

# Pitching Behaviors in Youth Baseball

## Comparison With the Pitch Smart Guidelines

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**Background:** The Pitch Smart guidelines aim to limit youth baseball pitching behaviors associated with overuse injuries. Despite many youth baseball leagues being compliant with the guidelines, during tournaments, pitch count restrictions or guidelines are often not followed.

**Purpose:** To perform a quantitative analysis of pitch counts in youth baseball players and evaluate compliance with regard to the Pitch Smart guidelines in the tournament setting.

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

**Methods:** Included in the analysis were 100 youth baseball teams that competed in the 8-and-under to 14-and-under age divisions during the 2019 tournament season. Pitching data were compared with the Pitch Smart guidelines. Violations were identified as (1) exceeding maximum daily pitch count, (2) inadequate rest between pitching events, and (3) pitching more than 1 event on the same day. Pitcher and game factors were analyzed for possible relationships to guideline violations using mixed-effects negative binomial regression models, with comparisons of violations using rate ratios (RRs).

**Results:** Analysis included 1046 pitchers and 2439 games. There were 1866 total Pitch Smart guideline violations, with 48.6% of pitchers having at least 1 violation. Inadequate rest was the most common reason for violation, with noncompliance occurring in 43.3% of pitchers. The highest rate of any violation (0.32 per appearance) occurred in the 8-and-under age division. High-volume pitchers had increased violation rates in each category compared with low-volume pitchers ( $P < .001$ ). Violation rates were increased more than twice the rate when pitchers participated in  $\geq 5$  consecutive games without a rest day when compared with a single game (RR, 2.48;  $P < .001$ ).

**Conclusion:** Noncompliance with Pitch Smart guidelines in tournament settings occurred in more than 90% of teams and almost half of all pitchers. Factors associated with noncompliance included younger pitcher age, high-volume pitching, and pitching in multiple consecutive games. Education of tournament directors, coaches, parents, and athletes regarding pitching guidelines is warranted in order to limit the risk of injury.

**Keywords:** overuse injury; youth baseball; pitch count; Pitch Smart guidelines

Baseball is one of the most popular sports for youth in the United States, with an estimated 8.6 million children ages 6 to 17 years participating annually in organized and recreation baseball.<sup>15</sup> While participation in baseball is beneficial for young athletes, a primary concern is the development of overuse injuries. Overuse injuries have been linked to certain pitching behaviors, such as high pitch counts, inadequate rest, and participation in year-round throwing without an offseason.<sup>6,9-12,17</sup>

The Pitch Smart guidelines (PSG) were developed with collaboration between Major League Baseball (MLB) and the USA Baseball Medical Safety and Advisory Committee

to foster healthy player development and avoid overuse injuries.<sup>13</sup> These guidelines provide recommendations for youth pitchers based on age and include daily pitch count limits and required rest between pitching events.<sup>13</sup> Additional recommendations include avoiding pitching multiple games on the same day, pitching more than 8 months per year, playing catcher and pitcher in the same game, and throwing breaking balls before age 13 years.<sup>13</sup>

There are more than 30 youth baseball organizations that follow the PSG, including Little League Baseball, Cal Ripken Baseball, American Legion, and PONY Baseball.<sup>13</sup> Despite being widely adopted in many youth baseball organizations, there remain baseball events in which PSG are not followed.<sup>13</sup> In baseball events such as tournaments and showcases, pitching guidelines frequently are not enforced

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and, as a result, have been shown to be associated with baseball-related injuries.<sup>3,11</sup> Moreover, despite the establishment of the PSG in 2014, a knowledge gap among athletes, parents, and coaches still exists.<sup>2,4,8,18</sup> The prevalence of PSG noncompliance in youth baseball settings without pitch count limits has yet to be established.

The purpose of this study was to evaluate pitch counts in youth baseball players, compare the frequency with which the PSG recommendations were violated, and identify associated factors leading to violations. We hypothesized that half of participating youth baseball teams would be non-compliant with the PSG recommendations.

