Validation of a Bilateral Weight Scale as an Assessment Tool in a Chiropractic Research Laboratory

Jeff Birkenmeier, BS, Steve Constantino, BS, Ray Wiegand, DC, Dennis Nosco, DC***

***-presenting author

Contribution from Logan College of Chiropractic, Chesterfield, MO 63006

ABSTRACT

INTRODUCTION: Bilateral weight scales were developed by chiropractors to measure balance in their patients. It has been part of chiropractic culture that if subluxation is a major problem and is corrected to a significant degree, the patient will normally have better balance. Two papers have been published, though none recently, describing bilateral (or 4 quadrant) weight scale validation as it relates to obtaining a reproducible and reliable measurement on the patient. However, no papers have been published that deal with the validation of the actual operation of the scales. Before any tool is used to make predictions about the results of chiropractic research or care, the instrument should be validated to prove that its results are, indeed, useable. The following student research project describes one such validation of a weight scale used at a local chiropractic college.

MATERIALS AND METHODS: The Chirotron Model 6800 Weight Analyzer (Chirotron, Seattle, WA) contains 6 separate force plates, two for the front of each foot and one for each heel. The scale averages readings for 8 seconds during the measurement. It presents a printout showing total weight, weight in each quadrant, % weight shift from neutral LR and AP and the ratio of LR to AP. The scale, which is essentially a 4-way weight scale, was tested for accuracy, precision, sensitivity, linearity (or Operating Range), reproducibility, system suitability (including ruggedness) using a combination of pre-calibrated free weights and human subjects. The human subject research required an IRB approval, which was obtained. The data was treated with appropriate statistical treatments.

RESULTS: It was found in a small trial that with human subjects the optimal time to make a balance measurement using this scale is around 20 seconds. The main error observed for each plate is an electronic rounding error of one pound per force plate which could lead to a MAXIMUM error of 7% A/P and 10% L/R error. Standard deviations from repeated measurements set the actual standard deviation at <3%, well below the limits for subtle change that occur from artificially inducing small changes in the weight
distribution of the subject. All total weight measurements were accurate to the nearest pound, irrespective of rounding errors from the electronics for individual pads. It was found that moving the equipment from one place in the lab to another may introduce additional error but it was difficult to separate that from error generated by making a single measurement without subject equilibration time.

**DISCUSSION:** The weight scale used in this study is very accurate for measuring total weight in spite of attempts. Also, the linearity of each pad is good at least up to 75 pounds. Rounding errors of up to one pound per plate, if they are additive, could cause relatively large (10-15%) error for 120-160 pound individuals, although this is not likely and the standard deviation is more likely the <3% measured in this study. Care should be taken in moving the machine from one place to another and then using it immediately.

**CONCLUSIONS:** The weight scale tested in this experiment was shown to be highly accurate and reliable. The electronic averaging may create data scatter in lower weight individuals. However this could be probably be substantially eliminated by repeated measurements or waiting a slightly long time (>20 seconds) before making the measurement after the subject steps on the scale. More detailed subject parameters to insure that readings obtained are the most diagnostic will be the subject of future experiments on this weight scale.

**ACKNOWLEDGEMENTS:** The authors and Logan College would like to thank Foot Levelers, Inc. for their financial support of this project.
Validation of a Bilateral Weight Scale as an Assessment Tool in a Chiropractic Research Lab

INTRODUCTION

Bilateral weight scales were developed by chiropractors to measure balance in their patients. There have been a number of papers published on the testing and use of weight scales as they relate to chiropractic [1-11]. It has been part of chiropractic culture that if subluxation is a major problem and is corrected to a significant degree, then the patient will normally have better balance. Weight scales are generally considered a Class II type device (i.e., some evidence for effectiveness in uncontrolled clinical studies, case or cohort studies or clinically-relevant basic science studies) with positive recommendations as that Class II device.

Two papers have been published, though none recently [1,2], describing bilateral (or 4 quadrant) weight scale validation as it relates to obtaining a reproducible and reliable measurement on the patient. However, no papers have been published that deal with the validation of the actual operation of the scales. In fact, the best referenced paper on weight scale validation does not contain any information about validation of the actual scale used to insure that it was measuring what it claimed to measure [1]. In the area of medical testing, the U.S. Pharmacopeia (USP) is the respected compendium. The USP describes, among other things, test methods used to validate that equipment works as it is designed to and produces meaningful results all the time and, usually, under a variety of conditions. Tests that are normally run on equipment that is used either directly or remotely in clinical studies include the following: Accuracy, Precision, Sensitivity, Linearity (or Operating Range), Reproducibility, System Suitability (including Ruggedness) and Calibration Methods. Accuracy defines the ability to correctly measure a quantity. Precision describes how sensitive the equipment is to smaller and smaller levels of change. Sensitivity defined the lower limit of change that can produce a change in the response of the instrument. Reproducibility describes being able to measure the same quantity and get the same value each time. Linearity, which is normally considered an electronics issue but can be a mechanical one, as well, is functionally defined as the range in which the response of the equipment gives useful information. System Suitability describes whether the system is useable under the conditions that it will normally be operated to measure what it normally measures. A sub-section of System Suitability is Ruggedness, which is defined as the ability of the equipment to measure its quantity accurately and reproducibly under all sets of conditions, even those outside of its normal operating parameters, both internal and external to the system. Calibration Methods describes regular checking of the equipment with known standards using a known protocol to insure that electronic or mechanical wear do not change the operation of the equipment and, therefore, the validity of the results.

