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QUANTIFICATION OF *IN VIVO* ACL ELONGATION DURING DYNAMIC JOINT MOVEMENTS: A NEW METHODOLOGY

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INTRODUCTION

Anterior cruciate ligament (ACL) injuries are common in movement tasks incorporating sudden changes in velocity, such as sidtestepping[1]. Current techniques adopted to quantify ACL strain are invasive as well as limited to slow, quasi-static movements[2,3]. This paper presents a method for non-invasive measurement of ACL elongation during dynamic movement tasks, validation of the method, and demonstrates its applicability to the analysis of sidestep movements.

METHODS

Combined high-speed video and magnetic resonance (MR) analysis techniques facilitated establishment of a relationship between 3D kinematics and anatomical ligament attachment locations. The location of one (reference marker) of a set of skin markers used during a stationary video recording was carefully maintained for ensuing MR scans, allowing ligament attachment sites to be defined in local segment coordinates (Fig. 1). Kinematic data generated from the same stationary reference frame were applied to the rigid segment model and the straight-line length between attachments was calculated at each time-step.

Model efficacy was evaluated by comparing predicted ACL lengths with directly measured lengths obtained from the MR scans over a series of static knee flexion angles (0°, 10°, 15°, 20° and 30°). ACL length changes during the stance phase of sidestepping were quantified for a single subject (n=10 trials) using the above technique, from which the patterns and magnitudes of ligament elongation were assessed. The sensitivity of these length measurements to marker movement and ACL attachment site errors was investigated. Random and prescribed perturbations were applied to the original data obtained for a single sidestepping trial, with 100 trials generated for simulated error. Perturbations of ±12mm and ±7mm were chosen to simulate maximum marker and insertion errors respectively. Comparisons could then be made between simulated and original output data.

RESULTS AND DISCUSSION

Predicted ligament lengths for static knee postures were consistent with measured values (±1mm) at all angles of flexion. Furthermore, length predictions as a function of flexion angle were similar to those reported previously[4]. ACL length patterns and magnitudes quantified for sidestepping demonstrated a distinctive elongation peak, occurring rapidly at 27.2 ± 4.7% of stance. This observation appears viable when the rigorous joint
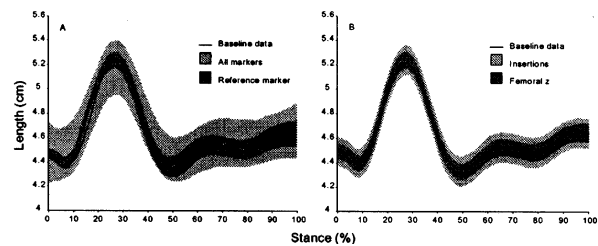
Fig. 2. Sensitivity of ACL length calculations during sidestepping to simulated external marker movements (A) and insertion location errors (B).

movements associated with sidestepping are considered. Direct comparison with similar investigations, however, was impossible. Data with simulated errors produced ligament length patterns similar to those quantified from original coordinate data (Fig. 2). While deviations in length magnitudes were evident for both the random and prescribed errors, peak elongation differences were small, especially for prescribed perturbations. Similar observations were made for ligament insertion location errors, with simulated random and prescribed (eg., femoral z) errors producing similar length patterns and only minor changes to peak elongation values when compared to baseline data.

CONCLUSION

The method presented appears to be a valuable tool for quantifying *in vivo* ACL length changes during a complex joint movement. Further, ligament length predictions do not appear to be overly sensitive to realistic marker and insertion errors that may occur. Ligament length measurements were extremely accurate for static knee angles but were unable to be validated for dynamic movements due to the inherent nature of the method. The adoption of a single point-to-point ligament length because of an inability to identify individual fibers in the MR scans is a potential methodological limitation when one considers the anatomical complexity of ligaments such as the ACL. Despite this fact, the technique has the potential to provide valuable information pertaining to *in vivo* ACL mechanics linked to complex joint movements and hence, insight into potential injury mechanisms.

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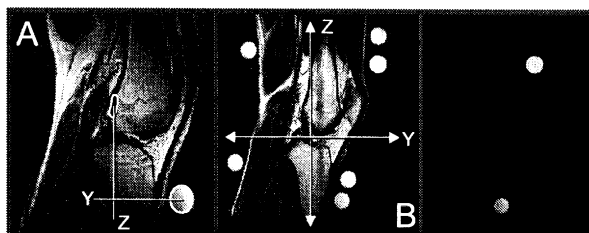4–BACH et al. (1997). *J Biomech 30*. 281–283.

Fig. 1. Sagittal slice used to calculate 3D attachment coordinates (A). 2D images (B) and (C) were also used for model validation at a number of static knee angles.