

# Evaluation of the plumb-bob method for reading greens in putting

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This study evaluated the validity of the plumb-bob method as used to determine the break of a putt. Two separate experiments were conducted to examine the consequence of violating inherent assumptions in the method. In the first experiment, a controlled putting environment was constructed to assess the plumb-bob method in determining the break of a putt, if the slope of the green was not constant from the position of the golfer behind the ball through to the hole. It was determined that if the slope of the green beneath the golfer was different from the slope between the ball and the hole, then the plumb-bob method would provide an incorrect indication of break. The second experiment examined the ability of a golfer to stand perpendicular to a slope. Half of the participants in the study deviated by  $\pm 1.5^\circ$  or greater from standing perpendicular to a slope. A  $+1.5^\circ$  error on a 1.4 m ( $\sim 4.5$  ft) putt translates into reading an extra 0.08 m of break and a missed putt. The plumb-bob method was found to be an invalid system for determining the break of a putt.

*Keywords:* balance, golf, physical model, putting.

## Introduction

According to the Professional Golf Association (PGA) Tour statistics listed on the PGA web site, the putting stroke accounted for approximately 41% of all strokes made during the average tournament round of golf in 2002 (PGA, 2002a,b). Hence, a golfer's putting performance plays a large role in the overall score. Putting performance is linked to handicap, but the exact form of the relationship is unclear. Carnahan (2002) demonstrated that handicap was a statistically significant explanatory variable of putting performance. However, handicap only accounted for approximately one-quarter of the variation in putting performance.

A golfer's putting performance is dependent upon three skills. First, the golfer must determine the club head speed required to displace the ball from its resting position to the hole. To determine this speed, the golfer needs to consider the rolling friction between the ball and grass, the vertical displacement of the hole relative to the ball, and the distance the ball must travel to reach the hole. Second, the golfer should execute a putting stroke where, at impact, the putter-head has only horizontal velocity in the direction of the target line,

and the plane of the putter-face is perpendicular to that line. Brooks (2002) describes three types of putting strokes commonly recommended by golf instructors that could produce the desired impact conditions. These strokes are in reference to the target line and are: the straight back to straight through; inside to inside; and inside to straight through. Brooks (2002) examined these strokes using mathematical models, but did not arrive at a conclusion regarding which stroke would be best. Finally, the golfer must predict the direction and magnitude of break in the putt to determine a target line. Assuming ideal club head speed, the predicted break depends on the magnitude of slope the golfer reads on the green between the ball and hole.

There is no accepted method for determining the slope of a green. Golfers often make assumptions based on visual cues from the surrounding landscape or use their kinaesthetic sense of balance to arrive at a conclusion. A popular system that has been used for decades is the plumb-bob method. According to Pelz (2000), one in seven golfers uses the plumb-bob method for reading the slope. This includes many professional golfers, such as Ben Crenshaw, who had the least putts per round on the PGA Tour in 1982 and 1994, and the best putting average in 1987. Some of the literature endorses the method (Foston, 1992; Stockton and Barkow, 1996), suggesting that if used correctly it can be a valid method for determining the slope of the green. Others (Farns-

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worth, 1997; Pelz, 2000; Werner and Greig, 2000), however, reject the procedure, citing inherent inconsistencies that lead to large possibilities for error.

Foston (1992) described the plumb-bob method as follows. The golfer stands behind the ball straddling an imaginary line that bisects the hole, golf ball and stance of the golfer. The golfer then suspends the putter at arm's length in front of the face allowing gravity to pull the shaft into a true vertical alignment. The golfer should be positioned far enough behind the ball so that both the ball and hole can be sighted within the length of the putter shaft. While sighting only out of the dominant eye, the golfer aligns the bottom of the shaft with the centre of the golf ball. Although not stated by Foston (1992), an implicit assumption in the plumb-bob method is that the golfer stands perpendicular to the slope of the green beneath the feet (Pelz, 2000). According to the theory, if there is any slope in the green, then the top of the shaft will be observed to be on the high side of the hole. For easier reference in this paper, the distance between the hole and the upper shaft will be referred to as plumb-bob separation (Fig. 1).