Weight scales are one of a number of research tools that can be used in chiropractic. However, before any tool is used to make predictions about the results of chiropractic research or care, the instrument should be validated to prove that its results are, indeed, useable. The following student research project describes one such validation of a weight scale used at a local chiropractic college.

MATERIALS AND METHODS

The research was carried out at a local chiropractic college. Human subjects were involved so the proposal was approved by the college IRB after approval through the college’s research review committee. Subjects signed consent forms.

The instrument undergoing validation in this study is the Chirotron Weight Analyzer Model 6800 (Chirotron, Inc., Seattle, WA). It contains 6 individual force plates that were designated for this study as indicated in Figure 1A. This instrument electronically averages data over an eight second period from the time the balance run is started. Logistically, it takes approximately 5 seconds after the person stands on the weight scale for the run to start. A sample printout is given in Figure 2.
General: The instrument was placed in the research lab and leveled using the four adjustable feet and a bubble indicator. In each of the measurements utilizing subjects, the subject's feet was placed in the center of the foot pads medially to laterally and anterior to posterior. Between each measurement run, the unit performed the standard automatic between-run calibration sequence. The instrument was tested for accuracy, precision, sensitivity, reproducibility, linear range and ruggedness. Some tests involved human subjects so, before beginning the testing, an experiment similar to that described by Mrozek [1] was performed to determine the optimal time to begin each test. In each test the weight and weight distributions were recorded. Pre-calibrated 3,5,15 and 25 pound plates and hand weights were used for all experiments not involving subjects.

Optimal timing of test initiation: Three subjects were tested after standing on the plate for 5, 20, 35, 50 and 65 seconds. It was determined that the 5 second waiting period before beginning the test was too short but if the test is started any time between 15 and 50 seconds after initially standing on the machine the test will produce a reproducible result. For the purposes of this testing, the minimum of 20 seconds was chosen as the best for this machine. No deviation in readings were observed when starting the test at various times using calibrated weights instead of human subjects. Therefore, timing of readings were not considered when calibrated weights were used.

Accuracy: To test accuracy of the unit, weight was placed on each of the six (6) individual load cells in gradation of 25, 50 and 75 pounds using 25±0.1 lb calibrated weights. Due to the close proximity of the load cells to each other and the size of the calibrated weight plates, a one-inch (1") diameter wood dowel of insignificant weight (less than 0.01 lb) was used to support the plates on the load cells. This dowel was moved to various locations on each load cell (mapped out in Figure 1B), thus moving the load. In order for the unit to function properly, the contralateral set of load cells must register a load, so a load of 25 and 50 pounds were employed during the measuring. Load readings were recorded for each of the locations.

Precision: To test accuracy, a calibrated 25 pound weight plate was placed on one set of 3 load cells, equivalent to one foot. Additional weight (using a combination of calibrated 3 and 5 lb weights (±0.1 lb)) was placed on the calibrated plate in succession of three (3), five (5), six (6), eight (8) and eleven (11) pounds. Load readings were recorded for each of the loads.

Sensitivity: Three different sensitivity experiments were completed: (a) In addition to being weighed normally with shoes, non-deforming foam blocks were placed under various parts of each foot and the subject weighed. Measurements were performed with the block under the 1) heel only, 2) ball of foot only and 3) entire foot. This was repeated for each foot at each of three (3) unit locations; (b) three (3) subjects were weighed one (1) time with shoes and another time without shoes in one location; (c) a single subject was placed on the scale 4 times alternating the hand that the subject held a three pound weight and then 8 pounds of weights.

Reproducibility: In order to test reproducibility, each subject's weight was recorded, the subject stepped off of the weight plates, the unit was reset to accept anew measurement and this method was repeated for a total of three (3) load measurements on each of three (3) subjects.

Ruggedness: In order to test ruggedness of the unit, one (1) subject was weighed at each of three (3) different locations. Each time the unit was moved, it was re-leveled with a bubble level.

