A VALIDATION STUDY OF A 'CENTER OF GRAVITY LOCATOR' (COGL)

by

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Introduction

Posturography involves the recording of postural position and sway, with measurements being obtained from two basic approaches: *statokinesimetry* and *stabilometry*. Statokinesimetry uses an X-Y recorder to measure the total length (in millimetres) of the movement of the vertical line from the body's centre of gravity (COG), as well as its area of movement, over a given period of time. The X indicates lateral movement, while the Y involves anteroposterior movement. Stabilometry analyses the X and Y movements separately. Propositions for the standardization of techniques have been proposed by Kapteyn et al., 1983.

Force platforms can be used to estimate the COG (Shimba, 1984), and they have been used in many studies as the criterion tool for quantifying body sway (e.g. Jansen et al., 1982; Nashner et al., 1982; Thyssen et al., 1982; Diener et al., 1984; Norre and Forrez, 1986; Aalto et al., 1988; Norre, 1993). Technically, they indicate the centre of pressure (COP) acting through the feet, which reflects not only the ground reaction force necessary to oppose gravity, but also the moments of force that are produced to maintain standing posture. Although the COP is only identical to the vertical line from the COG when there is no sway, over the period of a testing trial the mean COP should be a good representation of the mean COG. (For a fuller discussion of this, see Winter, 1990).

Force platforms are relatively simple to use, do not interfere with movement, and are not unpleasant or unsafe for subjects. They are quite expensive, however, and usually have to be embedded in concrete. For these reasons, they are generally found only in universities, hospitals, or other large institutions of research.

However, the assessment of body COG position and sway appears to have potentially important clinical applications in various health professions, in which the use of the criterion force platforms may not be possible. As a result, many force-plate type systems for evaluating balance and sway have now become commercially available. Roland et al. (1995) reported on the use of a relatively simple and economical load-sensitive platform (the SwayWeigh) to measure lateral body sway in order to assess balance dysfunction. With it, the percentage of a patient's total weight that was borne on the right foot enabled measurement of left-right weight distribution and lateral movement of the centre of gravity. Weerdt et al., 1989, had employed a similar platform to measure the rehabilitation of physiotherapy patients after cerebrovascular accidents.

The center of gravity locator (COGL) referred to herein is a four quadrant scale, which actually consists of four strain gauge weigh scales attached in a square pattern to a plywood under-surface (see figure 1). It is covered by two removeable wooden platforms - one for the left side and one for the right. The scales are electronically linked to a cable which attaches to the parallel port of a computer, to provide an easy data capture system without the need for an analog-to-digital (A-D) interface board for the computer. A simple-to-use DOS-based program comes with the scale, and provides the monitor with a visual analog output estimating the location and movement of the subject's center of gravity.

The COGL was first developed by the author (D.D.C.) in 1985 for use in his chiropractic practice. Twenty-two more were subsequently built and are currently being used in other private practices and research facilities. Normal clinical practice involves the practitioner standing the patient on the COGL for a preliminary test. If an asymmetry is present, and if other diagnostics warrant it, the patient is adjusted and re-tested. In theory, the patient's center of gravity should approach the mid-point of the grid, with anteroposterior (A-P) and right-left (R-L) values close to zero and with equal weight, therefore, on forefoot and rearfoot, right and left. However, since the A-P values depend on foot positioning on the platform, A-P location of the COG is meaningless. R-L location of the COG is independent of foot placement, since the right and left feet are on separate platforms.

Since standing posture involves both anteroposterior and right-left sway, the software provides a history function which traces the path that the center of gravity has followed over the sampling time. It calculates nine statistics to quantify the location and movement of the center of gravity and the weight of the subject (see table 1).

The standard deviation indicates the variability of the position over time, and is therefore a measure of postural 'sway' in the given plane. The weight standard deviation theoretically represents the usually very small movement of the center of gravity up and down as the person stands (i.e. 'weighting' and 'unweighting').

The standard error is a measure of the confidence we have that the measured mean is the true mean; i.e. a measure of the error we are likely to make with that assumption. It is calculated as the standard deviation of the center of gravity's position in the given plane, divided by the square root of the number of samples taken over the measurement period; i.e.:

$$S.E. = \frac{S.D.}{N^{0.5}}$$

If only one sample was taken, the standard error would be equal to the standard deviation. As the number of samples taken increases, the standard error decreases, and our confidence that the reported mean is the real mean improves. (Note: in all trials in this study, the default setting of 401 samples per trial was used.)

The private practitioners who use the COGL claim it appears to be objective, reliable, and valid for clinical purposes. The purpose of this study was to investigate these assumptions and to quantify these characteristics.