A scientific evaluation of the plumb-bob method has not been documented in the peer-reviewed literature. The technique is often used without a sound understanding of how it works, or how certain variables affect its performance. Pelz (2000) has stated that a necessary condition for the plumb-bob method to correctly indicate slope is a consistently graded green from where the golfer is standing behind the ball through to the hole. However, this condition of a constant grade between the golfer and the hole is certainly not met for most putts on real greens.

The objectives of this study were twofold. The first objective was to evaluate the validity of the plumb-bob method under conditions of changing slope using plumb-bob separation as the dependent measure. Also, the plumb-bob method is susceptible to human error. The golfer must stand perpendicular to the slope while executing the technique. Therefore, a second objective was to measure the deviation from perpendicular of an individual while attempting to plumb-bob on a sloped surface.

## Methods

### Experiment A: examining plumb-bob separation

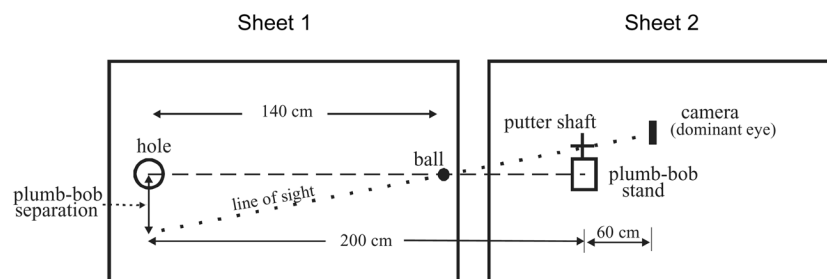
A controlled putting environment was constructed in a laboratory setting. The green was simulated using two sheets ( $1.2 \times 1.8$  m) of plywood surfaced with artificial turf (Fig. 1). A regulation size hole was constructed by painting a white circle 10.8 cm in diameter at one end of sheet 1. A golf ball was positioned on sheet 1, 1.40 m from the hole, on a line running from the centre of the hole to the midpoint of the base of a simulated golfer. To represent a golfer holding a putter, a putter shaft (head removed) was attached by a low friction ball-bearing joint to a metal stand. The ball-bearing joint allowed the putter shaft to attain true vertical alignment regardless of stand orientation. A digital camera, positioned behind the stand, recorded the visual perspective as seen by the golfer's dominant eye during the alignment of the shaft with the ball. The plumb-bob stand was positioned on sheet 2, 2 m away from the hole.

Six putting conditions were arranged to evaluate the effectiveness of the plumb-bob method for predicting the break of a putt under conditions of changing slope between the golfer and the hole (Table 1). Slope was measured as the angle between the surface of the sheet and the right horizontal.

A Nikon 995 digital camera with a Nikkor zoom lens recorded the images used in calculating plumb-bob separation for each of the six putting conditions.

