THE JOURNAL OF SPORTS MEDICINE AND PHYSICAL FITNESS
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J Sports Med Phys Fitness 2015 Mar 18 [Epub ahead of print]

THE JOURNAL OF SPORTS MEDICINE AND PHYSICAL FITNESS

Rivista di Medicina, Traumatologia e Psicologia dello Sport
pISSN 0022-4707 - eISSN 1827-1928
Article type: Original Article

The online version of this article is located at http://www.minervamedica.it

Injuries to young professional baseball pitchers cannot be prevented solely by restricting number of innings pitched

Short title: Injuries to young professional pitchers

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Congresses: None
Funding: None
Conflicts of interest: N/A
Acknowledgements: N/A

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ABSTRACT

Aim: The Major League Baseball schedule is longer and more intensive than minor and

amateur leagues. As a result, major league pitchers endure a considerably higher cumulative workload throughout the season. Ligament, tendon, muscle, and bone tissues in young pitchers need time to adapt to the workload a major league pitcher must endure. To mitigate the risk of overuse injury, and allow time for tissue adaptation to occur, most teams limit the number of innings a young pitcher may throw. This study examined the relationship between innings pitched and future injury in young professional baseball pitchers. **Methods:** All pitchers under 25 years of age that pitched at least one third of an inning in Major League Baseball during the 2002-2007 seasons were included in this study. Total innings pitched were accumulated for each season across three levels of professional baseball (Major League Baseball, and two levels of Minor Leagues). Regression analyses were preformed comparing innings pitched during a single season and difference in innings pitched over consecutive seasons to future injury, as measured by time spent on the disabled list. **Results:** No significant correlation was found between innings pitched and future injury or consecutive season innings pitched difference and future injury. No significant differences were found when pitchers were split into groups based upon consecutive season innings pitched difference cutoffs. **Conclusions:** Based upon the evidence presented, strength and conditioning coaches, sports medicine specialists, and team trainers cannot rely solely on inning counts to accurately measure the tissue demands of professional baseball pitching. Therefore, inning limits alone cannot be used to protect young professional pitchers against the threat of injury.

Key Words: baseball; pitchers; young; innings; injury; prevention

INTRODUCTION

Although Major League Baseball (MLB) does not publically disclose medical documentation pertaining to player injuries, they do publically disclose all roster transactions, including disabled list assignements. The disabled list (DL) is a mechanism within the rules of MLB that allows a player to be removed from the 25 man active roster for a period of 15 days or more. Player assignements to the DL are made by team management in conjunction with the team's medical staff. In order for a player to be placed on the disabled list, the team physician must deem the player to be injured, and complete a Standard Form of Diagnosis (15). Therefore, publically available DL data is a suitable means to evaluate MLB injury prevelance and has been used previously in a number of scientific studies (2, 9, 13).

From 1989 – 1999 there was a 40% increase in the number of players on the DL in MLB, with 367 injuries in 1999 alone (2). Throughout the last decade, the incidence of players placed on the DL has continued to rise with 536 injuries in 2008 (13). For the seasons between 2002 and 2009, the injury rate for pitchers was over one in four (9). The injury rate for MLB pitchers is nothing short of unacceptable, and most MLB teams have begun to take precautions in an attempt to lower the pitcher injury rate. The effectiveness of these precautions is still unknown. The most popular strategies to reduce injury risk are based upon reducing a pitcher's workload. Workload is often measured as either pitches thrown or innings pitched. Single game pitch count limits and full season inning limits are often placed upon pitchers, particularly those pitchers 25 years of age or younger.

Pitching workload metrics have been studied previously by Karakolis et al. (9) to determine if there is a correlation between cumulative workload during a given season and future injury rates. No significant correlation was found. A limitation to the previous study conducted was: no effort was made to separate young and older pitcher groups. Workload limits are most often placed on young pitchers, not older pitchers. Perhaps this is because innings pitched is a better predictor of injury for young pitchers.