RESULTS

Accuracy: All 84 tests using the 25 pound flat weights plus the dowel (28 with one weight plate, 28 with two weight plates and 28 with three weight plates) with a 25 pound counter weight on the contralateral side, all quadrants registered 25, 50 and 75 ± 1 pound, when one, two or three plates were loaded, respectively. Irrespective of the weight distribution between the quadrants the total weight always was equal to the weight placed on the scale. Moving the dowel to different parts of the quadrant seemed to have no effect on the values obtained. If separate hand weights are used for each quadrant, up to 25 lbs for each of 6 quadrants, the maximum error per quadrant is 1 pound and the overall weight is still identical to the weight on the scale.

Precision: Incremental weight additions of 1,3,5,8 and 10 pounds to an experiment where 25 pound weights were on each of four quadrants were measured identically measured to their weight in three trials. L/R and A/P either exactly matched or are in error by 2 pounds (4%). The total weight was always identical to what we placed on the scale.

Sensitivity:

a) With and without shoes: There was a change of greater than 4% on each of three trials in each quadrant of
b) Wedges under feet: The standard deviation per plate is about 10.2% of the weight

C) Alternating hands with weights. The mean difference from four runs was a 8 pound change L/R for a three pound weight and 13 pound change L/R with 8 pound held in one hand compared to the same person without any weights held in their hands.

Reproducibility: Total weight was identical for each individual each test. L/R and A/P variations were less than 4% in each of three separate runs.

Ruggedness: The movement of the dowels to different parts of each force plate has already been discussed. Moving the scale to different parts of the room and re-weighing the subject gave a slightly larger variation (1 SD = 10% of value on a single measurement).

DISCUSSION

Weight scales are only as useful as their weight ratios are. Overall weight is expected to be accurate but it is the balance (i.e., the weight ratios or % differences A/P and L/R) that are important. The experiments reported here show that, within rounding error of the electronics of one pound per force plate, this instrument generates reproducible weights on each plate and an overall weight identical to the weight placed on the scale. Thus the L/R weight ratio may be 49/49 but the overall weight will register as 100 pounds. This translates, for a 160 pound person to a maximum difference of 4 pounds (10%, 3 standard deviations) L/R and with an expected error of about 3% per half, and 2% per quadrant, very similar to what Vernon achieved in his repeat measurements. The scale in this study averages data over 8 seconds and thus less data points had to be collected to obtain the same answer that Vernon did. The scale was sensitive to rather subtle changes as removal of the shoes produced noticeable changes of over 6% in all of the six areas on the plate, although it is debatable whether shoe removal is a subtle change. Therefore, another sensitivity experiment was run where the subject held a 3 pound weight in one hand and then repeated the measurement with the weight in the other hand. The same was done for the 8 lb weight and the results compared to the mean of three runs without any weight. The average change in L/R ration was 8 pounds for the 3 pound weight and 13 pounds for the 8 pound weight. Given subtle changes in posture from holding a weight this is in the direction and reasonable for weight distribution changes.

CONCLUSION

The weight scales examined in this study did very well in measuring weight and distinguishing between instrument rounding error, subject-introduced variation and subtle changes in posture or weight shifts. These scales with the 20 second protocol before starting the test and then doing one measurement will be a very useful tool in future studies in this lab. Additional work may have to be done on the ruggedness of this equipment as the standard deviation for a single experiment (about 10.8% of the mean value) may cause a problem in subjects who manifest only small changes after chiropractic care or other stimuli. That standard deviation needs to be about 3% to be outside of stimuli that were used in this study.

REFERENCES


10. Seemann DC. A comparison of weight differential between a group that had a history of spinal problems or had been under care and a group that had neither a history of spinal problems nor been under care. The Upper Cervical Monograph. Sept. 1991; 5(2): 17-19.

Figure 1 – Abbreviations and locations for the locations of the various measuring points on the Chirotron Weight Analyzer

Anterior

LL  LM  RM  RL

LP  RP

Anterior

x  x  x  x
x
x  x  x
x  x  x

x  x  x
x  x  x
x  x  x

Posterior

LL = Left lateral plate, LM = Left medial plate
LP = Left posterior plate, RL = right lateral plate
RM = Right medial plate, RP = right posterior plate
X = spot where dowel (and weight) were placed

FIGURE 2 – Sample printout from Chirotron Model 6800 Weight Scale

Tue 22 Apr 2002
3:10 pm

PATIENT NR: 33
TEST NR: 1
17/12 0 0 11/18
54 LB #0 51 LB

1 LB #0 L/R
1% #0 DIFF

46 LB 0 0 A/P
28% ## DIFF

TOTAL WEIGHT
164 POUNDS

LR DEV = 3.5 LB
AP DEV = 8.9 LB

AP > LR BY 157%
CHNG:LR:11
AP:10