**Table 1.** Controlled putting environment conditions: slope was measured from the right horizontal

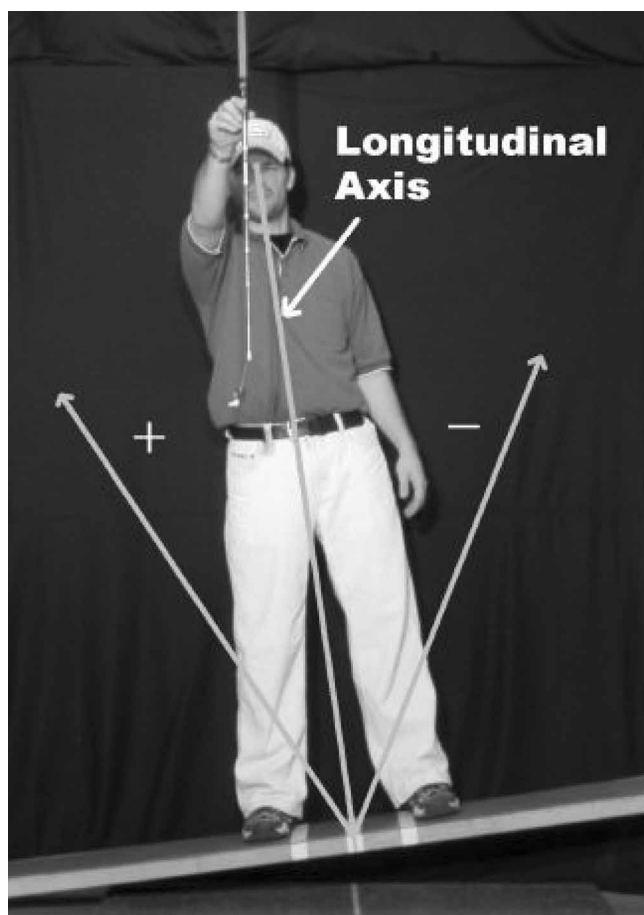
Condition	Slope of sheet 1	Slope of sheet 2
1	0°	0°
2	10°	0°
3	10°	10°
4	10°	8°
5	10°	12°
6	10°	-10°



**Fig. 1.** Controlled putting environment set-up as viewed from above. Both sheets are angled at 10° from the horizontal.

Plumb-bob separation was chosen as the dependent variable because it is the visual information the golfer uses to determine slope while plumb-bobbing. The camera remained a constant distance of 0.6 m behind the plumb-bob stand, so as to simulate the visual perspective of an actual golfer holding a putter at arm's length. The camera was repositioned laterally from the ball–hole line for each image to satisfy the provision that the camera lens, bottom of the putter shaft and ball were collinear. The camera moves off the ball–hole line just as the dominant eye of a plumb-bobbing golfer would move off the ball–hole line if he or she were standing perpendicular to a sloped surface (Fig. 2).

Plumb-bob separation was determined by analysing the digital image using the Microsoft Photo Editor software package. Photo Editor supplies the Cartesian coordinates for every pixel on the digital image, which allows distances to be calculated in pixel units. A scaling factor was determined for each digital image by calculating the distance of an object, in pixel units, whose real-world length was known. Plumb-bob



**Fig. 2.** A participant attempting to stand perpendicular to the slope of the platform. Positive and negative deviation angles are indicated.

separation was measured as the perpendicular distance from the ball–hole line, at the centre of the cup, to the shaft, as would be seen from the perspective of the golfer while employing the plumb-bob method (Appendix 1). The error associated with the plumb-bob separation calculation process was estimated by using the above method to predict the length of a stick whose real-world length was known (Appendix 1).

It should be noted that plumb-bob separation could have been defined in several arbitrary ways without affecting the results of the study. The relative plumb-bob separation distances across conditions would show the same trend providing the method was consistent for every measurement.

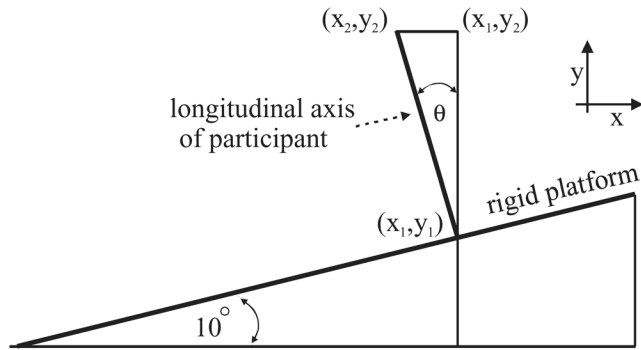
### **Experiment B: testing the ability to stand perpendicular to a slope**

Thirty-one individuals (10 females, 21 males) aged  $24.2 \pm 6.9$  years participated in the study, which was approved by the University of Saskatchewan Behavioural Research Ethics Board. Participants were instructed to stand on a tilted rigid platform such that the longitudinal axis of their body was perpendicular to the slope of its surface (Fig. 2). The rigid platform ( $0.3 \times 0.05 \times 2$  m) was angled at  $10^\circ$  from the right horizontal. The angle of the participant's longitudinal axis relative to a line perpendicular to the slope was the dependent variable. This angle will be referred to as the deviation angle.