Youth pitchers' tissues have been shown to adapt to joint loading during pitching (6,7). Continued tissue adaptation, up until skeletal maturity, to repetitive mechanical loading can be a logical reason to limit consecutive season (year-to-year) increases in cumulative workload for a young pitcher. The theory being, young pitchers' tissues have not had sufficient time to fully adapt to the cumulative workload experienced during a full MLB season. Following this theory, this may result in young pitchers' tissues accumulating a greater level of cumulative damage during a single season, when compared to older pitchers with suitable tissue adaptation. Since the accumulated damage is in theory of a greater level in young pitchers, the offseason may not be a sufficient period of time for the required healing/tissue adaptation to occur for the young pitcher to be able to pitch a greater number of innings the following season without an increased risk of injury.

Through anecdotal evidence, Verducci (14) has postulated that large year-to-year workload increases, as measured by innings pitched, in young pitchers can be detrimental to both a pitcher's performance and health. Verducci has termed this phenomenon the 'Year-to-Year Effect', although it is more commonly referred to as the 'Verducci Effect'. Somewhat arbitrarily, Verducci has decided that a year-to-year increase of greater than 30 IP is

particularly detrimental for pitchers 25 years of age or younger. To our knowledge, a full scientific investigation into this phenomenon has not been completed.

The purpose of our study was: 1) to determine if a correlation between innings pitched and future injury exists in a sub-section of the MLB pitching population consisting of only young pitchers; and 2) to determine if the year-to-year difference in total number of innings pitched between two consecutive seasons can be used as a significant predictor of injury the following season.

The null hypotheses for our study were: 1) innings pitched and future injury will not be correlated; and 2) year-to-year innings pitched difference will not be a significant predictor of future injury.

MATERIALS AND METHODS

Our study was designed to determine if the total innings pitched during a single season or the difference in total innings pitched during consecutive seasons can be used to predict future injury in professional baseball pitchers under the age of 25. Single season total innings pitched (explanatory variable), difference in total innings pitched between consecutive seasons (explanatory variable), and injury days (dependent variable) were compiled using real-world data from outside a controlled laboratory setting. Regression analysis and one-way analysis of variance were used to determine if there was an association between the explanatory variables and the dependent variable.

Subjects

Our study was completed using only publicly available data on professional athletes from outside a laboratory setting, not gathered for the purposes of scientific research, therefore Institutional Review Board permission was not required.

Inclusion in our study was restricted to pitchers under 25 years of age as of the first of January for the given MLB season (year N) during the span of the study. The pitcher must have pitched at least one third of an inning in MLB during year N, and on a major league roster for at least part of the following season (year N+1), to be included in the study. MLB level pitchers under 25 years of age for multiple seasons during the study were treated independently for each season under 25. Seven hundred sixty one independent pitcher-seasons during 2002 to 2007 were included in the study.

Data Collection

Major league innings pitched for individual pitchers in Major League Baseball were obtained from a baseball statistics website (fangraphs.com (3)) for the 2001-2007 seasons. Minor league innings pitched for the same group of pitchers during the same time period were obtained from two different baseball statistics websites (sabr.org (11) for 2001-2004; milb.com (12) for 2005-2007) for the following leagues: International League (AAA), Pacific Coast League (AAA), Eastern League (AA), Southern League (AA), and Texas League (AA). Unfortunately, innings pitched data was not available for the 2004 season of the Southern and Texas Leagues. Injury data was obtained from a website (driveline.com (8)) tracking all transactions involving the MLB disabled list (DL) for the 2003-2008 seasons. The injury data has been previously verified (9).

Total innings pitched for included pitchers was a summation of all innings pitched in each of the included leagues during that year. Injury days were reported as a total number of days spent on the MLB DL during the year N+1 season.

Statistical Analyses

A regression analysis was performed using the ordinary least squares method, where the explanatory variable was total innings pitched during year N and the dependent variable was number of days spent on the DL during year N+1. An additional regression analysis was performed using the difference in total innings pitched between consecutive seasons (year N and year N-1) as the explanatory variable and number of days spent on the DL during year N+1 as the dependent variable. A criteria of $p < 0.05$ was used to reject the null hypothesis.

