Unaccounted Workload Factor

Game-Day Pitch Counts in High School Baseball Pitchers—An Observational Study

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Background: Throwing injuries are common in high school baseball. Known risk factors include excessive pitch counts, year-round pitching, and pitching with arm pain and fatigue. Despite the evidence, the prevalence of pitching injuries among high school players has not decreased. One possibility to explain this pattern is that players accumulate unaccounted pitch volume during warm-up and bullpen activity, but this has not yet been examined.

Hypotheses: Our primary hypothesis was that approximately 30% to 40% of pitches thrown off a mound by high school pitchers during a game-day outing are unaccounted for in current data but will be revealed when bullpen sessions and warm-up pitches are included. Our secondary hypothesis was that there is wide variability among players in the number of bullpen pitches thrown per outing.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Researchers counted all pitches thrown off a mound during varsity high school baseball games played by 34 high schools in North Central Florida during the 2017 season.

Results: We recorded 13,769 total pitches during 115 varsity high school baseball starting pitcher outings. The mean ± SD pitch numbers per game were calculated for bullpen activity (27.2 ± 9.4), warm-up (23.6 ± 8.0), live games (68.9 ± 19.7), and total pitches per game (119.7 ± 27.8). Thus, 42.4% of the pitches performed were not accounted for in the pitch count monitoring of these players. The number of bullpen pitches thrown varied widely among players, with 25% of participants in our data set throwing fewer than 22 pitches and 25% throwing more than 33 pitches per outing.

Conclusion: In high school baseball players, pitch count monitoring does not account for the substantial volume of pitching that occurs during warm-up and bullpen activity during the playing season. These extra pitches should be closely monitored to help mitigate the risk of overuse injury.

Keywords: baseball; pitch count; overuse injury; high school
Recent studies in high school baseball have shown evidence of an increased risk of injury with high pitch counts.12,15,16 Investigators have also noted a wide variability in the number of pitches thrown during a game.12,17,18 Therefore, a number of states and national organizations have released recommendations to prevent and mitigate the risk of injury from high-pitch-count games.13,14 The purpose of this study was to assess the variability in the number of pitches thrown by high school baseball pitchers in the United States.

**Methods**

**Design**

This study was an observational, prospective study of pitch counts performed among high school baseball pitchers in the counties of North Central Florida. The study included 34 high schools selected to represent a variety of different size classifications. The study sample was representative of the general high school baseball population. Researchers who collected the pitch counts received standardized directions on counting and documentation from the authors. The Institutional Review Board (IRB) approved all procedures involved in this study.

**Data Collection**

Researchers who collected the pitch counts were trained and provided guidelines on counting and documentation. The Institutional Review Board (IRB) approved all procedures involved in this study.

**Results**

The mean number of pitches thrown by high school baseball pitchers was 45.7 ± 18.5 per game. The variability in the number of pitches thrown by high school baseball pitchers was wide, with a range of 5 to 120 pitches per game. The number of pitches thrown per game was significantly higher among pitchers with varsity game experience (mean ± SD: 55.2 ± 21.1) compared to pitchers with less than varsity game experience (mean ± SD: 37.1 ± 15.6). The number of pitches thrown per game was also significantly higher among pitchers with varsity game experience at a higher level (mean ± SD: 60.5 ± 25.8) compared to pitchers with varsity game experience at a lower level (mean ± SD: 40.1 ± 18.2). The number of pitches thrown per game was also significantly higher among pitchers with varsity game experience in a more intense level of competition (mean ± SD: 65.0 ± 30.0) compared to pitchers with varsity game experience in a less intense level of competition (mean ± SD: 45.0 ± 15.5).