While attempting to stand perpendicular to the tilted platform, participants performed the plumb-bob technique by holding a putter at arm's length and sighting out of their dominant eye so that the shaft bisected a camera lens 5 m away. Aligning the shaft of the putter with the camera lens represented aligning the shaft with the ball during an actual putt. Data were collected on a participant only after the researchers felt the participant clearly understood the objectives. Once positioned correctly on the platform, participants notified the researchers when they felt aligned at  $90^\circ$  to the slope and the putter shaft was bisecting the camera lens. Upon notification, a digital image of the participant was captured with the Nikon camera. Three trials were performed with a minimum of 3 min between trials. Participants were not given any verbal feedback regarding their performance.

It was not a requirement for participants to be active golfers. It was an assumption of the study that the average golfer would not possess any difference in the ability to stand perpendicular to a slope than an individual from the general population.

The digital images were analysed using the Microsoft Photo Editor software package. The digital camera was levelled with the floor of the laboratory before image capture. This allowed the angles in the digital image to coincide with the actual angles constructed in the



**Fig. 3.** Diagram of coordinates used to calculate deviation angle.

laboratory (Fig. 3). The longitudinal axis of the body was determined by constructing a line from a reflective marker that had been fastened between the participant's eyes, to a point on the platform at the centre of the participant's stance. The deviation angle of the longitudinal axis relative to a line perpendicular to the slope of the platform was then calculated for each trial (Appendix 2). The measurement error associated with this process was determined using methods suggested by Bland and Altman (1996) (Appendix 2).

## Results

For Experiment A, no plumb-bob separation existed with Condition 1 or 2, as the hanging putter shaft bisected the ball and hole (Fig. 4a,b). This implied that in both conditions the putt would follow a straight-line path to the hole even though there was a  $10^\circ$  change in the slope of the ball–hole surface between conditions. A plumb-bob separation of 0.3 m existed under Condition 3 when the plumb-bob stand, ball and hole were all angled at  $10^\circ$  from the right horizontal (Fig. 4c). This indicated that the putt would break to the left, as would be expected.

When the slope of sheet 2 was decreased to  $8^\circ$  in Condition 4, plumb-bob separation measured 0.2 m (Fig. 4d). Increasing the slope of sheet 2 to  $12^\circ$  in Condition 5 resulted in a plumb-bob separation of 0.4 m (Fig. 4e). More explicitly, given the above conditions, a  $\pm 2^\circ$  change in slope beneath the golfer would result in a  $\pm 0.1$  m change in intended target line even though the slope of the green between the ball and the hole remained the same.

A reversal of the slope of sheet 2 to  $-10^\circ$  resulted in a plumb-bob separation of  $-0.3$  m (Fig. 4f). This suggested the break of the putt had changed direction from the previous conditions despite an unchanged slope between the ball and hole. The scaling error ( $\pm 0.0005$  m) associated with using Photo Editor to determine plumb-bob separation was found to be

negligible in comparison to the precision required in the data (Appendix 1).

For Experiment B, the deviation angles, for each participant, were evenly distributed on either side of the line perpendicular to the slope, with the mean deviation angle ( $0.003^\circ \pm 2.05$ ) for all participants approaching zero degrees. The median for the absolute value of the deviation angles was  $1.5^\circ$ , indicating that half of the participants deviated from vertical by at least this magnitude. The error ( $\pm 0.02^\circ$ ) associated with the deviation angle measurement process was small, signifying that the assessment method used in this study was accurate (Appendix 2).