## METHODS

The study protocol was considered exempt from institutional review board approval. Included were 100 youth baseball teams in the state of Wisconsin participating in the age divisions 8-and-under (8U) through 14-and-under (14U) during the summer 2019 youth baseball season. Teams participating in tournaments, defined as  $\geq 2$  consecutive games played on the same day or on 2 consecutive days, were included. Teams participating in fewer than 5 games total were not included in the study. Teams were identified using the GameChanger platform,<sup>7</sup> an internet-based app for electronic mobile devices. The application allows for real-time game recording by coaches or other game observers and is used for scorekeeping, advanced statistics, and live game updates.<sup>7</sup> Cumulative season statistics were available upon completion of the season.

Team data recorded for each game included the date of the contest, outcome (win or loss), runs scored, and runs scored against. Pitch counts for all games were obtained for each pitcher. The published PSG (Table 1) were used to identify pitchers who exceeded maximum pitch count in a single game, had inadequate rest between games, or pitched in multiple games during the same day.<sup>13</sup> Player age was assumed to be the same age as the age division in which the team competed. The rate of PSG violation was determined for each age division. Factors assessed for a relationship with PSG violations included pitcher age, consecutive games played, game density, pitcher total pitches, rest days between games, pitch count category, relative pitcher volume, team runs scored, and team runs scored against.

Season data were calculated for each pitcher and used to determine pitcher volume relative to the entire team, which

TABLE 1  
Pitch Smart Guidelines for Pitch Counts<sup>13a</sup>

Age, y	Daily Maximum Pitches	Required Rest According to No. of Pitches				
		0 Days	1 Day	2 Days	3 Days	4 Days
7-8	50	1-20	21-35	36-50	NA	NA
9-10	75	1-20	21-35	36-50	51-65	>65
11-12	85	1-20	21-35	36-50	51-65	>65
13-14	95	1-20	21-35	36-50	51-65	>65
15-16	95	1-30	31-45	46-60	61-75	>76
17-18	105	1-30	31-45	46-60	61-80	>81

<sup>a</sup>NA, not applicable.

included pitcher game appearances (pitcher appeared in <25%, 25%-50%, or >50% of team games) and pitches thrown (pitcher threw <10%, 10%-20%, or >20% of entire team pitches). In addition, the frequency of pitch counts in each category of PSG was calculated. Volume stratification also occurred by separating the cumulative results of the 3 highest-volume individual pitchers per team at all age divisions.

Games were categorized as either consecutive or single, with single games having at least 1 day of rest before and after the game. Consecutive games were defined as 2, 3, 4, or 5 or more games without a day of rest between events and were used as a surrogate for tournaments. Game density was defined as the number of games played over a consecutive series of days without a day of rest between games. PSG violations that occurred during consecutive and single games were recorded.

Summary statistics are presented as means  $\pm$  SD or number (percent). For pitcher-specific outcomes, mixed-effects, negative-binomial regression models with the team as a random effect and log of the number of appearances as an offset were fit in order to estimate the rate (95% CI) of PSG violations per pitching appearance for possible factors associated with violation rate. For game-specific outcomes, similar mixed-effects, negative-binomial regression models were fit with the team as a random effect. Rate ratios (RRs) were calculated for comparisons of violation rates for different variables. R for Statistical Computing Version 3.5 was used for statistical analysis.<sup>14</sup> Statistical significance was set at a 5% significance level.

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Ethical approval for this study was waived by the University of Wisconsin–Madison (ID No. 2019-0145).

