ORIGINAL RESEARCH

A Multiple Parameter Assessment of Whiplash Injury Patients Undergoing Subluxation Based Chiropractic Care: A Retrospective Study

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Abstract — A retrospective study was conducted of 57 subjects who had experienced an acceleration/deceleration (whiplash) injury. Since patients presented at different intervals post injury, they were evaluated by time of onset of subluxation-based chiropractic care, and also as a collective population independent of differences in onset of care intervals. Variables including atlas/axis and Jackson's angles, range of motion, muscle strength, and a neck pain disability index, were assessed at the time of presentation and at a clinically determined point of maximum chiropractic improvement (MCI). As a function of onset of subluxation-based chiropractic care, results showed significant differences in three range of motion variables at presentation; left cervical rotation, right and left lateral cervical flexion, and one muscle strength variable at the point of MCI, right shoulder rotation. Collectively, in association with subluxation-based chiropractic care, the subject population showed significant increases in cervical flexion and extension, muscle strength, and a decrease in the neck pain disability index. Atlas/axis and Jackson's angles varied inversely from presentation to MCI, providing information for a model describing possible cervical dynamics during the restorative process following whiplash injury. Additionally, duration of care required to reach MCI was inversely related to the frequency of adjustments (expressed as a ratio of average adjustments/week) which were specifically administered for the correction of vertebral subluxation. This indicated that longer durations of care were correlated with the lower ratios (fewer adjustments/week), while shorter durations of care to reach MCI were correlated to higher ratios of average adjustments/week.

Key words: Vertebral subluxation, acceleration/deceleration injury, whiplash injury, maximum chiropractic improvement, outcomes assessment.

Introduction

The acceleration/deceleration injury, more commonly known as "whiplash," has been investigated from a wide range of perspectives, [1-14] including biomechanics, [15-19] treatment modalities,[20-30] duration of symptomatology,[31-37] and physical outcomes such as soft tissue injury, cervical degeneration, and changes in cervical curvature. [38-44]

Of all automobile accidents, 15% are attributed to rear-end automobile collisions, of which this mechanism of injury is associated with the whiplash syndrome. [45] Consequently, the majority of whiplash studies have revolved around assessment of post auto accident subjects. In this respect, during the acceleration part of the injury, the whiplash effect is created by a sudden hyperextension of the neck followed by a reflex hyperflexion during deceleration. The latter is believed to be responsible for the majority of the clinical manifestations of the whiplash which may include disc damage, strain of the neck extensor and flexor muscles and ligaments, often resulting in pain, and change in juxtaposition of osseous segments. In this regard, Dean et al demonstrated that up to 84% of subjects interviewed experienced pain after a rear impact automobile accident. This figure was approximately twice as frequent as pain reported among those involved in frontal collisions. [46]

From a biomechanical perspective, the advent of seatbelts has added a new dimension to this type of injury, with a reported 20% increase in the incidence of neck sprain being reported when seatbelts were being worn. [47] The primary reason that neck injuries are accentuated has been attributed to the shoulder harness abruptly restraining the decelerating trunk of the occupant while the head's inertia carries it forward unrestrained which results in a bending moment at the cervicothoracic region. This phenomenon may explain why more significant flexion injuries

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have recently been reported in comparison to the usual extension injury associated with whiplash. [48]

The mechanisms of whiplash injury, as well as factors which may affect the biomechanics of injury are important in characterizing each individual case, since Hohl [49] has reported as many as 25% of those experiencing whiplash injury continue to have chronic symptoms for up to five years. Watkinson et al, [50] have reported that 86% of rear end collision patients continue to have symptoms for up to 10.8 years. Even though 75% of whiplash injuries have been estimated to "recover" spontaneously, the criterion for such recovery has been based on the absence of pain or other symptoms. A paucity of information exists relative to following the course of spinal changes in asymptomatic whiplash cases. Consequently, little information is available which impacts on the long term implications in those putatively categorized as "recovered." However, Watkinson et al, have reported cervical spine degeneration in 68% of whiplash victims, of whom, 13% were asymptomatic. [50] It is reasonable, therefore, to presume that the long term effects of acceleration/deceleration accidents, even though asymptomatic, could likely initiate a sequalae of altered biomechanical processes and degeneration resulting in progressive cervical spine deterioration with accompanying neuropathies.

Although the medical approach to whiplash injury has emphasized immobilization and phasic exercises, a review by Barnsley et al, [51] concluded that neither method proved effective. Alternatively, although Koes et al found no difference between physiotherapy and manual therapy in the treatment of nonspecific back and neck complaints, [52] these authors demonstrated that manipulative therapy produced better symptomatic relief for whiplash injuries compared to physiotherapy after 12 months of care. [53]

The majority of findings reflecting ambiguity with regard to positive benefits of current therapies administered to whiplash patients, and the length of time required to realize improvement, elicits a high level of concern. Based on the numerous anecdotal reports concerning recovery following chiropractic spinal adjustments, the present study was undertaken to investigate possible benefits of subluxation-based chiropractic care in association with whiplash injury.

