Journal of Biomechanics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Short communication

Is the instrumented-pointer method of calibrating anatomical landmarks in 3D motion analysis reliable?

Gwenllian Fflur Tawy*, Philip Rowe

The Department of Biomedical Engineering, University of Strathclyde, Wolfson Centre, 106 Rottenrow, Glasgow G4 0NW, United Kingdom

ARTICLE INFO

Article history:
Accepted 13 January 2017

Keywords:
Motion analysis
Anatomical landmark calibration
Subject calibration
Protocol reliability
instrumented-pointer

ABSTRACT

Instrumented-pointers are often used to calibrate anatomical landmarks in biomechanical analyses. However, little is known about the effect of altering the orientation of the pointer during calibration on the co-ordinates recorded. Incorrect positioning of a landmark influences the axes created, and thus the kinematic data recorded. This study aimed to investigate the reliability of the pointer method for anatomical calibration. Two points were drawn onto a fixed box to resemble knee joint epicondyles, then a custom-made pointer was used to define the positions of these landmarks in three-dimensions. Twenty different pointer-orientations were chosen, and the position of the pointer in each of these orientations was recorded 8 times. Euclidean distances between single points were calculated for both landmarks and compared statistically ($\alpha = 0.05$). Average Euclidean distances between all reconstructed points were 3.2 ± 1.4 mm (range: 0.3–7.1 mm) for one landmark and 3.3 ± 1.5 mm (range: 0.3–7.9mm) for the other. The *x*- and *y*-co-ordinates recorded differed statistically when the pointer was moved about the *X* and *Y* axes (anterior/posterior and superior/inferior to landmark) ($p < 0.05$). No statistical differences were found between co-ordinates recorded when the pointer was moved around the *Z* axes ($p > 0.05$). ICC values for all co-ordinates were excellent, highlighting the reliability of the method (ICC > 0.90). These results support this method of anatomical calibration; however, we recommend that pointers be consistently held in a neutral oriented position (where the handle is not anterior, posterior, superior or inferior to the landmark) during calibration, to reduce the likelihood of calibration errors.

1. Introduction

The use of skin-surface reflective markers to represent bony anatomical landmarks has been described as inaccurate, unreliable, and time consuming (Alexander and Andriacchi, 2001; Baker, 2006; Benedetti et al., 1998; Benoit et al., 2006; Sholukha et al., 2013).

One notable source of error is ‘soft tissue artefact’ (STA) (Baker, 2006; Leardini et al., 2005; Peters et al., 2010). STA is caused by the movement of a marker in relation to its underlying bony position (Cappozzo et al., 1996; Leardini et al., 2005). As the markers are often attached directly to skin, movement of the limb naturally causes the soft tissue (especially skin and fat) surrounding the bone to move (Baker, 2006; Cappozzo et al., 1996). Consequently, the marker attached to the skin may move to a position where it no longer truly represent the position of the bony anatomical landmark. This error can be amplified if the marker is placed on clothing; especially if the clothing is loose-fitting (Baker, 2006; Benedetti et al., 1998).

Placement errors translate to errors in kinematic and kinetic data as they affect the anatomical axes calculated from marker positions (Alexander and Andriacchi, 2001; Benoit et al., 2006; Della Croce et al., 2005).

An alternative method of calibration uses a pointer attached to a cluster of asymmetrical markers; an instrumented-pointer (Benedetti et al., 1998; Cappozzo et al., 1995). This method involves creating a local co-ordinate system from the markers on the pointer. This technique, known as C.A.S.T (calibrated anatomical systems technique), was introduced by Cappozzo and colleagues in 1995 (Cappozzo et al., 1995). The C.A.S.T method has been successful in orthopaedic surgery to calculate the mechanical axis of the femur (Belvedere et al., 2011; Smith et al., 2014). It is also commonly used in biomechanical research (Besier et al., 2003; Cappozzo et al., 1995; Fantozzi et al., 2003; Hagemeister et al., 2005; Lin et al., 2015, Remelius et al., 2014).

Implementing a C.A.S.T is believed to have advantages over individual reflective markers stuck onto skin or tight clothing, such as reduced soft tissue artefact (depending on the type of cluster

* Corresponding author.
E-mail addresses: gwenllian.tawy@gmail.com, gwenllian.tawy@strath.ac.uk (G.F. Tawy), philip.rowe@strath.ac.uk (P. Rowe).

http://dx.doi.org/10.1016/j.jbiomech.2017.01.019
0021-9290/

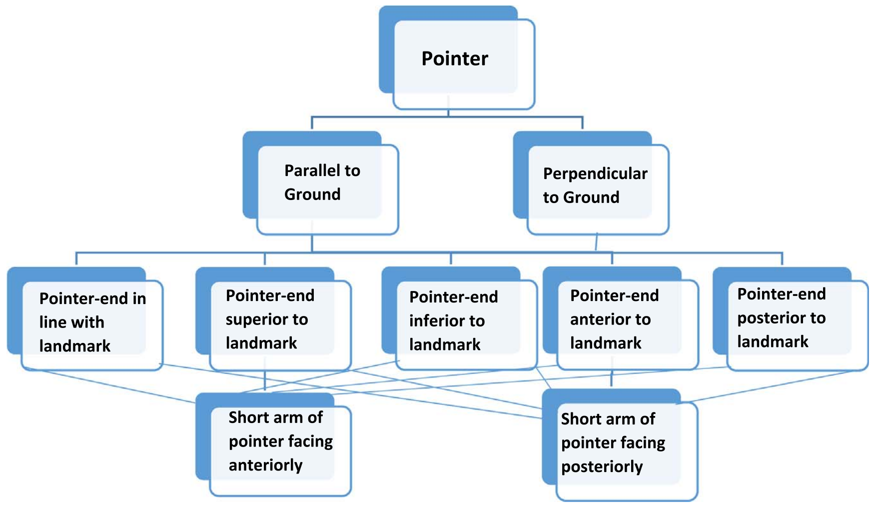

Fig. 1. Twenty combinations of pointer orientations used to investigate the effect of orientation on the landmark co-ordinates recorded.

