106 Journal of Manipulative and Physiological Therapeutics
Voume 15•Number 2 • February, 1992
0161-4754/92/1502-0106 $03.00/0 © 1992 JMPT

The Assessment of Cervical Intersegmental Mobility before and after Spinal Manipulative Therapy

STEVEN G. YEOMANS, D.C.

ABSTRACT

The objective of this study is to assess the changes in cervical intersegmental spinal mobility before and after the use of spinal manipulative therapy (SMT). Two systems of mensuration are utilized in 58 case studies. The results are then compared to previously defined normal values and the efficacy of SMT is objectively assessed. Of the 58 case studies presented, results reveal that post-SMT mobility is significantly (p<.05) greater than the pre-SMT data, with exception of the C1 segment of both the male and female treatment groups utilizing the Henderson et al. mensuration method. Although both systems displayed improved post-SMT scores, one system appeared to be a more sensitive form of mensuration, while the other is more inclusive, not depending on radiographic findings alone. (J Manipulative Physiol Ther 1992; 15:106-114).

Key Indexing Terms: Chiropractic, Cervical Vertebrae, Spine, Motion.

INTRODUCTION

Practitioners utilizing spinal manipulative therapy have long had an interest in understanding spinal biomechanics. More recently, the study of manipulation and how it affects the biomechanics of the cervical spine has attracted a larger audience, including other allied health professions, and radiography has been utilized as a method of assessing spinal biodynamics (1-17). The data derived from these studies help to establish protocols by which, when correlated with the patient history and mechanism of spinal injury, the type and location of tissue injury can be better appreciated.

This study will restrict its discussion to the utilization of cervical stress radiography in the sagittal plane for assessing cervical spinal mobility. Two methods of assessing mobility will be applied to 58 case studies (12, 15). By assessing spinal mobility before and after spinal manipulative therapy (SMT), the effect of SMT will be directly investigated. In addition to the history and objective physical findings, this may serve the practitioner with data leading to an accurate assessment and appropriate treatment of the condition. Several methods of assessing mobility and defining instability will be reviewed.

METHOD

A total of 58 subjects, consisting of 36 females and 22 males, were selected in a nonrandom fashion from the patient population of two private practices. Inclusion criteria included all patients under the age of 50 who had not received SMT prior to 6 months of the initial presentation date. Exclusion criteria included any patient who failed to comply with the therapy frequency or post-SMT radiographic/template evaluation. Informed consent was obtained from the subjects participating in this study. X rays and associated templates were evaluated utilizing the techniques described previously by Henderson et al. (6) and White et al. (15, 18). The average female age is 37 and male age 39 with an average age of 38.

To better understand the diagnosis of the 58 cases presented in this study, three diagnostic categories were utilized. The first category was that of headaches, which included 29 of the 58 cases (50%). The second diagnostic category included those who presented with objective nerve root findings (brachial paresthesia and/or motor paresis). This category included 16 (27%) cases in which the motor and/or sensory division of the nerve root tested abnormal, utilizing deep tendon reflexes, sensory perception (two-point discrimination and/or

---

* Private practice of chiropractic. Postgraduate faculty member of National College of Chiropractic, Lombard, IL 60148.

Submit reprint requests to: Steven G. Yeomans, D.C., 404 Eureka St., Ripon, WI 54971-0263.

Paper submitted September 28, 1990.

Wharton pinwheel) and segmental muscle testing. The third diagnostic group includes 13 (23%) cases who presented with soft tissue-oriented problems only There were overlaps of these three diagnostic categories, as many of the samples in the nerve root group had a soft tissue component present. The intention of this study was not to specifically focus on the diagnosis and the effects of SMT, but rather the pre- and post-SMT quantification changes utilizing two available and previously described methods of determining mobility and clinical instability.

In an attempt to improve objectivity of this study, X-ray names and dates were blocked until the templates were traced, measured and the data collected. In addition, templating techniques were performed prior to review of individual case histories and physical examination findings to reduce author bias. As a result, it was unknown to the author as to which template represented the pre- vs. post-SMT template as well as the specific clinical data associated with each case.

To more specifically define the SMT method utilized in this study, this author applied SMT to the hypomobile, restricted motion joints. Static and motion palpation, cervical stress X-ray and ranges of cervical motion assessment methods were used in determining the degree of mobility and the manipulative level. The manipulative approach utilized was that of a high-velocity, low-amplitude thrust, in a specific line of drive given at the endpoint of the normal passive range of motion. This was often accompanied by an audible crack, signifying the sudden release of gas from the synovial and tissue capsule (19). The frequency of SMT application averaged three applications per week, ranging between 2-6 wk, and if maximum rehabilitation had not been achieved, a gradual reduction in the frequency of SMT was employed until a plateau in clinical symptomatology was achieved.

Since each case study was individual and unique from a diagnostic standpoint, the length of time necessary for maximum rehabilitation was not standardized. With regard to the case studies submitted, therapy was continued for as long as 6 months and as short as 3 wk, with a mean therapy value of 7.9 wk.

