Journal and Proceedings, Royal Society of New South Wales, Vol. 112, pp. 93-99, 1979

Analysis of a Chiropractor's Data

GEOFFREY K. ALDIS AND JAMES M. HILL

ABSTRACT. Data from a chiropractor is studied with the view to obtaining a mathematical model of the alteration in the position of the atlas bone due to adjustment. The particular chiropractor believes that the patient's illness, for example low back pain, is primarily due to misalignments of the atlas bone, which he attempts to correct by applying a mechanically produced force. We find that there is considerable variation in the response of individual patients, indicating that a 'population' model is not applicable. In attempting to restore the atlas bone to its 'normal' position the chiropractor takes 'before' and 'after' X-rays, from which the displacements of the bone due to the applied force are measured. Statistically significant differences in before and after adjustment measurements are demonstrated both for the total sample and also when the sample is broken down into age, sex and adjustment type categories. It was found that there was not a transition from small misplacements of the atlas in the young to larger misplacements in the old.

INTRODUCTION

Chiropractic therapy has never been accepted by the medical profession. This is partly due to its original association with mystical philosophy and also to the lack of scientific evidence to support its theories and its claims to effectiveness. In spite of this, chiropractors enjoy widespread support amongst the community. Studies (see Webb, 1977, page 49) indicate that many people seek chiropractic treatment and obtain relief after dissatisfaction with conventional medical treatment. Rather than reflect badly on chiropractic or medicine, the above suggests that there is a need for objective research to assess the clinical value of spinal manipulation. The present paper is concerned with a description of a chiropractor's adjustment technique and a statistical analysis of his patients' records to examine the position of the uppermost neck vertebra (the atlas) before and after adjustment. In keeping with these aims, the study was not intended to confirm or disprove chiropractic theories as they relate to the health of the patient, but rather to examine the mechanical effectiveness of adjustment in displacing the atlas.

Both chiropractic and established medicine hold the view that excessively rubbing, stretching or compressing nerves will adversely affect the areas these nerves supply, for example skin, kidney or muscle. Basic to all chiropractic is the notion of the misalignment of vertebrae or 'subluxation'. To the chiropractor, a vertebra need only be displaced a degree or more from its 'normal orientation' to be regarded as a subluxation. The medical profession considers that small displacements of vertebrae do not contribute to ill-health, but chiropractors regard them as the basic cause. Accordingly, chiropractors will attempt to restore the bones to their correct positions, while the medical profession will not.

This study was prompted by a chiropractor, who in attempting to improve his adjustment technique, approached us to consider the possibility of obtaining a mathematical model of his particular method. The adjustment technique is adapted from that originally proposed by Pettibon, 1968. It is not used by the majority of Australian chiropractors, and therefore our results are not readily extendible to include them. However, the overriding importance of this chiropractor's therapy is that it uses X-rays and employs a constant mechanically-produced adjusting force. These enable numerical values for vertebral displacements to be obtained, and unlike manual adjustments, enable an adjustment to be repeated almost exactly. In the following section we give a full description of the therapy. Briefly, three angular displacements of the atlas bone from 'normality' are measured from X-rays of the head and neck. A constant mechanically produced force is then applied to the temporal bone of the skull in an attempt to reduce the angular displacements. A second set of X-rays is then taken in order to measure the new angular displacements of the atlas. The displacement of the atlas due to the applied force can be calculated from this data.

Originally we proposed a deterministic force-displacement model, relating the displacement of the atlas caused by adjustment to the direction of the applied force. We found, however, that there is considerable variation in the response of different individuals to the applied force. This precluded the possibility of obtaining a single model applicable to more than one individual. Due to the random nature of the response we were led to a statistical analysis of the data. This is given in the fourth section. It should be borne in mind that the value of our statistical analysis is dependent on the quality of the data used. A discussion of the data is given in the third section. To the authors' knowledge, no analysis of chiropractors' data has appeared in the literature previously. From the statistical analysis we find evidence that the chiropractor reduces atlas misalignments at the population level. We also find that in the mean, older people (age 50 and above) do not have much larger total misplacements than

young people (age less than 30). We also find that the response to adjustment is uniform across the categories male/female and age less than 30/age 30 to 50/age 50 and older. We remark that in the following sections we have deliberately avoided strict anatomical terminology wherever there is no ambiguity in doing so. For instance, we will refer to the lateral tip of the transverse process of the atlas simply as the 'atlas tip' to improve readability.

