

Pitch Volume and Glenohumeral and Hip Motion and Strength in Youth Baseball Pitchers

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Context: Increased pitch volume and altered glenohumeral (GH) and hip range of motion (ROM) and strength contribute to injury risk in baseball pitchers. Although these factors affect one another, whether they are related is unknown.

Objective: To examine relationships among cumulative and seasonal pitch volume, ROM, and strength of the GH and hip joints in youth baseball pitchers.

Design: Cross-sectional study.

Setting: Baseball practice facilities.

Patients or Other Participants: A total of 28 healthy baseball pitchers (age = 13.9 ± 2.9 years).

Main Outcome Measure(s): A demographic and pitching questionnaire was used to quantify pitch volume. Glenohumeral internal-rotation (IR) and external-rotation (ER) ROM and strength of the throwing arm; total arc of motion (IR + ER ROM); and bilateral hip IR, ER, and total arc of motion ROM and strength in IR, ER, and abduction were measured. A goniometer was used to assess ROM; a handheld dynamometer, to assess strength. Frequency analyses and bivariate correlations (age covariate) described data and identified relationships.

Results: Correlations between years of competitive play and increased strength in lead-leg hip IR ($r = 0.52$, $P = .02$) and abduction ($r = 0.48$, $P = .04$) and stance-leg hip IR ($r = 0.45$, $P = .05$) were fair to good. The number of months played in the last year had a fair correlation with decreased GH IR strength ($r = -0.39$, $P = .04$) and increased stance-leg hip IR strength ($r = 0.44$, $P = .05$). Limited pitch time had a fair correlation with increased GH ER ROM ($r = 0.40$, $P = .04$) and an excellent correlation with increased lead-leg hip IR ROM ($r = 0.79$, $P < .001$). Increased innings pitched per game had a fair to good correlation with decreased GH IR strength ($r = -0.41$, $P = .04$) and stance-leg hip ER ROM ($r = -0.53$, $P = .03$). More pitches per game had a fair to good correlation with increased GH ER ROM ($r = 0.44$, $P = .05$) and decreased stance-leg hip ER ROM ($r = -0.62$, $P = .008$).

Conclusions: The significant relationships identified in this study suggest the need to further examine youth and adolescent cumulative and seasonal pitch guidelines.

Key Words: upper extremity, injury risk, throwing athletes

Key Points

- Significant relationships between cumulative and seasonal pitch volumes and range of motion and strength of the glenohumeral and hip joints were present in healthy young baseball pitchers.
- Pitch guidelines should be examined and consideration given to limiting the number of months pitched per year and the number of innings pitched per game in a month.
- Injury-prevention programs should include glenohumeral internal-rotation strength exercises and hip external-rotation range-of-motion stretches.

Approximately 27 million child and adolescent athletes in the United States participate annually in organized youth athletics.¹ More than 2 million Little League players² and almost 500 000 male student-athletes play interscholastic baseball.¹ Although involvement in sport has many health and social benefits, the high physical demands of sport participation are also associated with an increased risk for injuries, particularly overuse upper extremity injuries in baseball pitchers.³ Shanley et al⁴ reported that baseball pitchers were 3.6 times more likely to sustain an upper extremity injury than position players, with injury rates of 37.4% and 15.3%, respectively (baseball and softball combined). The increased frequency and throwing volume, particularly in young pitchers, emphasizes the need to gain more insight into injury-risk factors.

Recognition of rising upper extremity injury rates in youth baseball led to pitch-frequency and -count guidelines.⁵ Limiting participation in high-load and high-repetition throwing activities was well intended, but not all baseball associations adopted these guidelines, and many would argue that the guidelines were not broad enough to effectively reduce injury risks and rates. In recent years, authors^{5–7} reported that increased shoulder and elbow pain and injuries were associated with cumulative (years of competitive play, months played per year) and seasonal (pitchers per inning, innings per game, games per season) measures of pitch volume. Better tracking of pitch volume and a greater understanding of its role in injury risk are clearly needed.