Since medical, physiotherapy, and manipulative therapy approaches constitute the majority of investigation into care regimens for those having experienced whiplash injury, with little to no significant benefits reported, the present study has evaluated certain clinical outcomes of whiplash patients under subluxation-based chiropractic care. [54]

A unique methodological approach involved in this study, differentiating it from most other whiplash related investigation, revolves around the chiropractic concept of vertebral subluxation. [54] While physiotherapy and spinal manipulative therapy are non-specific in force application to the spine, primarily being administered to affect overall mobility of osseous segments for conditions such as headache and neck pain, [55] subluxation-based chiropractic involves administering a specifically vectored force (adjustment) into an osseous segment(s) which has been clinically determined to be a component part of vertebral subluxation.[56] Consequently, certain assessments serve the dual purpose of indicating improved function within the whiplash patient as well as indicating, along with other evaluations, the reduction of vertebral subluxation. Inherent in this approach, therefore, is both a concern for promoting functional recovery as well as assessing the efficacy of subluxation-based chiropractic care, which is tantamount to reduction of vertebral subluxation.

The present retrospective study was designed to evaluate changes in whiplash patients under subluxation-based chiropractic care. Concomitant with reduction or correction of vertebral subluxation, assessments of range of motion, muscle strength, and self-reported neck pain disability measures[57] were also studied. The objective of the study was to identify changes which could be attributed to both improvement in mobility and physical function as an index of whiplash recovery, and reduction of vertebral subluxation. In this regard, this article includes a characterization of subjects from the onset of subluxation-based chiropractic care compared to the point of maximum improvement of the presenting signs of whiplash injury.

Methods and Materials

Subject Population

The study, conducted in the private office setting, involved subjects (37 females and 20 males) ranging in age from 17 to 70 years. All patients, by history, were considered to have experienced whiplash injury. Patients were considered eligible for the study if the following inclusionary factors were met: 1) involvement in a rear-end motor vehicle accident as an occupant in the forward vehicle, 2) remained fully conscious after the accident, with no subsequent diagnoses of serious medical symptoms such as gross neurological dysfunction, muscle paralysis, or physiological systems failure, 3) willingness to comply with the chiropractic care regimen presented, and 4) ability to comprehend English sufficient to complete the study questionnaire.

Patients meeting the above criteria were informed of the protocols and objectives of the study. For those participating, herein referred to as "subjects," written consent was obtained to use information regarding their particular case.

Whiplash Assessment Procedures and Measures

During the initial chiropractic examination, signs, symptoms, and cervical spine structural integrity generally associated with whiplash injury were recorded for each subject. The assessments included: 1) evaluation of cervical x-rays and digitized lateral cervical radiographs, 2) cervcial range of motion (ROM) measurements, 3) computer assisted dynamometer testing of shoulder muscle strength and 4) self-reported neck pain disability scores. [57]

Cervical Radiographs

Cervical radiographic images were taken of each subject in the anterior/posterior open-mouth, and lateral planes in the neutral, flexion and extension positions, at the initial visit, and in some instances during the course of clinical care. Patient positioning was standardized for all subjects for both the pre and post radiographs. Anterior/posterior open mouth and lateral cervical x-

rays were used to assess structural integrity of the cervical spine, as well as the misalignment component of vertebral subluxation.[56]

The atlas/axis angle,[58] which provides information relative to flexion/extension relationship of the atlas to the axis, and Jackson's angle, [59] which assesses the segmental location of stress points in the cervical spine, were derived from lateral cervical digitized radiographs.

Range of Motion

Range of cervical motion included extension, flexion, left and right lateral flexion and left and right rotation. All measurements were made with dual inclinometers, following the method of Gerhardt. [60]

Muscle Strength

Muscle strength testing was conducted using a Lafayette Instrument Nicholas Manual Muscle Tester (MMT), Model 01160 (Lafayette Instruments, Lafayette, Indiana). The instrument, through a force transducer, recorded the resistance generated by the target muscle group (usually a limb). In the present study, each subject's shoulder muscle strength was determined by the method of Kendall. [61] In this method, the subject raises the limb to a specified height (same for all subjects) and maximally resists the examiner's efforts to depress it. The examiner places the MMT between his hand and the subject's limb. Before testing, a downward force is gradually applied for approximately one second, to allow the subject to adapt to the force by maximally recruiting muscle fibers. The examiner then applies additional force until the limb collapses, at which time the test is completed. According to Kendall, the peak resistive force achieved is considered to be the maximum strength effort for the motion recorded. Data obtained in this fashion was processed through an analog-digital converter routed through software (Myologic Diagnostics, Inc., Kirkland WA.) which displayed the results in graphic form. Three specific muscle strength tests were applied:

1. Shoulder Abduction -The seated subject was instructed to abduct the left arm to 90 degrees, fist clenched, straight out and parallel to the floor. The examiner, standing in front of the subject, placed his left hand on the subject's left shoulder and his right hand (holding the MMT) just proximal to the subject's wrist. While stabilizing the proximal shoulder joint, force was applied by the examiner's right hand sufficient to overcome the subject's resistance. The test was then repeated on the contralateral side, with the examiner shifting hands.

