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Biomechanical characterization of cervical spinal manipulation in living subjects and cadavers

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ABSTRACT

Background: Cervical spinal manipulative therapy (cSMT) is a common therapeutic modality used in the treatment of neck pain and headaches. Cadaveric necks have been used as a model for assessing the effects of cSMT on vertebral artery mechanics. However, there have been no previous studies comparing the biomechanical indices of cSMT performed in living subjects versus cadavers.

Methods: The preload force, peak force and duration of cSMT performed by two chiropractors were recorded in 28 subjects with and without neck pain, and in five cadavers.

Results: There were no statistical differences in terms of the preload, peak force and duration of cSMT in living subjects with versus without neck pain. However, all three parameters differed statistically in living subjects versus cadavers; and both preload and peak forces were significantly higher for cadaveric cSMT; the average peak force was 190.3 ± 85.5 N (mean ± SD) in living subjects, versus 283.9 ± 53.6 N in cadavers. Furthermore, the duration was significantly faster for cadaveric cSMT (175 ± 100 ms in living subjects versus 120 ± 30 ms in cadavers. These observations were consistent for both chiropractors.

Conclusions: When performed in cadavers, cSMT tends to be more "aggressive" in terms of all biomechanical indices used to describe cSMT.

1. Introduction

Cervical spinal manipulative therapy (cSMT) is a common therapeutic modality used in the treatment of neck pain and headaches (Hurwitz et al., 2008; Bronfort et al., 2010). Historically, there has been an issue with the use of cSMT and the development of vertebral artery dissections (VADs). Although risk of a VAD associated with cSMT has been reported to be small (Guidelines Committee, 2005) and can be explained by the fact that patients in the prodromal phase of developing a spontaneous VAD may visit a chiropractor for symptoms such as headache and neck pain (Cassidy et al., 2008), others maintain that there is a causal relationship between cSMT and VAD (Ernst, 2010).

The forces generated during cSMT have been well-characterized. We have previously reported that a Diversified-style cervical manipulation averages 100–150 N of peak force over 150–200 ms (for review, see Downie et al., 2010; Herzog and Symons, 2001). Other laboratories have also reported similar values (Gerrit et al., 2003). In general, the causality between cSMT and VAD is based on the assumption that the movements of the head and neck during cervical manipulation may stretch the vertebral artery (VA) to the point where it begins to tear, either microscopically or grossly. Therefore, in a previous study, Symons et al. (2002) used a cadaveric neck model to investigate whether the strains experienced by the VA during cSMT would be sufficient to mechanically disrupt the VA. They measured average strains of approximately 6% in the V3 segment of the VA during cSMT over the baseline obtained with the neck in the neutral anatomic position. With reference to Fig. 1, the V3 segment of the VA can be defined as the segment coursing from the foramen transversarium of C2 (just below the arrow labelled "vertebral artery") until it pierces the dura mater just cephalad of C1. In comparison, they reported average strains of approximately 5% and 12% in the V3 segment during ipsi- and contralateral rotation of the neck, respectively, and strains of 12% during an extension/contralateral rotation maneuver of the neck. They observed gross mechanical failure of the V3 segment at approximately 53% strain.

Some of the limitations of the previous study included the fact that there was no biomechanical characterization of the cSMT performed on the cadaveric specimens, and only a single chiropractor performed all of the manipulations. Thus, it was difficult to extrapolate these results to a typical chiropractor. Recently, Wuest et al. (2010) addressed these two issues by recording the forces generated during cSMT by two different chiropractors using the same cadaveric model as described above, but while measuring the VA strains simultaneously. They reported cSMT preload and peak

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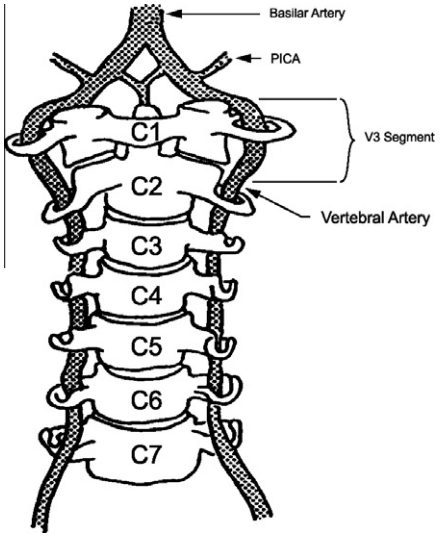

Fig. 1. Schematic representation of the anatomic relationships of the vertebral artery from the anterior perspective. PICA, posterior inferior cerebellar artery.

forces, respectively, of 72 and 200 N and 170 and 273 N for the two chiropractors. Simultaneously, they recorded average strains in the VA of 2.2% to 3.1% during cSMT, and 13% during contralateral rotation.