Recognizing alterations in physical characteristics, specifically range of motion (ROM) and strength, may help us to identify injury risk and develop targeted prevention

strategies.^{3,4,8–13} Pitchers often present with an altered glenohumeral (GH) ROM profile, such that external rotation (ER) is increased and internal rotation (IR) is decreased due to humeral retroversion in the throwing arm compared with the nonthrowing arm.^{14,15} The additional loss of IR ROM resulting from posterior soft tissue contracture has been identified as an injury risk factor.¹⁶ Similarly, deficits in GH strength, particularly in ER, the ER:IR ratio, and the supraspinatus muscle, are associated with increased injury risk.¹¹ The body of research to date examining GH ROM and strength alterations in pitchers has guided injury-prevention programming. However, while addressing GH ROM and strength deficits, clinicians must also consider and integrate other joints, such as the hips, in the rehabilitation program and modify throwing practices to successfully and effectively prevent injury.

The lower extremity and particularly the hips are integral to force generation and transfer through the kinetic chain during the throwing motion. Stance-leg (ipsilateral leg to the throwing arm) ROM and strength are needed to move and stabilize the pelvis as the body shifts over the leg from the cocking phase, through ball acceleration, and into ball release while the lead leg (contralateral leg to the throwing arm) must position the foot using hip rotational ROM as the body progresses toward the plate. More recently, increased emphasis on the hips and their role in the pitching motion has led to the study of hip ROM and strength—specifically, how these measures compare bilaterally and between positions and whether they are related to GH ROM.^{17–20} Results varied, yet few investigators⁹ examined hip measures in young baseball players, and to our knowledge, no one has assessed relationships between pitch volume and hip ROM and strength.

Determining whether associations exist among pitch volume and GH and hip ROM and strength in youth pitchers can offer insight into injury risk factors and evidence-based recommendations for injury-prevention programs. Therefore, the purpose of our study was to determine whether correlations existed between cumulative and seasonal pitch volumes and ROM and strength of the GH and hip joints in youth baseball pitchers.

METHODS

Design

We used a prospective, cross-sectional design. Participants completed a self-reported demographic and pitching history questionnaire. Responses from the questionnaire allowed us to assess cumulative and seasonal pitch volumes, which were then used as quantitative and categorical variables, respectively, in our correlation analyses. Throwing-arm (GH joint) and bilateral hip (stance- and lead-leg) ROM and strength were the dependent quantitative variables. Specifically, GH and hip IR ROM, ER ROM, and total arc of motion (TAM) were measured in degrees; GH as well as hip IR, ER, and abduction strength were measured in kilograms (kg) of force.

Participants

A convenience sample of 28 healthy male baseball pitchers was recruited from youth baseball leagues and

local high schools. Team coaches allowed the researchers to attend practices to recruit, obtain consent, and test pitchers. At the time of the study, participants were on a baseball roster with no activity restrictions. Baseball pitchers who self-reported a history of nerve injury or were not currently cleared to fully participate in baseball due to a medical condition were excluded from the study. We described the study to both the parents or guardians and pitchers and answered all questions. Before testing, parental consent and participant assent were obtained. The institutional review board approved this study.

Procedures

Data collection occurred over a 3-week period in the first half of the spring baseball season. Testing of each participant occurred in a single, field-based, 30-minute session. Participants completed the self-report questionnaire that asked about demographics (age, height, mass, arm used to pitch, current level of play) and cumulative and seasonal pitch volumes. If needed, a parent or guardian assisted the pitcher in completing the questionnaire. No information was collected from the coaches to confirm the accuracy of the self-reported responses. The cumulative pitch-volume variables of years of competitive play and months played in the last year were numeric write-in responses. Other pitch-volume questions and responses were categorical; they asked about pitching in the last month (endorsement of limited pitch time, times pitched per week, innings pitched per game, pitches per game, and days per week on which more than 40 pitches were thrown).

Shoulder Assessments. A standard goniometer with a bubble level was used for all ROM measures in this study. For all throwing-arm GH ROM measures, the participant lay supine on a table with the shoulder abducted to 90° and the elbow flexed.^{7,18} A towel roll was placed under the arm to maintain humeral position. One examiner stabilized the scapula while passively rotating the participant's GH joint into IR and ER until an end feel was detected. A second examiner aligned the moveable arm of the goniometer along the ulnar border and recorded the angle in degrees. Intrarater reliability for the GH ROM measures was high (intraclass correlation coefficient [ICC] = 0.96–0.98).