TABLE 2  
Summary of 2019 Youth Baseball Season<sup>a</sup>

	Age Division <sup>b</sup>							Total (100 Teams)
	8U (14 Teams)	9U (15 Teams)	10U (15 Teams)	11U (14 Teams)	12U (14 Teams)	13U (14 Teams)	14U (14 Teams)	
Total games	26.1 ± 6.5	17.0 ± 10.2	16.3 ± 12.1	27.8 ± 7.5	37.2 ± 15.6	20.7 ± 11.8	29.2 ± 12.3	24.7 ± 12.9
Total team pitches	2863 ± 720	1805 ± 1188	1574 ± 1097	2901 ± 729	3525 ± 1378	2078 ± 1214	2888 ± 1161	2503 ± 1252
Pitchers per team	9.9 ± 1.6	10.3 ± 2.4	9.8 ± 1.7	11.4 ± 2.3	11.4 ± 2.2	9.6 ± 2.8	10.9 ± 2.9	10.5 ± 2.3
Pitcher games per year	8.5 ± 6.6	5.2 ± 5.2	5.0 ± 3.8	7.3 ± 5.3	8.9 ± 6.9	5.6 ± 4.3	6.6 ± 4.7	6.8 ± 5.6
Pitcher throws per game	33.99 ± 16	33.52 ± 16	31.81 ± 15	34.72 ± 18	34.87 ± 19	38.65 ± 19	40.27 ± 23	35.41 ± 18

<sup>a</sup>Data are presented as mean ± SD.

<sup>b</sup>Age divisions consisted of 8-and-under (8U) through 14-and-under (14U).

TABLE 3  
Pitching Volume Summary by Pitch Count, Pitcher Appearances, and Pitches Thrown

	Age Division <sup>a</sup>							Total
	8U	9U	10U	11U	12U	13U	14U	
Pitch count occurrences, n (%)								
1-20 pitches	252 (21)	179 (22)	200 (27)	261 (24)	365 (25)	152 (20)	232 (23)	1641 (23)
21-35 pitches	407 (35)	307 (38)	261 (35)	338 (32)	442 (31)	206 (27)	245 (24)	2206 (32)
36-50 pitches	343 (29)	213 (26)	194 (26)	261 (24)	354 (25)	190 (25)	212 (21)	1767 (25)
51-65 pitches	177 (15)	71 (9)	79 (11)	143 (13)	180 (13)	142 (19)	153 (15)	945 (14)
>65 pitches	0 (0)	39 (5)	11 (1)	67 (6)	91 (6)	65 (9)	162 (16)	435 (6)
Appearances, % pitchers								
<25% games	45.3	42.9	38.1	49.4	52.8	48.9	55.9	47.7
25%-50% games	27.3	40.9	44.2	40.6	41.5	45.2	41.4	40.2
>50% games	27.3	16.2	17.7	10.0	5.7	5.9	2.6	12.0
Percentage of total team pitches thrown, % pitchers								
<10% pitches	57.6	55.8	50.3	61.9	59.1	57.0	55.9	56.9
10%-20% pitches	29.5	34.4	44.2	28.1	34.6	27.4	35.5	33.5
>20% pitches	12.9	9.7	5.4	10.0	6.3	15.6	8.6	9.7

<sup>a</sup>Age divisions consisted of 8-and-under (8U) through 14-and-under (14U).

## RESULTS

### Season Pitch Counts

Pitching data were collected for 100 teams, which consisted of 1046 pitchers competing in 2439 games (Table 2). Pitchers most frequently threw between 21 and 35 pitches per game, while the majority of pitchers appeared in fewer than 25% of total team games and threw less than 10% of total team pitches during a season (Table 3).

