THE REPEATABILITY OF UPPER LIMB MODELS: ANATOMICAL LANDMARK VS. CLUSTER/FUNCTIONAL MARKER SETS

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SUMMARY

Though there are multiple methods available to calculate an individual's upper limb kinematics during functional tasks, little research has directly compared the repeatability of available upper limb kinematic modelling methodologies. For this investigation, two direct kinematic modelling approaches were compared. 1) An anatomical modelling technique (ANAT), that uses specific anatomical landmarks to define joint centers and axes, and 2) a calibrated anatomical system technique (CAST), with a functional joint axis approach (FCAST). In random order, two testers fitted eight cricket bowlers with both ANAT and FCAST marker sets in two independent testing sessions. During each testing session, participants were instructed to bowl 12 trials of various delivery types. Elbow joint flexion-extension (F/E) angles at upper arm horizontal (UAH), ball release (BR) and extension range were compared within session to provide a between model analysis (ANAT vs. FCAST) and between sessions to provide a measure of model inter-tester repeatability. An interclass correlation coefficient showed medium to strong (> 0.7) inter-tester repeatability for both modelling methods in all three variables. A paired t-test showed that there were significant between-model differences in elbow F/E angle at UAH and BR. Although no significant differences in extension range were observed, differences in the discrete variables (UAH and BR) could lead to different clinical interpretations of the same data. A third method (inverse kinematics) is currently being investigated to determine if either the ANAT or FCAST methods are supported, however research investigating model accuracy to a 'gold standard' is needed before recommendations can be made.

INTRODUCTION

The upper limb is incredibly versatile, capable of moving effortlessly through large ranges of motion across multiple planes of movement. This is useful for overhead throwing/hitting sports, but cumbersome from a modelling perspective as it is difficult to accurately measure, quantify and define overhead kinematics [1,2]. In the context of cricket bowling, the ability to accurately estimate an athlete's upper limb kinematics (elbow flexion/extension joint angles) is critical when assessing bowler legality

allowable elbow extension threshold $< 15°$). The International Cricket Council currently support the use of three dimensional opto-reflective kinematic data capture with a direct kinematic (DK) modelling approach to assess a bowler's legality. A DK modelling approach uses external kinematic markers placed on the skin of an athlete to estimate joint centers, upper limb segments, joint axes of rotation and in turn joint angles (i.e. elbow F/E) [3,4]. Consequently, different marker set configurations in the DK modelling approach may have a significant effect on kinematic outputs, and the downstream ruling concerning a bowler's legality [5]. A number of marker set configurations exist [6-8], but there are two commonly used in the assessment of cricket bowler legality: an anatomical landmark based model and a cluster based model. For the purpose of this study there will be two investigations 1) the repeatability of both marker sets in calculating elbow F/E is to be investigated between-testers across two independent data collection sessions, and 2) the two methods will be directly compared to determine if differences exist in elbow F/E estimates.

METHODS

A dataset consisting of eight cricket bowlers of mixed characteristics (male/female; fast/spin bowler) and experience (local club, national or international) was collected. Each bowler completed two independent biomechanical testing sessions, with a different examiner for each. In each session the bowler had both an anatomical based marker set and a CAST [9] based marker set applied by the examiner.

Anatomical Model (ANAT): two kinematic markers were placed over the skin of specific anatomical landmarks either side of the shoulder, elbow and wrist to estimate the joint centers as well as the F/E axes of the elbow and wrist.

CAST/Functional model (FCAST): semi-rigid clusters of three kinematic markers were placed over the skin of the acromion, mid-humerus, distal posterior portion of the humerus and the distal posterior portion of the forearm. A regression equation was used to define the shoulder joint center [10]. A functional method was used to define the elbow joint center and the F/E axis [11]. Kinematic markers

placed on the skin of the radial and ulnar styloid processes were used to define wrist joint center and F/E axis.

Bowlers were required to bowl four deliveries/trials of three variations/types (n=12). For fast/medium paced bowlers (>100km/h) delivery variations included good length, yorker and bouncer/short balls. For spin bowlers variations included off-break, fast and doosra deliveries. All kinematic data was collected with a Vicon Mx system at 250 Hz.