A statistical analysis using a one-tailed *t* test as well as a Z-distribution analysis were utilized. A control group for comparing data pre- and post-SMT is derived from the "normal" data obtained from the Henderson-Dormon study. A 95% confidence interval is utilized to represent the range of "normal" intersegmental motion and is presented in Table 1. Figures 4 and 5 display the 95% confidence interval by a solid bar line in a graph form.

TABLE 1. 95% confidence interval for normal values (data from the Dormon-Henderson study). This represents the high and low value within the 95% confidence interval for both mal and female patient groups for each spinal level. In addition, the average, standard deviation and estimated error are listed for each corresponding spinal level. This information is derived from the Dorman-Henderson study. The 95% interval was calculated using the following expression: sample average ± ($t*SD/\sqrt{n}$); where t = 2.131, *n* = 16 for male cases and t = 2.160, *n* = 14 for the female cases. Sample average and standard deviation vary at each spinal level. The estimate error is $t*SD/\sqrt{n}$.

Level	Average	SD	Est. Error	Hi	Lo
A. Male cases (*n* = 16 *t* = 2.131)					
C0	8.16	3.53	1.88	10.04	6.28
C1	7.97	2.75	1.47	9.44	6.50
C2	0.33	0.18	0.10	0.43	0.23
C3	0.44	0.12	0.06	0.50	0.38
C4	0.49	0.09	0.05	0.54	0.44
C5	0.44	0.13	0.07	0.51	0.37
C6	0.31	0.12	0.06	0.37	0.25
B. Female cases (*n* = 14 *t* = 2.160)					
C0	9.11	2.44	1.41	10.52	7.70
C1	8.93	2.68	1.55	10.48	7.38
C2	0.47	0.08	0.05	0.52	0.42
C3	0.50	0.11	0.06	0.56	0.44
C4	0.55	0.13	0.08	0.63	0.47
C5	0.50	0.11	0.06	0.56	0.44
C6	0.34	0.11	0.06	0.40	0.28

RESULTS

Utilizing the Henderson et al. (12) mensuration technique and normative data compared to our subjects, the average intersegmental motion, as well as the associated *p*-values for each spinal level, are listed in Table 2. A statistically significant increase ($p < .05$) in mobility was achieved post-SMT at each level with the exception of C1 for both the female and male groups ($p = .29$ and $p < .25$, respectively). These results are illustrated in graphic form (Figure 1, A-D). In order to calculate the normal range (control group), a 95% confidence interval was constructed using data obtained from the nonpainful, normal subject group from the Henderson study. For example, considering that the percent sagittal body diameter of the C2 level for females is 0.47 ± 0.08 mm, the 95% confidence range results in a 0.42 to 0.52 range. This range represents a true population average, in that 95% of the time the normal female population will fall within the 0.42 to 0.52 range. The 95% confidence interval for each spinal level for both male and female patient groups are listed in Table 1.

The mean data of the case studies utilizing the methods described by Panjabi and White (15,18) are described (Table 3). The nine categories are given in the upper horizontal column. The total stability score is

TABLE 2. Average intersegmental motion before dn after therapy. A and B represent the total pre- and post-SMT mobility data utilizing the Henderson et al. mensuration technique for male and female patient groups, respectively. The occiput and C1 levels are absolute measurement in millimeters of motion, whereas C2 and C6 are ratios of the amount of glide or tilt (horizontal movement) over the sagittal mid-body diameter. C) The p-values are listed for both patient groups under the corresponding spinal level. Note that the *p*-value of C1 for both groups fall over the $p < .06$ value.

	CO	C1	C2	C3	C4	C5	C6
A. Male cases							
Pre-SMT							
Average	7.23	7.36	0.26	0.27	0.28	0.27	0.19
SD	3.91	2.95	0.11	0.09	0.12	0.13	0.08
Post-SMT							
Average	8.75	7.68	0.37	0.37	0.38	0.36	0.30
SD	5.49	3.11	0.13	0.12	0.12	0.12	0.14
B. Female cases							
Pre-SMT							
Average	7.88	7.82	0.32	0.34	0.34	0.33	0.23
SD	4.53	3.55	0.12	0.12	0.13	0.12	0.10
Post-SMT							
Average	8.47	8.00	0.47	0.47	0.48	0.46	0.37
SD	4.12	3.59	0.16	0.14	0.15	0.14	0.13
C. *p*-values							
Female	$p = .043$	$p = .28$	$p < < .001$	$p < < .001$	$p < < .001$	$p < < .001$	$p < .001$
Male	$p < .05$	$p < .25$	$p < .001$	$p < .001$	$p < .001$	$p < .001$	$p < < .001$

