Motion Capture Assessment of Athletic Injury Risk

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Injury Risk in Elite Sport

- What are we trying to solve?

Stress

- 20%
- 30%
- 50%

Stress Response

- Biomechanical
- Wellbeing
- Psychology
- Fatigue
- Physiology
- Biochemical
Movement Assessment - Injury risk?

Movement assessment is an important part of the athlete screening process used to identify precursors to injury.

Both non-contact and contact injuries can originate from abnormal movement patterns.

The most common dysfunctional movement patterns for the lower body include excessive hip adduction, hip internal rotation and knee valgus/varus.
Limitations of current methods?

Despite progress in theoretical and practical movement assessment, there is a clear lack of definitive standardisation for assessing movement competence and injury risk. For example, movement screens are often only designed to test basic levels of function (or rule out pain/dysfunction).

Such tests often fail to offer the discriminant validity needed to identify subtle variations in movement parameters that precede injury in high level athletes.
Time

Specificity

Sensitivity

Score = 1
Errors = 3
Torso not parallel to tibia
Femur not below parallel
Knees not aligned over toes

Score = 1
Error = 1
Knees not aligned
Motion Capture - a potential solution?

The tangible value in screening lies in identifying *specific* root causes of maladapted movement patterns.

The proliferation of low-cost motion capture devices provides optimism for gathering and monitoring movement data objectively within sports settings.
Overhead Squat

The overhead squat is a multi-joint, multi-level movement that requires triple flexion-extension of the lower limbs, thoracic extension and core stability to perform successfully.

Overhead squat is commonly used to detect asymmetry and immobility during functional movement.
Assessment content?

- Knee valgus/varus at peak squat
- Trunk angle
- Ankle Dorsiflexion
- Knee flexion
Data Display

Sagittal Left

Frontal

Sagittal Right

Hip Angle

Knee Angle

Valgus/Varus Angle

Ankle Angle

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Limitations of Motion Capture?

‘Accuracy deficits larger than 5° indicate missing important kinematic information.’

.... 5° inaccuracies can mean

Varus is recorded as Valgus....
Marker-less
Marker-based
## Vicon V Kinect

<table>
<thead>
<tr>
<th>Vicon</th>
<th>Kinect</th>
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<tbody>
<tr>
<td>Marker-based motion capture.</td>
<td>Markerless motion capture.</td>
</tr>
<tr>
<td>Accepted reference standard lab system for measuring movement.</td>
<td>Requires correction algorithms to improve accuracy for measuring movement.</td>
</tr>
<tr>
<td>Uses global coordinate systems</td>
<td>Does not use a global coordinate system</td>
</tr>
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What has been done so far?
Calibration & correction for dynamic movements

Rationale:

During dynamic movement limb length discrepancy is evident between Vicon and Kinect for knee measurements.

Objectives:

To examine the impact of a calibration procedure to correct limb length on knee joint position during CMJ.

Outcomes:

For corrected data, the accuracy was improved to less than the intra-individual variation measured using VICON. The precision was < 3 degrees indicating excellent repeatability for this measurement in the athlete.

Table 1: CMJ post-jump knee flexion results for each of the three jumps.

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kinect</td>
<td>corrected</td>
</tr>
<tr>
<td>CMJ 1</td>
<td>65.2°</td>
<td>71.7°</td>
</tr>
<tr>
<td>CMJ 2</td>
<td>62.9°</td>
<td>68.9°</td>
</tr>
<tr>
<td>CMJ 3</td>
<td>64.4°</td>
<td>68.9°</td>
</tr>
<tr>
<td>demean ± std</td>
<td>64.4° ± 1.1°</td>
<td>69.8° ± 1.6°</td>
</tr>
<tr>
<td>p-value (v. Vicon)</td>
<td>0.039</td>
<td>0.157</td>
</tr>
</tbody>
</table>
Our research study:

Whole-body magnetic resonance imaging enables assessing spatial accuracy and precision of skeletal joint locations inferred from motion capture systems’

Objectives:

To assess the accuracy of Kinect skeleton and investigate potential improvements

Outcomes:

Large deviations were found between Kinect joint centre and MRI joint centre.
Correction for joints covered by large muscle mass is necessary. This could be implemented with a volumetric calibration scan using Kinect depth data.
Current Investigation?

**Methods:** A single-case comparison was completed between Vicon and Kinect.

**Processing & Analysis:** The raw data is processed to correct for limb length variations using the calibration information. A coordinate transformation was used to convert the joint localisation data from Kinect space to real world coordinate space. The precision and accuracy of measurements was assessed between both systems using Matlab.
Methods

A single-case comparison was completed between Vicon and Kinect.

A 6 camera Vicon system was positioned in a circular fashion around the athlete so that all body segments were visible enabling 3D reconstruction. Markers were placed on the athlete.

The markers tracked multiple body segments in the sagittal, coronal and transverse planes using the calibrated anatomical system technique. The movement was captured using a Vicon system (operating at 100fps).
Processing & Analysis

The raw data is processed to correct for limb length variations using the calibration information.

A coordinate transformation was used to convert the joint localisation data from Kinect space to real world coordinate space.

The precision and accuracy of measurements was assessed between both systems using Matlab.
## Results

<table>
<thead>
<tr>
<th>Angle at max squat</th>
<th>Accuracy (Vivon V Kinect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee Flexion [°]</td>
<td>0 (Left) 1 (Right)</td>
</tr>
<tr>
<td>Knee Valgus/Varus [°]</td>
<td>10 (Left) 4 (Right)</td>
</tr>
<tr>
<td>Ankle Dorsiflexion[°]</td>
<td>-6 (Left) -6 (Right)</td>
</tr>
<tr>
<td>Trunk Angle[°]</td>
<td>5 (Left) 4 (Right)</td>
</tr>
</tbody>
</table>
Implications?

Traditionally, motion capture systems are expensive, technically demanding and require a specialised laboratory setting with highly trained individuals.

The markerless motion capture approach offers sufficient precision to reliably measure biomechanical outputs from the overhead squat.

Further refinements to measurement procedures using depth corrections will be investigated to improve accuracy between the reference standard Vicon and Capture.
Future Directions

Larger cohort investigation (10 participant study completed)

- Future post-processing development (enhanced depth correction)

- Longitudinal study using EMR data (200 participant study in University of Oregon)
References


Giblin, S., Meldrum, D., McGroarty, M., O’Brien S., Wetterling, F. ‘Bone length calibration can significantly improve the measurement accuracy of knee flexion angle when using a marker-less system to capture the motion of countermovement jump’ IEEE International Conference on Biomedical and Health Informatics