Methods

This validation study consisted of three phases:

1. Basic Lab Testing with Standard Weights
   The purpose of this phase was to assess the technical capabilities of the COGL.
   A set of known weights (weightlifting disks) was used to initially calibrate the COGL and then to get repeated readings with a variety of total weights, to establish test-retest reliability coefficients. The weights were then stacked in various configurations (both symmetrically and asymmetrically - see figure 2) on a 1 metre plywood plank with a measurement scale on it, in order to assess the COGL's ability to detect center of gravity location.

2. Testing with 'Normal' Subjects
   The purpose of this phase was to assess the performance of the COGL in measuring the position and involuntary movement of the center of gravity of 'normal' (asymptomatic) subjects, and to establish initial norms for standing with eyes open and with eyes closed. Thirty-one subjects stood on the COGL for two sessions on each of two visits to the lab, for a total of four sessions per subject. Visits were kept one week apart. One of the sessions on each visit involved standing with the eyes closed, while the other allowed the eyes to be open. The four possible orders for the four sessions were randomly assigned, without replacement in each cycle, to all subjects (see figure 3).

   For the first session of the first visit, each subject was asked to stand on the COGL so that the feet were symmetrically but comfortably positioned on a plastic grid taped to the platforms. The feet were then adjusted until the centre of gravity was centred on the monitor display. These new foot positions were recorded and were used again for all subsequent sessions. The subjects were instructed to look straight ahead and stand comfortably still.

The COGL software came with no documentation other than a limited on-line help file, and there was apparently no way of controlling sampling frequency. Default duration trials lasted about 15 seconds, with 401 samples being collected each time. This translates to a sampling frequency of about 27 Hertz.

3. <u>Testing with 'Clinical' Chiropractic Patients</u>
   The purpose of this phase was to use examine the current use of the COGL in a single private 'upper cervical' chiropractic practice, by measuring the pre- and post-adjustment COG positions and sway movements of 27 patients. Following an intial session with eyes open, 18 of the patients underwent chiropractic adjustment and were re-measured (eyes open) on the COGL.

Results

<u>PHASE 1 - BASIC LAB TESTING WITH STANDARD WEIGHTS</u>

The test-retest reliability (r) value over all trials with the standard weights was 0.99, indicating that the COGL has a high level of reliability/stability. It should be noted, though, that there were significant differences ($p<0.001$) between weights that were recorded before and after the COGL had been calibrated. In other words, if *absolute* values for weights are needed, it is important that the COGL be calibrated before use, especially if it has been moved since the last calibration. If *relative* position and movement of the centre of gravity is all that is required, calibration may not be necessary, especially if the unit has not been moved.

When the stacked weights were moved from symmetrical to asymmetrical positions, the COGL was found to be extremely sensitive to even slight changes in the A-P or R-L location of the center of gravity. A single 35 pound (15.9 kg) weight registered statistically different positions (A-P and R-L means) when its centre of gravity was moved as little as 2 mm in any direction.

PHASE 2 - TESTING WITH 'NORMAL' SUBJECTS

A-P Means (average anterior-posterior ***position*** of center of gravity)

No significant difference was found in the A-P Means between 'eyes open' and 'eyes closed' sessions, with the foot positions being controlled. There appeared to be more variation, however, in the A-P means under the 'eyes closed' condition. Figure 4 shows the A-P Means under both 'eyes open' and 'eyes closed' conditions.

R-L Means (average right-left ***position*** of center of gravity)

No significant difference was found in the means of the R-L Means between 'eyes open' and 'eyes closed' sessions. Figure 5 shows the R-L Means under both 'eyes open' and 'eyes closed' conditions.

Weight Means

As should be expected, no significant difference was found in the means of the Weight Means between 'eyes open' and 'eyes closed' sessions. (The mean weights for the subjects should be identical under the two conditions.) Figure 6 shows the Weight Means under both 'eyes open' and 'eyes closed' conditions.

A-P Standard Deviations (amount of anterior-posterior ***sway*** of center of gravity)

There was significantly more A-P sway in the 'eyes closed' condition than in the 'eyes open' condition ($p < 0.001$). Figure 7 shows the A-P Standard Deviations (in pounds) under both 'eyes open' and 'eyes closed' conditions, while figure 8 shows these standard deviations as a percentage of the subject weight.

R-L Standard Deviations (amount of right-left ***sway*** of center of gravity)

There was significantly more R-L sway in the ‘eyes closed’ condition than in the ‘eyes open’ condition ($p < 0.05$). Figure 7 shows the R-L Standard Deviations (in pounds) under both ‘eyes open’ and ‘eyes closed’ conditions, while figure 8 shows these standard deviations as a percentage of the subject weight.