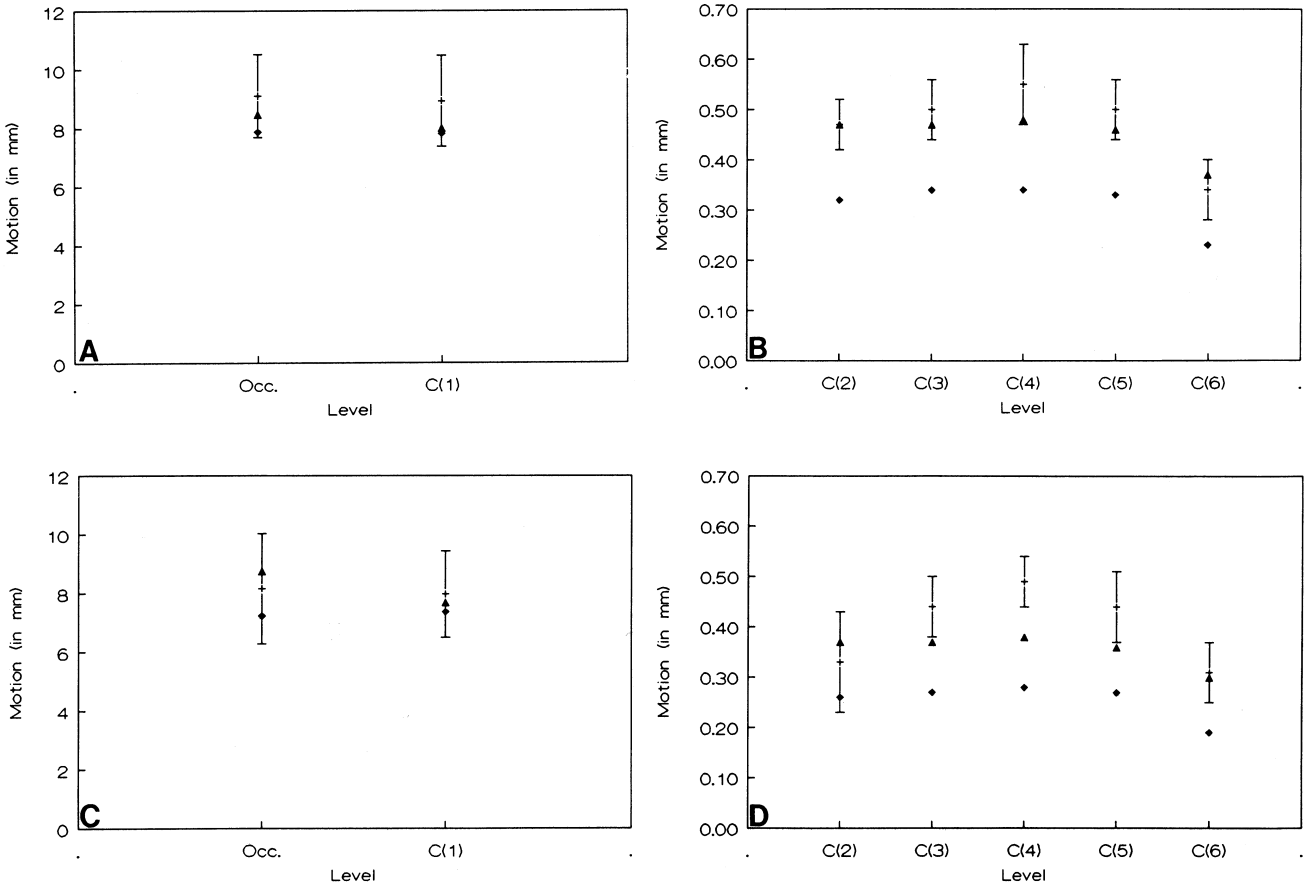

Figure 1. The vertical bar lines represent the 95% confidence interval of "normal" spinal mobility as defined by the Henderson study. (◆), represents the pre-SMT value; (▲) represents the value after spinal manipulative therapy; (+), represents the Dorman-Henderson mean 95% interval value. *A* and *B* represent the female case group for occiput and C1, and C2-C6, respectively. *C* and *D* represent the male case group, similarly.

TABLE 3. The mean data of the pre- and post-SMT results are listed below each category utilizing the checklist for the diagnosis of clinical instability as presented by Panjabi and White (13) for each patient group. The standard deviations listed following the mean totals fall within a statistically significant degree ($p < .05$).

	Anterior	Posterior	>3.5	>11°	Stretch Test	Spinal Cord	Nerve Root	Disk	DLA	Total	SD
Pre-SMT female	0.16	00	0.59	0.38	00	0.06	1.03	0.84	0.08	3.03	2.13
Post-SMT female	0.16	00	0.59	0.22	00	00	0.08	0.80	0.03	1.94	1.72
Pre-SMT male	0.49	00	0.29	0.09	00	00	1.29	0.90	0.42	2.95	2.13
Post-SMT male	0.49	00	0.29	0.09	00	00	0.20	0.86	0.37	2.23	1.82

given in the far right vertical column giving both the pre- and post-SMT scores. The last column is the calculated standard deviations for both patient groups. Analysis of Table 3 data shows that the pre-SMT average of instability scores are significantly ($p < .05$) greater than post-SMT averages. This was found true for both male and female patient groups.

DISCUSSION

Assessing sagittal plane motion is not a new concept and has attracted the interest of many investigators. Cineradiography, as well as plain film X ray, have been utilized to assess motion of the cervical spine (1, 3, 5–12, 15, 16, 20–22). The former offers a moving assessment of cervical motion, whereas the latter reveals the extreme static and points of cervical motion. A comparison of the two methods was investigated by Woesner (1), who found both methods important in the assessment of pathomechanics of the cervical spine. The improvement in detail provided by plain film flexion/extension cervical X ray facilitated the diagnostic accuracy of the two techniques (1, 11). From a practical standpoint, plain film stress radiography may be utilized by field practitioners with standard X-ray equipment.

