Report article

Development of new methods to calibrate centre of pressure obtained from force platform

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Abstract

Kinetics and kinematics data are measured using force platforms and three-dimensional cameras in the gait analysis laboratory. Reducing errors related to the force platform when collecting data was necessary. This study describes a new calibration method for centre of pressure of laboratory force platforms using a sandal with extended bar. Firstly, a subject was asked to put his weight vertically on various places of the force platforms using the sandal to create a correction table. Secondly, nine validation trials were conducted to examine the accuracy of the force platforms after correction. The data taken from the centre of pressure and the motion capture were analyzed. Then the erroneous position of the centre of pressure data was translated to the correct position by using weighted average of the vector mostly close to the validation point. The method used in this study allowed to reduce the maximum error from 24.6 mm to 2.7 mm.

Introduction

Three-dimensional (3D) motion analysis is widely used in clinical decision making and sport biomechanics [1]. Modern gait analysis laboratories are equipped with 3D multi-cameras and force platforms (FP) that enable the researcher to take the kinetics and kinematics data. FP are used to measure the vertical, anterior-posterior and medio-lateral components of the ground reaction force (GRF) vector. It can also be used to calculate the centre of pressure (COP) of a subject exerting force on it. The joint moment can be calculated by combination of the kinematic data and the kinetic data [2]. A previous study reported that errors up to ±30 mm when measuring the COP with piezoelectric force platforms were generated. These errors could be due to the deformation of the top plate and transducers; a correction algorithm was then proposed by Bobbert et al to correct the deformation when calculating a point of force application [3]. Joint moments will be affected if there is an error in the system. Valid results of the joint moments can only be obtained if the determination of the COP is accurate.

To calibrate the force platforms, heavy devices have been used [4]. However these devices were difficult to move during the data collection. A

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previous study also used a rigid rod with a pointed tip at each end to calibrate the force platform [5]. The former method requires a subject to exert force by using a hand held loading-bar. Hence the force applied might not be efficient to get adequate magnitude of GRF equivalent to the adult's weight. Andrea et. al also developed a re-calibration device of approximately 5 kg and composed of a triaxial load cell, a triangular stage and a template. However this device required an amplifier before calibrating the force platform [6]. To avoid this difficulty, an alternative method should be used. The new method will use a sandal with extended bar in this study. A subject will apply force on the various points of the force platforms using the sandal. At the same time a new method to correct the COP was developed. The purpose of the present study is to develop a new method to correctly calibrate the location of the COP using a simple tool.

Materials and Methods

The new calibration device is consisted of a bar of approximately 1m long and 35 mm diameter fixed on the top of the wooden sandal. A metallic ball point of 20 mm diameter was attached to the sole of the wooden sandal. Three markers set on the device; one on the top of the bar and the other two in front and behind the sandal respectively (Figure 1). The three markers represent the local coordinate system (LCS). These markers were used to determine the location of the centre of the ball point described below: a metallic tube of 16 mm inner diameter and 22 mm long was embedded in a wooden base-plate and was placed on the floor. The ball point of the calibration device was placed in the inner diameter of the tube then the extended bar was rotated (Figure 2). The marker positions were taken with infrared cameras (VICON, Oxford Metrics, UK). The Matlab (Math Works, USA) script was used to determine the centre of the rotation of the ball point as the stationary point during the motion. The location of the centre of the ball point in the LCS of the calibration device was stored in the computational program.

A male tester (30 years old with 64 kg weight) was asked to put one leg on the sandal and he was ordered to put his weight on many places of the

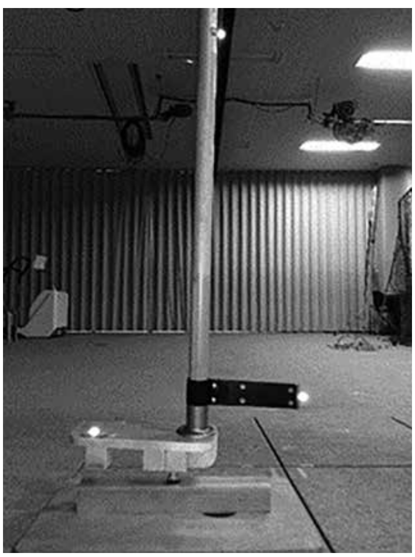

Figure 1. Device used for the calibration.