A handheld dynamometer (Hoggan Health Industries, Salt Lake City, UT) was used for all strength measures in this study. For all throwing-shoulder strength measures, the participant was seated upright on a table with the shoulder abducted to 90° and the elbow flexed. The participant was instructed to internally (“push forward”) and externally (“push back”) rotate against the examiner's manual resistance, which was applied to the distal forearm while the examiner held the dynamometer and stabilized the shoulder. The amount of force used to resist the examiner was recorded in kilograms. Intrarater reliability for shoulder strength measures was good (ICC = 0.72–0.81).

Hip Assessments. For all bilateral hip ROM measures, the participant was prone on a table with the hips adducted (neutral position) and the knees flexed to 90°. One examiner stabilized the hip and then passively rotated it into IR and ER until an end feel was detected. A second examiner aligned the moveable arm of the goniometer along the tibial border and recorded the angle in degrees.^{9,20} Intrarater

Table 1. Frequency of Self-Report Pitch-Volume Variables

Variable	Frequency (% Endorsed)
Cumulative pitch volume	
Months played in last y	
≤1	1 (3.6)
2–4	6 (21.5)
5–7	4 (14.3)
8–10	7 (25)
>10	10 (35.7)
Seasonal pitch volume ^a	
Endorsement of limited pitch time	12 (44.4)
Times pitched/wk	
1–2	18 (75.0)
3–4	5 (20.8)
≥5	1 (4.2)
Innings pitched/game	
1–2	11 (44)
3–4	10 (40)
5–6	3 (12)
≥7	1 (4)
Pitches/game	
<40	5 (23.8)
40–60	9 (42.9)
61–80	2 (9.5)
81–100	4 (19.0)
101–120	0 (0.0)
>120	1 (4.8)
Days/wk >40 pitches thrown	
1–2	9 (45.0)
3–4	5 (25.0)
5–7	6 (30.0)

^a Missing data: endorsement of limited pitch time (n = 1), times pitched/wk (n = 4), innings pitched/game (n = 3), pitches/game (n = 7), and d/wk >40 pitches thrown (n = 8).

reliability for hip ROM measures was high (ICC = 0.93–0.98).

For bilateral hip IR and ER strength²¹ measures, the participant was seated on a table with the thigh supported and the legs hanging over the edge of the table. The pitcher was instructed to internally (“push out”) and externally (“push in”) rotate against the examiner’s manual resistance, which was applied to the distal leg while the examiner held the dynamometer and stabilized the thigh. Then, the player was positioned side lying on a table with both hips and knees flexed to 90°. The participant was instructed to abduct and externally rotate the hip slightly while raising the entire limb against the examiner’s manual resistance,²¹ which was applied to the distal lateral thigh while the hip was stabilized. The amount of force used to resist the examiner for all hip-strength measures was recorded in kilograms. Intrarater reliability for hip-strength measures was high (ICC = 0.81–0.95).

Statistical Analysis

Before data collection, we performed pilot testing on a sample of youth baseball pitchers (approximately 7) and young adults (approximately 10). The same examiner collected 2 sets of ROM and strength data in the same session separated by approximately 20 minutes. The examiner was blinded to the data, which were then used to calculate the intratester reliability of each assessment.

For this study, we used the average of 2 measurements for all shoulder and hip assessments. The collected data were analyzed descriptively (mean, standard deviation, frequency). Pearson product moment correlations with age as a covariate were used to examine relationships between cumulative and seasonal pitch volumes and throwing-shoulder, lead-leg and stance-leg hip ROM and strength. Correlation coefficients were interpreted as follows: 0.00–0.25, *little or none*; 0.25–0.50, *fair*; 0.50–0.75, *moderate to good*; and 0.75 and above, *good to excellent*.²² Alpha was set a priori at ≤.05, 2 tailed. Data analyses were performed using SPSS (version 22.0; IBM Corp, Armonk, NY).