Assessment of cervical spine total range of motion rather than intersegmental motion are described by Hviid (2) and Conley (3). Jackson (4) discusses cervical stress lines during flexion/extension X ray, where the intersection of two lines drawn vertically from the posterior aspect of the vertebral bodies of C2 and C7 indicate the focus of greatest stress. Assessing cervical motion also includes the change of difference in angulation between two adjacent vertebra, and this is discussed by various authors (2, 5–8, 20, 23).

Pre- and post-SMT comparison studies exist in the literature. Betge (9) used Orbitomo cineradiography on 50 patients pre- and post-SMT and displayed improved sagittal plane mobility. Similarly, Leung (10) studied 60 subjects comparing static palpation for tenderness, motion palpation for fixations and hypermobilities, static X ray and cineradiography. Cineradiography revealed the greatest sensitivity for functional abnormality assessment. It was also revealed that women were more subject to cervical problems; this correlates with our findings. In the 60 subjects from that study, 48 motor unit fixations were adjusted and reexamined by cineradiography, and improved mobility by "removing spinal fixation" were noted in this observational study. Jirout (11) examined 250 subjects pre- and post-SMT and showed sagittal, frontal and horizontal plane motion improvement post-SMT. Although these studies revealed improved post-SMT results, none went so far as to utilize a quantified method of assessment.

Henderson and Dormon (12) presented a method of quantification for cervical sagittal plane motion of 16 male and 14 female asymptomatic individuals aged 18–35 yr old, in an attempt to establish normative values of intersegmental motion (see Table 4). Templating techniques were utilized at the endpoints of cervical flexion and extension to quantify the tilt (rotary) and glide (translatory) components of each segment in reference to the adjacent level. A percentage of intersegmental movement was obtained by taking the amount of translation (horizontal movement measured in millimeters) over the mid-body sagittal diameter for spinal segments C2-C6. The percent sagittal body diameter (%SBD) was then calculated by x/y = %SBD (Figures

TABLE 4. Average total intersegment motion (C_0-C_1).* Proportion sagittal body diameter translation total excursion C2-C3 through C6–C7.‡ The mean and standard deviation values for occiput-C1 and C1–C2 for total sagittal plane excursion is listed in addition to the C2–C6 intersegmental motion (expressed as %SBD) for male and female groups (12).

	Males		Females	
	Mean	SD	Mean	SD
C0	8.16	3.53	9.11	2.44
C1	7.97	2.75	8.93	2.68
C2	0.33	.18	0.47	.08
C3	0.44	.12	0.50	.11
C4	0.49	.09	0.55	.13
C5	0.44	.13	0.50	.11
C6	0.31	.12	0.34	.11

* Values in millimeters.
‡ Values in percentage.

2 and 3). The occiput and C1 are measured directly in millimeters of absolute movement and are, therefore, subjected to magnification effects (Figure 4). In addition, quantification of increased and reduced mobility