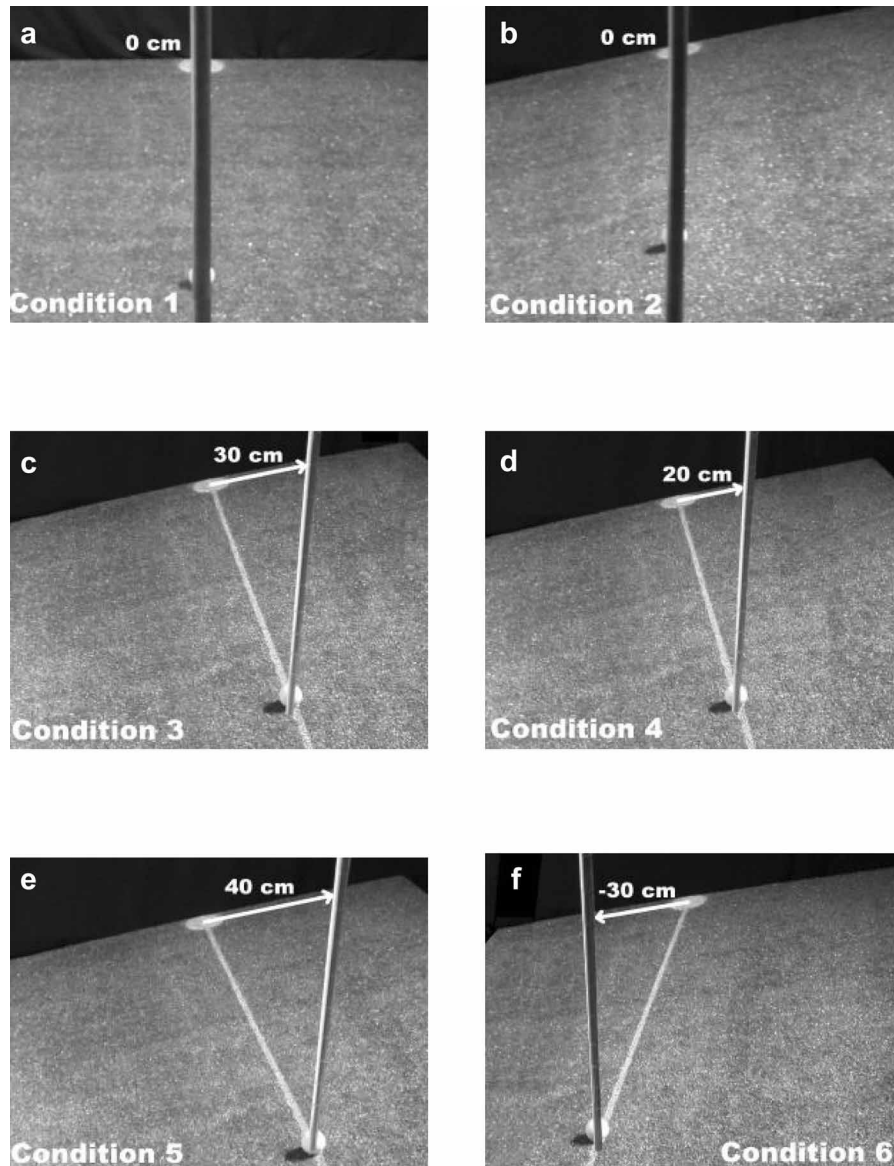
## Discussion

The results from this study indicate that the plumb-bob method is highly inconsistent. Altering the slope beneath the golfer's feet has a large influence on the visual perspective of the golfer. This is of vital importance, as the plumb-bob method relies entirely on the golfer's visual perspective. As suggested by the theory, when no slope existed (Condition 1), the upper shaft bisected the hole. However, when the surface beneath the simulated golfer remained horizontal, and the surface supporting the ball and hole was inclined to  $10^\circ$  (Condition 2), the upper shaft still bisected the hole. Complying with plumb-bob theory, this suggested that no slope existed and that the ball would follow a straight path to the hole. Obviously, this would not be the case, as a  $10^\circ$  slope would cause the putt to break considerably. The theory appeared to hold when the simulated golfer, ball and hole were all inclined at  $10^\circ$  (Condition 3) and the plumb-bob separation measured 0.3 m on the high (right) side of the hole. This plumb-bob separation suggested the putt would break to the left, as would be expected.