RESULTS

A total of 28 right-handed (n = 21) and left-handed (n = 7) pitchers (age = 13.9 ± 2.9 years, height = 167.9 ± 20.0 cm, mass = 61.3 ± 18.6 kg) were tested. Pitchers reported 6.4 ± 3.5 years of competitive play, and most currently played at the secondary school level (middle school, n = 7; secondary school, n = 15; other [ie, youth club], n = 6).

Self-reported pitch volumes are presented descriptively (frequency and percentage) in Table 1. Descriptive statistics (mean, standard deviation) for the shoulder and hip ROM and strength measures are presented in Table 2.

Correlations between cumulative and seasonal pitch volumes and GH and hip ROM and strength variables are shown in Tables 3 and 4. Regarding cumulative pitch volume, years of competitive play was significantly correlated with increased hip strength, specifically lead-leg IR ($r = 0.52$, $P = .02$), lead-leg abduction ($r = 0.48$, $P = .04$), and stance-leg IR ($r = 0.45$, $P = .05$). The number of months played in the last year was significantly correlated with decreased GH IR strength ($r = -0.39$, $P = .04$) and increased stance-leg hip IR strength ($r = 0.44$, $P = .05$). Seasonal pitch volume (describing pitching over the last month) was also significantly correlated with ROM and strength variables. An endorsement of limited pitch time was significantly correlated with increased GH ER ROM ($r = 0.40$, $P = .04$) and increased lead-leg hip IR ROM ($r = 0.79$, $P < .001$). A greater number of innings pitched per game was significantly correlated with decreased GH IR strength ($r = -0.41$, $P = .04$) and decreased stance-leg hip ER ROM ($r = -0.53$, $P = .03$). A larger number of pitches per game was significantly correlated with increased GH ER ROM ($r = 0.44$, $P = .05$) and decreased stance-leg hip ER ROM ($r = -0.62$, $P = .008$). The number of times

Table 2. Glenohumeral and Hip Range of Motion and Strength in Baseball Pitchers (Mean ± SD)

Joint	Range of Motion, °			Strength, kg		
	Internal Rotation	External Rotation	Total Arc of Motion	Internal Rotation	External Rotation	Abduction
Glenohumeral, throwing arm	48.1 ± 12.6	103.4 ± 10.8	151.5 ± 13.8	12.0 ± 4.1	8.2 ± 2.2	Not applicable
Hip, lead leg	33.1 ± 8.9	30.3 ± 7.3	63.4 ± 8.8	8.7 ± 2.8	8.5 ± 2.9	14.1 ± 3.3
Hip, stance leg	30.2 ± 6.6	30.0 ± 7.5	59.8 ± 9.6	9.0 ± 3.0	7.9 ± 2.1	13.6 ± 3.2

Table 3. Correlation Coefficients Between Pitch Volume and Glenohumeral Range of Motion and Strength in the Throwing Arm

Variable	Range of Motion			Strength	
	Internal Rotation	External Rotation	Total Arc of Motion	Internal Rotation	External Rotation
Cumulative pitch volume					
Years of competitive play	0.33	-0.13	0.21	-0.10	0.29
Months played in last year	0.12	-0.23	-0.07	-0.39 ^a	0.00
Seasonal pitch volume					
Endorsement of limited pitch time	-0.26	0.40 ^a	0.09	-0.05	-0.19
Times/wk pitched	-0.19	0.28	0.04	0.04	0.40
Innings pitched/game	-0.21	0.05	-0.16	-0.42 ^a	-0.32
Pitches/game	-0.04	0.44	0.28	-0.07	-0.04
Days/wk >40 pitches thrown	0.00	0.30	0.19	-0.15	0.05

^a $P < .05$.

pitched per week and days per week on which more than 40 pitches were thrown were not significantly correlated with any ROM or strength variables ($P > .05$).