Both the ANAT and FCAST models were used to calculate elbow F/E angles for all bowling deliveries (n = 192). Elbow F/E at UAH, and BR, as well as extension range (peak elbow flexion minus peak elbow extension) was calculated using both models.
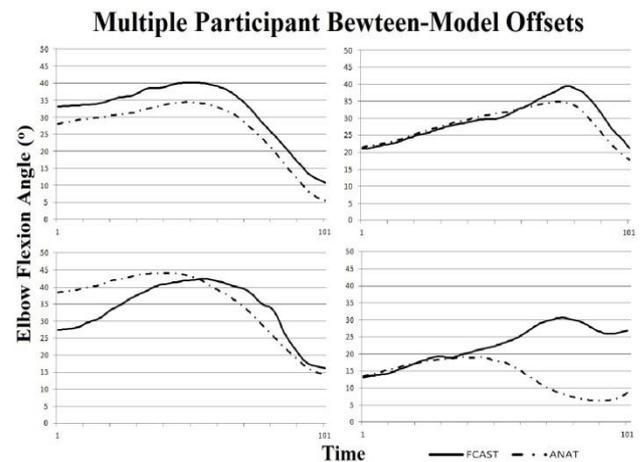
Inter-tester (between session) repeatability of the ANAT and FCAST was determined using an intra-class correlation (for each of the three elbow F/E variables). Cohen's [12] recommendations were used to interpret the correlation: weak < 0.2, moderate ≈ 0.5, strong > 0.8. Between-model comparisons were made using matched pairs t-tests.

RESULTS AND DISCUSSION

Both ANAT and FCAST models were shown to have moderate (BR) to strong (range, UAH) (intra-class correlation = 0.741 to 0.963) inter-tester repeatability (Figure 1). When compared, the models returned significantly different elbow F/E angles for UAH and BR (Figure 1). However, there were no significant differences when the elbow extension ranges were compared between models. The laws of cricket require elbow extension range to be less than 15° (excluding hyperextension) in order to be declared legal. Applied to this dataset, both models return the same ruling on legality for all participants. However if a future participant presented with hyperextension, the differences in discrete elbow F/E angles could result in the two models returning different legality rulings (Figure 2).

The largest limitation of this study is the lack of a gold standard measurement, which limits the conclusions that

Figure 1: The statistical analyses between-model and between-tester. The first panel gives the layout and each following panel represents a variable. T-value is the t-test result, Sig. is the significance value from that t-test, and ICC is intra-class correlation value.

can be drawn on which method provides more accurate elbow F/E angles. It is currently being investigated whether an inverse kinematic modelling approach produces results that support either ANAT or FCAST results. If inverse kinematic elbow F/E angles closely match either model it can be speculated that that model better represents elbow

Figure 2: The waveform differences between ANAT and FCAST. Shown is a representative delivery from four bowlers. "Time 1" = UAH, "Time 101" = BR.
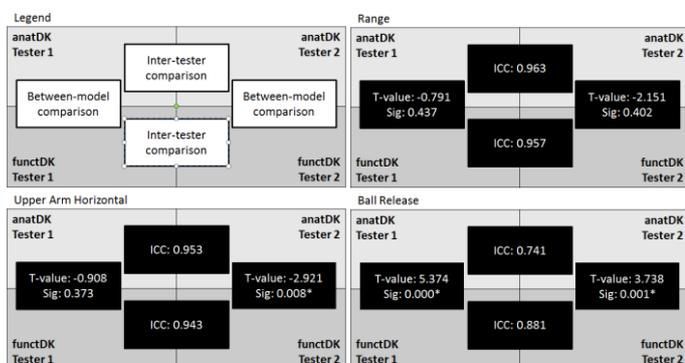
F/E during cricket bowling.

CONCLUSION

ANAT and FCAST kinematic models were both shown to be repeatable between two testers across two testing sessions. There were significant differences in the two method's discrete elbow F/E angles (UAH, BR), however absolute elbow extension ranges showed no such differences. A third method under investigation, inverse kinematics, may support either ANAT or FCAST, however the lack of a gold standard measurement prevents any conclusions being drawn on which presented method best represents true elbow F/E.

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