DESCRIPTION OF THERAPY

The chiropractor's therapy is based on the assumption that subluxation of the atlas is the primary cause of the misalignment of the rest of the spine, and consequently contributes to all illness. For example, the chiropractor treats lower back pain not associated with a 'slipped' disc by adjustment of the atlas. This is a departure from conventional chiropractic practice which tends to adjust the spine near the point of discomfort. The chiropractor believes that if the atlas can be 'correctly' aligned with respect to the skull, then the rest of the spine will tend to reorganise itself into a normal configuration.

Three X-rays of the head and neck are taken. The first is taken from the side and is used to determine the position of the so-called S-line, along which the second X-ray (rear view) is taken (see Figs. 1a and 1b). For details of the S-line and other chiropractor terms the reader is referred to Pettibon, 1968. The third X-ray is taken along a line perpendicular to the S-line (see Figs. 2a and 2b). This view is the view obtained by looking along the arrowed line in Fig. 2a. In terms of their influence on the well-being of the patient, the chiropractor considers the three most important angles are in order:

(i) atlas laterality,
(When viewed from behind, the normal atlas lies along a line perpendicular to a mid-skull line. (see Fig. 1b). Atlas laterality is a measure of how far from 'horizontal' the atlas lies.)

(ii) lower angle,
(This angle is a measure of the amount to which the vertebrae below the atlas are out of line with the atlas (see Fig. 1b). A line is drawn through the centre of the second and third vertebral bodies. The lower angle is the deviation of this line from the perpendicular to the atlas plane line.)

(iii) atlas rotation,
(Ideally a line drawn through both lateral tips of the atlas should lie perpendicular to the skull midline (see Fig. 2b). Atlas rotation is a measure of how far the atlas is rotated from this position. Atlas rotation is measured on the side of atlas laterality.)

The case shown in Figs. 1 and 2 has atlas laterality left 2° and atlas rotation left posterior 2°.

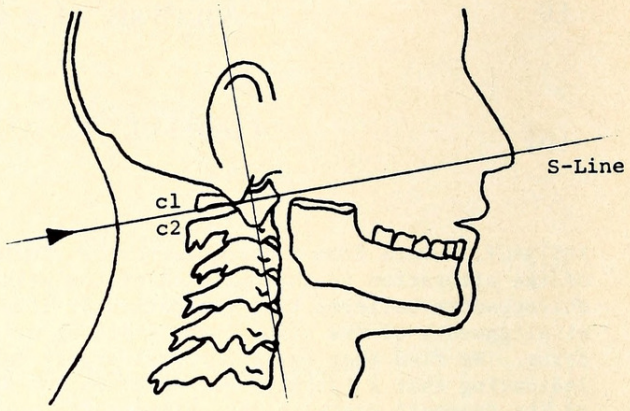

Fig. 1a. Lateral view of the neck, c1 is the atlas and c2 is the axis. (The view obtained by the rear X-ray is that seen along the S-line in the direction of the arrow.)

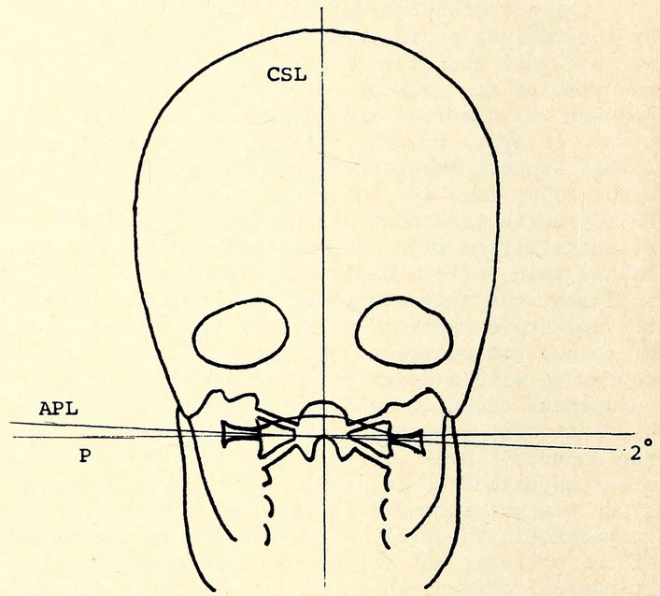

Fig. 1b. Rear X-ray showing an atlas laterality of left 2 degrees. (CSL is centre skull line, APL is atlas plane line and P is perpendicular to CSL.)