DISCUSSION

We examined relationships between cumulative and seasonal pitch volumes and ROM and strength of the GH joint and lead- and stance-leg hips in healthy youth baseball pitchers. Overall, fair to moderate correlations were found. Cumulative pitch volume was correlated most often with increased hip-strength measures, whereas seasonal pitch volume was correlated with both increased and decreased (depending on the variable) GH and hip ROM and strength measures. Our results suggest specific pitch volume and ROM and strength relationships that warrant further investigation into injury risk factors and injury-prevention strategies in youth baseball pitchers.

Pitch Volume and GH ROM and Strength

Endorsement of limited pitching and number of pitches per game in the last month were both correlated with increased GH ER ROM. It is interesting that these findings were somewhat contradictory, indicating that both decreased and increased pitching were related to greater GH ER ROM. Although increased GH ER ROM is an established adaptation in pitchers^{3,10,23-25} and is important for maximal cocking in preparation for ball acceleration,

GH ER ROM can be achieved and maintained in several ways. The reason for and duration of the pitchers' endorsement of limited pitching were unknown, yet all pitchers reported being healthy at the time of our study. It is feasible that younger athletes played other positions more often than they pitched or that more passive strategies involving rest and stretching performed during the limited pitching period contributed to the increased GH ER ROM and thus the positive correlation. Alternatively, pitching itself is also effective in increasing GH ER ROM: specifically, a high volume of pitches over a short bout (ie, during a game) may affect GH ER ROM more than other pitch-volume variables. Hurd et al¹⁰ measured GH ROM in uninjured high school pitchers and found that the age of the pitcher negatively predicted ER ROM, such that ER ROM decreased as a pitcher aged. Similar to our results, age correlated highly with ROM measures. We included age as a covariate in our analyses to remove its influence and permit examination of the variables of interest. Our results indicate that GH ER ROM was related to seasonal pitch volume and that further investigation is warranted to better understand how alterations in pitch volume affect ER ROM.

Measures of muscle strength in baseball pitchers have also been studied^{11,25-28} extensively to establish the presence of sport-specific adaptations and injury risk factors. Our findings showed that more months pitched in the past year and more innings pitched per game in the last month were significantly correlated with decreased GH IR

Table 4. Correlation Coefficients Between Pitch Volume and Hip Range of Motion and Strength

Variable	Range of Motion						Strength					
	Lead Leg			Stance Leg			Lead Leg			Stance Leg		
	IR	ER	TAM	IR	ER	TAM	IR	ER	AB	IR	ER	AB
Cumulative pitch volume												
Years of competitive play	-0.05	0.21	0.12	0.11	0.13	0.16	0.52 ^a	0.44	0.48 ^a	0.45 ^a	0.38	0.36
Months played in last year	-0.15	0.07	-0.06	0.09	0.03	0.07	0.42	0.28	0.43	0.44 ^a	0.30	0.40
Seasonal pitch volume												
Endorsement of limited pitch time	0.79 ^b	-0.33	0.33	0.32	-0.03	0.24	-0.05	0.15	-0.31	0.07	-0.22	0.15
Times/wk pitched	0.26	-0.13	0.10	0.20	-0.20	0.04	0.04	-0.01	-0.15	-0.09	-0.03	-0.07
Innings pitched/game	0.08	-0.03	0.04	-0.10	-0.53 ^a	-0.41	-0.25	-0.26	0.04	-0.27	-0.16	0.24
Pitches/game	0.34	-0.18	0.13	0.02	-0.62 ^b	-0.40	-0.25	-0.18	-0.21	-0.07	-0.06	0.11
Days/wk >40 pitches thrown	0.13	0.05	-0.14	-0.16	-0.18	-0.24	0.38	0.02	0.13	0.10	-0.09	0.19

Abbreviations: AB, abduction; ER, external rotation; IR, internal rotation; TAM, total arc of motion.