Analysis beyond the linear regression was performed to determine if an optimal year-to-year innings pitched increase could be determined. Year-to-year innings pitched differences less than minus 30 IP were not included in this analysis. Innings pitched difference cutoffs were selected at: 10, 20, 30, 40, and 50 innings pitched increases. For each cutoff level, all pitcher-seasons with innings pitched differences less than the cutoff were placed in a 'less than' group, and all pitcher seasons with innings pitched differences greater than the cutoff were placed in a 'greater than' group. For each group, injury rate was reported as the percentage of pitchers in the group to be placed on the DL for any period during the following season, and injury days were reported as the average number of days on the DL for all members in the group. One-way analyses of variance were performed for each cutoff, to determine if the average number of DL days for the 'less than' and 'greater than' groups were significantly different. A criteria of $p<0.05$ was used to reject the null hypothesis.

RESULTS

The results of our study showed that for young pitchers total number of innings pitched in a season was not a significant predictor of injury the following season (Figure 1). The difference in number of innings pitched between two consecutive seasons also was not a significant predictor of injury (Figure 2).

Further investigation of year-to-year innings pitched differences (Figure 3) revealed for a cutoff of 10 IP year-to-year increase, injury rate was markedly less for the pitchers in the less than cutoff group compared to the greater than cutoff group (23.21% and 26.29% respectively). For the 30 IP increase cutoff, the injury rate was nearly identical for both groups (25.40% for the less than group, and 25.00% for the greater than group). The largest disparity in injury rate was found in the 40 IP increase cutoff, where the less than group had a remarkably higher injury rate than the greater than group (26.54% and 23.44% respectively).

With respect to average number of days spent on the DL for each group (Table 1), no statistically significant differences were found. However, similar trends as reported in injury rate were present. For the 10 IP increase cutoff, the average number of days on the DL for the less than cutoff group was less than the average number of days on the DL for the greater than group (14.76 days and 17.79 days respectively). Average time spent on the DL for the 30 IP less than group was similar to that of the greater than group (16.27 days and 17.15 days respectively). The greatest difference was again noticed for the 40 IP increase cutoff (18.54 days for the less than group and 14.28 days for the greater than group).

DISCUSSION

In this study, evidence is presented to show that neither number of innings pitched in a given season nor the year-to-year change in number of innings pitched are significant predictors of future injury. Therefore, neither limiting innings pitched during a season nor limiting year-to-year innings increases are likely effective in reducing the risk of future injury. One possible reason for the ineffectiveness of limiting innings pitched is: innings pitched is not an accurate surrogate measure for cumulative workload.

In the most general (Newtonian) sense, work is defined as either a force crossed by a linear displacement or a torque crossed by an angular displacement (5). In theory, for a pitcher work can be calculated through a biomechanical assessment of a pitchers delivery using kinematics (joint angles and displacements) and kinetics (joint reaction torques and forces). To the author's knowledge, this has never been done. However, through biomechanical assessment of collegiate level pitchers, Fleisig and colleagues (4) were able to show considerable variability in many joint kinematics and reaction kinetics during pitching. Variability was shown between types of pitches thrown, and between the pitchers that threw the pitches. From these findings, it is not a stretch to assume that considerable variability also exists in work done for each pitch.

Injury is a result of workload exceeding the capacity of the body tissues (10). Therefore, two possible explanations exist as to why innings pitched was not a statistically significant predictor of injury. 1) The tissue capacity for each pitcher may have been too variable that even though workload was known, injury still could not be predicted. 2) The cumulative

work done by two different pitchers throwing the same number of innings was too variable, and therefore true workload was not known. Given that the number of pitches thrown per inning is variable, the distribution of pitch types thrown in a given inning is variable, and the afore mentioned variability between individual pitchers mechanics, it is not difficult to understand why simply counting total number of innings pitched is not an accurate measure of cumulative workload.