The tips of the atlas are convenient lever arms for displacing the upper neck vertebrae. The chiropractor differs from other chiropractors in the manner in which he applies the adjusting force. Firstly, instead of manipulating the atlas directly with his fingers, he uses a mechanically produced force. Secondly, instead of applying the force directly onto the tip of the atlas, he applies the force onto the temporal bone. The skull is struck slightly superior to the atlas tip, and either slightly anterior or posterior to the tip. Force is transmitted through the joint between the skull and atlas and some passes through muscle and soft tissue directly onto the tip. One reason why the chiropractor prefers this method is that in some patients the bony mastoid process (behind the ear) is

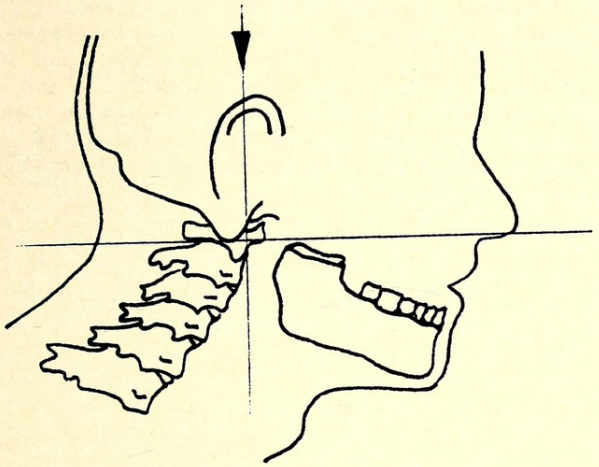

Fig. 2a. Lateral view of the neck. (The view obtained with the vertex X-ray is that seen along a line perpendicular to the S-line in the direction of the arrow.)

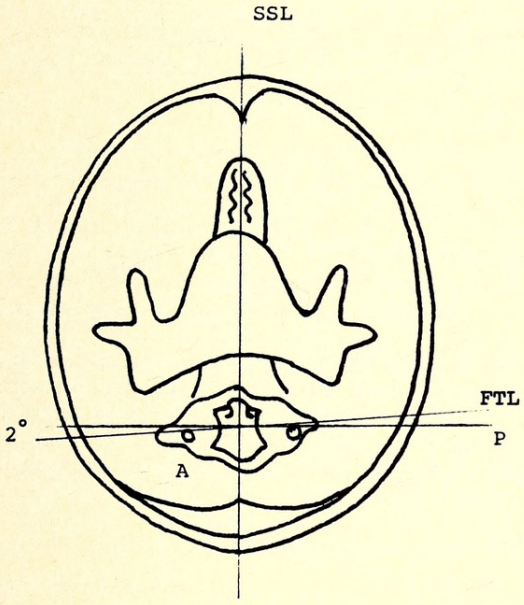

Fig. 2b. Vertex X-ray showing a left posterior atlas rotation of 2 degrees. (SSL is sagittal skull line, FTL is foraminal transverse line, P is perpendicular to SSL and A is atlas.)

particularly large and blocks direct access to the tip of the atlas. Another reason is that the shape of the joints between the skull and the atlas suggests that a force directed from above moves the atlas more efficiently.

If a person has a left (right) atlas laterality then the adjusting force is applied to the left (right) side of the skull. The adjustment is called a left (right) adjustment. If the atlas tip on the side of laterality is misplaced anteriorly, then the adjusting force is applied slightly anterior to the tip and directed backwards. The reverse applies for posterior misplacements. In addition to being anterior or posterior, an adjustment is either 'into the angles' or 'against the angles'. An 'into' adjustment is indicated if the atlas laterality and lower angle are both directed to the same side. An 'against' adjustment is performed if the atlas laterality and lower angle are directed towards opposite sides.