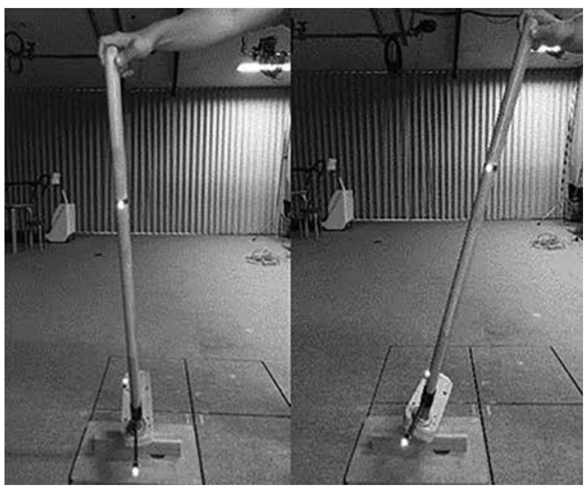

Figure 2. The ball point of the device was put in the inner diameter of a metallic tube embedded in the wooden base-plate.

two AMTI (Advanced Mechanical Technology Incorporation, USA) force platforms (Figure 3). While taking the data, the subject grabbed a handrail at his lateral side to stabilize his balance. The weight was applied as vertically as possible on the force platforms.

The location of the three marker set on the calibration device were collected with 11 VICON system cameras (Oxford Metrics, UK) at a sampling rate of 100 Hz to calculate the location of the center of the ball point and at the same time the force platforms data were collected at 1 kHz to calculate the COP. For each position the COP and the marker position data were taken at about three seconds. Ten points on the progression direction and 9 points on the lateral direction calibration trials were taken on each force platform (a total of 10 times 9 trials were taken to cover the surface of each force platform) to make the correction table (Figure 4). Then the other nine trials were used to check the accuracy of the force platform.

The subject approved his consent in participating in this study and approval from the ethical committee of the Niigata University of Health and Welfare was obtained (No. 17810).

Figure 3. Subject applying weight vertically on the force platform.

Data processing

A computational program was developed using Matlab to calculate the position of the COP before and after the calibration. With a motion capture system, a computational program was used to calculate the contact point of the ball point with the force platform. This contact point is the COP taken from the motion capture system (COP_v). The COP_v data were assumed to be at the correct position. However the data of the COP from the force platform (COP_f) contain error. The 90 trials were used to create the correction table.

The correction table contains a list of the COP_f and the correction vectors. The correction vectors are the vectors from COP_f to COP_v (eq.1).

Correction vector at each COP_f in the correction table = vector from COP_f to COP_v (1)

To validate the correction method, the nine validation trials were used with the correction table. The following equations were used to correct the COP position.

From the correction table, correction vectors of four points most closely to the COP_f were used for the weighted average to create the correction vector for the COP_f (eq.2). Then the correction vectors for the COP_f are added to the COP_f to make the corrected COP. (eq.3)

Correction vector for the COP_f of the validation trials = $(C_1/r_1+C_2/r_2+C_3/r_3+C_4/r_4)/k$. (2)

Here, C_1, C_2, C_3, C_4; Correction vector at each closer point in the correction table

r_1, r_2, r_3, r_4; distance from the validation point to each closer point in the correction table.

$k = 1/r_1+1/r_2+1/r_3+1/r_4$

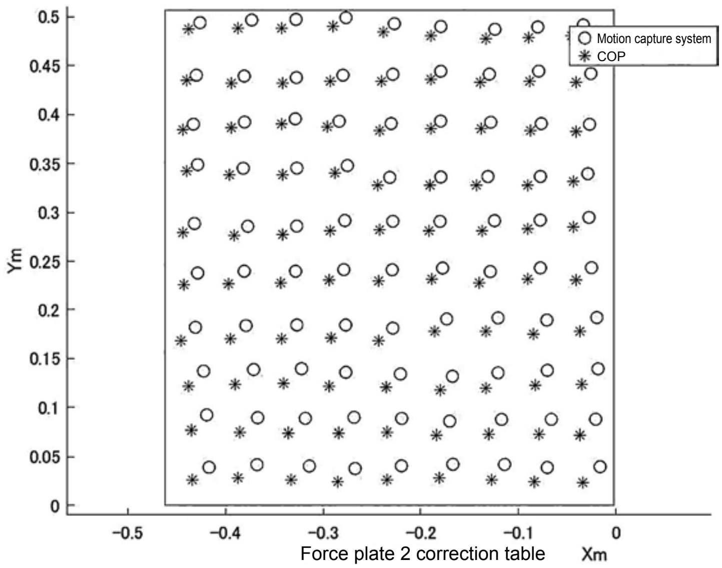

Figure 4. Graphical representation of the correction table made from the trials taken on the force platform 2.
○ : The position of COP data taken by the motion capture system
* : The COP taken by force platform before calibration

