alberta Infant Motor Scale; Bayley: Bayley Scales of Infant Development II;.
*1=8 Sessions vs. Baseline; *2=4 months vs. Baseline; *p<0.05.

Table 3. Neck range of motion of individual infant participants with Congenital Muscular Torticollis (CMT)

	Infant	Neck rotation PROM (deg)	Neck rotation AROM (deg)	Neck lateral flexion ROM (deg)
1	Pre	67.4	67.4	10
	Post	73.3	70.6	43.7
	Post 4 mos.	84.8	72.3	48.1
2	Pre	59.2	46.5	13.8
	Post	69.2	69.2	42.5
	Post 4 mos.	78.1	57.5	59.9
3	Pre	68.3	49.9	27.1
	Post	69.4	58.9	35.2
	Post 4 mos.	84.3	59.8	45.2
4	Pre	51.1	32.5	31.7
	Post	78.4	78.4	44
	Post 4 mos.	95.5	88.2	44.2
5	Pre	59.3	55.7	40.4
	Post	77.9	67.2	45.5
	Post 4 mos.	63.2	63.2	44
6	Pre	52.4	45.7	19.6
	Post	75.6	55.4	51.4
	Post 4 mos.	69.6	58.2	49
7	Pre	66.8	41.9	27.7
	Post	70	47.7	24.9
	Post 4 mos.	47.4	40.3	38.3
8	Pre	60.2	25.3	25.2
	Post	68.9	47.1	37.3
	Post 4 mos.	78.4	56.8	46.5
9	Pre	56.9	54.2	28.8
	Post	77.5	62.7	42
	Post 4 mos.	82.1	69.3	58.2
10	Pre	47.2	47.2	27.1
	Post	66.8	66.8	43.6
	Post 4 mos.	84	66.3	51

ROM: range of motion (best performance on 3 measures of ROM of side of neck with greatest tightness); CMT: congenital muscular torticollis; PROM: Passive range of motion; AROM: Active range of motion; Pre: baseline prior to intervention; Post: after 8 sessions of neural/visceral manipulation; Post 4 mos.: 4 months following last intervention session; "Normal" rotation in our study was 95° instead of 110°.

The mean Social Emotional Composite score at baseline compared to the mean score at 4 months post intervention was significantly different by paired t test (p=0.01) as was the comparison of the mean sensory score at baseline and group mean 4 months after treatment (p=0.001) as shown in Table 4. Thus, all infants were developing well according to social-emotional and sensory measures (Table 4).

Table 4. Gross motor and social emotional development of individual infant participants with congenital muscular torticollis

Infant	Adjusted age at referral	Testing session	AIMS raw (%ile)	Bayley social-emotional composite score
1	3 mos.	Pre	12 (43%ile)	100
		Post 4 mos.	52 (1%ile)	95
2	7 mos.	Pre	30 (62%ile)	95
		Post 4 mos.	58 (75%ile)	135
3	5 mos.	Pre	10 (22%ile)	95
		Post 4 mos.	48 (50%ile)	90
4	8 mos.	Pre	24 (4%ile)	75
		Post 4 mos.	58 (90%ile)	145
5	7 mos.	Pre	25 (5%ile)	85
		Post 4 mos.	54 (5%ile)	125
6	3 mos.	Pre	10 (22%ile)	85
		Post 4 mos.	58 (90%ile)	80
7	4 mos.	Pre	11 (5%ile)	90
		Post 4 mos.	55 (50%ile)	110
8	2 mos.	Pre	7 (12%ile)	90
		Post 4 mos.	55 (50%ile)	105
9	1 mo.	Pre	3 (1%ile)	85
		Post 4 mos.	58 (90%ile)	100
10	4 mos.	Pre	24 (57%ile)	95
		Post 4 mos.	58 (90%ile)	100

Pre: baseline prior to intervention; Post 4 mos.: 4 months following last intervention session; Bayley Composite Score: Standard score with mean of 100 Standard Deviation of 15; AIMS: Alberta Infant Movement Scale; %ile: percentile.

DISCUSSION

This article reports the first trial of an 8-session PT intervention using a NM/VM approach in infants with CMT. This feasibility study sought to determine whether infants with CMT would accept NM/VM intervention, tolerate the ROM testing by photography and demonstrate ROM gains over the course of the treatment. Stability of gross motor and social emotional development of the infants was monitored during the study to ascertain differences in infant interactions, play or sleep routines.