In setting the patient up for adjustment, the chiropractor instructs the patient to lie on his side on a movable couch, with his head on its side on a padded block. The side of the head for adjustment faces upward. The set up for 'against' and 'into' adjustments is slightly different, but in both cases the weight of the upper body is supported by the head and shoulder, with the length of the neck suspended above the couch.

An important reference line is the 'adjusting line'. It is noted on the lateral X-ray where this line crosses surface features of the face and side of the head, such as the outline of the nose, lips, ear, etc. The position of this line varies between patients and between different types of adjustments. Before adjustment the adjusting line is marked across the side of the patient's head with a skin pencil. The adjusting couch, with the patient correctly set up on it, is moved into position so that the adjusting line is in line with a reference line on the adjusting apparatus. The couch is then secured in this position.

The adjusting tool is a thin metal arm which may be directed at the skull from any angle. The arm is connected to the main framework of the adjusting apparatus, and may be raised and lowered, and moved left or right on threaded drives. The metal arm is spring-loaded, able to be cocked and released manually. The direction of the metal arm is set according to the chiropractor's experience from past adjustments. The metal contact point is then positioned over a point on the skull. The arm is continually cocked and released as it is gradually lowered onto the skull. The chiropractor feels the skull to determine when the arm first makes contact. After contact has been made once and another light contact made as the arm is backed off slightly, the adjustment is completed and the arm is fully backed off.

Another set of X-rays is taken immediately after the first adjustment. These are taken as a check on how effective the adjustment has been and to give information for future adjustments. The patient is only expected to maintain the corrected neck alignment for a relatively short length of time (3 days) and is advised to return for further adjustments until he can 'hold' the adjustment for several weeks. At these further adjustments X-rays are not usually taken.

QUALITY OF DATA

Data was collected from a random sample of 140 new patients' records. These covered approximately an 18 month period. The values of the angles atlas laterality, lower angle and atlas rotation both before and after the first adjustment were collected. In addition, the type of adjustment, adjusting angle, and the direction of the adjusting force were collected for each patient. Ages at the time of the first X-ray for 122 of the patients were recorded, as were the sexes of 128. The angles

were measured by the chiropractor with a protractor having a half degree marking separation. Angles were measured to the nearest quarter of a degree with an error of plus or minus a quarter.

Several points should be made about the accuracy of the data. Firstly, there is no guarantee that the measurer (the chiropractor) is an unbiased observer. Secondly, there is variation between individuals in the location of anatomical landmarks used for measuring the angles. Thirdly, some anatomical structures have indistinct outlines or are blunt structures in X-ray views. Fourthly, while the X-ray set-up procedure is well-defined, it cannot guarantee exact results.

These points make it difficult for the authors to assess the true accuracy of the measurements. Nevertheless, in the authors' opinions, the data is sufficiently accurate to warrant a cautious statistical treatment, especially since the data collected is probably the best available from chiropractors in Australia at the moment. The authors would have preferred to substitute a correctly designed experiment for the collection of patients records, but the X-ray programme involved would have made funding prohibitive in an introductory study such as the present one.

STATISTICAL ANALYSIS OF DATA

Patients' records were examined under the categories total sample, males, females, age 0 to 29 years, age 30 to 49, age 50 and over, 'against' and 'into' adjustments. To examine the distributions of the neck angles in the different categories two approaches were considered. The first was to examine the mean positions of the three neck angles and associated variances both prior to and after adjustment. Values obtained are given in Table 1 (atlas laterality), Table 2 (lower angle) and Table 3 (atlas rotation). Negative values denote left-handed angles.

The results of F and t-tests are also shown in the tables. For each category and angle an F test tested the null hypothesis:

$$\text{Variance after adjustment} \geq \text{Variance before adjustment},$$

at the 0.05 level of significance. The degrees of freedom in each case were N-1, N-1, where N is the number in the category. For each category and angle, t-tests tested the null hypothesis:

$$|\text{Mean after adjustment}| \geq |\text{Mean before adjustment}|,$$

at the 0.05 level of significance. The degrees of freedom in each case were 2N-2, where N is the number in the category.

All cases in which the null hypothesis was rejected are denoted by an asterisk next to the calculated values of F or t. In the case of t-tests this indicates a significant improvement in the angle from adjustment at the population level. In the case of F-tests, a statistically significant result indicates a significantly smaller spread about the mean after adjustment.