In this study, we extend the findings from the two previous reports to include both force time histories measured from five cadavers and 28 live human subjects by two chiropractors. We then compare the force–time histories from cSMT performed on the cadaveric specimens to cSMT performed on living healthy volunteers and patients with neck pain. We hypothesized that a chiropractor may manipulate a subject's neck differently, in terms of biomechanical indices, if he or she was aware beforehand that the patient was in pain, in no pain, or deceased.

2. Methods

The methods used are essentially the same as those previously reported (Wuest et al., 2010).

2.1. Live subjects

We enrolled a total of 28 subjects at the Human Performance Laboratory, Faculty of Kinesiology, University of Calgary. The characteristics of these subjects are summarized in Table 1 below. A brief history and examination were performed in all cases to exclude those with contraindications to cervical spinal manipulation. The presence (+) or absence (−) of neck pain was scored simply by asking the subject whether he or she was currently experiencing any neck pain. Written informed consent was obtained from all subjects. This study protocol was approved by the Conjoint Health Research Ethics Board of the University of Calgary.

Table 1
Subject characteristics.

Total number (*n*)	28
Age (years)	34.1 ± 11.4
Gender (M/F)	18/10
No neck pain (−NP)	17
Current neck pain (+NP)	11

2.2. Cadavers

A total of five fresh, un-embalmed, post-rigor cadavers were obtained from the Department of Anatomy, Faculty of Medicine, University of Calgary. There were two males and three females, with an average age at death of 88 ± 7 years (mean ± SD) and a range of 80–99 years old. Prior to measuring the cSMT forces in situ, the neck was dissected to expose the vertebral arteries as previously reported (Symons et al., 2002; Wuest et al., 2010). An anterior midline incision was made on the neck, and the flaps of skin were reflected laterally to allow for dissection. Roughly a tablespoon of tissue was removed during this procedure. The flaps of skin were then closed together at the midline before the cSMT force measurement procedure was performed.

2.3. Spinal manipulation

On both live subjects and cadavers, Diversified-style spinal manipulations were performed by two of the authors (BPS, SW) who are practising chiropractors licensed in Alberta. Both were trained at the Canadian Memorial Chiropractic College. Chiro 1 is male, has a body mass index (BMI) of 26 kg/m^2 and has 14 years of practice experience. Chiro 2 is female, has a BMI of 21 kg/m^2 and has 6 years of experience. The manipulations were performed bilaterally at the upper (C2–C3) and lower (C4–C5) cervical spine. However, in the live subjects, the spinal level may have varied by a segment depending on the examination and palpation findings, as well as the patient's subjective pain.

2.4. Force measurements

The forces applied during the SMT were measured using a thin, flexible pressure pad (Pedar System; Novel Inc, München, Germany) as described previously (Gerrit et al., 2003; Wuest et al., 2010). Briefly, the pressure transducer pad was in the form of an insole (shoe size 10), containing individual pressure sensors of 5 mm^2, and the data were collected at a 100 Hz sampling frequency. The pressure transducer pad was unloaded and recalibrated to zero force before each maneuver. Preload forces, defined as the force immediately preceding the treatment thrust, and peak forces, defined as the greatest force measured during the treatment, were quantified by integrating the contact pressures measured by the pressure pad over the entire contact area between

Table 2
Cervical manipulation in live subjects.

	Preload (N)	Peak Force (N)	Time (ms)
Chiro 1: normal	47.7 ± 25.1	177.4 ± 64.4	150 ± 40
Chiro 1: neck pain	64.2 ± 25.6	177.2 ± 47.3	130 ± 30
Chiro 1: normal + NP	56.0 ± 28.3	177.3 ± 95.7	140 ± 40
Chiro 2: normal	107.1 ± 30.7	203.3 ± 57.7	240 ± 80
Chiro 2: neck pain	120.8 ± 59.0	202.9 ± 86.0	180 ± 70
Chiro 2: normal + NP	114.0 ± 51.3	203.1 ± 88.0	210 ± 100
All normal	77.4 ± 45	190.4 ± 70.7	195 ± 100
All neck pain	92.5 ± 61.6	190.1 ± 91.6	155 ± 80
Overall normal + NP	85.0 ± 56.0	190.3 ± 85.5	175 ± 100

Table 3
Cadaveric cervical manipulation.

	Preload (N)	Peak Force (N)	Time (ms)
Chiro 1: cadaver	115.6 ± 22.5	236 ± 18.6	110 ± 10
Chiro 2: cadaver	208.4 ± 35.7	331.8 ± 48.8	130 ± 20
All cadavers	162.0 ± 45.1	283.9 ± 53.6	120 ± 30