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Key measurement principles to strengthen the reliability of loading device technologies: Implications to health care practice

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ABSTRACT

Introduction: In practice, reliability of the load measurement device is carried out as a standard practice prior to data collection to eliminate errors in measurement. However, reliability alone cannot confirm the goodness of a measurement device. The other key measurement variables such as accuracy, hysteresis, eccentricity error, uncertainty could affect the device output. This study highlights the importance of several key measurement principles to strengthen the reliability of loading device technologies in health care practice.

Aim: To describes a method of testing the key measurement principles necessary to test the goodness of a load measurement technology at clinical or research setting.

Material and methods: A customized load measurement device was used to elucidate the calibration procedure. To determine the accuracy and hysteresis, a series of ten equally spaced standard loads ranging 10–100 kg was applied from no load to maximum load over device platform. The applied loads were removed in the same order as initially placed. In addition, the repeatability was tested with a load of 20 kg for five trials. Furthermore, the eccentricity error was determined by applying loads over five different quadrants.

Results and discussion: The result of the method demonstrated that the device has excellent accuracy and repeatability, with no errors in hysteresis, uncertainty, eccentricity.

Conclusions: In addition to reliability, the other proposed key measurement variables are proven essential to test the goodness of a loading device in research and clinical practice.

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1. Introduction

In healthcare practice, it is fundamental to objectively measure the kinematic data such as limb loading, center of gravity, and force integrals. The current technology to quantify force related measurements in clinical and research practice requires equipments such as the force platform, dual weighing scale, and Nintendo Wii balance board.[1,2] These devices were used to measure static and dynamic vertical ground reaction forces in pounds or kilograms with certain possible inaccuracies.[3] As a gold standard practice, the calibration of measurement devices is carried through approved national accreditation bodies. Nevertheless, the calibration process is challenging when considering the cost, time, portability of the system and the frequency of calibration.[4]

In common health care practice, any measurement data obtained from load measurement technologies needs to be valid and reliable.[5,6] Specifically, the device must give a true representation of the load with a variable of measurement quantified as errors. One of the possible causes of error or inconsistency in measurement technologies is attributed to poor calibration.[7,8] If the initial calibration is poor, then the data derived from such measurement devices propagates errors all along the measurement output. Consequently, the device output results may affect the clinical and research outcome.

In practice, reliability of the loading device is carried out as a standard practice prior to data collection as a calibration procedure to eliminate errors in measurement data. However, reliability alone cannot confirm the goodness of a measurement device. The other key measurement variables such as accuracy, hysteresis, eccentricity error, uncertainty could affect the device output. Accuracy and uncertainty are important as any inconsistencies in the loading measurement could have a negative impact on patient care in terms of errors in diagnosis and treatment.[9] In common practice, loading measurement is commonly evaluated in standing, hence postural sway or any shift of body weight could increase or decrease the loading values. If there are errors in hysteresis the difference or change in loading values could not be captured by the measurement device with accuracy. Further, in practice for the evaluation of loading, the participant is required to stand in the middle of loading platform. If the participant stands at any segment of the platform other than the center, ideally the reading should be the same as that of the center. If there is eccentricity error in the device, the measurement reading differs between segments of the same measurement platform.

The ability of a practitioner to objectively test the key calibration measurement variables prior to its clinical or research application may produce good output results. To our knowledge, no literatures have discussed on the clinical or lab calibration procedures of these measurement systems. Therefore, this study describes a method of in-house calibration appropriate for calibration of load measurement devices used to measure vertical ground reaction force in practice. Such knowledge of key calibration measurement variables may enable clinicians and researchers to understand and carried out calibration in day-to-day practice for weighting accuracies.

2. Aim

The aim of this paper was to describe a method of testing the key measurement principles necessary to test the goodness of a load measurement technology at clinical or research setting.

3. Materials and methods

The common terminologies related to calibration are explained in Table 1. The procedure of calibration was tested using a customized clinical load measurement device (CLMD). The followings are the technical specification of CLMD, it consists of a square platform measuring 15×15 cm with a maximum weighing capacity of 100 kg and a precision of 0.02 kg. When a load is applied, the resultant force is acquired by the square sensor platform. The platform produces electrical signals of 2.5 mV/kg, which is applied, to the amplifier to obtain single

Table 1 – Common terminologies related to calibration.

Terminologies	Descriptions
Error	Error refers to any deviation in the measurement output values to the true value.
Accuracy	The capability of the platform scale to provide the measurement output values as close as possible to the actual measurement value.
Precision/repeatability	The capability of a device to show consistent measurement values under the same conditions.
Eccentricity test/Shift test/Corner test	Eccentricity test is a method of testing the platform scale where the platform is loaded asymmetrically in a distinct way.
Hysteresis	Hysteresis is the difference in the measurement output of a device as the applied load increases from minimum value to a maximum value, and consequently decreases from maximum to minimum over the same range.
Uncertainty	Uncertainty is a measurement variable describing the range of values within which the true value of a load measurement quantity lies.
Standard weight	Standard weight is the weight that complies with the recommendation of the International Organization of Legal Metrology (OIML)/global legal metrology.
Applied load	Applied load refers to the standard load administered to the platform scale for the purpose of calibration.
Reference load	Reference load an object or material of any shape of known weight usually calibrated against standard weights. Reference loads and used in calibration in the absence of standard weights.
Maximum operating capacity	Maximum operating capacity refers to the maximum weight applied to the load-receiving component of the platform scale under standard operating conditions.