In addition, frequency histograms of the three angles before and after adjustment for the total sample are given in Figs. 3a, 3b and 3c. We notice that all variances of the post-adjustment angle distributions are less than the corresponding pre-adjustment variances. This is well illustrated in Fig. 3b. All means except the "age less than 30 pre-adjustment lower angle" are between -1 and 1 degree but lower angle readings show a bias towards the negative or left-handed side. Also atlas rotations show a post-adjustment bias to negative or anterior rotations.

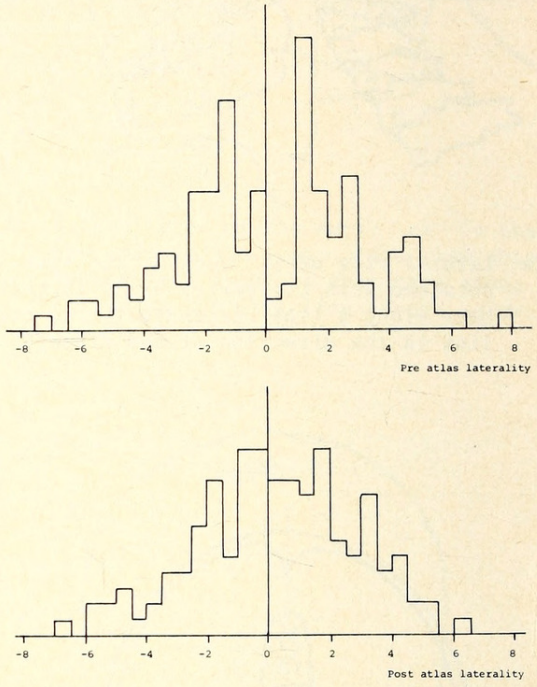

Fig. 3a. Frequency histograms for pre and post atlas laterality for 140 cases (angles in degrees).

The second approach to examining the angle distributions gave more information about the extent to which each patient's angles were misplaced from zero. A measure TDZ (total deviation from zero) was defined using the absolute value of each angle's misplacement from zero.

$$\text{TDZ} = |\text{Atlas Laterality}| + |\text{Atlas Rotation}| + 0.5|\text{Lower Angle}|.$$

The range of lower angle readings was approximately twice that of the other two angles, hence the 0.5 factor. Mean TDZ values and variances were calculated for the sample categories and F and t-tests were performed in the manner previously described. Results are shown in Table 4. We notice that all mean TDZ values are reduced by adjustment indicating that the chiropractor has achieved a nett correction. In all but two categories, reductions were statistically significant. Also, all but one of the variances are reduced. The female means are fractionally higher than the male means and the female variances are quite high compared with the males. The 'age 50 and over' group shows larger means than the other age groups. Also the 'age less than 30' group has higher mean TDZ values than the 'age 30 to 50' group. Against and into adjustments can be compared from entries in Tables 1, 2, 3 and 4. Both atlas laterality and atlas rotation appear to be reduced in a similar manner by both against

TABLE 1
ATLAS LATERALITY

Category	Before Adjustment (Degrees) Mean	Variance	After Adjustment (Degrees) Mean	Variance	Number in Category	F (calculated)	t (calculated)
Total sample	.04	8.68	.09	6.75	140	1.28*	-.17
Males	-.62	8.13	-.38	6.52	66	1.25	.49
Females	.61	8.68	.42	6.51	62	1.33	.39
Age less than 30	-.33	9.20	-.35	7.45	36	1.23	-.02
Age 30 to 50	.56	7.70	.51	4.70	52	1.64*	.10
Age 50 and older	-.51	9.51	-.26	8.30	34	1.15	.34
Against adjustments	.76	8.89	.65	6.71	64	1.32	.22
Into adjustments	-.59	5.56	-.37	5.36	61	1.04	.52

TABLE 2
LOWER ANGLE

Category	Before Adjustment (Degrees) Mean	Variance	After Adjustment (Degrees) Mean	Variance	Number in Category	F (calculated)	t (calculated)
Total sample	-.76	14.06	-.54	9.74	140	1.44*	.54
Males	-.97	14.86	-.70	11.41	66	1.30	.43
Females	-.66	13.61	-.29	8.38	62	1.62*	.62
Age less than 30	-1.31	10.32	-.51	7.34	36	1.41	1.12
Age 30 to 50	-.47	13.15	-.88	9.15	52	1.44	-.61
Age 50 and older	-.88	20.49	-.15	14.32	34	1.43	.71
Against adjustments	-.82	18.99	-.14	11.68	64	1.63*	.97
Into adjustments	-.91	11.94	-.93	7.23	61	1.65*	-.04