2. Shoulder Flexion - The subject, seated, was instructed to hold the arm forward and parallel to the floor. Strength was determined by placing the MMT on the subjects extended arm and exerting force sufficient to overcome resistance.

3. Shoulder Lateral Rotation - The subject was seated with the test arm held in front and bent at the elbow (as if arm wrestling). Strength was determined by placing the MMT on the subject's test forearm and exerting a medial force sufficient to overcome resistance.

Self-Reported Neck Pain Disability Index

Self-reported quality of life responses were derived from the Neck Pain Disability Index (NPDI).[57] The ten part NPDI questionnaire covered a broad spectrum of activities believed to be impacted by neck pain. These included: pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleeping, recreation, and overall average of the items.

Vertebral Subluxation Assessment and Adjustment Protocol

Concomitant with the whiplash assessment, each patient was also evaluated for the presence of vertebral subluxation on a per visit basis. In addition to the case history, the chiropractic examination utilized information obtained from the whiplash assessment concerning computer-aided manual muscle strength testing and range of motion measurements. Other indicators of vertebral subluxation included: standing posture measurements with visual characterization of the lateral and anterior/posterior spinal curves, motion and static muscle and bony palpation of the spine and contiguous structures. Additionally, signs of neurological involvement included the Derefield-Thompson leg check, [62] and manual muscle testing challenges. [63]

In regard to the plan of care, the frequency of administered adjustments was determined from an evaluation of chiropractic examination findings on the first visit after the accident, and every 10 visits, or 2 weeks (which ever came first). Cessation of chiropractic care relative to whiplash injury occurred when ROM and muscle strength parameters appeared to stabilize. Generally this was determined over any three consecutive visits, except in those cases when subjects expressed marked clinical improvement in a very short time. Regardless of the time period of care, the interval of maximum chiropractic improvement (MCI) constituted the end point of data collection relative to the present study. However, it is important to recognize that many patients continued under care for the correction of vertebral subluxation, per se, as part of maintaining the extent of stabilization or maximum chiropractic benefit which had been achieved for the whiplash injury.

Statistical Analysis

Subject data, when categorized into groups, was analyzed by a multiple analysis of variance (MANOVA). Significant findings ($p<0.05$) were further evaluated between groups using Tukey's post hoc least square's test, and/or by a two tailed T-test for paired samples, or two sample assuming unequal variances. Relative relationships between variables were assessed by Pearson's correlation.

Results

Onset of Chiropractic Care

The 57 subjects meeting the inclusion criteria presented for

Table 1. Differences* in Range of Motion and Muscle Strength Variables Among Subjects Presenting at Varying Onset of Care Intervals Following Acceleration/Deceleration Injury.

	ROM *(degrees)*		Muscle Strength *(Kg of resistance)*	
Variables and Onset of Care Intervals	Initial	MCI	Initial	MCI
1. Left Rotation				
1- Month	—	70.8 ± 8.4	—	—
1-3 Months	—	64.1 ± 8.1	—	—
2. Left Rotation				
1-Month	—	70.8 ± 8.4	—	—
3-6 Months	—	57.0 ±14.5	—	—
3. Left Rotation				
3-6 Months	—	57.0 ±14.5	—	—
12-24 Months	—	71.5 ± 9.6	—	—
4. Right Shoulder Rotation				
3-6 Months	—	—	8.9 ± 3.1	—
6-12 Months	—	—	15.2 ± 5.2	—
5. Left Lateral Flexion				
3-6 Months	—	33.3 ±10.0	—	—
12-24 Months	—	45.0 ± 7.6	—	—
6. Right Lateral Flexion				
3-6 Months	—	31.3 ± 9.6	—	—
12-24 Months	—	46.3 ± 9.1	—	—
7. Right Lateral Flexion				
6-12 Months	—	32.5 ±15.1	—	—
12-24 Months	—	46.3 ± 9.1	—	—

* The five onset of care intervals (see Methods) were first evaluated at presentation (initial) and at MCI against all variables by ANOVA. Significant variables ($p<0.05$) were then evaluated by a Tukey test and a two tailed t-test for unequal variances ($p<0.05$). Values reported above were significant between the on-set intervals indicated. The (—) symbol represents no difference in values between any onset of care intervals.

chiropractic care over differing periods of time following the acceleration/deceleration accident. Based on the recorded range, subjects were initially grouped into the following "onset of care from date of accident" categories: (a) up to one month, (b) 1-3 months, (c) 3-6 months, (d) 6-12 months, and (e) 12 - 24 months. Of the total 57 subjects, 25 (44%) commenced care within one month. The remaining number of subjects diminished in magnitude from 10 at 1-3 months (18%), to 7 at both 3-6 months and 6-12 months (12%), then slightly elevating to 8 (14%) at 12-24 months.