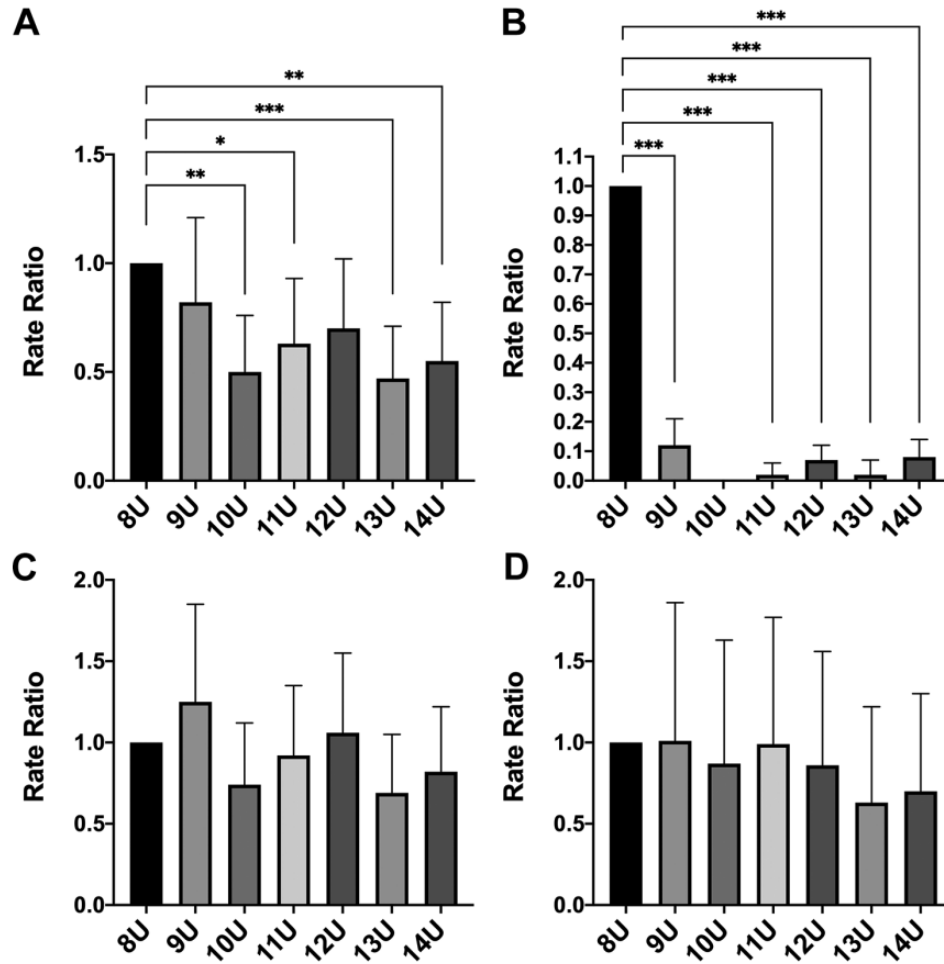
### Pitch Smart Guideline Violations

There were a total of 1866 violations: 214 for violating maximum pitch count, 1335 for inadequate rest, and 960 for pitching on the same day. Ninety-four percent of teams had at least 1 pitcher violate guidelines. When evaluating games, noncompliance occurred in 46% for any violation, 7.4% for maximum pitch count, 31.2% for inadequate rest, and 25.3% for same-day pitching. When evaluating pitchers, noncompliance occurred in 48.6% for any violation,

9.5% for maximum pitch count, 43.3% for inadequate rest, and 26.7% for same-day pitching. Per pitching appearance, total violations ranged from 0.147 to 0.316, maximum pitch count violations ranged from 0 to 0.126, inadequate rest violations ranged from 0.11 to 0.201, and same-day violations ranged from 0.038 to 0.060 among all age divisions (Figure 1). The 8U group had the highest violation rate for any reason and for maximum pitch counts, the 9U group had the highest violation rate for inadequate rest, and both the 8U and 9U groups had the highest rate of same-day violations.

### Game Factors Associated With Violation Risk

A single, nonconsecutive game event had a total violation rate of 0.27. In comparison, the violation rates per game for 2, 3, 4, and 5 or more consecutive games with rate ratios using a single game as the reference were 0.32 (RR, 1.19; *P* = .264), 0.587 (RR, 2.17; *P* < .001), 0.64 (RR, 2.38; *P* < .001), and 0.67 (RR, 2.48; *P* < .001), respectively (Figure 2). Factors including game density (games per day)



**Figure 1.** Comparison of violation rate ratios by age division (reference: 8U age division) for (A) any violation, (B) maximum pitch count violation, (C) inadequate rest violation, and (D) same-day pitching violation. Age divisions consisted of 8-and-under (8U) through 14-and-under (14U). Error bars represent 95% CI. \* $P < .05$ ; \*\* $P < .01$ ; \*\*\* $P < .001$ .

for tournaments, number of consecutive games played, number of days between games, and team runs scored for both participating teams also influenced the rate ratio for violations for each additional unit (Table 4).

