# BALANCE SYSTEM™ SD AND BIOSWAY™

LOG TRANSFORMATION

| | |
|---|---|
| 950-440 | System, Balance SD, 115 VAC 15.6” display |
| 950-441 | System, Balance SD, 230 VAC 15.6” display |
| 950-444 | System, Balance SD, 100 VAC 15.6” display |
| 950-450 | Optional FreeSway Handles |
| 950-460 | BioSway, 15.6” display |

BIODEX
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FN: 20-124-CLR

# BALANCE SYSTEM™ SD (version 4.x)
# AND BIOSWAY™

This document provides log transformation information that can be used when interpreting the performance of individuals during testing on the Balance System SD and BioSway.

Additional information and resources are available upon request or directly from the Biodex website: www.biodex.com/balance.

Here, the user can find information from compliance to clinical support, and if the desired information is not found, Biodex can be contacted directly at supportservices@biodex.com.

Thank you,

Biodex Medical Systems, Inc.

## Contact information

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# Log Transformation

## REPORT ENHANCEMENTS TO THE CLINICAL TEST OF SENSORY INTEGRATION AND BALANCE

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The purpose of this section is to present the methods used to interpret and display an individual's score on the Clinical Test of Sensory Integration and Balance (CTSIB) performed on the Biodex Balance Systems relative to a selected normative database. The Biodex Balance Systems provide line graphs and a mark (i.e., black triangle) depicting the location of an individual's CTSIB scores relative to the selected reference database. The middle vertical lines provide an indication of the reference database mean and the colored bars represent one, two, and three standard deviation units from the reference database mean. Thus, if the triangle is located to the right of the black vertical line, the individual scored higher than the reference database mean, which suggests poorer balance performance. Further, if the triangle appears in the yellow zone, the patient is between one and two standard deviations units worse than the mean, and if the triangle appears in the orange zone, the individual scored between two and three standard deviation units worse than the mean. Thus, practitioners can not only interpret whether an individual scores better or worse than the reference database mean, but also have an indication regarding the magnitude of the distance.

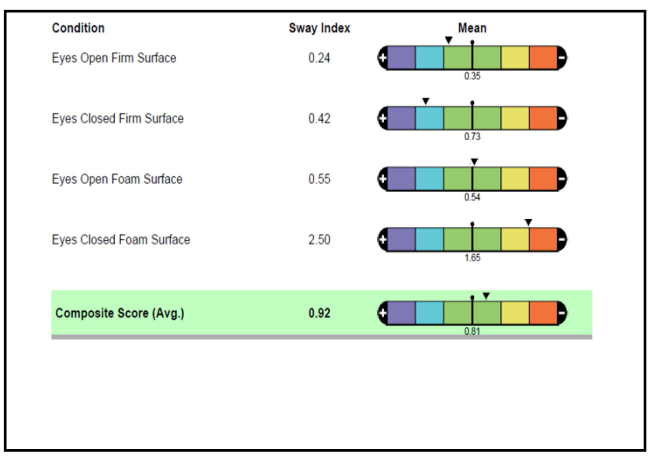


*Figure D.1. On screen and report output of CTSIB testing with line graphs in original (raw) units. The color boxes represent one, two and three standard deviations from the reference database mean. The triangle represents the individual score relative to selected reference database.*

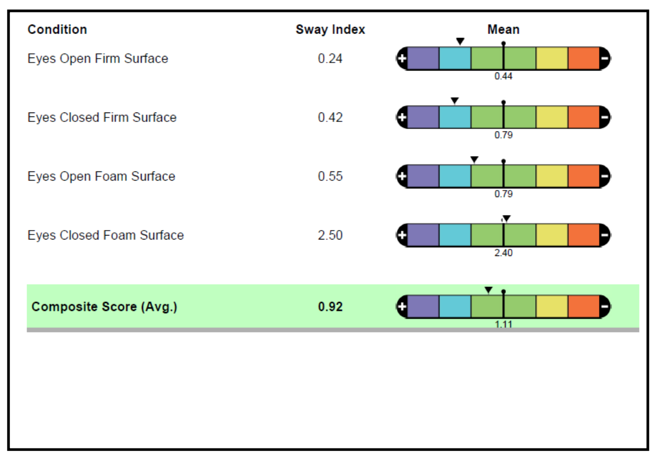


*Figure D.2. On screen and report output of CTSIB testing with line graphs in natural log transformed units. The color boxes represent one, two and three standard deviations from the reference database transformed mean. The triangle represents the individual score relative to selected reference database.*

Figure D.1 is consistent with how units have always been traditionally provided by previous Biodex Balance Systems. On Figure D.2, the line graphs are drawn using the selected reference database that has undergone natural log transformation.