The categories were established to determine if subjects, presenting for care at various time intervals after the accident, exhibited significantly different profiles on presentation. Presentation assessments relative to whiplash, as previously described, included: two cervical spine angles (in degrees), a neck pain disability index, six range of motion assessments (in degrees), and six muscle strength determinations (in kilograms) comprising a total of fifteen variables. Among these variables within the five "onset of chiropractic care" categories, the only significant variation was observed between the 3-6 month and 6-12 month groups with regard to muscle strength for right shoulder lateral rotation ($p<0.05$). The 3-6 month group exhibited a lower average strength of 8.9 ± 3.1, compared to 15.2 ± 5.2 for the 6-12 month group. With this one exception, time from the date of the accident to onset of chiropractic care did not result in statistically significant differences in the presenting variables studied.

When these same five categories were compared (Table 1) at

Table 2. Changes * in Range of Motion and Muscle Strength in Subjects Receiving Subluxation Based Chiropractic Care Following Acceleration/ Deceleration Injury

	Range of Motion (degrees)		*Muscle Strength (Kg of resistance)*	
	Initial	MCI	Initial	MCI
Cervical ROM (degrees)				
1. Ext.	**50.8 ± 15.0**	**58.3 ± 12.3**		
2. Flex.	**48.3 ± 12.2**	**53.5 ± 10.2**		
3. Left Lat. Flex.	40.0 ± 10.6	40.8 ± 8.51		
4. Right Lat. Flex.	38.8 ± 10.4	39.6 ± 10.0		
5. Left Rot.	65.6 ± 14.1	66.2 ± 13.0		
6. Right Rot.	65.1 ± 13.6	66.2 ± 13.4		
Muscle Strength (kilograms)				
1. Left Shoulder Abd.			**7.0 ± 3.2**	**10.8 ± 4.2**
2. Right Shoulder Abd.			10.0 ± 14.0	12.1 ± 4.3
3. Left Shoulder Flex.			**6.8 ± 3.1**	**11.0 ± 4.2**
4. Right Shoulder Flex.			**8.3 ± 3.8**	**12.2 ± 4.5**
5. Left Shoulder Rot.			**8.6 ± 3.5**	**13.5 ± 4.5**
6. Right Shoulder Rot.			**11.1 ± 4.1**	**15.8 ± 4.3**

* Numbers (mean ± std. dev.) in **bold** are significantly different ($p<0.05$), employing a two tailed paired sample t test.

the point of maximum chiropractic improvement (MCI), significant differences ($p<0.05$) in degrees of ROM were observed in three of the total fifteen variables. These included left cervical rotation which was significantly greater in the one month group (70.8 ± 8.4) than both the 1-3 month (64.1 ± 8.1) and 3 - 6 month group (57.0 ± 14.5). Moreover, the 12 -24 month group showed a significantly greater ROM (71.5 ± 9.6) than the 3 - 6 month group.

Additionally, in the 3-6 month group, left lateral cervical flexion (33 ± 10.0) was significantly less ($p < 0.05$) than the 12-24 month group (45 ± 7.6). Right lateral cervical flexion was also significantly less ($p<0.05$) in both the 3-6 month group (31 ± 9.6) and 6-12 month group (32.5 ± 15.1) compared to the 12 - 24 month group (46.3 ± 9.1).

In regard to these three ROM variables, the data revealed that the extent of MCI in terms of ROM is affected by the time of onset of chiropractic care following whiplash injury. However, no statistically significant difference was observed with regard to the other 12 variables studied.

Frequency of Chiropractic Care and Maximum Chiropractic Improvement

Because of the differences observed in three ROM variables following chiropractic care in subjects presenting at different intervals of time following whiplash injury, it was of interest to determine if the frequency of care was significantly different among the groups. Adjustive care was normalized to a frequency for each subject by dividing the total adjustments administered by the duration of care in weeks. The frequencies, ranging from 0.24 to 3.50 with a median of 1.50 and an average of 1.61 ± 0.83, showed no significant variation between the five onset of care categories. Since neither the frequency of adjustive care nor the time required to reach maximum chiropractic improve-