TABLE 3
ATLAS ROTATION

Category	Before Adjustment (Degrees) Mean	Variance	After Adjustment (Degrees) Mean	Variance	Number in Category	F (calculated)	t (calculated)
Total sample	-.17	6.37	-.27	5.15	140	1.24*	-.37
Males	-.46	5.61	-.48	4.64	66	1.21	-.07
Females	.09	6.97	-.07	5.73	62	1.22	.04
Age less than 30	-.48	6.06	-.57	5.26	36	1.15	-.16
Age 30 to 50	-.28	4.94	-.26	4.25	52	1.16	.06
Age 50 and older	.15	8.12	-.07	6.64	34	1.22	.12
Against adjustments	.32	6.57	-.10	5.98	64	1.10	.49
Into adjustments	-.36	5.75	-.26	4.47	61	1.29	.24

TABLE 4
TOTAL DEVIATION FROM ZERO OF NECK ANGLES

Category	Before Adjustment (Degrees) Mean	Variance	After Adjustment (Degrees) Mean	Variance	Number in Category	F (calculated)	t (calculated)
Total sample	6.02	6.33	5.13	5.63	140	1.12	3.01*
Males	5.92	5.33	5.05	4.88	66	1.09	2.20*
Females	6.11	7.57	5.21	6.42	62	1.18	1.88*
Age less than 30	5.97	6.41	5.12	6.76	36	0.95	1.39
Age 30 to 50	5.49	5.81	4.64	4.43	52	1.31	1.90*
Age 50 and older	6.88	6.07	5.94	5.57	34	1.09	1.59
Against adjustments	6.45	7.38	5.39	6.89	64	1.07	2.23*
Into adjustments	5.56	4.61	4.74	4.16	61	1.11	2.08*

* Null hypothesis rejected at 0.05 level of significance.

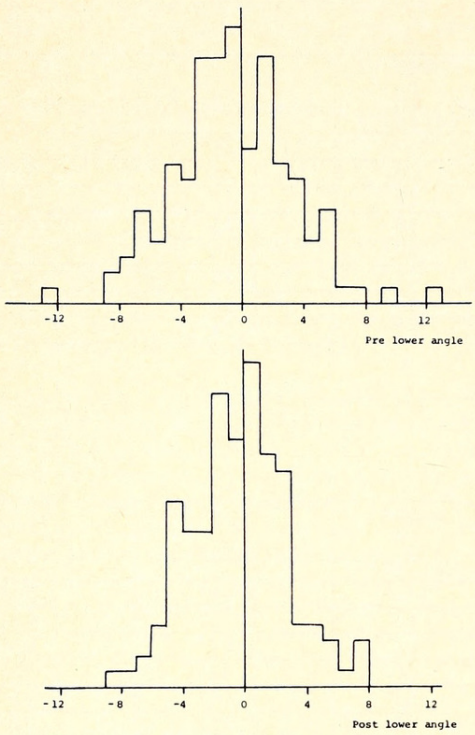

Fig. 3b. Frequency histograms for pre and post lower angle for 140 cases (angles in degrees).

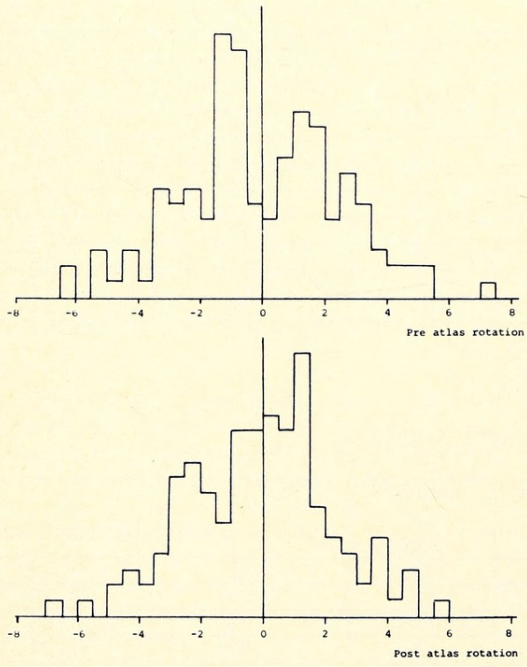

Fig. 3c. Frequency histograms for pre and post atlas rotation for 140 cases (angles in degrees).

and into adjustments. However, the against adjustment appears to be more effective than the into at reducing the lower angle. Table 4 shows that the TDZ is affected in a similar manner by both against and into adjustments.