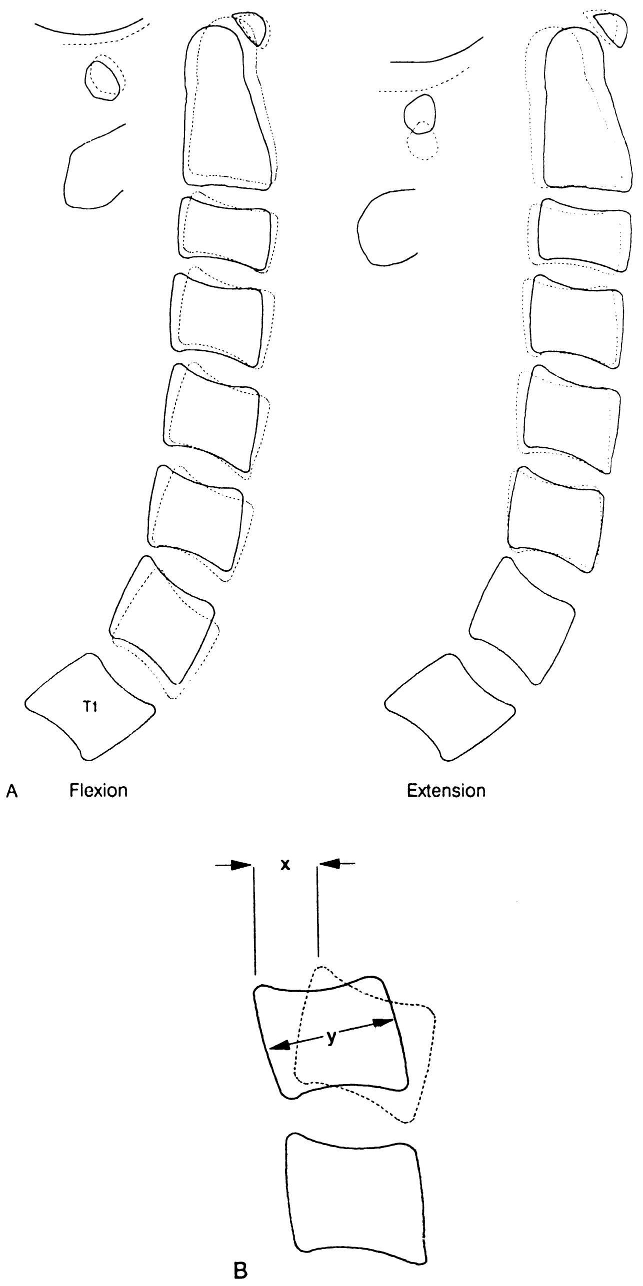

Figure 2. *A*, Completed template study. The solid lines represent neutral, and the interrupted lines depict the extreme flexed or extended position in relation to the vertebra below. *B*, Roentgenomentric analysis of intersegmental motion of C2-C3 through C6-C7. The ratio of estimated translation (*x*) to sagittal body diameter (*y*) provides motion values denoted "percent body diameter" (%SBD) (12).

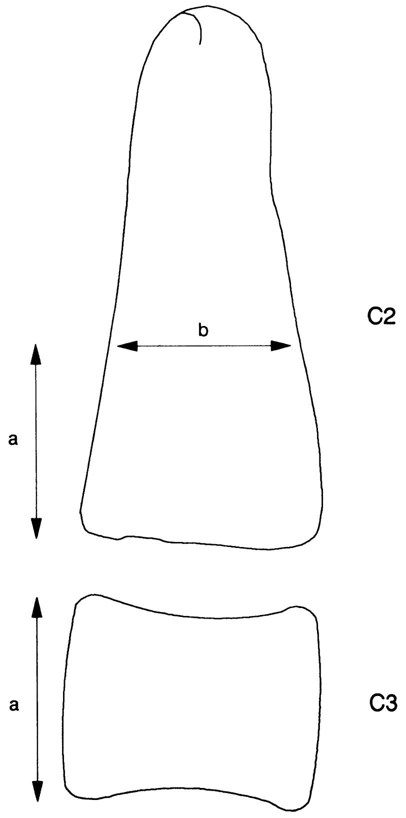

Figure 3. Roentgenometric analysis of intersegmental motion at C2-C3. Motion is measured as translation of a point on the posterior aspect of C2 at a distance (*a*) from its posterior inferior aspect. This motion is expressed as a percentage of the sagittal diameter of C2 (distance *b*) (12).

were offered, and the terms instability, hypermobility, hypomobility and fixation were defined (Table 5).

Other methods of quantifying sagittal plane motion have been introduced as well (2, 5, 8, 18, 20, 24). For example, White and Panjabi (18) and Lane (20) measured the angle formed by each cervical segment in flexion and extension. In doing so, they found a paradoxical motion between the occiput and C1, where the angle is reduced, rather than increased, during cervical flexion. This paradoxical motion has also been supported by cineradiography (5) and by others using flexion stress X ray (13, 20) and was also noted by this author. Ehni (24) found a range of 10–15° of motion to occur between each cervical segment in full flexion and extension. Lysell (8) reports angular motion as well as progressively larger changes in the axis of rotation as one ascends the cervical spine. This then reveals more relative glide vs. tilt in the upper cervical spine, and vice versa in the lower cervical spine.