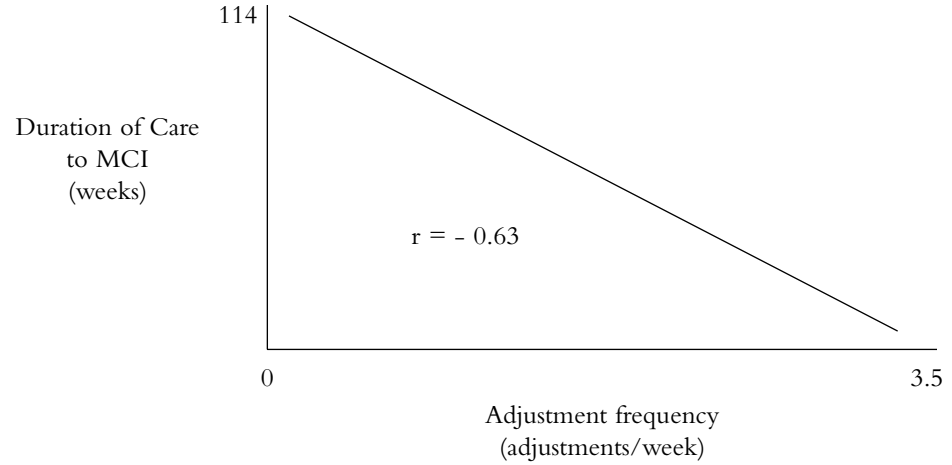

Figure 1. Correlation between frequency of adjustments and duration of care to MCI. Adjustment frequency was normalized by dividing the total number of adjustments administered by the number of weeks to reach MCI. When plotted against the number of weeks to attain MCI, a Pearson's correlation coefficient of r = - 0.63 reflected an inverse relationship between the adjustive frequency and the duration of care to achieve MCI.

ment varied significantly between the five categories, it was of further interest to evaluate the subject population independent of time of onset categorization.

When considering the subjects as one uniform population, the range of times to reach MCI varied from 2 to 114 weeks, with a median of 24 weeks, and an average of 29 ± 24 weeks. Since, overall, there was a considerable range in both the frequency of adjustive care and the duration of care to attain MCI, a correlation between these two factors was evaluated. Analysis revealed a negative correlation coefficient (r = - 0.63), indicating that the longer durations to reach MCI were correlated with the lower frequencies of care while the shorter durations of care to reach MCI were correlated with the higher frequencies of adjustive care (Figure 1).

Changes in Whiplash Subjects Following Chiropractic Care

Changes from initial findings (presentation) to the point of MCI (post) were recorded for the fifteen variables, as previously described for each subject (see methods). These included:

Neck Pain Disability Index (NPDI)

The NPDI questionnaire has been shown to reflect a high degree of reliability and internal consistency.[57] Scores encompassed a battery of questions spanning ten areas related to quality of life topics believed to be influenced by neck pain. The questionnaire is designed to reflect a low score where little disability is incurred and graduating higher scores when increased gradations of disability are reported. The present study focused on each subject's net composite score of these ten areas, rather than evaluating differences in the individual topics. The population of 57 subjects scored an average of 30.89 ± 17.71 on presentation, and a significantly lower score of 22.40 ± 14.40 at MCI (p = 0.001).

Range of Motion (ROM)

Range of motion (in degrees) was determined for the cervical spine in flexion, extension, right and left lateral flexion, and right and left rotation. (Table 2). Interestingly, ROM expressed an average increase of only 2% respectively for right rotation, left rotation, left lateral flexion, and right lateral flexion. However, both pre and post flexion (48.26 ± 12.24 versus 53.51 ± 10.21) and pre and post extension (50.79 ± 15.01 versus 58.32 ± 12.33) increased significantly (p = 0.001).

Muscle Strength

Muscle strength (in kilograms of resistive force) increased in all directions tested. (Table 2). Although increased from pre to post by 21%, right shoulder abduction was not statistically significant. Significant changes were observed for all other strength tests. Left shoulder abduction increased from 7.0 ± 3.2 to 10.8 ± 4.2 (56%). Left shoulder flexion increased by 61% from 6.8 ± 3.1 to 11.0 ± 4.2, and right shoulder flexion by 47% (8.3 ± 3.8 to 12.2 ± 4.5). Left shoulder lateral rotation expressed an increase of 58% from 8.6 ± 3.5 to 13. 5 ± 4.5, and right shoulder lateral rotation increased by 42% (11.1 ± 4.0 to 15.8 ± 4.3).

Cervical Angles

Presentation findings

Data (in degrees) for the atlas/axis angle, from 56 of 57 subjects presenting for chiropractic care, ranged from 1.9 to 37.8 with a median of 14.4 and an average of 15.6 ± 7.0. Jackson's angle (in degrees) for 52 of 57 presenting subjects ranged from 0.4 to 50.5 with a median of 15.0 and an average of 17.6 ± 12.5. Relative to the "typical" cervical lordotic curve, the atlas/axis angle is reported as 1-2 degrees, and Jackson's angle is 39 degrees. Consequently, presenting angle values for those experiencing whiplash injury were not "typical."

Table 3. Changes* in Atlas/Axis and Jackson's Angles From Presentation to MCI.