Weight Standard Deviations (weight ***oscillations*** - i.e. ‘weighting’,‘unweighting’)

No significant difference was found in the standard deviations of the subjects’ weights between ‘eyes open’ and ‘eyes closed’ sessions. It thus appears that weight oscillation was not affected by having the eyes closed.

Comparison of Average Sway in All Three Planes

Figure 7 compares the average amount of sway in all three planes: A-P, R-L, and Up-Down (i.e. ‘weighting’ and ‘unweighting’). It can be seen that R-L sway is greater than A-P sway with eyes open. With eyes closed, however, there is a bigger increase in A-P sway, to the point where it almost equals R-L sway. Closing the eyes has little effect on the very small amount of weight sway. Figure 8 shows the same comparisons expressed as a percentage of the subject weight.

Effects of Sessions and Visits

The visit numbers and session numbers had no significant effects on any of the variables, suggesting that no accommodation or learning was involved here.

Correlations among Sway Directions and Weight Oscillations

Somewhat weak but significant ($p < 0.001$) correlations were found among A-P sway, R-L sway, and weight oscillations, with the highest among them ($r = 0.58$) being found between A-P sway and R-L sway (calculated on the measurements taken on all sessions). People with larger A-P sway tend to have larger R-L sway, and vice-versa, although individual prediction of one sway from the other is only about 35% better than by chance alone. Figure 9 shows the scatterplot of these two variables, while Table 2 contains the correlation matrix and associated Bonferroni probabilities.

PHASE 3 - TESTING WITH ‘CLINICAL’ CHIROPRACTIC PATIENTS

Figure 10 compares weight oscillations among ‘Normals’ and ‘Clinicals’ with that found on the static weight disks that were used in the basic study. While weight standard deviations actually occurred during recordings made with the weight disks (and thus must reflect electronic noise and/or some degree of motion in the floor), significantly greater weight standard deviations occurred with the ‘Normals’ ($p < 0.01$), and even greater ones with the ‘Clinicals’ ($p < 0.001$).

Figure 11 compares values obtained from the ‘Normals’ during their first ‘eyes open’ session to those from the ‘Clinicals’ (also eyes open) during their pre-adjustment session. Since the ‘Clinicals’ had different weights than the ‘Normals’, all comparisons were made by expressing the variables as a percentage of the subjects’ weights.

It was considered inappropriate to compare differences in A-P means, since the Clinical subjects had not been centred on the platform first, but had been aligned with respect to a fixed toe bar on the platform. Weight means were also different, of course, and were not compared. There was no significant difference found for R-L position mean or R-L sway, but significantly greater sway values occurred among ‘Clinicals’ with A-P Sway ($p < 0.01$) and weight oscillations ($p < 0.001$).

Of the 27 patients who were initially tested with the COGL, 19 were given upper cervical chiropractic adjustments and were then re-tested. Figure 12 shows the R-L means of these patients both before and after adjustment. While there was a reduction in R-L asymmetry as a result of the adjustments in 15 of the Clinicals, 4 became more asymmetrical. The differences resulting from the adjustments were not considered statistically significant, although more subjects should be examined to see if this trend continues.

Figure 13 shows difference scores calculated by subtracting the absolute value of the second measurement from the absolute value of the first. Positive scores in Figure 13 thus indicate a reduction of any center of gravity deviation, while negative scores indicate a worsening alignment.

Discussion

The COGL is undoubtedly reliable and, if calibrated properly, precise in measuring the position and sway of the centre of gravity of subjects. As expected, it showed greater amounts of both A-P and R-L sway in ‘eyes closed’ as opposed to ‘eyes open’ conditions.

There is still some question, however, as to the effectiveness of its use as described in this particular chiropractic practice. The difference in R-L position deviations and R-L sway between ‘Normals’ and ‘Clinicals’ was not found to be significant in this study, and R-L position deviations were not significantly reduced as a result of chiropractic adjustment. Mean R-L position deviations appear to be reasonably large even among ‘Normals’, and appear to be not restricted to pathology or medical conditions.

Significant differences did appear in this study, however, in A-P sway and weight oscillations - neither of which were used for diagnosis in the chiropractic practice. More research needs to be done to assess which of the variables measured by the COGL may be useful for diagnostic and treatment assessment purposes.