The amount of horizontal translatory intersegmental

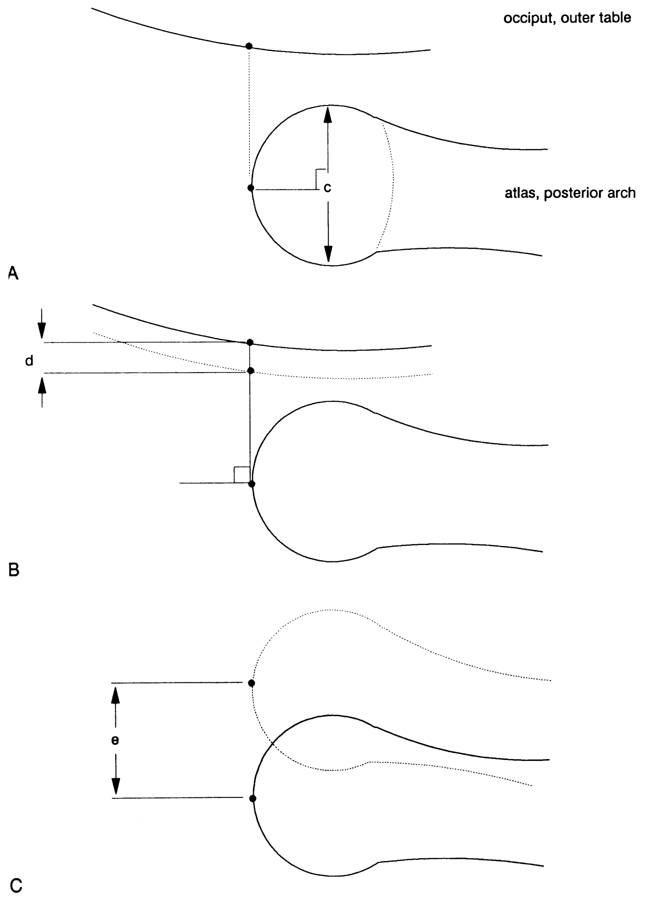

Figure 4. Roentgenometric analysis of occiput-C1 and C1-C2 motion. *A*, Determination of reference points. For the atlas, a point is chosen at the intersection of the cortex and a perpendicular bisector of the greatest vertical dimension of the posterior tubercle (*c*). *B*, Motion for occiput-C1 is expressed as absolute displacement of the reference point demonstrated in Figure 3 (a). This motion value is not related to a vertebral dimension, and is, thus, subject to magnification. *C*, Motion for C1-C2 is expressed as absolute displacement of the reference point demonstrated in Figure 3 (a). This value is also subject to magnification (12).

motion has been discussed (5, 8, 18, 21, 24, 25) with various opinions given. For example, White et al. (14) reported a maximum displacement of 3.5 mm necessary prior to defining instability. Green et al. (26) report that 1–3 mm may be considered as subluxated and that 3.5 mm or greater is only seen in frank dislocation, fracture or pseudosubluxation. Other indices are also used in the determination of clinical instability. One determination is that greater that 11° of tilt in flexion, neutral or extension, when compared to the adjacent vertebral interspaces, represent instability. White et al. (15) presented a nine-factor scoring "checklist" whereby cervical spinal stability is assessed. A point system is utilized and the total score, which includes radiographic exam findings, physical neurological exam data and considerations for "anticipated dangerous loading" regarding the individual's occupational anthropometric/ergonomic factors and lifestyle habits, is calculated. One category called "positive stretch text" is performed by lateral cervical X rays during cervical traction while carefully monitoring the neurological functions. A positive test represents visual displacement of two consecutive vertebral bodies and signifies advanced ligament disruption. A total score of 5 or more is considered clinically unstable (see Table 6).

In this study, the hypotheses that SMT enhances intersegmental mobility and reduces factors that constitute clinical instability are investigated. The purpose of this is to provide data and information which can be utilized by practitioners attempting to qualify and/or quantify clinical instability and intersegmental mobility. In addition, the concepts of increased (hypermobility, instability) and decreased (hypomobility, fixation) mobility are reviewed.

TABLE 5. Classification of cervical intersegment motion in the sagittal plane. A classification of cervical intersegmental motion in the sagittal plane utilizing the standard deviations as a measure for increased (instability) or decreased (fixation) mobility (12).

			Total Ratio Range	
	Described motion	Notation	Male	Female
1.	Instability	+ + + +	0.69	0.75
2.	Absolute hypermobility (X + 1 SD)	+ + +	0.68	0.74
3.	Relative hypermobility		0.57	0.63
4.	Normal mobility	+ + X ± 1 SD	0.46	0.52
5.	Relative hypomobility		0.35	0.41
6.	Absolute hypomobility (X – 1 SD)	+	0.24	0.30
7.	Articular fixation (X – 2 SD)	0	0.23	0.29
8.	Paradoxical motion		Reverse Motion	

TABLE 6. A nine factor checklist for assessing lower cervical instability includes clinical, ergonomic as well as radiographic data. A score of 5 or greater indicates clinical instability (15).

Element	Point Value
Anterior elements destroyed or unable to function	2
Posterior elements destroyed or unable to function	2
Relative sagittal plane translation > 3.5 mm	2
Relative sagittal plane rotation > 11°	2
Positive stretch test	2
Spinal cord damage	2
Nerve root damage	1
Abnormal disc narrowing	1
Dangerous loading anticipated	1
Total of 5 or more = unstable	15

The Henderson et al. mensuration method reveals improved ranges of intersegmental motion at all spinal levels, with the exception of the C1 level, for both male and female groups where the difference in the pre- vs. post-C1 values are not statistically significant ($p < .25$ and $p < .29$, respectively). The most logical explanation for this finding may be observed in Figure 1, A–D, where for both male and female patient groups, the prespinal manipulative measurement fell within the 95% confidence interval at both the occiput as well as at the C1 level. The large standard deviation may represent the reason that a statistically significant change did not occur. The large standard deviation may be present because the occiput and atlas movements are derived from direct measurements rather than measured as a ratio and, as a result, magnification effects produced a wide range in measurements. Variations in magnification are due to patient phenotype (body size), shoulder width (larger magnification with broad shoulders) and vertebra size (large bone structure creates greater magnification). Figure 5 represents an alternative technique of occiput and atlas mensuration. This approach maintains the use of a ratio and, therefore, may reduce the problems associated with direct mensuration and the associated magnification effect, which may have affected the results of the occiput and atlas measurements in this study. A future study utilizing this alternative form of mensuration is necessary to establish normative data to which actual case study data can be applied.