Subjects	Atlas/Axis Angle (degrees)		Jackson's Angle (degrees)	
	Presentation	*MCI*	*Presentation*	*MCI*
1.	**22.1**	**23.6**	**10.9**	**5.2**
2.	**25.4**	**25.7**	**5.3**	**1.4**
3.	**14.1**	**17.9**	**11.4**	**8.5**
4.	14.5	11.0	9.3	8.3
5.	**8.5**	**4.9**	**26.4**	**37.0**
6.	**12.5**	**13.6**	**39.9**	**23.9**
7.	**28.3**	**30.1**	**18.8**	**17.2**
8.	**6.4**	**18.4**	**50.5**	**5.3**
9.	15.2	13.1	31.5	8.7
10.	1.9	20.6	27.4	29.3
11.	**23.9**	**29.6**	**30.3**	**20.2**
12.	17.0	20.4	5.5	9.6
13.	**15.9**	**15.1**	**5.3**	**7.0**
14.	**12.1**	**15.6**	**36.6**	**16.6**
15.	**9.3**	**8.1**	**12.1**	**14.7**
16.	**13.8**	**20.3**	**17.5**	**11.2**
17.	**20.0**	**10.7**	**3.1**	**14.6**
18.	**37.8**	**34.0**	**11.3**	**15.5**
19.	15.0	18.5	1.7	11.6
20.	**13.2**	**15.8**	**35.5**	**24.6**

* Values in **bold** varied inversely. That is, when one angle decreased from presentation to MCI, the other increased, and vice-versa.

Findings at MCI

Atlas/axis angles were determined for 27 of the 57 subjects at MCI (post). In comparison to the presenting group, post values for the atlas/axis angle ranged from 2.5 to 30.1 with a median of 17.9 and an average of 17.3 ± 7.7. Jackson's angle for 22 of 57 subjects ranged from 1.4 to 29.3 with a median of 14.7, while averaging 15.5 ± 9.3. However, neither the atlas/axis nor Jackson's angle were significantly different from their respective presenting values. However, based on the observation that average values for the atlas/axis and Jackson's angle varied inversely, relative to one another from presentation to MCI, a further evaluation of their relationship on a subject by subject basis was conducted.

Twenty of the 57 subjects were examined radiographically at presentation and at MCI intervals (Table 3). Both atlas/axis and Jackson's angles were determined for these subjects at both intervals. Among the twenty subjects, fifteen varied inversely. That is, when the atlas/axis angle increased or decreased, Jackson's angle changed in the opposite direction. In five subjects, both angles varied in the same direction.

Since the subject population included either a decrease or increase in the atlas/axis and Jackson's angle from presentation to MCI, these groups (increasing versus decreasing angle) were compared by ANOVA with all other variables. No significant differences were observed.

Consequently, while both the presenting atlas/axis and Jackson's angles were "atypical" among the subject population, their variation was not significant over the course of care, nor did their variation correlate to changes in the other variables. They did, however, show a strong inverse relationship to one another in regard to change.

Discussion

Interval from Time of Injury to Onset of Care

The majority of variables studied (11 out of 15) did not differ significantly between subjects presenting for care from up to one month to two years post injury. It was concluded, generally, that the time of presentation after injury was neither a differentiating factor in the variation of physical or physiological measurements reported on presentation or at the putative point of maximum chiropractic care. However, since four variables did vary as a function of time of on-set of care, it is apparent that some mechanism(s) which affect range of motion and neuromuscular function

are time related and affect the outcome of chiropractic care. In that regard, the three ranges of motion that varied significantly (left cervical rotation, and bilateral cervical flexion), did so at MCI, not at presentation. Of these three, a decreased range of motion was observed only with left rotation between groups that presented for care up to one month compared to one to six months post injury. Comparatively, increased ranges of motion were observed with left rotation and bilateral flexion between groups presenting from 3 to 6 months versus one to two years post injury. Relative to range of motion, these findings imply that post injury, early initiation of care may enhance restoration of certain ranges of motion. Alternatively, after a critical time period, other types of cervical range of motion may be equally enhanced by the long term natural healing process concomitant with subluxation-based chiropractic care.

A similar finding regarding muscle strength was observed between subjects initiating care from 3 to 6 months versus one to two years. In this case, the stronger muscle activity of right shoulder rotation was seen in subjects presenting for care between one and two years, as opposed to 6 to 12 months post injury. This also suggests that a longer period of healing may be influential in exacerbating improvement after a certain critical time elapses following whiplash injury. Relative to whiplash injury, these findings must await more thorough interpretation until an increased body of information is available in the literature which relates the effects of time of on-set of care to clinical outcomes.

Frequency of Care

The influence of adjustment frequency on duration of care to achieve maximum chiropractic improvement is of interest. The inverse relationship between the number of adjustments, normalized to a weekly frequency, to MCI indicates the necessity for timely subluxation-based care. This finding should not be interpreted as suggesting that "more is better." If non-specific manipulative thrusts (manipulative therapy for restoration of joint mobility) are frequently administered to the cervical spine, a detrimental effect could be imparted to a patient. However, the subluxation-based chiropractor does not clinically administer non-specific manipulative thrusts, but affects an adjustment for the specific purpose of correcting vertebral subluxation. Consequently, an adjustment is administered only when sufficient indicators of subluxation are present and the involved osseous segment(s) have been identified.