The natural log transformation provides a more accurate method of interpreting the individual's performance relative to the selected reference database by adjusting the reference database to more closely resemble a normal (i.e., bell shaped curve) distribution of scores. By using this transformation, the usual distribution of scores relative to the mean apply. Specifically, it can be expected that 68% of healthy individuals will score within one standard deviation of the mean (green boxes), 95% of healthy individuals will score within two standard deviations of the mean (blue and yellow boxes), and 99% of healthy individuals will score within three standard deviations of the mean (purple and orange boxes).

## BACKGROUND

Interpretation of an individual's score with respect to reference (i.e., normative) data is a common challenge faced by many practitioners. One approach to interpreting an individual's score is to consider the distance of the scores from the mean in standard deviation units. A prerequisite to using this approach is that the reference database must be normally distributed (i.e., bell shaped curve). When the reference database is normally distributed, it is possible to take advantage of certain probability ranges within the distribution of the reference database. 68% of the scores will be within one standard deviation, 95% of the scores will be within two standard deviations, and 99% of the scores will be within three standard deviations. If practitioners consider individuals scoring beyond (i.e., outside) 95% of the reference database as reflective of pathology, they would seek individuals demonstrating scores that exceed two standard deviations from the reference database mean for intervention or more extensive evaluation. In the case of balance testing, higher scores of center of pressure movement (i.e., Sway Index) are considered to reflect a deficiency in balance ability. Thus, the practitioner would be prudent to consider an individual with a Sway Index greater than two standard deviations from the mean as indicative of postural instability.

Many metrics of human performance used by practitioners have minimum or maximum scores. Center of pressure movement is one such measure. Maintaining balance with very little corrective action and body sway would produce Sway Indices that would approach zero. In contrast, individuals demonstrating postural instability would demonstrate sway indices that could become extremely large. The effect of this characteristic on reference databases is to produce reference distributions that deviate from being normally distributed. Specifically in the case of Sway Indices, the reference distributions become positively skewed. Because of the skewness, the probability ranges of the normal distribution cannot be immediately applied. In these circumstances, a data transformation becomes necessary prior to standardizing the scores. Common transformations to improve normality include square root or logarithmic (e.g., base 10, natural log). Specific to logarithm transformations, is the useful feature that it moves large values closer together while moving small values farther apart. As a result, positively skewed distributions become closer to a normal distribution.

## METHODOLOGY AND RESULTS

A review of several large databases of Clinical Test of Sensory Integration and Balance (CTSIB) testing conducted on the Biodex Balance Systems revealed, similar to other human performance measures that have a minimum value, the existence of slight to moderate positive skewness. The purpose of this section is to describe the process of deciding upon the natural logarithm transformation and standardization method that is used to interpret an individual's performance on each of the CTSIB conditions.

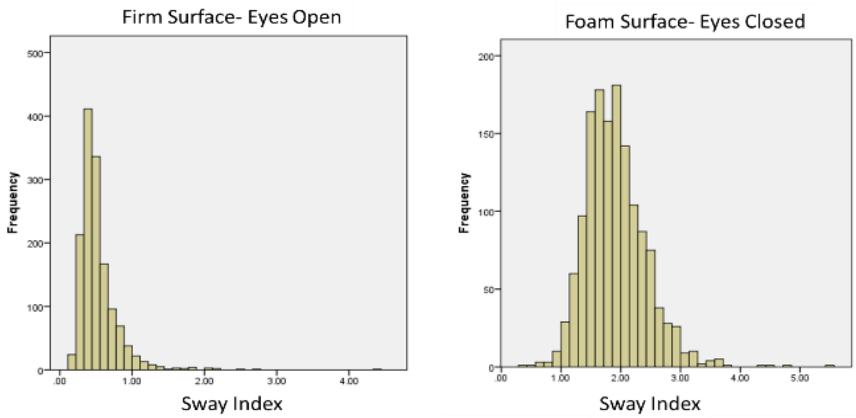


*Figure D.3. Positive skewness was more evident in the less challenging (left) than the more challenging (right) CTSIB conditions.*

Exploratory analysis of the five commonly used reference databases with CTSIB testing on the Biodex Balance Systems yielded varying degrees of positive skewness (range: 0.5 to 6.3), particularly for the less challenging CTSIB conditions (Figure D.3). Additionally, the exploratory analyses revealed the lower boundaries of two standard deviations from the mean to cross zero for two of the conditions (Table D.1).