Alternatively, total pitches thrown may be a better predictor of injury since counting pitches thrown instead of innings pitched eliminates one level of variability. Bradbury and Foreman (1) were able to show that number of pitches thrown in previous games were a small but statistically significant predictor of future performance (as measured by ERA). Although Bradbury and Foreman discussed injury risk, none of the criterion measures for the study were injury metrics. Karakolis et al. (9) showed that for the entire major league pitching population, pitches thrown were not a significant predictor of future injury, however, their study failed to examine a young pitcher only sub-section of the population.

As in any scientific study, some limitations in the methodology used for this study exist. First, innings pitched data from the 2004 Southern and Texas Leagues was not available. Since the amount of data not available was relatively small, this limitation is not believed to have a significant affect on the reported results. Second, pitchers that had a year-to-year decrease of more than 30 IP were not included in the optimal year-to-year innings pitched differences cutoff assessment. This additional exclusion criterion was added because it was believed that a precipitous drop off in year-to-year innings pitched, though uncommon, might have been a result of an injury not reflected in our DL data or a performance drop off

not accounted for in this study. Third, there is a concern that the excretion level may be different between Minor and Major Leagues causing differences in tissue loading between the two. This is unlikely, since young Minor League pitchers are trying to prove themselves worthy of a spot on a Major League roster and will be fully exerting themselves for this reason. Finally, total number of pitches thrown was not included in this study because the data was not available.

In future, a study may be conducted to determine if counting total number of pitchers thrown during a season is a better predictor of future injury. Although this future study may be worthwhile, it is not likely to yield the desired predictive relationship. It is more likely that in order to better prevent injury in professional baseball pitchers, biomechanical assessments are required for each individual pitcher, so that individual pitcher workload can be assessed and limited for each player. These biomechanical assessments may still not yield the desired predictive abilities, and it may be found that strength and conditioning programs developed to build tissue capacity are the most effective means of preventing injury.

CONCLUSIONS

Based upon the evidence presented, strength and conditioning coaches, sports medicine specialists, and team trainers cannot rely solely on inning counts to accurately measure the tissue demands of professional baseball pitching. Therefore, inning limits alone cannot be used to protect young professional pitchers against the threat of injury. Although gradually increasing the total number of innings pitched per season over the first few years of a young Major League Baseball pitcher's career sounds like a good idea in theory, there does not appear to be any evidence to support this strategy. Alternatively, coaches and trainers should seek to develop strength and conditioning programs that build soft tissue capacity during the offseason and promote recovery within season. Young (not skeletally mature) pitchers have a greater ability for tissue adaptation than their older counterparts. Therefore, training programs should be specifically targeted for young pitchers, since that is the sub-population that can gain the most benefit from this alternative strategy.

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Figure 1 - Number of days spent on the disabled list (DL) during year N+1 versus total innings pitched during year N. Each point in the scatter plot represents a given player in a single season during the time span of the study. The trend line shown was determined using an ordinary least squares approach, with the resultant regression equation shown in the top right. R^2 is the coefficient of determination.

Figure 2 - Number of days spent on the disabled list (DL) during year N+1 versus the difference in number of innings pitched between year N and year N-1. The trend line shown was determined using an ordinary least squares approach, with the resultant regression equation shown in the top right. R^2 is the coefficient of determination.

Figure 3 – Injury rate for pitchers in the less than and greater than cutoff groups for the five innings pitched difference cutoffs. Injury rate is reported as the percentage of pitchers in the each cutoff group, which spent time on the disabled list during the year N+1 season. The innings pitched difference is the difference in number of innings pitched between year N and year N-1

Table 1

Cutoff (IP)	Injury Days						
	Less than cutoff			Greater than cutoff			p value
	n	Average	SD	n	Average	SD	
10	224	14.76	34.43	407	17.79	38.05	0.310
20	274	15.27	34.82	357	17.82	38.27	0.382
30	311	16.27	36.52	320	17.15	37.13	0.765
40	358	18.54	39.82	273	14.32	32.36	0.142
50	388	18.24	39.38	243	14.28	32.21	0.169