Neurological Deficit Etiology

Since the operational definition of vertebral subluxation contains a neurological component, [54] it is reasonable to assume in the case of whiplash injury that uncorrected vertebral subluxation, either arising from or contributing to the biomechanical and neuro- physiological phenomena associated with the injury, will prolong those aspects of the condition linked to neuropathology. It is also reasonable that correction of vertebral subluxation, and its accompanying neurological component, may enhance recovery from a whiplash injury if the neurological deficit is subluxation related. This likely accounts for the relationship between duration of care and adjustment frequency observed in the present study.

It is probable that those subjects of longer duration of care, receiving fewer adjustments/week, had neurological lesions not associated with vertebral subluxation. Consequently, even though subluxation correction occurred when present, the ramifications of whiplash injury manifesting as joint fixation, muscular strain and sprain, and changes in cervical spine biomechanics collectively contributed to and perpetuated cervical pain, weak upper extremity musculature, and restricted cervical range of motion. In those subjects who received a higher frequency of adjustments, and also expressed shorter spans of care to reach maximum improvement, it is likely any neuropathological component present was associated with vertebral subluxation. Thus, correction of the subluxation resulted in a reduction of the neurological affects on such parameters as cervical pain, restricted range of motion, and muscular weakness.

These findings emphasize the importance of vertebral subluxation in whiplash injury patients. While improvement may eventually be recognized in the absence of subluxation, it is proposed that correction of the subluxated condition, when it is present, serves to significantly reduce the time required to reverse the pathomechanics and pathophysiology associated with whiplash injury.

Efficacy of Care

In the present study, the link between amelioration of whiplash injury and frequency of adjustive care also serves as an outcomes assessment for the efficacy of vertebral subluxation correction. Although subluxation correction is not administered for the specific purpose of correcting any given condition, it is apparent that the whiplash population serves as a model upon which to gauge the result of subluxation-based care. In this regard, it is apparent that when vertebral subluxation was present and subsequently corrected, improvement from whiplash injury was enhanced. In consideration of literature reports [46, 47] which have indicated that pain and other associated dysfunctions of whiplash injury last up to several years in 25% to 86% of patients, it is noteworthy that the median duration to significant improvement in the majority of variables studied in this investigation was 24 weeks, with an average of 29 ± 24.4 weeks for 57 subjects.

It is also important to differentiate the benefit of subluxation correction from therapeutic benefit. Although significant improvement was realized in a number of dysfunctional areas, primarily associated with neurological function, the intent of the care regimen was subluxation correction, not whiplash therapy. Consequently, it is not surprising that effect size, [64] which expresses therapeutic benefit, was low even among variables that showed positive statistical change. While it is evident that the plan of care benefited the subjects in several areas of function, it is not implied that this benefit be labeled as whiplash injury therapy.

Changes in Cervical Range of Motion and Muscle Strength

When the subject population was considered independent of

time of onset of chiropractic care categorizations, changes from initiation of care to MCI revealed a more consistent pattern with regard to cervical range of motion and muscle strength. All cervical ranges of motion increased, if only slightly, from onset to MCI, with significant increases in anterior to posterior extension and flexion. Additionally, all aspects of muscle strength showed an increase, each significant in change with the exception of right shoulder abduction. Although no specific test of neurological function was performed in the present study, this extent of improvement in range of motion and muscle strength is suggestive of improved neurological function from a state of intersegmental facilitation resulting in lowered threshold for motor responses, as suggested by Goodhart, [65] Denslow et al, [66] and Leisman et al. [67] In the present study, these findings are also consistent with neck pain disability scores which decreased from time of onset of care to MCI, suggesting an overall improvement in function relative to factors believed to impact cervical neck pain.

Based on these findings it was concluded that the subluxation-based chiropractic regimen positively influenced a significant restoration of cervical extension and flexion ranges of motion as well as all measurements of muscle strength, suggesting a pattern of recovery including neurological function.

Changes in Cervical Angles

Although changes in range of motion, muscle strength, and the neck pain disability index were all in the positive direction, suggesting a pattern of improved neuromuscular integrity, cervical angle indicators of biomechanical integrity of the cervical spine were not as clear. Since it was not the intention of this study to investigate cervical biomechanics, pre-and post-radiographic images of the cervical spine were not obtained for all subjects. This precluded an assessment of the population in regard to changes in spinal curvature and stages of spinal degeneration. The two angles studied, however, provide some insight into the dynamics of the cervical spine from on-set of care to MCI. The atlas/axis angle, which is typically 1-2 degrees open to the anterior, was not observed in the subject population. Virtually every subject presented with angles in excess of that range. This suggested an extension of C1 relative to C2, which could occur if C1 independently rocked superior and posterior, or if C2 was flexed forward, forcing C1 superior and posterior into extension.