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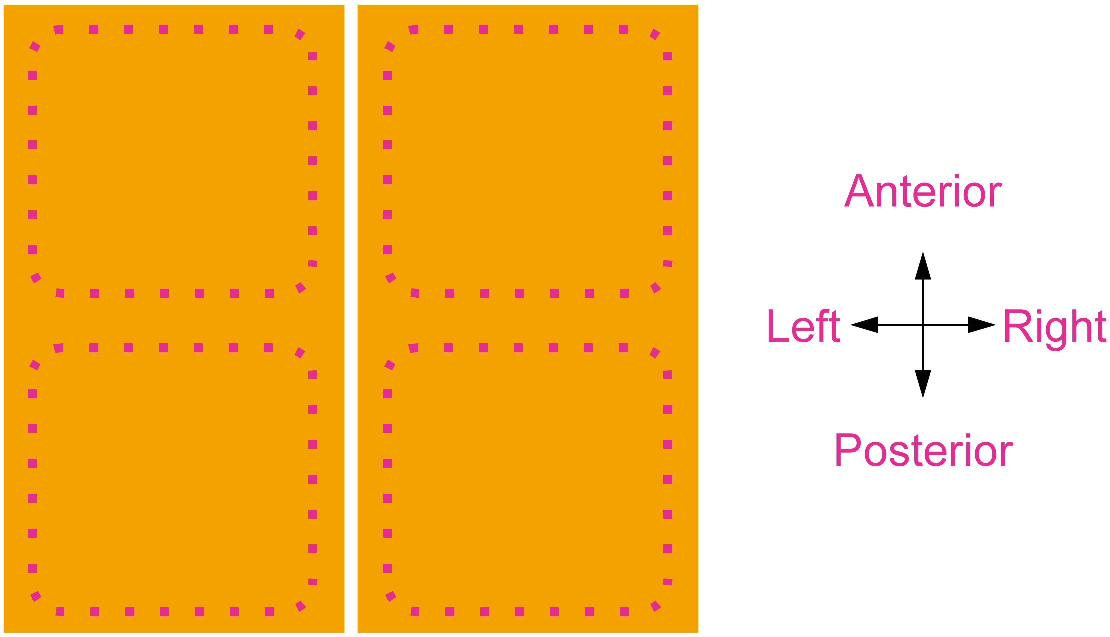

Fig. 1: Schematic representation of top view of the COGL.
Relative positions of the four strain gauge weigh scales under the two wooden platforms are indicated by the dotted lines.

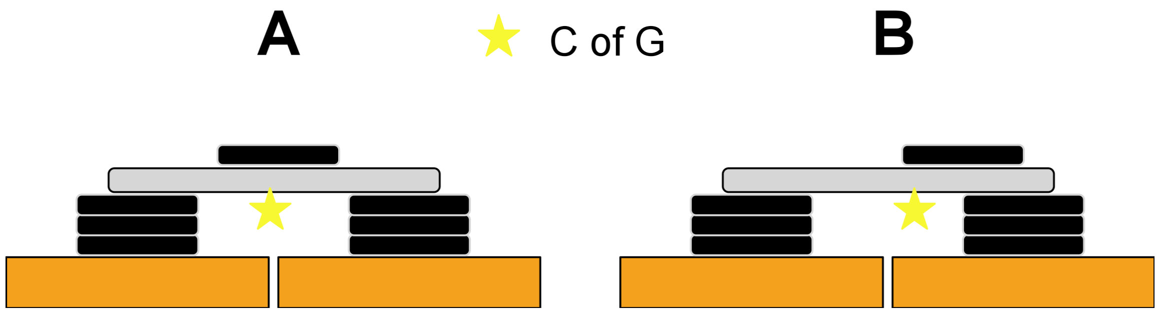

Fig. 2: Schematic representation of basic lab testing. Weights were stacked symmetrically (A) and asymmetrically (B) to test for reliability and sensitivity.

1	**OPEN**	**CLOSED**	**OPEN**	**CLOSED**
2	**OPEN**	**CLOSED**	**CLOSED**	**OPEN**
3	**CLOSED**	**OPEN**	**OPEN**	**CLOSED**
4	**CLOSED**	**OPEN**	**CLOSED**	**OPEN**

Fig. 3: Four orders of tests. These were randomly assigned to subjects.

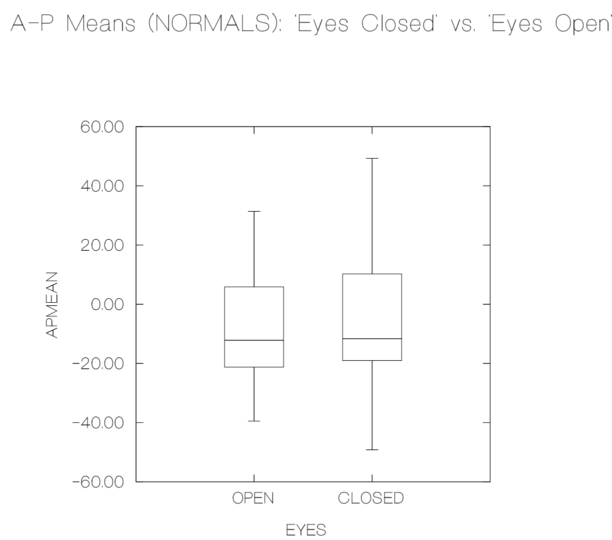

Fig. 4: A-P Means (Average A-P Position): ‘Eyes Closed’ vs. ‘Eyes Open’. (Negative numbers indicate posterior means; positive numbers indicate anterior means.)