*Table D.1. Results of the exploratory analysis conducted on the five most commonly used reference databases for CTSIB testing on the Biodex Balance Systems.*

| Database | N | Clinical Test of Sensory Integration and Balance Conditions | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Firm Surface- Eyes Open | | Firm Surface- Eyes Closed | | Foam Surface- Eyes Open | | Foam Surface- Eyes Closed | |
| | | $\bar{X}$±SD | Skew | $\bar{X}$±SD | Skew | $\bar{X}$±SD | Skew | $\bar{X}$±SD | Skew |
| EC1 | 487 | .39±.26 | 6.3 | .80±.29 | 1.6 | .68±.28 | 2.9 | 2.30±.56 | .5 |
| CT1 | 135 | .57±.22 | 1.3 | .66±.25 | 1.4 | .94±.35 | 1.2 | 1.44±.48 | 2.1 |
| CD1 | 536 | .49±.20 | 2.1 | .71±.30 | 2.0 | .86±.35 | 4.5 | 2.01±.58 | .9 |
| BD1 | 100 | .26±.09 | 1.9 | .53±.20 | 1.2 | .38±.11 | .6 | 1.05±.35 | .9 |
| CD2 | 1507 | .52±.27 | 4.1 | .71±.34 | 4.6 | .77±.26 | 2.1 | 1.90±.49 | .9 |

Thus, to improve using the multiples of the standard deviation to interpret scores, further analyses were conducted to identify the optimal data transformation. Specifically, Box-Cox Transformational Analyses were conducted to determine the optimal data transformation. This procedure examines a variety of transformations, followed by plotting of the skewness value against each transformation. By examining the plots (Figure 4), the optimal transformation that best reduced the skewness (closest to zero) across the four CTSIB conditions could be identified.

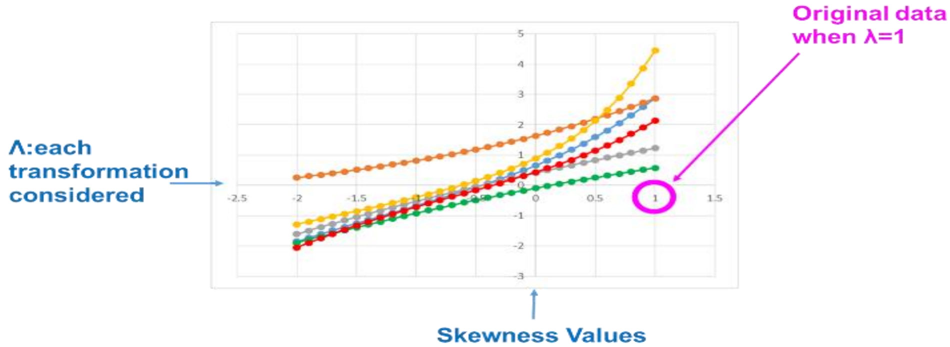


*Figure D.4. Example plot (Firm surface-eyes closed) following the Box-Cox transformational analyses on each of the reference databases (lines graphed). By examining the plot, the transformation (horizontal axes) that produces the minimal skewness value (vertical axes) could be identified. On the horizontal axes (λ) zero corresponds to a natural logarithm transformation and one corresponds to the original data (no transformation).*

Across the four CTSIB conditions, examination of the plots revealed that a natural logarithm transformation would best minimize skewness (Figure 5).

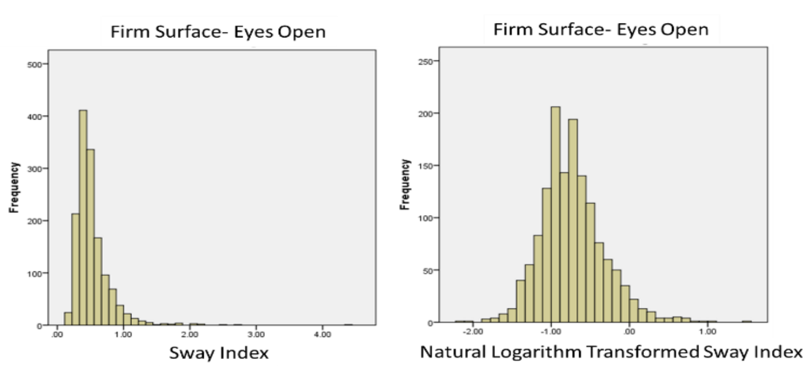


*Figure D.5. Distribution of Firm Surface-Eyes Open prior to natural logarithm transformation (left) and following transformation (right).*

In summary, by providing the option to have an individual's score and reference database natural logarithm transformed, users can more accurately interpret an individual's CTSIB performance proportionally relative to the distribution of the selected reference database.

## TICK MARK (black triangle) POSITION CALCULATION

The tick marks appearing on the colored bars of a CTSIB (Sensory) test result are described above as depicting the score's (Sway Index) location in relation to the normative database being referenced. To calculate the exact position of the tick mark, the offset position from the Mean is calculated in SD (Standard Deviation) units, since the width of each colored segment, or bar, is one SD in width. So, since the SD is in natural log units, you need to take the natural log of both the Mean and Sway Index, compute the delta of the 2 values, then divide by the SD. The resulting value will be in terms of 1 colored box width percentage when multiplied by 100.

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