#### Pitcher Factors Associated With Violation Risk

Among the different age divisions, the highest-volume pitchers threw 19.6% to 24.0% of total team pitches and accounted for 18.3% to 35.7% of total team violations. The second-highest-volume pitchers threw 16.0% to 20.2% of total team pitches and accounted for 14.4% to 28.1% of total team violations. The third-highest-volume pitchers threw 14.3% to 16.4% of total team pitches and accounted for 10.3% to 24.8% of total team violations. The total number of violations for the individual top pitcher, the combined top 3 highest-volume pitchers, and all pitchers based on age division are shown in Figure 3.

The number of violations per 50 pitches for pitchers appearing in fewer than 10% of total games was 0.29 (range, 0.23-0.36); comparatively, pitchers appearing in

10% to 20% of the total games had 2.07 violations (range, 1.73-2.48; RR, 7.23 [95% CI, 6.04-8.66];  $P < .001$ ), and pitchers appearing in more than 20% of the total games had 4.38 violations (range, 3.45-5.57; RR 15.29 [95% CI, 12.03-19.44];  $P < .001$ ). The number of violations per 50 pitches for pitchers throwing fewer than 25% of the total team pitches was 0.18 (range, 0.14-0.23); comparatively, pitchers throwing 25% to 50% of the total team pitches had 1.65 violations (range, 1.33-2.05; RR, 9.25 [95% CI, 7.47-11.45];  $P < .001$ ), and pitchers throwing more than 50% of the total team pitches had 4.89 violations (range, 3.75-6.39; RR, 27.5 [95% CI, 21.06-35.92];  $P < .001$ ).

Each year of increasing pitcher age had a protective effect against any violation (RR, 0.91 [95% CI, 0.86-0.96];  $P = .001$ ), maximum pitch count violation (RR, 0.60 [95% CI, 0.49-0.74];  $P < .001$ ), and inadequate rest violation (RR, 0.96 [95% CI, 0.93-0.98];  $P = .002$ ). For every incremental 50 pitches thrown, there was an increased risk for any violation (RR, 1.24 [95% CI, 1.22-1.25];  $P < .001$ ), maximum pitch count violation (RR, 1.25 [95% CI, 1.21-1.28];  $P < .001$ ), inadequate rest violation (RR, 1.23 [95% CI,

1.22-1.25];  $P < .001$ , and same-day pitching violation (RR, 1.20 [95% CI, 1.17-1.22];  $P < .001$ ) (Figure 4).

DISCUSSION

This analysis including 100 youth baseball teams demonstrated that the majority of teams (>90%) and nearly half of all individual pitchers had at least 1 PSG violation,

confirming and surpassing our hypothesis. The most common reason for a pitcher to violate the PSG was because of inadequate rest (43.3% of pitchers, 0.11-0.201 violations per appearance), followed by pitching on the same day (26.7% of pitchers, 0.038-0.060 violations per appearance), while maximum pitch count violations occurred the least (9.5% of pitchers, 0-0.126 violations per appearance). The PSG were introduced in 2014 through collaboration of MLB and USA Baseball and were built on previously published youth baseball pitch count recommendations.<sup>1,5,13</sup> The PSG are evidence-based recommendations from studies that have evaluated the relationship of pitching behaviors with arm pain, fatigue, and injuries in youth baseball players.<sup>6,9-12</sup> While there are many youth baseball leagues and organizations that are fully compliant with the PSG, widespread adoption across all youth baseball events is lacking.<sup>13</sup> To our knowledge, no study has specifically evaluated PSG compliance by youth baseball pitchers with regard to pitch count limits and required rest or risk factors for noncompliance since the PSG were developed.