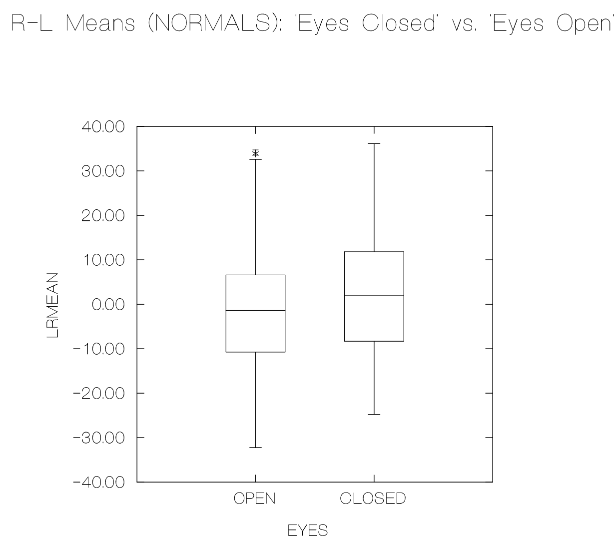

Fig. 5: R-L Means (Average R-L Position): 'Eyes Closed' vs. 'Eyes Open'. (Negative numbers indicate left means; positive numbers indicate right means.)

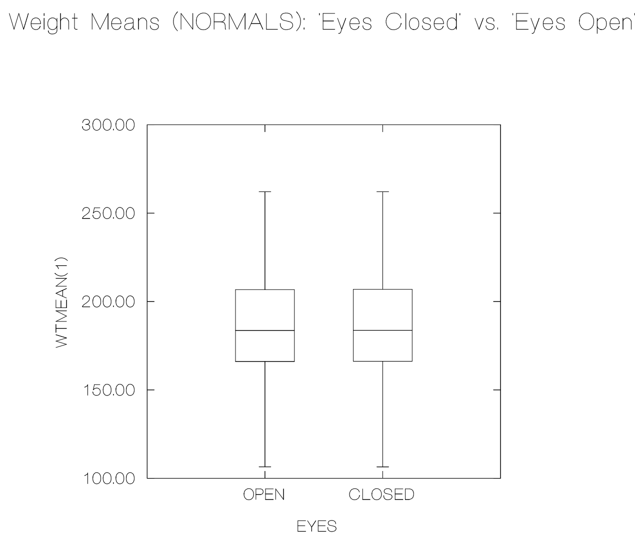

Fig. 6: Weight Means (Average Weight): ‘Eyes Closed’ vs. ‘Eyes Open’.

Fig. 7: Comparison of Sway in Three Planes.

