Gait & Posture 32 (2010) 536–539

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

A novel device for improving marker placement accuracy

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ARTICLE INFO

Article history:
Received 23 March 2010
Received in revised form 2 June 2010
Accepted 20 July 2010

Keywords:
Foot
Kinematics
Repeatability
Instrumented gait analysis
Marker placement error

ABSTRACT

Background: Repeatability of marker placement has been acknowledged as a major factor affecting the reliability of multi-segment foot models. A novel device is proposed that is intended to reduce marker placement error and its effect on the reliability of inter-segmental foot kinematic data is investigated.
Method: The novel device was tested on eight healthy subjects. Landmarks were identified and indicated on the subject's foot at the start of testing using pen, and these points were used to guide placement. Markers were twice attached by a podiatrist using a standard approach, and twice by a researcher who used the novel device. Replacement accuracy and the kinematic reliability of the foot model data for both techniques were analysed.
Results: The mean marker placement variability using the novel device placement device was 1.1 mm (SD 0.28) compared to 1.4 mm (SD 0.23) when using standard placement techniques. Results suggest that these reductions in placement error tended to improve the overall reliability of the multi-segment data from the foot model.
Discussion: The novel device is a simple and inexpensive tool for improving the placement consistency of skin-mounted markers.

1. Introduction

The increasing popularity of gait analysis techniques based on motion tracking of skin-mounted reflective markers has brought with it an increase in the complexity of the biomechanical models available to represent the studied anatomy. This is perhaps most apparent in the case of the foot. Having traditionally had its intricate structural anatomy of 28 bones and numerous soft tissue elements represented as a single rigid vector, the past decade has seen a large number of multi-segment foot models appearing in the literature, each attempting to describe the role of the foot in gait more fully [1–4].

The increased complexity inherent in these multi-segment models has placed extra emphasis on the repeatability of marker placement for reliability studies, mainly due to the relatively small angular movements between many of the segments. It has been demonstrated that differences in marker placement can be a significant source of error in the kinematic measurement of the spine [5], the knee [6], and a recent assessment of 12 gait analysis laboratories identified marker placement variation between examiners as the principle cause of variability between centres [7]. In multi-segment foot models it has been suggested that discrepancies in marker placement is the primary cause of variability in repeatability studies [8].

A novel device is proposed that is intended to improve the repeatability of marker placement when a landmark has been indicated and the aim of this study was to assess its effectiveness when used in a multi-segment foot model based protocol. It was hypothesised that by using the novel device (a) variation in marker placement between trials would be reduced, and (b) this would translate to an improvement in the repeatability of the inter-segmental kinematic data.

2. Methods

2.1. Novel device

The device being investigated is intended to improve marker placement accuracy when landmarks have been identified and a target placement point has been marked on the skin at the start of the testing session.

Reflective markers (7 mm diameter with flat base (Qualysis AB, Gothenburg, Sweden)) had 1 mm diameter holes drilled centrally, perpendicular to their base. These markers were then threaded on to a 1 mm diameter flexible polystyrene wire (Relish Models, Selby, UK), which was bent over at each end to prevent the markers falling off (Fig. 1). The number of markers on the device can be varied according to the number required for the studied model.

When attaching the markers to the foot using the novel device, first a piece of transparent double sided tape was adhered over the pen marks on the subject's foot. Then, the end of the plastic wire was placed on the target mark and was used to guide the marker down to the skin where it adhered to the tape. The plastic wire was then removed and placed over the next target mark, with the process continuing until all the markers are attached. None of the subjects in this study reported any discomfort when the markers were attached using this

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doi:10.1016/j.gaitpost.2010.07.016

Overall reliability between tests was shown to be high. As expected, ICC values were high compared to those presented in previous studies [2,9] and this was thought to be a result of having a pen mark to guide the placement of the marker on the landmark. Previous studies have demonstrated low repeatability for movements occurring in the transverse plane [9]; with the use of the novel device improvements were noted in the transverse plane in three out of four segments. These findings add further confirmation to the evidence that marker placement error plays a key role in inter-trial repeatability. The most notable improvement in reliability was observed in the midfoot segment; this supports the use of the novel marker placement device as almost all tracking markers for this segment were replaced using the device.

There are limitations with this study and the device presented. Skin motion is, as always, a problem in studies such as this and it is suggested that this may be the reason that some markers showed more error than others when using the novel device. For this study the markers had the central hole drilled by hand and it was noted that a few had a slight but noticeable offset from the centre. Therefore, it would be expected that refinements to the manufacturing technique – perhaps the introduction of a jig to hold the marker while the hole is being drilled or the inclusion of the hole feature during the moulding of the marker itself – would result in further improvements to the accuracy of marker placement. The hole did not appear to have any noticeable effect on the motion capture system's ability to identify its position.

Although ideal for situations where markers are required to be removed and replaced in the same position during a single test session or at least testing that takes place during one day, longer term reliability trials that commonly require week long intervals still pose a problem due to the difficulties in having a mark indicating the landmark, made by pen or otherwise. It is suggested that this technique would be most applicable when comparisons are being made between barefoot and shod walking, where markers often have to be removed to allow the subject to put a shoe on and then replaced, often with some difficulty due to the limited space provided by holes cut into the shoe. The device could easy be used when performing motion analysis of other anatomy.

5. Conclusion

The novel device is a simple and inexpensive tool for improving the consistency of skin-mounted marker placement for intra-day studies where markers have to be removed and replaced. Results suggest that the reduction in the error related to marker placement tended to improve the overall quality of the CMCs reported between sets of trials, thus improving the between test repeatability of the multi-segment model.

Acknowledgements

This study was carried out as part of the A-FOOTPRINT project (www.afootprint.eu) and was funded by the European Commission Framework Seven Program (grant no. NMP2-SE-2009-228893). RS is funded by the Arthritis Research UK, grant reference number 18381.

Conflict of interest statement

None of the authors of this study have any financial or personal relationships with other people or organisations that could inappropriately influence (bias) their work.

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