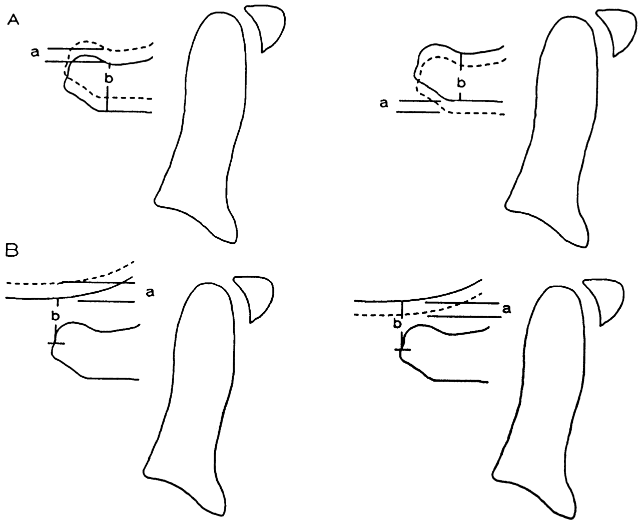

Figure 5. *A*, To obtain a ratio of atlas motion, the distance of the greatest vertical dimension of the posterior arch (*b*) is divided into the flexion and extension template movement (*a*). This results in a percentage of posterior arch movement (*b-a*). *B*, similarly, if the vertical distance between the most posterior of the tip of the atlas and occiput is divided into the templated occipital movement in flexion and extension, a ratio is produced. This represents the percentage of occipital motion (*b-a*).

It appears that from a quantification standpoint, the sensitivity of the Panjabi and White scoring system is less than that described by Henderson et al., when directly measuring intersegmental motion; however, the greater inclusive data of clinical as well as radiological information favor the use of this scoring system in a clinical setting.

When utilizing the checklist for clinical instability scoring system, 13 cases revealed a score of 5 or greater, indicating clinical instability. Similarly, utilizing the Henderson et al. approach, eight case studies revealed pre-SMT measurements to exceed 2 SD, thus defining instability. It was observed that hypomobility was often noted adjacent to the unstable segment. By applying specific SMT to the hypomobile region adjacent to the unstable segment, thus improving the reduced motion (i.e., releasing the fixation), the increased biomechanical load placed on the unstable segment, in turn, decreased, and an improved measurement was noted.

This observation is important when discussing degenerative joint disease and the process by which degenerative change takes place. As has been observed in previous studies (12, 14, 16, 18, 22, 24, 25, 27), hypermobility often occurs adjacent to a fixation of hypomobile region. This is especially noted following spinal fusion or adjacent to an arthritic segment (12, 14, 25). By restoring mobility in the hypomobile area prior to the onset of capsular laxity leading to articular degeneration, the process or rate of degeneration may be reduced as long as significant ligament damage and laxity have not yet occurred.

To help determine whether SMT is safe in terms of utilization adjacent to an unstable region, the practitioner of SMT must recognize the following warning signs:

1. Widening of the interspinous space;
2. Subluxation/dislocation of a facet joint;
3. Compression fracture of the adjacent vertebral endplate (usually the anterior portion); and
4. Acute loss of cervical lordosis (occurring within a 2–3 vertebra section) (17). Extra care must be exercised in these cases to assure patient safety when spinal manipulation is utilized. Patient pain tolerance, when setting up the manipulative procedure, is also a very important index in assessing safety when spinal manipulation is utilized. Patient pain tolerance, when setting up the manipulative

> procedure, is also a very important index in assessing safety of the manipulation.

Future clinical studies utilizing a specific time interval for assessing pre- vs. post-SMT mobility change and/or a series of specific time intervals may improve the understanding of the point at which maximum mobility is achieved. In addition, due to the numerous approaches or techniques of SMT available, each technique could be individually tested as to its ability to change mobility, thus allowing those who employ SMT to utilize those techniques proven most efficacious. Because different diagnoses were present in this study, future studies may restrict themselves by diagnosis. The lack of a therapeutic control group in this study places this in an "observational" vs. and "experimental" category of research, and the relatively small sample studied by Henderson et al. (12) may have affected the final "normative" data in their study. Obviously, there is much need for further clinical studies, and the two methods of mensuration presented here could be utilized.

With reference to the sensitivity of the two scoring systems of mobility assessment, the system suggested by Panjabi and White may be favored, perhaps, in injuries where gross tissue damage is suspect. The Henderson et al. approach, however, offers a defined form of intersegmental mobility assessment where specific quantification can be utilized. All in all, both approaches offer the practitioner a method of objectively enhancing the decision making process by which the therapeutic approach can be applied.

CONCLUSION

This study has included a review of the literature and the use of two scoring systems assessing cervical spinal stability in the sagittal plane. Furthermore, the efficacy of SMT was investigated utilizing 58 case studies. Utilizing the Henderson and Dorman (12) approach, the results indicate improved spinal mobility following SMT at each spinal level tested to a statistically significant degree ($p < .05$), with the exception of C1 mobility. The Panjabi and White (15, 18) approach utilized a nine-factor checklist, with each factor worth 1 to 2 points, which includes both X-ray as well as physical examination and ergonomic considerations. A score of 5 or greater is representative of clinical instability. This system appears to be inclusive of information other than purely radiographic data, but appears less sensitive when compared to the Henderson et al. scoring in assessing quantification of specific intersegmental spinal mobility. Again, a statistically significant difference in the pre- vs. post-SMT scores was obtained.