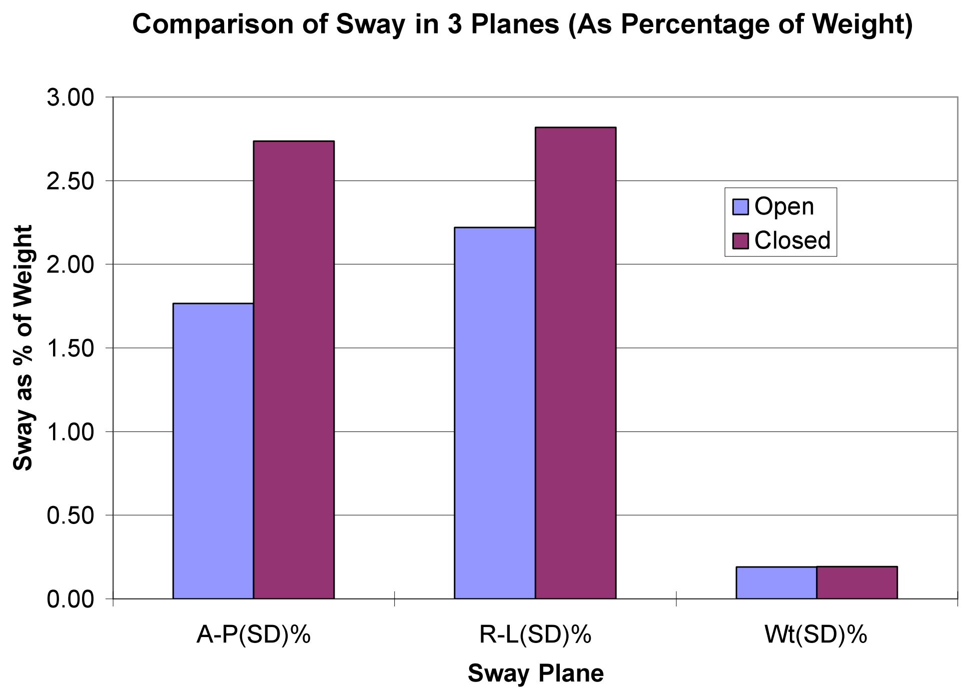

Fig. 8: Comparison of Sway in Three Planes, as a Percentage of Weight.

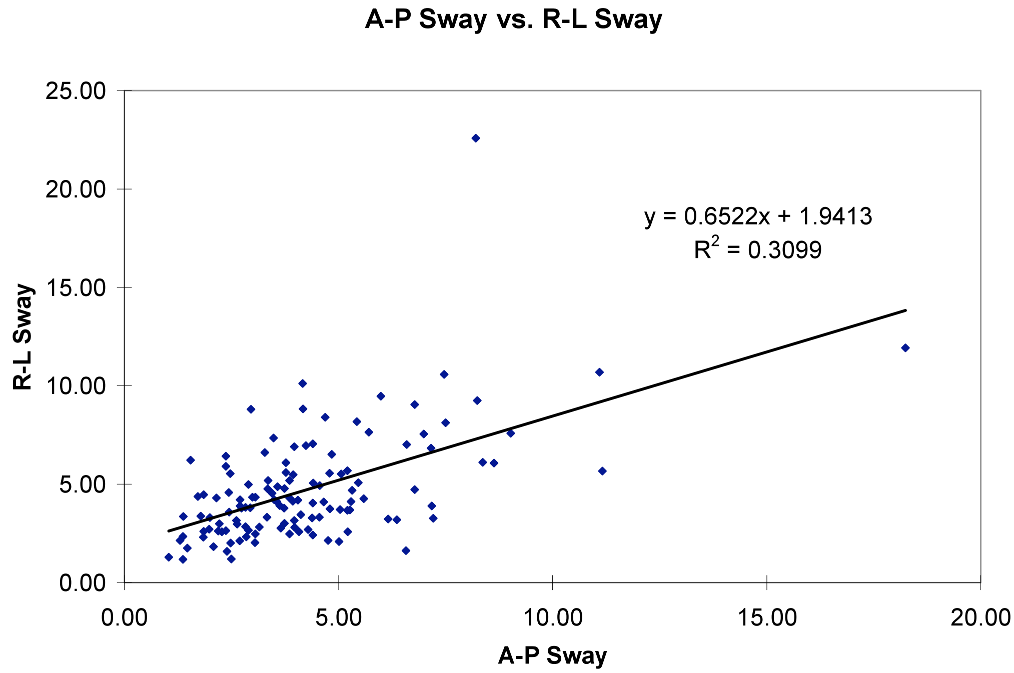

Fig. 9: Scatterplot of A-P Sway versus R-L Sway. Pearson r = 0.58.

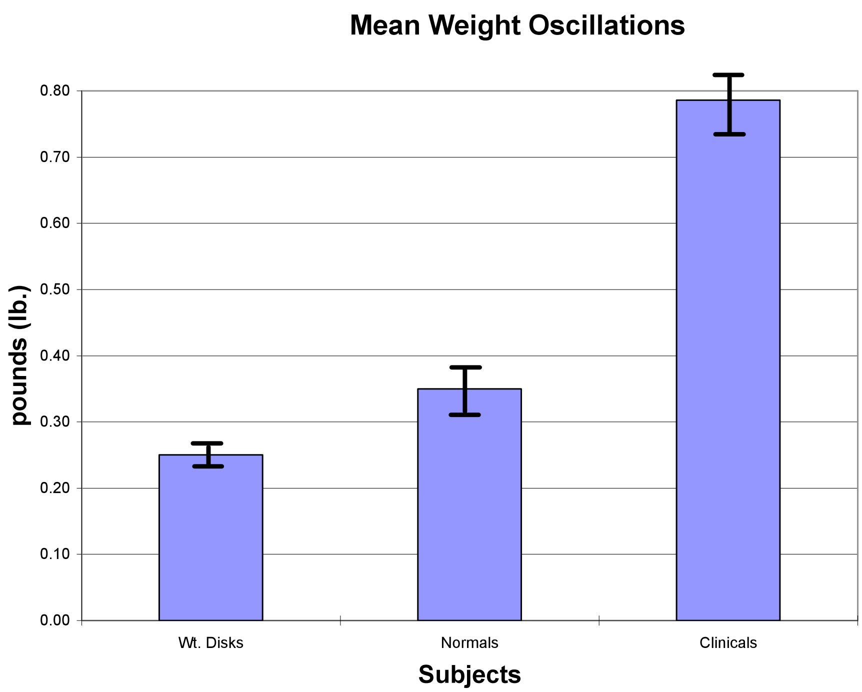

Fig. 10: Mean weight oscillations in pounds.