Moreover, a Jackson's angle of 39 degrees is formed typically at the C4 - C5 disc interspace by intersecting lines drawn from the posterior body of C2 and C7. The location of the intersecting lines is purported to indicate the point of maximum cervical stress. Since the angle is derived from the posterior body of two vertebral segments, a shift in position of either or both segments would result in either an increase or decrease in the magnitude of the angle, as well as the intersection point or point of maximum cervical stress. An increase in the angle would shift the intersection point superior, while a decrease in the angle would shift the intersection point inferior. In only 6% of presenting subjects was the angle greater than 39 degrees. The remainder expressed a Jackson's angle of less than 39 degrees.

Since the position of C7 relative to extension or flexion would effect Jackson's angle, while the position of C2 in extension or flexion would effect both Jackson's angle and the atlas/axis angle, the two angles were considered individually and together. Among the subjects for which data was available regarding both angles on presentation and at MCI, no significant changes were observed when considered separately. However, evaluating the two angles together, 75% of the subjects showed an inverse relationship, while the remaining 25% varied directly. This suggests that two different cervical mechanisms could be at play in the body's process of seeking the most stable biomechanical state. If the atlas shifted superior and posterior (extension) allowing the axis to move anterior (flexion), the atlas/axis angle would increase and Jackson's angle would decrease if C7 did not change in position. If, however, the atlas moved forward in flexion, and the axis shifted superior and inferior (extension) a decrease in the atlas/axis angle would result with an increase in Jackson's angle if no movement occurred with regard to C7. This mechanism would account for the inverse pattern observed in the present study between the two angles.

Conversely, if C7 shifted forward in flexion with no subsequent movement of the atlas or axis, Jackson's angle would increase. If the atlas/axis angle was already increased the two would vary together. An extension movement of C7 with no change in the position of atlas and axis would produce a decreased Jackson's angle. If the atlas/axis angle was already decreased, the two would also vary directly. Furthermore, if the atlas/axis segments and the C7 segment both shifted in the same or opposite directions, the same results would be produced as postulated for movement of only the atlas/axis or C7. Either of these mechanisms could account for instances in which the two angles varied directly in the present study.

Re-definition of Maximum Chiropractic Improvement

The observation that the cervical spine continued to be in a dynamic state at the same time that muscle strength and cervical extension and flexion appeared maximally improved is of interest. It is postulated that movement(s) occurring in the cervical spine allowed sufficient neurological integrity to result in significant improvement in upper extremity muscle strength. The extent and quality of cervical movement also allowed significant increase in ranges of motion in the same plane (extension and flexion). It is further postulated that adequate movement within the cervical spine had not yet occurred to allow significant changes in the other cervical ranges of motion, bilateral flexion and rotation. The observation that bilateral flexion and left rotation were signficantly increased in patients presenting for care from one to two years post injury may be related to the time required for the natural healing process to eventually produce restorative biomechanical changes permitting greater range of motion. The restriction of left rotation in patients presenting after one month up to six months post injury may also be a reflection of the beginning of restorative movements in the cervical spine. While these segmental movements progressively lead to healing they may intermittently limit range of motion in certain directions to preserve integrity. Alternatively, patients presenting up to one month post injury may have greater movement in certain planes prior to initiation of the dynamic restora-

tive processes which will later produce biomechanical changes which limit range of motion.

Consequently, it appears that maximum chiropractic improvement should be defined in broader terms than significant increases in muscle strength, certain ranges of motion, and improved patient function. It is essential as well that no one of these components be used singly as a guide to improved care, as important changes in the restoration process may be occurring in asymptomatic patients. For example, while these elements are indicative of efficacy of care, as well as representing positive change, it is also apparent that the cervical spine continues to exhibit change even when other measures are suggesting that stabilization has occurred. It may be incumbent upon the subluxation-based chiropractor, therefore, to monitor changes in the cervical spine until biomechanical stabilization is consistent with such variables as muscle strength, ranges of motion, and other parameters unique to each individual practice.

Conclusions

As presented in the Introduction, whiplash injury has been extensively studied from a variety of perspectives. Adding an additional perspective, information from the present study suggests that certain variables, some of which may be related to the time of onset of care following an injury, ultimately influence the dynamics involved in the restoration process of the cervical spine following acceleration/deceleration injury. However, a greater emphasis on imaging the cervical spine will be necessary to more thoroughly evaluate the findings of this study. Further investigation is planned to address, more closely, changes in cervical spine curvature coupled to degenerative changes. Since gender and age effects were not assessed in the present study, future investigation should also include these parameters. The relationship between the duration required to attain MCI and the frequency of adjustments suggests that consistent subluxation-based chiropractic care is important in enhancing the restorative process, although the mechanisms of this process remain speculative at present.

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