Our data revealed that pitcher-related factors were shown to influence noncompliance with the PSG. One of the most important factors affecting noncompliance with the PSG was the volume of total pitches thrown by individual pitchers. Despite teams using an average of 10 pitchers, the single highest-volume individual pitcher accounted for 20% to 25% of total team pitches and accounted for up to 36% of total team violations. Similarly, the top 3 pitchers by pitch count combined on each team accounted for more than half of team pitches thrown and up to 76% of total team PSG violations. These findings suggest that most youth baseball teams use a small, select group of pitchers to throw the majority of total team pitches, which results in higher rates of PSG violation for the individual and potentially puts the athlete at risk for overuse injury.

Pitcher age was also related to noncompliance with the PSG, with younger age divisions having more violations

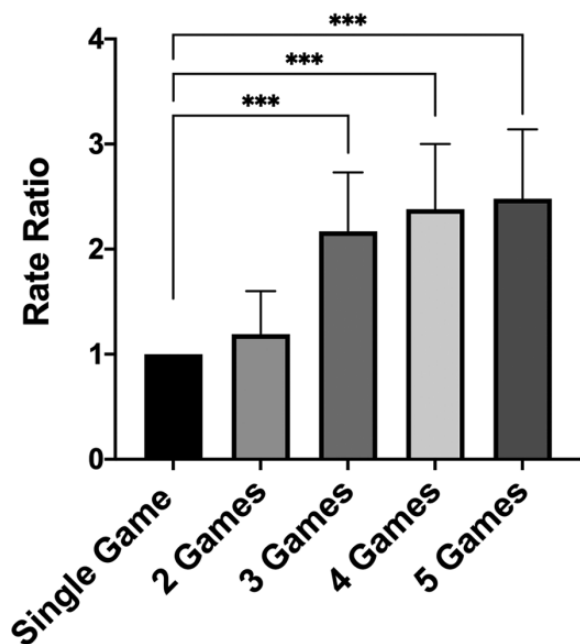
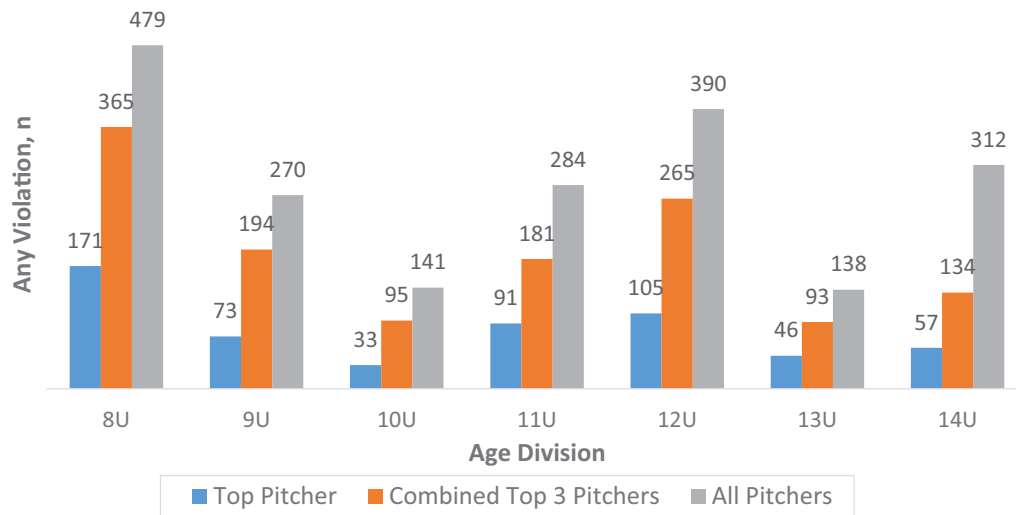


Figure 2. Comparison of rate ratios for any violation by number of games played (reference: single game). Error bars represent 95% CI. \*\*\* $P < .001$ .