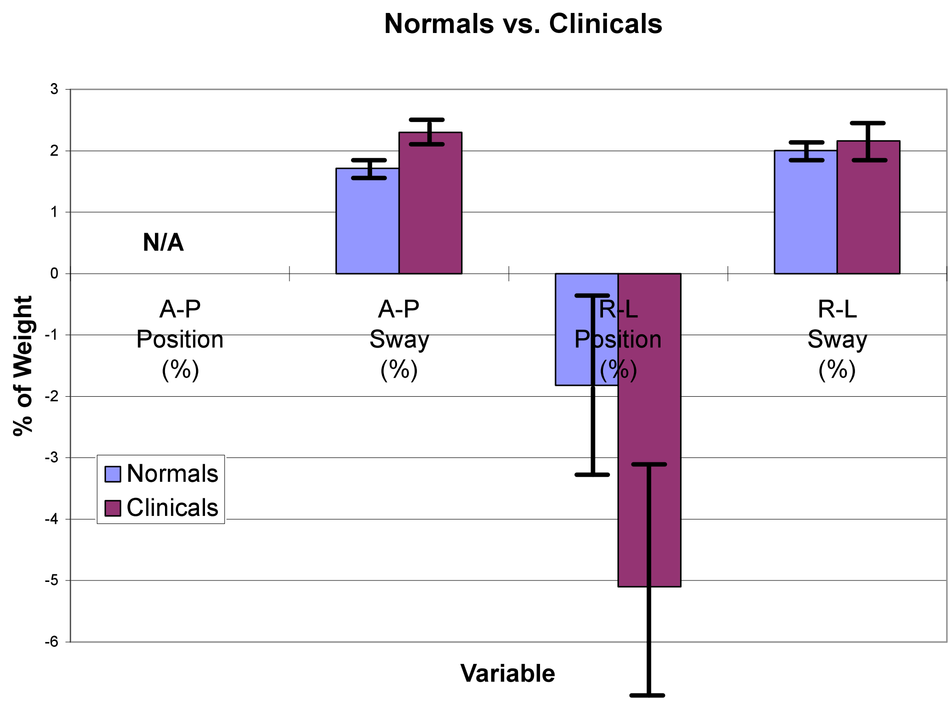

Fig. 11: Normals Versus Clinicals as Percentage of Weight.