However, relatively small adjustments to the slope beneath the simulated golfer resulted in proportionately large changes in plumb-bob separation. An increase in the slope beneath the simulated golfer from  $10^\circ$  to  $12^\circ$  (Condition 4) resulted in a 0.1 m change in plumb-bob separation to 0.4 m, even though the slope of the ball–hole surface remained unchanged. Similarly, a change in slope beneath the simulated golfer from  $10^\circ$  to  $8^\circ$  (Condition 5) resulted in a  $-0.1$  m change in plumb-bob separation to 0.2 m.

A complete reversal of slope ( $-10^\circ$ ) beneath the simulated golfer relative to the slope of the ball–hole surface (Condition 6) clearly demonstrated the inherent flaw in the plumb-bob technique. According to the plumb-bob separation reading of  $-0.3$  m, the putt would break up, rather than down, the  $10^\circ$  slope of the ball–hole surface.





**Fig. 4.** Images of plumb-bob separation as viewed from the perspective of the participant for all six conditions of changing slope.

The results demonstrate that plumb-bob separation is directly dependent upon the slope beneath the golfer's feet. This is a fundamental problem, as the slope beneath the golfer's feet has no consequence on the break of the putt. Furthermore, Condition 2 clearly demonstrates that the slope of the green between the ball and the hole has no influence on the plumb-bob separation reading. This is an inherent flaw in the technique, as this is the only slope that will have an effect on the break of the putt.

The slope of the green beneath the golfer's feet affects plumb-bob separation because the head of a golfer standing perpendicular to a slope will shift off the ball-hole line. When the head is shifted off the ball-hole line, the gaze of the dominant eye intersects the ball-

hole line at the position of the ball and thus plumb-bob separation is visible. If the golfer does not stand perpendicular to the slope but rather parallel to gravity, then plumb-bob separation will always be zero.

Half of the participants had an average deviation angle of  $1.5^\circ$  or greater while plumb-bobbing on a slope. Participants were also equally likely to stand at an angle less than  $90^\circ$  as they were to stand at an angle greater than  $90^\circ$ . Furthermore, on average an individual participant's range of deviation angles across trials was  $1.5^\circ$ . This implies that participants were not systematic in their error in standing perpendicular to the slope. It is possible that the laboratory conditions would make it easier to stand at  $90^\circ$  due to the visual reference of a structured surrounding with straight walls and floors.

The visual references surrounding an actual green on a golf course are much more ambiguous, with rolling hills and no true vertical or horizontal reference such as a wall and a floor.

A  $1.5^\circ$  deviation of the golfer from standing perpendicular to the side slope will have the same effect on the plumb-bob separation reading as altering the slope beneath the golfer's feet by  $1.5^\circ$ . On a putt similar to that analysed in this paper, if the golfer were misaligned by  $1.5^\circ$ , the plumb-bob separation would be in error by approximately 0.08 m. More specifically, if the golfer were standing at  $91.5^\circ$  to the slope, then the plumb-bob separation would be 0.38 m, but if the golfer were standing at  $88.5^\circ$ , then the plumb-bob separation would be 0.22 m. This is a large amount of variability for the intended target line of a putt that is 1.4 m ( $\sim 4.5$  ft).