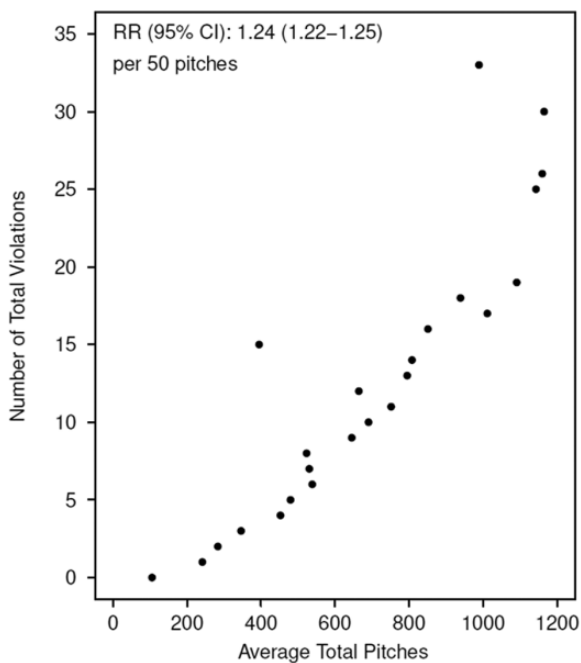
TABLE 4  
Game Factors Associated With Pitching Violations<sup>a</sup>

	Violation Type			
	Total	Maximum Pitch Count	Inadequate Rest	Same-Day Pitching
Game density				
RR (95% CI)	1.84 (1.69-2.01)	0.54 (0.41-0.71)	1.37 (1.23-1.53)	2.86 (2.54-3.22)
<b>P value</b>	<b>&lt;.001</b>	<b>&lt;.001</b>	<b>&lt;.001</b>	<b>&lt;.001</b>
Consecutive games				
RR (95% CI)	1.60 (1.53-1.68)	1.12 (0.99-1.27)	1.77 (1.67-1.87)	1.52 (1.43-1.62)
<b>P value</b>	<b>&lt;.001</b>	.065	<b>&lt;.001</b>	<b>&lt;.001</b>
Rest days				
RR (95% CI)	0.84 (0.81-0.86)	0.99 (0.96-1.03)	0.69 (0.66-0.72)	0.89 (0.87-0.92)
<b>P value</b>	<b>&lt;.001</b>	.646	<b>&lt;.001</b>	<b>&lt;.001</b>
Runs scored				
RR (95% CI)	0.98 (0.97-0.99)	1.00 (0.97-1.03)	0.98 (0.97-0.99)	0.99 (0.97-1.00)
<b>P value</b>	<b>.001</b>	.857	<b>.002</b>	.144
Opponent runs scored				
RR (95% CI)	1.02 (1.01-1.03)	1.03 (1.00-1.06)	1.03 (1.02-1.05)	0.98 (0.96-1.00)
<b>P value</b>	<b>.001</b>	<b>.029</b>	<b>&lt;.001</b>	<b>.031</b>

<sup>a</sup>Bolded  $P$  values indicate statistical significance ( $P < .05$ ). RR, rate ratio.



**Figure 3.** Number of violations according to pitcher volume within each age division. Age divisions consisted of 8-and-under (8U) through 14-and-under (14U).



**Figure 4.** Total violations per total pitches.

than older age divisions. The higher overall PSG violation rate in the youngest (8U) age division was primarily driven by the high rate of maximum pitch count violations, as there were no differences between age divisions with regard to inadequate rest or same-day pitching violations. Specifically, the maximum pitch count violation rates were more than 10 times higher in the 8U group compared with any other age division. This finding is likely in part explained by the structure of the PSG, in which

recommended pitch counts are tiered according to age. The 7- to 8-year age group recommendations include a maximum pitch count of 50 pitches per day, which subsequently increases to 75 pitches per day in the 9- to 10-year age group. Despite lower pitch count limits, the 8U teams still participate in a similar number of games and innings as the older teams during tournaments. One strategy would be to expand the 8U roster to have more pitchers available to pitch in baseball games. However, reduced playing time for athletes already on the roster would be an undesired consequence, especially in the setting of tournaments in which teams and parents are paying for participation. Pitchers in the youngest age divisions should be most protected from noncompliance, as the youngest athletes are a high-risk group that should focus on technique and skills rather than winning in competition. Careful attention to pitch counts in these younger age divisions is warranted given the higher violation rates and potential for overuse injury.