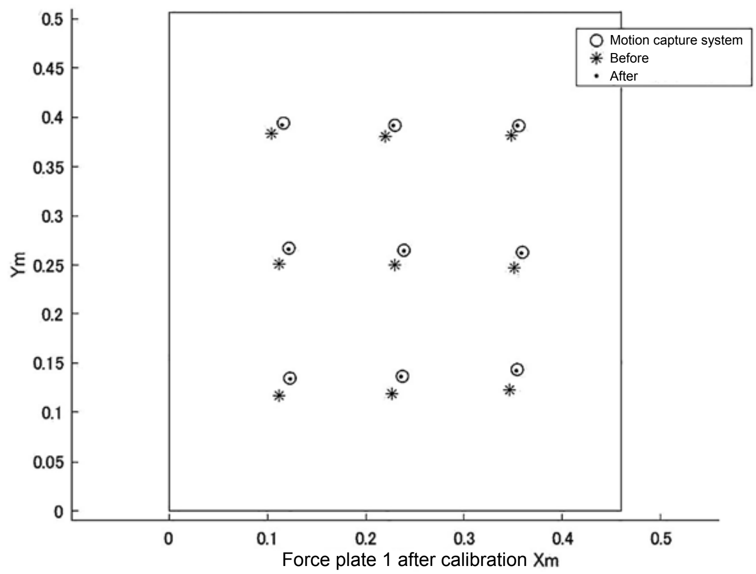

Figure 5. Position of COP_v and COP_f data of the force plate 1 after calibration.
○ : The position of COP data taken by the motion capture system
* : The COP taken by force platform before calibration
• : The new position of COP after calibration

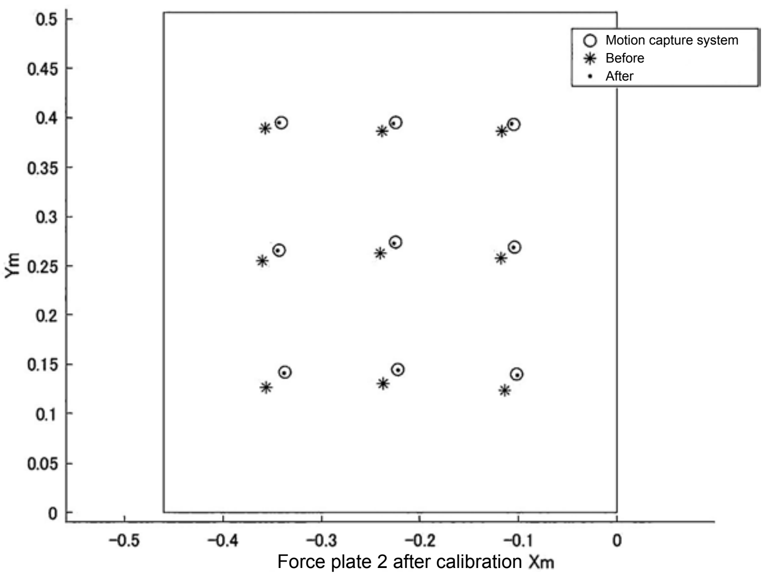

Figure 6. Position of COP_v and COP_f data of the force platform 2 after calibration.
○ : The position of COP data taken by the motion capture system
* : The COP taken by force platform before calibration
• : The new position of COP after calibration

Corrected COP_f = COP_f + Correction vector for the validation trials (3)

Results

Figure 4 shows graphic representation of the correction table of the COP_v and COP_f data for the 90 trials on one of the force plate. The same graphic representation was also obtained for the other force platform. This correction table contains the correct data of the motion capture system and the erroneous data of COP. Figure 5 and 6 show the position of COP_v and COP_f data before and after calibration of the two force platforms. Before the calibration, the maximum difference between COP_v and COP_f was 22.2 mm and 24.6 mm respectively for the FP 1 and FP 2. And after calibration the maximum was reduced to 2.5 mm and 2.7 mm respectively.

Discussion

The present paper reported the development of new method to calibrate the COP of FP using simple tools. The effectiveness of this methods was tested on two commercial FP in a gait analysis laboratory. The results in figure 4 show the difference between the COP data from the motion capture system (COP_v) and the erroneous COP data from the FP (COP_f). Before the calibration of the FP, the error recorded at the COP was very significant about 22.2 mm for the first FP and 24.6 mm for the second FP. Motion capture systems and FP are used in clinical decision making and research in biomechanics to estimate the net joint moments for analysis. The influence generated from the FP could be critical in analyzing the data. Reducing the errors that influence the accuracy of data measurement is very necessary. Andrea et al. developed a portable system to re-calibrate the FP and the system was effective in reducing the error up to 11mm maximum. More over their system needs an amplifier when collecting the data and the device is about 5 kg weight [6]. James et al also developed a FP calibration system by applying symmetrically single point force on two force platforms and could reduce the COP error at about 1 mm, however errors generating from the two feet could cancel out [7].

The validation data were used to check the translation of the position of these erroneous COP_f position to the correct position. The method used in this study allows to correct the position of the COP data. This calibration method reduced systematic error related to COP up to 22 mm maximum when collecting kinetics and kinematics data. The calibration device described in this paper is composed of a common wooden sandal especially used when wearing Japanese traditional wear kimono. It is a light weighted device less than 1.35 kg. It is therefore portable and can be used to calibrate the force platform of the gait analysis laboratory.

Conflicts of interest

None declared.

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