The plumb-bob method is also sensitive to several other factors. For a putt of any length, standing further behind the ball while plumb-bobbing will decrease plumb-bob separation, while standing closer to the ball will increase plumb-bob separation. The putter must also be orientated in a specific way to hang vertically due to the position of the centre of gravity of the head relative to the shaft. Finally, wind will also hamper a golfer's attempt to lightly dangle a putter shaft in a true vertical alignment.

Although the plumb-bob method is not a valid means for determining the break of a putt, there may be a limited value in vertically hanging a putter shaft to determine the slope of the green at the hole. If the putter can be held vertically, so that the hole is viewed directly behind the shaft, then the angle the plane of the hole makes with the vertical can be visually determined. However, this only provides information about the slope of the green immediately around the hole.

This study has tested the validity of the plumb-bob method based on the assumption that information derived from plumb-bob separation is the only benefit that the method provides to the golfer. However, it is possible that the plumb-bobbing technique might be used as part of a putting routine ritual that provides mental relaxation time for the player who perceives himself or herself under pressure to make the putt.

## Conclusions

The high sensitivity of the plumb-bob method to confounding factors means that it will never be a reliable method to determine the intended target line. If the slope of the green beneath the golfer is opposite in direction to the slope between the ball and the hole, the plumb-bob method will actually suggest that the ball will break up the slope of the hill. This clearly identifies an inherent flaw in the method. The plumb-bob method

can only be used to determine the direction of break in a putt when there is a constant slope between the golfer and hole and only if the golfer can stand exactly perpendicular to the slope of the green. Even if this ideal situation arose, it would be undetectable by the golfer. Hence, a golfer would not know when the plumb-bob method could be effectively employed. Under any set of circumstances, it is unlikely that the plumb-bob method could provide any reliable information regarding the break of a putt that could not be determined using a visual inspection of the green. The plumb-bob method is not a valid system for determining the break of a putt.

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## Appendix 1

Plumb-bob separation was the perpendicular distance from the ball–hole line at the centre of the cup to the

putter shaft (Fig. 4). The right angle was formed between the plumb-bob separation line and the ball-hole line. The Cartesian coordinates at each end of this line were determined in Photo Editor allowing the distance between the points to be calculated. A conversion factor was applied to determine plumb-bob separation in centimetres. The conversion factor was determined by calculating the ratio of the pixel unit length of an object to its real-world length.

To determine the error associated with calculating plumb-bob separation using Photo Editor, repeated measures were performed. Sixteen images of two sticks of known length were captured. The first stick was used to determine a scaling factor. The scaling factor was applied to predict the length of the second stick. The error for each image was measured as the absolute value of difference between the actual and predicted length of the second stick. The error estimate was determined by calculating the average error for all 16 images.

$$\text{Scaling Error} = \left[ \sum_{i=1}^{16} \text{ABS} (\text{Actual}_i - \text{Predicted}_i) \right] / 16$$

## Appendix 2

The deviation angle of a participant was measured as the angular displacement of the longitudinal axis from a line perpendicular to the slope of the platform (Fig. 3). The angle of the participant's longitudinal axis relative

to the vertical was calculated and the deviation angle was determined using this value. If the participant was standing perpendicular to the platform, then his or her angular displacement from the vertical would equal the angular displacement of the platform from the horizontal. Applying the Cartesian coordinates shown in Fig. 3, the following equation was used to determine the participant's angular displacement from the vertical:

$$\begin{aligned} \text{Subject angle from vertical} = \\ \text{Tan}^{-1}[(X_1 - X_2)/(Y_1 - Y_2)] \end{aligned}$$

The deviation angle was determined by calculating the difference between the angle of the platform from the horizontal and the angle of the participant from the vertical:

$$\text{Deviation angle} = \text{platform angle} - \text{subject angle}$$

The error associated with the deviation angle measurement process was assessed by performing repeated measures on each trial. The digital images for all 93 trials were evaluated on three separate occasions to determine the deviation angle of the participant in the image. A standard deviation was determined for the three calculations of the deviation angle for each image. The average of these standard deviations was used as an estimate of the measurement error associated with the process.