The total sample data was examined with correlation coefficients to determine whether the displacement of an angle on adjustment was related to its initial position. Because of the expected symmetry of positive and negative initial positions, a correlation coefficient was calculated for both positive and negative segments of the initial position range. The results are shown in Table 5. None of the coefficients show a strong linear relationship between displacement and initial position, although lower angle shows some symmetry about zero in its response. Graphs of displacement against initial position for the age and sex categories reflected the lack of a strong linear relationship and did not suggest a non-linear relationship, but rather a random one.

CONCLUSIONS

Analysis of the data shows that while the chiropractor achieves a nett improvement in angles at the population level, individual responses to adjustment vary greatly. With the possible exception of the lower angle, displacement of an angle on adjustment appears to be unrelated to its initial position. These findings suggest that there is no simple predictive model which could be reliably used. Patient - specific information is obtained by studying the response to the first adjustment, and the chiropractor may well achieve more predictable results with further adjustments. Unfortunately, X-rays are not usually taken at further adjustments. As well as the statistically significant values of t and F, evidence for differences between before and after values lies in the fact that the same patterns were evident in all divisions of data, either as the total sample, the two sexes, or the three age-groups. Variances were consistently smaller after adjustment and mean positions of angles and TDZ (total deviation from zero) were consistently closer to zero after adjustment.

The authors expected that the gradual tightening of ligaments and subsequently decreased freedom of movement of joints with age would have been reflected in the response to adjustment. It was therefore surprising to find that the response to adjustment of all age groups was similar. The TDZ values before and after adjustments indicated that the '50 and older' age group had slightly larger initial and final misplacements than the other two age groups. However there was not a transition from small misplacements in the young to large misplacements in the old.

An interesting point arising from the frequency histograms of atlas laterality (Fig. 3a) is that the distribution prior to adjustment appears bimodal, and after adjustment appears more like the Gaussian or Normal distribution. The chiropractor regards atlas laterality as the atlas angle most important to the patient's health. Data from a healthy population could resolve the question of whether the atlas laterality distribution is normally skew and thereby whether it is a likely factor contributing to the health of the patient.

TABLE 5

CORRELATION COEFFICIENTS ρ_{xy} OF DISPLACEMENT (Y) AGAINST INITIAL POSITION (X) FOR THE TOTAL SAMPLE

	ρ^{+}_{xy} of Positive Initial Position	Number Data Points for ρ^{+}_{xy}	ρ^{-}_{xy} of Negative Initial Position	Number Data Points for ρ^{-}_{xy}
Atlas Laterality	.25	70	-.05	70
Lower Angle	.20	57	-.35	83
Atlas Rotation	.24	66	.12	74

Further work could include examination of neck angle distributions of a healthy sample, and of individuals over a period of time without adjustment. However, the transition from an introductory survey of patients' records to the implementation of an experimentally designed X-ray investigation would require a considerable funding commitment.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to the chiropractor who prompted this investigation. Evidently in making all his data freely available to us he invited the possibility of severe criticism. This research was supported by a University Research Grant.

REFERENCES

Pettibon, B.R., 1968. PETTIBON METHOD, CERVICAL X-RAY ANALYSIS AND INSTRUMENT ADJUSTING, Pettibon and Associates Research Organisation, Tacoma, Washington 1968.

Webb, E.C., 1977. REPORT OF THE COMMITTEE OF INQUIRY INTO CHIROPRACTIC, OSTEOPATHY, HOMEOPATHY AND NATUROPATHY, Australian Government Publishing Service, Canberra 1977.

Department of Mathematics,
The University of Wollongong,
WOLLONGONG, N.S.W. 2500

(Manuscript received 28-6-78)

(Manuscript received in final form 18-8-79)