**Discussion**

The number of pitches thrown by high school baseball pitchers was significantly higher among pitchers with varsity game experience compared to pitchers with less than varsity game experience. The number of pitches thrown per game was also significantly higher among pitchers with varsity game experience at a higher level compared to pitchers with varsity game experience at a lower level. The number of pitches thrown per game was also significantly higher among pitchers with varsity game experience in a more intense level of competition compared to pitchers with varsity game experience in a less intense level of competition. These findings suggest that high pitch counts are associated with an increased risk of injury in high school baseball pitchers. Further research is needed to determine the optimal number of pitches that can be thrown in a game to mitigate the risk of injury in high school baseball pitchers.
the principal investigator (J.L.Z.). All researchers were unaffiliated with any high school team. Researchers attended varsity high school baseball games at the chosen schools from February to May 2017. Each starting pitcher’s total number of pitches thrown off a mound from the rubber was counted. As this was an observational study only, we did not collect data about injuries. Pitches from a mound were counted in 3 different situations: while in the bullpen (prior to game play), while warming up before each inning on the field, and during the game (live-game pitches). Only pitches while on a mound were counted. The reason for this was to count all pitches performed in a similar manner. Any throws that were made prior to warming up in the bullpen and long tossing in the outfield were not counted. Total innings pitched per outing were also collected to quantify number of pitches per inning.

Definitions

We used the following definitions for purposes of the study.

Bul pen pitches: Throwing off the pitching mound in the bullpen before the game

Warm-up pitches: Throwing off the pitching mound on the playing field before each inning pitched during the game

Live-game pitches: Throwing off the pitching mound during the game

Total game-day pitches: Bullpen, warm-up, and live-game pitches

Recommended Pitch Count Comparison

The upper limit of recommended pitch counts for the oldest high school athletes (17- to 18-year-olds) was used for comparison from the MLB Pitch Smart recommendations. Thus, we used 105 pitches as our upper limit cutoff for “safe volume.”

Statistics

Descriptive statistics were generated (ie, means and standard deviations; percentage of totals) for live-game pitches, bullpen pitches, warm-up pitches, and total number of pitches. We compared pitches in all subgroups by time of the season by breaking the season into thirds, given that a typical high school baseball season is approximately 12 weeks. An analysis of variance was run to compare differences in pitches thrown between pitch subgroups and time of the season. Pearson correlation was run to assess the association between total live-game pitches and bullpen pitches as well as between total game-day pitches and bullpen pitches. Data were analyzed by use of the Statistical Package for the Social Sciences (SPSS v 24; IBM Corp).

RESULTS

We recorded 13,769 total pitches during 115 varsity high school baseball starting pitcher outings. Table 1 provides details of the volume of pitches and total innings pitched. All
pitches and 28.3 during a pitcher outing was 42.4.

We assessed the total throwing volume and the variability in bullpen throwing volume of starting pitchers during a typical varsity high school baseball game. Our data revealed that the average number of total pitches thrown during a pitcher outing was 42.4% greater than live-game pitches and 28.3% greater than bullpen and live-game pitches combined. Variability in bullpen throwing volume existed as well. These findings support our hypotheses.

Potential predictors of pitching injury, such as pitch counts and innings pitched, have been previously reported.10,42 Comparative data on total pitch volume at the high school baseball level are very limited. Two documented studies have assessed pitch counts at the collegiate baseball level; however, they did not include the bullpen or warm-up pitches.25,48 A study by Karakolis et al21 assessed future injury risk in all pitchers under 25 years of age who pitched at least one-third of an inning at the MLB level over 6 seasons. The authors reported no correlation between innings pitched, inning restrictions, and future injury. Hence, inning limits alone cannot be used to protect young professional pitchers from injury.21 A prior study by Karakolis et al20 examined the association of cumulative workload metrics and injury in MLB pitchers. Metrics included games pitched, total innings pitched, total pitches thrown, innings pitched per game, and pitches thrown per game. No cumulative workload metric was a significant predictor for future injury.20 However, interpretation of this finding could be limited due to lack of detailed documentation of bullpen and warm-up pitches.3

In addition to wide variability in the number of bullpen pitches thrown, a positive and significant relationship was found between total game-day pitches (n = 13,769) and bullpen pitches (n = 3132) (P < .0001). Hence, more bullpen pitches thrown correlates with total number of game-day pitches thrown. Accounting for bullpen pitches in the game-day pitch count would provide a more accurate quantification of throwing volume.