This research project was conceptualized in response to parental concerns that manual stretching elicited stress responses for their infants with CMT. Rahlin[20] observed infants crying during manual stretching. Cheng et al.[26] reported 9.2% of infants with sternomastoid tumors receiving manual stretching had snapping of the sternocleidomastoid muscle, a complication signifying a possible tear or rupture of the muscle. Although it is difficult to accurately assess discomfort, our results were achieved without crying, spitting up and aversion to touch after therapy (infant behaviors reported after manual stretching). All infants accepted NM/VM intervention. During ROM testing using photography, infants experienced more discomfort, with fussing and resistance to head turning for PROM measures. To minimize these responses, caregivers were present, and examiners engaged the infants in play. Measures were taken only when the infants tolerated handling to ensure reliability. Similar to previous studies using photography or video[4, 39], infants in our study tolerated the measures.

Our third objective, to demonstrate ROM gains in infants receiving NM/VM intervention, was also met. As a group, the infants in this sample made statistically significant improvements in cervical ROM measures immediately following therapy and retained ROM gains four months after therapy was discontinued. According to the current guidelines for CMT[19], three infants in this study were considered "Grade 2: Early moderate between 0–6 months of age with cervical rotation ROM limitation of 15–30°", four infants were considered "Grade 3: Early severe with cervical rotation ROM limitation of 30° or greater", and three infants were referred for services after 7 months of age and considered "Grade 6: Late severe with limited cervical ROM of 30° or greater". In our study, lateral flexion was measured similar to these authors. Even though the infants' lateral flexion significantly improved, they did not reach 70°, possibly due to the research protocol limitations of eight sessions that did not allow individualization of the number of sessions by infant. Although all infants' active rotation significantly improved, only one infant reached 95°, perhaps again due to the limit of 8 therapy sessions. Similar to the results of other studies in infants with CMT under one year of age who received manual stretching[2], the infants in this sample showed significant changes in cervical ROM with NM/VM therapy. The ROM gains remained 4 months post intervention. Infant No. 7 was later diagnosed with mild hemiparesis, which may have contributed to the decrease in cervical ROM between the last treatment and 4 months post intervention measurement.

These results were noteworthy as the infants in this study showed significant changes in ROM with therapeutic intervention limited to 45 minutes every 2 weeks for a total of eight sessions, with no stretching or handling between sessions. The

recommended intervention guidelines[19] for infants with CMT with cervical rotation limitations of 15–30° or greater, are passive stretching frequently throughout each day, as well as handling, active positioning and strengthening exercises. The duration of treatment depends on age and severity of CMT. Studies recommend a minimum of 1.5 months[17] and a maximum of 36 months[40], with the majority of studies citing a range of 4–6 months duration for intervention[19].

NM/VM intervention during this study was individualized during the 8 sessions since there were no consistent patterns of tissue restriction in all infants[2]. Some infants had more involvement in the head and neck while other infants also had involvement in the upper and lower extremities and twists through the spine. Most infants had plagiocephaly, which is consistent with findings of other investigators[11, 41], with an increase in this condition being linked to the 1992 American Academy of Pediatrics' recommendation that infants sleep in the supine position. Consistent with van Vlimmerman et al.'s previous findings that treating young infants with PT helped to diminish plagiocephaly and positional preference[42], our research therapist found that using NM/VM approach for plagiocephaly helped reshape the head, diminished the head and cervical turning toward that flattened side of the head, and decreased the static cervical position related to torticollis. Plagiocephaly was not specifically measured in this study, thus will require further investigation.

From analysis of the daily chart notes, we discovered that there were no consistent patterns of tissue restriction in the infants, which reinforces that each infant must be assessed and treated specifically and thoroughly in an individualized manner[2]. Many of our infants had involvement of the vagus and accessory nerves, which exit the cranium at the jugular foramens. The accessory nerve innervates the sternocleidomastoid and trapezius, thus treating this nerve helped to reduce the tension/spasm in these muscles. The vagus nerve provides parasympathetic innervation to many of the organs supporting autonomic body functions[43]. Sleep, digestion and reflux were not systematically measured; however, many parents anecdotally reported that after treatment of the vagus nerve, their infants were calmer, had less reflux, improved sleep and digestion.