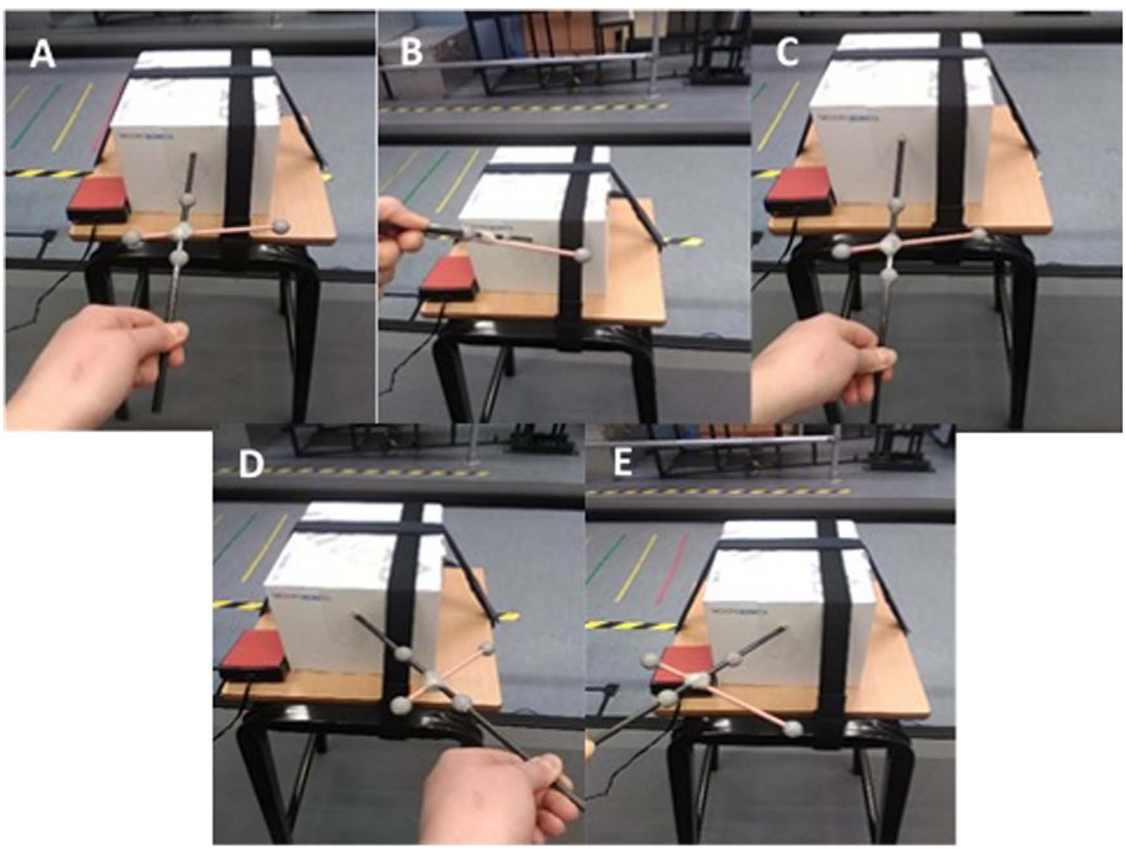

Fig. 2. Examples of 5 pointer orientations investigated in this study. In all cases the pointer is parallel to the ground. The pointer-end is A: in line with the landmark, B: superior to the landmark, C: inferior to the landmark, D: posterior to the landmark, E: anterior to the landmark.

used and activity carried out) (Besier et al., 2003). Preparation of an individual is also quicker and simpler (Benedetti et al., 1998).

Despite these benefits, it is currently unknown whether the way in which the pointer is held against a landmark (its orientation) during calibration affects the co-ordinates recorded. Thus, this investigation aimed to determine whether changing the orientation of the pointer significantly influences the 3D-position of two virtual landmarks used to create an axis. This investigation could therefore be used to identify pointer orientations which should be avoided during anatomical landmark calibration.

2. Methods

2.1. *Pointer development*

A pointer with 4 fixed retro-reflective markers was created then labelled as a cluster in Vicon Tracker software (ver.2.2, Vicon Motion Systems, Oxford). A local co-ordinate system was created within the pointer using this software. A temporary marker (without its base of support) was used to determine the position of the pointer tip relative to the fixed markers on the pointer. This information was used to calculate the position of a virtual point (representing the tip of the pointer) into the local co-ordinate system of the wand. Marker width was taken into consideration in these calculations.

Please cite this article as: Tawy, G.F., Rowe, P., Is the instrumented-pointer method of calibrating anatomical landmarks in 3D motion analysis reliable? Journal of Biomechanics (2017), http://dx.doi.org/10.1016/j.jbiomech.2017.01.019