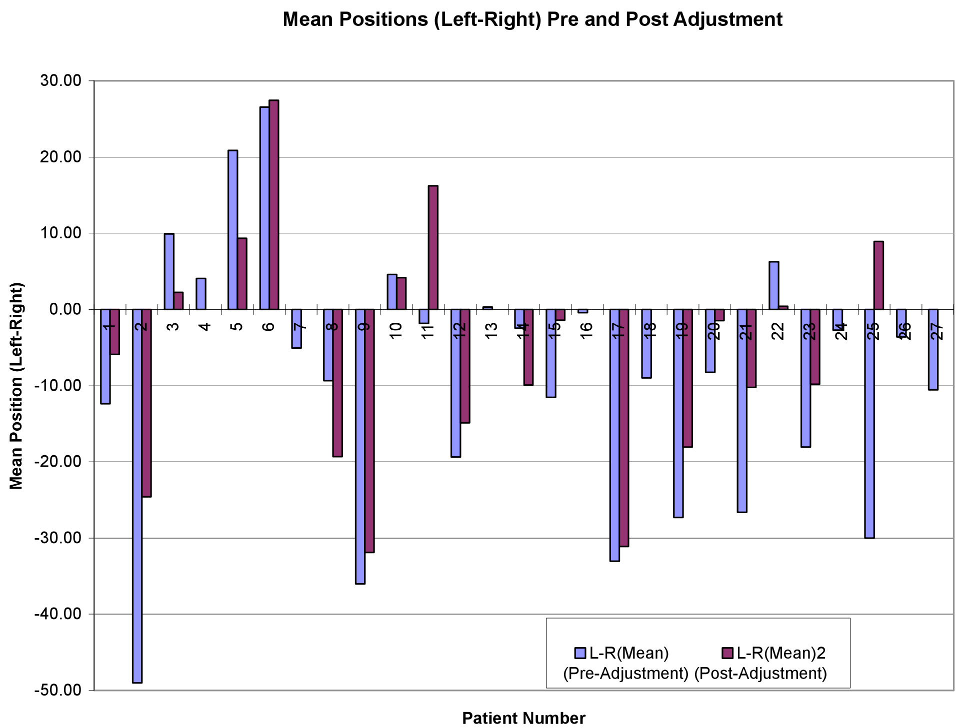

Figure 12: R-L Means of 27 patients during clinical screening, and of 18 of those patients after adjustment.

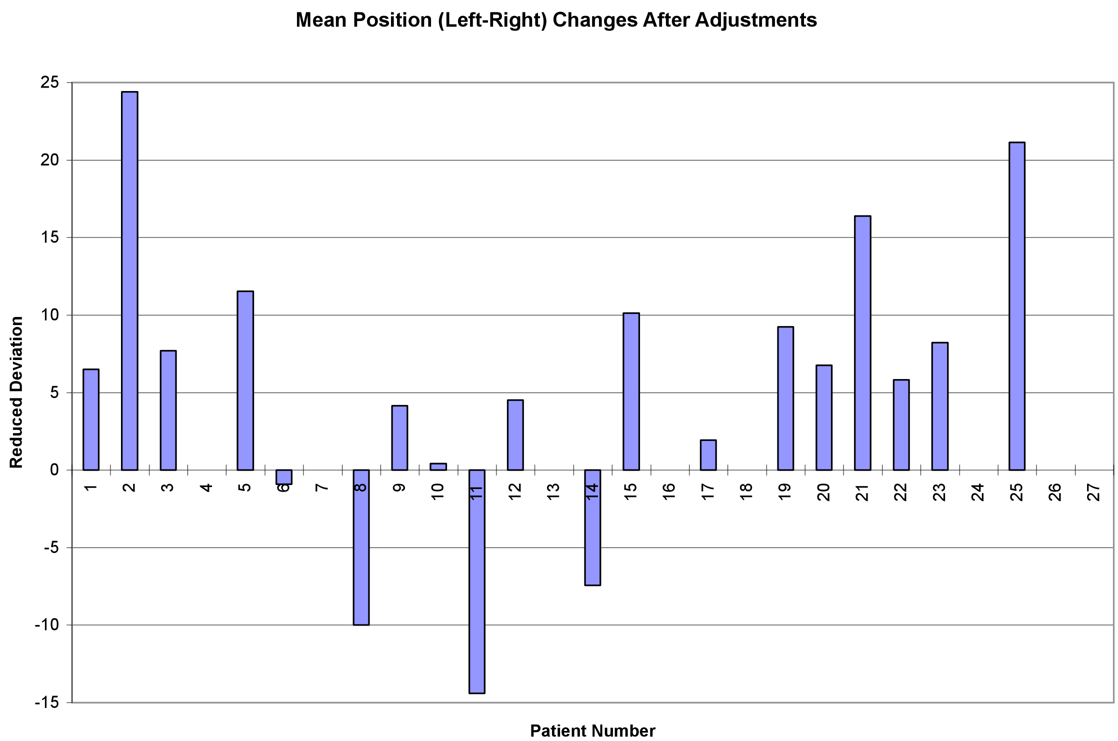

Figure 13: Difference scores for 19 patients are calculated by subtracting the absolute value of the second (post-adjustment) measurement from the absolute value of the first (pre-adjustment) measurement. Positive scores thus indicate a reduction of any center of gravity deviation, while negative scores indicate a worsening alignment.

COG Location	COG Movement	Weight
A-P Mean	A-P standard deviation	Weight Mean
	A-P standard error	
R-L Mean	R-L standard deviation	
	R-L standard error	
	Weight standard deviation	
	Weight standard error	

Table 1: Nine COGL Statistics.

PEARSON CORRELATION MATRIX

	A-P St. Dev.	R-L St. Dev.	Wt. St. Dev.
A-P St. Dev.	1.00		
R-L St. Dev.	0.58	1.00	
Wt. St. Dev.	0.34	0.37	1.00

MATRIX OF BONFERRONI PROBABILITIES

	A-P St. Dev.	R-L St. Dev.	Wt. St. Dev.
A-P St. Dev.	0.000		
R-L St. Dev.	0.000	0.000	
Wt. St. Dev.	0.000	0.000	0.000

Table 2: Correlation matrix and Bonferroni probabilities describing the relationship between A-P sway, R-L sway, and weight oscillation.