With the exception of positioning alternatives during sleep, and "tummy time", the parents were not instructed in any home exercises or handling activities. This protocol was designed specifically to isolate the results of NM/VM. While being involved in a research project with professional attention or other unreported influences (educational or internet materials on positioning, handling, infant massage etc.) may have influenced outcomes, it is unlikely so many infants would increase ROM by attention or educational materials alone. However, changes between the end of intervention and 4 months post were not significant for cervical rotation suggesting additional therapy was required. Beyond this research, it is recommended that infants receive more frequent treatments (one time/week) including VM/NM, AROM, handling and developmental suggestions to achieve optimal ROM of the cervical spine.

Based upon the predictive validity, reliability and standardization of the AIMS, Kaplan et al.[19] in the Clinical Practice Guidelines, recommend its use to document gross motor development of infants with CMT between the ages of 1–18 months. Infants in our study showed statistically significant improvements on the AIMS between baseline and four months post intervention, supporting the use of PT using a NM/VM with the absence of negative consequences to their gross motor development. All infants with the exception of Infant No. 1 scored within age expectations across the study. Percentage scores of Infant No. 1 decreased over the course of the study, despite increases in his raw scores, possibly due to his preterm birth history and signs of mild neuromotor differences as he developed. Snider et al.[44] reported motor delays in 26.3% preterm infants at 12 months using the AIMS as an outcome measure. Previous studies have documented motor delays in infants with torticollis[14] and plagiocephaly[41]. Motor delays in these studies are thought to be due to infants having decreased time in prone. Although inclusion of a control group to document effects of treatment was beyond the limits of a feasibility study, many of the babies in our study not only had involvement in their neck, but also in their spines and at least one upper extremity. The treating therapist noted that as the infants gained more flexibility in their spine and extremities, their skills in prone, rolling and transitions improved.

Lastly, there was a significant improvement between baseline and 4 months post-intervention for the Social Emotional Score and Sensory Processing Score. Rahlin[20] observed infants crying during manual stretching while other researchers[12] investigated other stress responses (changes in sleep, vomiting, drinking, mood). Throughout our study, infants receiving NM/VM intervention scored age appropriately on socio-emotional parameters. Such results suggest the infants' sensory defensiveness was not increased and may have decreased with the therapeutic handling as reflected in the Bayley Sensory scores.

Anecdotal reports of parents during the course of treatment suggested side benefits of decreased spitting up and more regular sleep/wake patterns. The improvements in the social-emotional scores correspond to the parents' reports of their infants being calmer, less irritable, more responsive and more tolerant to touch, movement, auditory and visual stimuli. Karmel-Ross and Lepp[21] hypothesized that irritability in infants with torticollis may be a response to pain from a perinatal or intrauterine compartment syndrome, which may be caused by continuous stimulation of the interstitial nocioceptors due to compression in-utero, as nerves and arteries, as well as muscles and joints are compressed, and perhaps ischemic.

Limited research studies are available documenting the efficacy of PT using a NM/VM approach in children and no studies have documented use of this approach in infants. Clinicians using this approach with infants and children report positive results anecdotally. Our study supports the use of physical therapy using the NM/VM approach with infants, and thus supports need for additional studies.

Limitations. Major limitations of this feasibility study were the small sample size, the lack of a control group and being limited to a specific number of sessions. Because of these limitations, the findings are only preliminary and require more rigorous study using control groups to determine actual efficacy of PT using the NM/VM approach with infants with CMT.

Finally, without a control group who received only parental interaction, results are not free from the Hawthorne effect, that is, changes being attributed to the additional support and interaction of the parents and children with a caring professional.

Results of this feasibility study support our aim to successfully implement a PT intervention using a NM/VM approach with infants having CMT. All infants not only tolerated the intervention but pre and post measures indicated significant changes in their cervical ROM. Other measures showed typical progression in the infants' motor and social emotional development.

Future Direction for Research. Future studies comparing NM/VM to traditional manual stretching in a larger sample of infants with CMT is warranted to further support this intervention. Studies are needed to determine the amount of therapy required to impact changes at different ages using NM/VM in infants, toddlers and young children with CMT as well as studies stratifying infants receiving NM/VM into types of CMT (sternocleidomastoid pseudotumor, muscular torticollis, postural torticollis) with corresponding levels of PT intervention. Interesting anecdotal information from parents suggests future investigations which might include a systematic collection of data on changes in infant sleep patterns, eating patterns, episodes of reflux, pain responses during therapy and at home, and a more in-depth look at social engagement of infants during and post intervention.

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Conflict of interest

The authors declare no conflict of interest. At the time this research was completed, Prisca Werbelow and Jessie Swartzentruber were occupational therapy graduate students at the University of New Mexico.

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