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On the influence of soft tissue coverage in the determination of bone kinematics using skin markers

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Abstract

Accurate measurement of underlying bone positions is important for the understanding of normal movement and function, as well as for addressing clinical musculoskeletal or post-injury problems. Non-invasive measurement techniques are limited by the analysis technique and movement of peripheral soft tissues that can introduce significant measurement errors in reproducing the kinematics of the underlying bones when using external skin markers. Reflective markers, skeletally mounted to the right hind limb of three Merino-mix sheep were measured simultaneously with markers attached to the skin of each segment, during repetitions of gait trials. The movement of the skin markers relative to the underlying bone positions was then assessed using the Point Cluster Technique (PCT), raw averaging and the Optimal Common Shape Technique (OCST), a new approach presented in this manuscript.

Errors in the position of the proximal joint centre, predicted from the corresponding skin markers, were shown to be phasic and strongly associated with the amount soft tissue coverage, averaging 8.5 mm for the femur, 2.8 for the tibia and 2.0 for the metatarsus. Although the results show a better prediction of bone kinematics associated with the Optimal Common Shape Technique, these errors were large for all three assessment techniques and much greater than the differences between the various techniques. Whilst individual markers moved up to 4 mm from the optimal marker set configuration, average peak errors of up to 16, 5 and 3 mm (hip, knee and tibio-metatarsal joints respectively) were observed, suggesting that a large amount of kinematic noise is produced from the synchronous shifting of marker sets, potentially as a result of underlying muscle firing and the inertial effects of heel impact. Current techniques are therefore limited in their ability to determine the kinematics of underlying bones based on skin markers, particularly in segments with more pronounced soft tissue coverage.

Keywords: Skin markers; Bone positions; Musculoskeletal kinematics

Introduction

Knowledge regarding joint and segment kinematics is important for the understanding of normal movement and function, as well as for addressing clinical musculoskeletal or post-injury problems. Whilst skeletal motion may be measured using a variety of techniques such as percutaneous tracking markers combined with digital videofluroscopy [6,21] and bone pins [6,19], for example, the applicability of these methods is limited due to their invasive nature. Measurement of reflective markers attached to the skin using optical systems can provide knowledge of body segment positions and has particular applications in the determination of in vivo joint kinematics. As a direct result, assessment of pre- and post-operative knee kinematics for tibial translation [3], the

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minimal soft tissue coverage, could not be precisely reconstructed. This indicates that current analysis techniques have somewhat limited capabilities in improving the kinematics of underlying bones from skin marker measurements alone.

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