Correlates With History of Injury in Youth and Adolescent Pitchers

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Purpose: To determine the factors within pitcher demographic characteristics, pitching history, and pitch kinematics, including velocity, that correlate with a history of pitching-related injury. **Methods:** Demographic and kinematic data were collected on healthy youth and adolescent pitchers aged 9 to 22 years in preseason training during a single preseason using dual orthogonal high-speed video analysis. Pitchers who threw sidearm and those who had transitioned to another position were excluded. Players were asked whether they had ever had a pitching-related shoulder or elbow injury. Multivariate logistic regression analysis was performed on those variables that correlated with a history of injury. **Results:** Four hundred twenty pitchers were included, of whom 31% had a history of a pitching-related injury. Participant height ($P = .009$, $R^2 = 0.023$), pitching for more than 1 team ($P = .019$, $R^2 = 0.018$), and pitch velocity ($P = .006$, $R^2 = 0.194$) served as independent correlates of injury status. A model constructed with these 3 variables could correctly predict 77% of injury histories. Within our cohort, the presence of a 10-inch increase in height was associated with an increase in a history of injury by 20% and a 10-mph increase in velocity was associated with an increase in the likelihood of a history of injury by 12%. Playing for more than 1 team increased the likelihood of a history of injury by 22%. **Conclusions:** Pitch velocity, pitcher height, and pitching for more than 1 team correlate with a history of shoulder and elbow injury. Current recommendations regarding breaking pitches may not prevent injury. Pitchers should be cautioned about pitching for more than 1 team. Taller pitchers and high-velocity pitchers may be at risk of injury.

Pitching is one of the fastest human motions, with arm internal rotation velocities exceeding 7,000°/s in professional pitchers.[1] These speeds place enormous torques on the shoulder and elbow, regularly exceeding 1,000 N in professional pitchers.[1] These forces reliably produce pain and injury within the shoulder and elbow.[2-4] Over the course of a single season, over half of all overhand baseball pitchers aged 9 to 14 years will have shoulder and elbow pain,[5,6] and the incidence of shoulder and elbow injury among pitchers is increasing.[3,7-9]

Previous studies at the American Sports Medicine Institute (ASMI) have identified pitch counts and pitching while fatigued; breaking pitches, specifically the curveball and the slider; and lack of rest, specifically pitching on multiple teams or for greater than 9 months per year, as predictors of shoulder and elbow pain in youth and adolescent pitchers.[5,6,10] These factors have since been codified into injury-prevention recommendations.[11,12] Although these studies also performed video pitching analysis on a subset of pitchers within their original cohorts, none of the kinematic factors measured as a portion of the analysis correlated with shoulder or elbow pain during the season.[5,6]

Laboratory pitching motion-analysis biomechanical data conflict with these findings. Several authors have shown no difference in shoulder and elbow torques between the fastball, the curveball, and the slider.[7,13] In

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addition, numerous studies have demonstrated that maximal shoulder external rotation, elbow flexion at ball release, initiation of trunk rotation after front-foot contact, shoulder abduction at foot strike, and elbow flexion at front-foot contact correlate with shoulder and elbow torques.[14-17] Shoulder and elbow torques predict elbow injury in overhand pitchers.[18] It thus follows that kinematic measurements, which can be reliably measured with video motion analysis,[5,6,15,18-24] should correlate with pain and injury in empirical studies. If kinematic factors that correlate with injury could be identified, then at-risk pitchers could potentially be identified with motion analysis and injuries could be prevented.

We performed a cross-sectional study to determine which demographic and kinematic variables correlate with pitching-related injury. The specific aim of this study was to determine the factors within pitcher demographic characteristics, pitching history, and pitch kinematics, including velocity, that correlate with a history of pitching-related injury. We hypothesized that velocity and kinematic variables such as elbow flexion angle at ball release and maximal shoulder external rotation would serve as the most important correlates of a history of pitcher injury.

Methods

This study was approved by our institutional review board (protocol No. 13090101). This is a single-episode cross-sectional study that was performed during a single preseason. All possible youth and adolescent overhand baseball pitchers from our metropolitan area were recruited and underwent a standardized evaluation. We included overhand pitchers aged 9 to 22 years currently in preseason training. We excluded pitchers aged younger than 9 years, sidearm or "submarine"-style pitchers because their kinematic data were believed to be too substantially altered at baseline, pitchers who had transitioned to another position and did not plan to pitch during their upcoming season, and pitchers unable to pitch because of pain at the time of evaluation. The age cutoff of 9 years was chosen to allow better comparison with past studies performed at ASMI and because USA Baseball recommendations were not available for pitchers aged younger than 9 years. Pitchers with a history of injury or current discomfort were included if they felt able to throw and were throwing in practice. No participants were aware of the study hypothesis. No a priori power analysis was performed, and as many players as possible were recruited.

Data Collection

Participants, and where possible their parents, completed a self-administered survey to obtain demographic information, pitching history, and injury history. All data were collected between November 26, 2013, and March 23, 2014. The data collection form is shown in Figure 1. Participants were asked if they had any current discomfort and if they had ever had a history of a pitching-related injury. All surveys were administered in paper format in a standardized fashion by 2 study authors (T.S., M.L.). Completed surveys were reviewed with all participants to ensure clarity and completeness. Participants used their own self-definition of the term "injury" based on their and their parents' interpretation of the data collection form (Fig 1). All injuries reported by the participants were included, and no objective follow-up was performed to determine injury data accuracy. Of note, data regarding pitch counts were collected but not used as a covariate in this study because participants were frequently unable to accurately recall the number of pitches thrown per game, week, season, and year; thus we considered it inappropriate to report these data in this single-episode study because of excessive recall bias. Participants then underwent a standardized physical examination. With the participant in the supine position with the shoulder at 0° of flexion and 90° of abduction and the elbow at 90° of flexion with the scapula stabilized anteriorly by one of the examiner's hands, the shoulder was brought into full passive external rotation and full passive internal rotation while a second examiner, viewing from the lateral aspect and using a goniometer, measured rotation. These measurements were then used to calculate total arc of rotation, glenohumeral internal rotation deficit, and glenohumeral external rotation excess.

Once survey data had been collected, all participants underwent video motion analysis similar to that previously described.[5,6,15,18-24] Participants were filmed at 210 Hz in high definition from both the frontal and lateral views while pitching from a regulation practice mound as appropriate for the pitchers' age. Pitch speed was simultaneously collected with a radar gun (JUGS Sports, Tualatin, OR). Participants were provided with as much time as necessary to perform their routine warm-up. Once participants felt ready to pitch at 100% velocity, they then pitched while being filmed. All pitches were fastballs pitched from the wind-up position. All pitches were thrown over a regulation distance for the pitchers' age at an appropriately positioned and sized strike-zone target. A single pitch that the participant believed was representative of the participant's best effort was recorded for each pitcher.

Video data were analyzed using a standardized protocol by 2 study authors (T.S., M.L.; Dartfish, Atlanta, GA). In all cases the dominant extremity was measured. In all cases the individuals performing the measurements were blinded to the participant's injury status. Those kinematic variables previously shown to correlate with kinetic variables were identified a priori and