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# Elite Athlete Motor and Loading Actions on The Upper Limb in Baseball Pitching

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**Abstract**

In baseball, pitchers are the players that are most prone to injury. Most injuries occur at the elbow and shoulder of the throwing upper limb. It is widely accepted that understanding the loading in the joints during pitching is a key factor to prevent injuries. To deepen the understanding of the joint actions this study proposes to split the net joint actions into two part: the motor actions and the stability actions representing respectively the actions generating the joint motion and the actions maintaining the joint integrity. The actions represent the actions applied on the distal segment of the joint. Eight youth elite pitchers participated the study and performed 5 fastball pitches while equipped with skin markers. Three pitches per pitchers were used to compute the joint actions with an inverse dynamics method. The results indicate at the elbow a maximal elbow stability moment in adduction (52±5Nm) on the lower arm at maximal external rotation and a motor action in flexion (38±10Nm) during the acceleration phase. At maximal internal rotation the maximal stability shoulder loading occurred, with a pulling force of 520±80N, a downward force of -290±95N and a depression moment of 65±17Nm. The motor actions at the shoulder were mainly a forward force (93±46N) and an exorotation moment (24±12Nm) during the arm acceleration phase. This study suggest that the main action of the shoulder is to stabilise the joint, with a maximal load at maximal internal rotation, and that the main action at the elbow is avoiding hyperextension, with a critical phase at maximal external rotation. Further study is needed to link the stability actions to injury risk.


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*Keywords:* pitching, baseball, joint loading, joint moment, elbow, shoulder

## 1. Introduction

In baseball, pitchers are the players that are most prone to injury. Indeed, between 1989 and 1999, 48% of injured players in MLB were pitchers [1]. In those 48%, shoulder and elbow represented the most frequently injured joints with respectively 27.8% and 22% of the days spent injured. In a longitudinal study over 2 years with 298 youth pitchers between 8 and 12 years old, Lyman et al. [2] showed that 31.9% of the pitchers had shoulder pain (29% in superior aspect) and 25% had elbow pain (68% on the medial side). These injury rates are very high and occur at any age, thus efforts should be made to reduce those rates.

It is widely accepted [3] that understanding the loading occurring at the shoulder and elbow during pitching is a key factor to prevent injuries. Correlations between pitching technique and increased joint loading has been conducted [4] showing, as an example, that an open lead foot angle at foot contact and an excessive shoulder exo-rotation and horizontal adduction was linked to increased joint loading. However most studies consider only the net intersegmental actions [5–8] in the upper limb joints. The net actions represent the sum of every intersegmental actions (muscle actions, articular surface actions, ligaments actions…) at one joint.

For a better understanding of the joint actions, the net joint actions can be split up into two components, the motor actions and the stability actions. The motor actions are defined as the actions of the proximal segment generating the joint motion (rotation and translation) of the distal segment with respect to the proximal one. The stability actions are defined as the actions of the

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proximal segment on the distal segment maintaining the joint integrity. This study will describe the method used to obtain the motor and stability moment and will quantify these mechanical parameters to gain insight in the upper limb pitching mechanics.

## 2. Method

First, for the sake of clarity, the pitching motion phase and events are pictured in fig. 1.

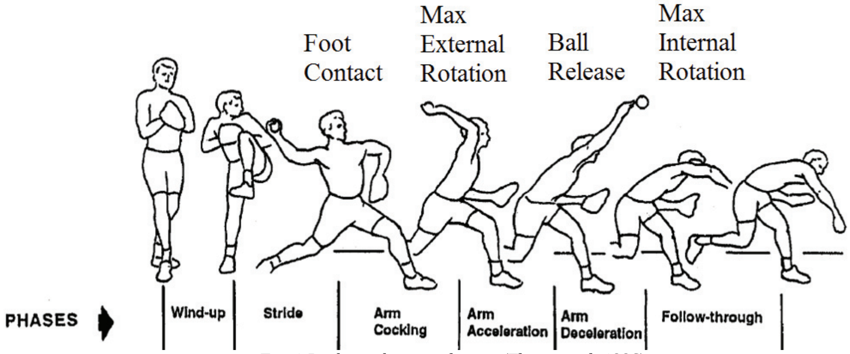


Fig. 1:Pitching phases and event (Fleisig et al. 1996)

### 2.1. Measurements

Eight right-handed pitchers from the Dutch AAA team (age: 16.1 ± 0.7years, size: 1.82 ± 0.8m, weight: 76.9 ± 8.1 kg) participated in this study. After having been informed of the aims and procedures of the experiment, all players and/or their legal representatives signed an informed consent form. The Faculty of Human Movement Sciences' local ethical committee approved this research projects.

The pitchers were equipped with skin markers on the full body. For the present study, only the upper limb (UL) and thorax markers where used. These markers include four markers on the thorax (Incisura Jugularis, Xiphoid Process, $7^{th}$ Cervical Vertebrae and $10^{th}$ Thoracic Vertebrae), and six on the throwing upper limb (Acromion, Medial and Lateral Humerus Epicondyle, Radial and Ulnar Styloid, Interphalangealis Proximal III). Each pitcher performed five fastball pitches from a pitching mound. Three pitches among the five performed were used in the study leading to a total of 24 pitches. The pitches were selected on the basis of the quality of the kinematic data. The motion of the markers was recorded by a 10-camera (T40S, 100Hz) VICON system.

### 2.2. Rigid-Body Model

A rigid-body model of the upper limb and thorax was used. The proposal from the ISB [9] was used for the definition of the local coordinate systems (LCS) and joint coordinate systems (JCS) (fig. 2). The glenohumeral (GH) joint position, the position of the segment centre of mass, the segment mass and the segment matrices of inertia were determined with regression equations [10]. The wrist, elbow and GH joints were modelled as spherical joints. To model the motion of the scapular girdle in a simplified way, the GH joint position with respect to the thorax was not constrained and thus, the shoulder joint also had three degrees of freedom in translation.

The ball was modelled as an homogeneous sphere of 145g and 36.8mm radius according to the Major League Baseball rules. The ball centre of mass was assumed to be overlapping with the hand centre of mass. The ball release (BR) was modelled by linearly decreasing the ball mass (from 100% to 0% of mass) during the 20ms before ball release. This time period is the mean value of the last half of the acceleration phase of the upper limb.

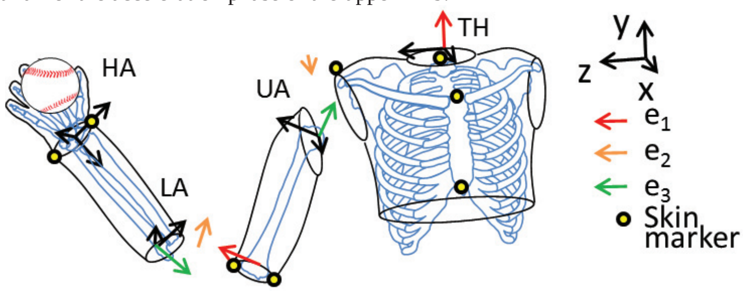


Fig. 2. LCS & JCS of the upper limb (HA: Hand, LA: Lower Arm, UA: Upper Arm, TH: Thorax), $e_1$, $e_2$ and $e_3$ represent the 3 axis of the corresponding JCS