In addition to pitcher factors, game factors also affected PSG compliance. Consecutive games played without a day of rest increased the risk of a violation occurring, as playing 5 or more consecutive games increased the rate of any violation more than 2 times compared with a single, nonconsecutive game. In addition, playing more games per day during tournaments increased the rate of a violation, while having more rest days between games protected against violations. Understanding factors that increase the risk for PSG noncompliance, especially in tournaments, may help identify aspects of competition structure to focus on and change in order to decrease injury risk. With an already established relationship in youth baseball pitchers between tournament play and injury, these results suggest quantity and frequency of games during tournaments may be a contributing factor to injury.<sup>3,11</sup> As a result, pitching multiple games over a short period of time with inadequate rest does not appear to align with keeping youth athletes safe and

healthy. Oversight and regulation at the organizational level may be needed to improve on the pitching structure at tournaments to limit the risk factors for pitcher PSG noncompliance.

Despite popularity of the PSG, the vast majority of teams and approximately half of the pitchers in this study were noncompliant. This finding demonstrates that knowledge of and adherence to pitch count limits and rest recommendations are still lacking at an alarmingly high rate, which has previously been shown in the literature.<sup>2,4,8,18</sup> A survey of youth baseball athletes demonstrated that 84.5% of participants were unaware of pitching guidelines, while more than 60% would continue throwing with a tired arm or injury.<sup>2</sup> In a survey of coaches, 73% reported following guidelines, yet only 43% answered questions correctly about the guidelines.<sup>4</sup> Furthermore, Knapik et al<sup>8</sup> noted that only 44.3% of coaches were compliant with pitching recommendations, while 51% of youth coaches lacked knowledge of the guidelines. Parents also lack understanding, as only 55% to 62% answered PSG questions correctly; however, athlete injury risk decreased with improved parent understanding of the guidelines.<sup>18</sup> Improved education of coaches, families, and participants is necessary so that pitching behaviors can be followed and modified to adhere to the PSG and limit the risk of injury to the athlete.

The main strength of this study is the robust data set collected from youth baseball teams and pitchers of different ages, which was possible through use of the GameChanger app. The popularity of this software in youth baseball has increased given its ease of use in recording team and player statistics, and it is now used by more than 550,000 youth sports teams.<sup>7</sup> The app allowed for review of discrete data from multiple teams with overlapping schedules in various geographic locations, which previously would have required a significant amount of resources. The use of an app provides coaches with an easy and effective system for recording data such as pitch counts and is a novel method for reporting pitch counts that could assist with future research efforts in this area.

A primary weakness of the study is the lack of inclusion of pitcher fatigue, arm pain, and injuries in relation to compliance with the PSG. Instead of direct recording, compliance with the PSG was used as a surrogate for fatigue, arm pain, and injuries. Furthermore, several PSG recommendations were not evaluated, including use of breaking pitches, pitching throughout the year, pitching for multiple teams, and avoiding playing catcher and pitcher during the same game.<sup>13</sup> It is also quite common for pitchers to play on more than 1 team and have many high-effort throws throughout a season outside of game pitches, including warm-up pitches and work with pitching coaches.<sup>16</sup> Considering these factors, our study likely underestimates the actual rate of noncompliance with the PSG and risk for injury. Moreover, data were collected on youth baseball teams from a small geographic region during a single summer season, which may limit the generalizability to all youth baseball athletes around the country. This study being conducted in the state of Wisconsin, which follows a restricted baseball season secondary to weather, as most competition is limited to starting in late May to June, again likely underestimates

the number of violations that would be seen in warmer climates with longer baseball seasons.

## CONCLUSION

Noncompliance with the PSG occurred in nearly half of games, with approximately half of the competing pitchers incurring a violation. Factors associated with increased guideline violation included young age, high-volume pitching, and participating in multiple games on consecutive days. Education of tournament directors, coaches, parents, and athletes regarding pitching guidelines is warranted to limit the risk of injury.

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