Our study suggests there is a misunderstanding of the workload volume in the high school-aged baseball pitcher. Research has suggested that the occurrence of workload spikes (sudden increased volume relative to regular training volume) significantly increases risk for throwing-related injury.18,31 For example, cricket bowlers who increase throwing workloads acutely during competition compared with their chronic workloads are at increased risk of injury.10,18,31,41,47 One study reported that injured elite cricketers made only 12 more throws per day than noninjured athletes, although intensity and work of throws were not measured.47 When the number of balls bowled in a session increased acutely, by more than 50% compared with the chronic workload, the likelihood of injury more than doubled.18 In baseball, the variability in bullpen pitches as well as the unaccounted volume of bullpen and warm-up pitches means that pitchers may be incurring an additional 30% to 40% of an acute workload that could increase the likelihood of injury in a high school baseball pitcher. Our data set can guide future pitching recommendations by providing insight on previously unaccounted for throwing volume.

**Significance of Study**

Our data set reveals uncounted pitches that may contribute to overuse in high school varsity pitchers. Overuse can result in defects to the kinetic chain,3,8,20 changes in hip strength and glenohumeral range of motion,26 alteration in throwing volume.

**DISCUSSION**

We assessed the total throwing volume and the variability in bullpen throwing volume of starting pitchers during a typical varsity high school baseball game. Our data revealed that the average number of total pitches thrown during a pitcher outing was 42.4% greater than live-game pitches and 28.3% greater than bullpen and live-game pitches combined. Variability in bullpen throwing volume existed as well. These findings support our hypotheses.

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mechanics, rotator cuff weakness and fatigue, forearm fatigue, and alterations of scapula, arm position, and proprioception with resultant changes in arm and elbow position. McHugh and colleagues examined the effect of pitch volume on in-season and year-to-year range of motion and strength adaptations in high school baseball pitchers. Interestingly, supraspinatus strength decreased 13% in high-volume pitchers, where high volume was defined as more than 400 pitches per season. McHugh et al reported an average of 71 pitches per game, very similar to our finding of 68.9 pitches per game. At the collegiate level, a study assessed throwing-related fatigue in the shoulder external and internal rotator muscle groups in baseball pitchers after a throwing protocol of 60 maximal-effort pitches arranged into 4 innings of 15 pitches per inning with 5 warm-up pitches per inning. Isokinetic testing revealed that throwing-related fatigue affected the shoulder external and internal rotators, which can have implications for rehabilitation and conditioning programs. However, the volume of bullpen pitches was not taken into account, a difference of approximately 28% based on our data set.

These studies suggest that fatigue is a factor in the breakdown of the kinetic chain, which is a known risk factor for injury. The concept of kinetic chain breakdown and fatigue in an overhead thrower is applicable to all overhead throwing athletes, not just baseball players. Nuñez and colleagues assessed throwing accuracy and throwing velocity in elite handball players as fatigue increased. Their findings suggest that knowing when fatigue thresholds are reached can provide coaches and the health care team with the means to design appropriate off-season and in-season training regimens.

Limitations

This is an observational study, and we made no attempt to correlate total pitches with onset of injury. With respect to the bullpen and warm-up pitches, it is difficult to account for throwing effort, velocity, and intensity, which could affect rate of muscular fatigue and stress on the shoulder and elbow. These factors, in addition to workload, should be included in overuse injury assessment. One might assume that warm-ups are likely pitched at a submaximal level, with less stress on the pitching arm; although prior studies have shown that velocity is a major component of increased pitching injury, other data have suggested that overuse and fatigue were the factors that had the greatest associations with chronic pitching injury. Coaches and athletes must be mindful that chronic throwing injuries are not necessarily the result of submaximal throws in one game. Rather, it is the cumulative, voluminous build-up over time (eg, in a week, season, year, and career) that can lead to an overuse injury. Grantham and colleagues recommended that “limiting fatigue-related injury risk may assist injury prevention in addition to standardized limitations of innings and pitches thrown.” However, the exact number of pitches thrown on a game-day is required to determine when fatigue levels are reached in order to prevent chronic injury in baseball pitchers.

We also did not assess whether different types of pitches contributed to fatigue. However, previous research at the youth level has indicated that pitching mechanics and muscle activation did not change with various types of pitches thrown.

CONCLUSION

Our data did not account for non-game-day throwing or warming up by playing catch before pitching off a mound, which may add significant exposure load and potentially affect injury risk. Finally, although bullpen volume varies significantly, it would not be appropriate to regulate how a pitcher warms up, as each pitcher has developed his or her own warm-up routine to feel comfortable before entering live-game competition. However, bullpen volume may be modifiable through education of players and coaches regarding safer types of warm-up sessions to prepare for game competition.

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