An alternative mensurating approach for occiput and atlas mobility was introduced in an attempt to improve accuracy by providing a ratio rather than a direct measurement. This reduces the error produced by magnification effects. A future study to assess a "normal" population group is necessary to clinical utilization of this technique.

Much work in the future is needed to obtain continued objective data regarding SMT. This is especially true due to the multiple SMT approaches available. Based on the data presented in this study, it is suggestive that SMT enhances mobility in a hypomobile joint, and is not contraindicated when instability is present if specific and careful application of the technique is utilized at the adjacent hypomobile segment.

ACKNOWLEDGEMENTS

I wish to thank Don Styba, D.C. (Madison, WI) for the contribution of 16 case studies to this project. Also, many thanks to Dr. Michael Zindrick, M.D. (Hinsdale, IL), who contributed not only the statistical significance analysis, but offered continued support during the 4-yr period of this study. Finally, thank you to you Raj Behal (La Grange, IL) for preparing the graphs and statistical tables.

REFERENCES

1. Woesner ME, Mitts MG. The evaluation of cervical spine motion below C2: a comparison of cineroentgenographic and conventional roentgenographic methods. Am J Radio 1972; 115:148–54.
2. Hviid H. Functional radiography of the cervical spine. Ann Swiss Chiro Assoc 1963; 3:37–65.
3. Conley RN. Stress evaluation of cervical mechanics. J Clin Chiro 1974; 1:3.
4. Jackson R. The cervical syndrome, 4th ed. Springfield, IL: CC Thomas, 1977.
5. Howe JW. Cineradiographic evaluation of normal and abnormal cervical spinal function. J Clin Chiro 1972; (Archives Ed) 2: Winter.
6. Henderon DJ. Kinetic roentgenometric analysis of the cervical spine in the sagittal plane: a preliminary study. In: Haldeman S. ed. Exploring hte spine. ICA Review 1981; 35:2.
7. Grice AS. Preliminary evaluation of 50 sagittal cervical motion radiographic examinations. J Can Chiro Assoc 1977; 21:33–4.
8. Lysell E. The pattern of motion in the cervical spine. In: Hirsch C, Zotterman Y, eds. Cervical pain. Toronto: Pergamon Press, 1972.
9. Betge G. The value of cineradiographic motion studies in the diagnosis of dysfunctions of the cervical spine. Bull Eur Chiro Union 1977; 25: 20–7.

10. Leung ST. The value of cineradiographic motion studies in diagnosis of dysfunctions of the cervical spine. Bull Eur Chiro Union 1977; 25: 28–43.
11. Jirout J. Contribution of radiology to the problem of segmental movement restriction in the cervical spine. In: Lewit K, Gutmann G, eds. Rehabilitacia, proceedings of the IVth congress Prague: International Federation of Manual Medicine, 1975.
12. Henderson DJ, Dormon TM. Functional roentgenometric evaluation of the cervical spine in the sagittal plane. J Manipulative Physiol Ther 1985; 8:219–27.
13. Wackenheim A. Functional atlanto-occiptal block. Neuroradiology 1971; 3:80–1.
14. White AA. Johnson RM, Panjabi MM, Southwick WO. Biomechanical analysis of clinical stability in the cervical spine. Clin Orthop 1975; 109:85–96.
15. White AA, Southwick WO, Panjabi MM. Clinical instability in the lower cervical spine. A review of past and current concepts. Spine 1976; 1:15.
16. Fielding W. Normal and selected abnormal motion of the cervical spine from the 2nd cervical vertebra to the 7th cervical vertebra based on cineroentgenography. J Bone Joint Surg 1964; 46A:1779-81.
17. Webb JK, Broughton RB, McSweeny T, Park WM. Hidden flexion injury of the cervical spine. J Bone Joint Surg 1976; 58B:322.
18. White AA, Panjabi MM. Clinical biomechanics of the spine. Philadelphia: J.B. Lippincott, 1978.
19. Sandoz R. The significance of hte manipulative crack and of other articular noises. Ann Swiss Chiro Assoc 1969; 4:47.
20. Lane GR. Cervical spine: its movement and symptomatology. J Clin Chiro 1971: (Archives Ed):1.
21. Wiesel SW, Rothman RH, Atlanto-occipital hypermobility. Orthop Clin N Am 1978; 9:4.
22. Jirout J. Changes in the mobility of cervical vertebrae in the frontal and horizontal plane after manipulation of segmental blocade. Neurol Neurochiro 1977; 40:135–8.
23. Arlen A. Biometrische roentgen-funktionsdianosdiagnostikder. In: Halswirbelsaule, F. Heidelberg: Fischer, 1979.
24. Ehni G. Cervical arthorosis: diseases of the cervical motion segments. Year Book Medical Publisher: Chicago, 1984.
25. Nachemson A. The role of spinal fusion (question 8). Spine 1981; 6:3.
26. Green JD, Hare TS, Harris JH. Anterior subluxation of the cervical spine. AJNR 1981; 2:243–50.
27. Kirkaldy-Willis WH. Managing Low Back Pain. New York: Churchill-Livingstone, 1983.