^a $P < .05$.^b $P < .01$.

strength. It is important to note that (1) recall of pitching over time is less reliable than immediate recall and (2) due to the nature of field testing and available resources, participants performed a “make” concentric strength test and eccentric strength was not measured. Although GH IR strength, specifically concentric strength, is important for ball acceleration and its contribution to the ER:IR ratio, these results are surprising and contrary to those of previous researchers. Several groups^{11,26,29} identified concentric strength deficits in GH ER, the ER:IR ratio, and the supraspinatus as predictors of injury over loss of IR strength. Glenohumeral IR strength deficits may not be an injury risk factor, but they do contribute to the ER:IR ratio; changes in either ER or IR may affect this relationship, disrupting the ideal 76% balance.³⁰ Based on our results, increased pitch volume may negatively affect concentric GH IR strength. Further investigation of eccentric GH IR strength is warranted. In addition, Yang et al⁷ identified self-reported arm tiredness as being associated with increased injury risk. How a pitcher’s perception of tiredness relates to muscle strength and fatigue measures is unknown and is an area for additional study. Our findings suggest that resting within a season and over the course of a year and integrating GH IR strength exercises into a global injury-prevention program throughout the season should be considered.

Pitch Volume and Hip ROM and Strength

Seasonal pitch volume was related to hip ROM. Pitchers who endorsed limited pitching in the previous month were more likely to display increased IR ROM in the lead-leg hip. Hip IR in the lead leg is important for absorbing forces as the pitcher pivots the body forward, driving toward home plate. It is interesting to note that increased hip IR was strongly related ($r = 0.79$) to limited pitching. We can assume that limited pitching equated to increased rest; however, we would need to know more details about the pitcher’s limited pitching to definitively conclude that rest was related to increased hip IR ROM. Conversely, increased innings pitched per game and pitches per game over the last month were related to decreased stance-leg hip ER ROM. Limited stance-leg hip ER ROM could restrict a pitcher during ball acceleration as the body shifts over the stance leg by moving from hip IR into ER. If hip ER ROM is limited, compensation along the kinetic chain, such as increased GH ER ROM, may occur. Sauers et al¹⁸ observed that professional pitchers displayed less stance-leg hip ER than position players but could not explain this difference. In conjunction with our results, the mechanism for diminished ER ROM may be increased pitch volume, suggesting that hip ROM adaptations may develop in pitchers. Further research is needed to substantiate this potential mechanism and determine whether it is an injury risk factor. Clinically, it is important for pitchers to perform ROM stretches to maintain hip ER ROM, particularly those who report increased seasonal pitch volume.

Increased hip strength is important for force generation, transfer, absorption, and stabilizing the body as it moves over the lower extremity during the pitching motion.^{17,31,32} Our results suggest that hip strength can be achieved over time while playing one’s sport. An increased number of

playing years was related to increased lead-leg hip IR and abduction strength, and increased numbers of years of play and months played per year were related to increased stance-leg hip IR strength. Because we controlled for age in our analyses, we can deduce that increased cumulative pitch volume may lead to increased hip strength. However, we do not know whether pitchers in the current study were competing in other sports or performing strength training or other activities that may also have influenced hip strength. Given that testing occurred in the first half of the spring baseball season, it is possible that the participants played a winter sport or were involved in preseason conditioning. In addition, manual strength testing of the hip musculature may not reliably assess true strength. Yet the size difference between pitchers and investigators likely aided in our excellent intrarater reliability established before data collection. The notion of advantageous sport-specific adaptations or external activities in hip strength as a result of increased pitch volume requires further study. Clinically, young pitchers with limited pitch volume may benefit from targeted hip strengthening to improve performance and prevent injury.

The current study had several limitations. This was a cross-sectional study; therefore, we could not capture changes over time to comprehensively assess cumulative and seasonal pitch volumes and ROM and strength measures. Also, all collected information was self-reported, and recall over the last month and last year is difficult for young baseball pitchers. Additional information pertaining to pain, fatigue, injury, and specific details about the endorsement of limited pitching may provide more insight into the significant relationships found. Finally, the significant relationships we noted were of fair strength ($r =$ approximately 0.40), restricting our ability to make strong clinical recommendations without further investigation. Our data contained variability in the frequency of the seasonal variables. Future researchers should consider separating data to compare low-frequency and high-frequency pitchers for other pitch-volume, GH, and strength variables.

In conclusion, we identified significant relationships between cumulative and seasonal pitch volumes and ROM and strength of the GH and hip joints in healthy youth pitchers. Our results suggest the need to further examine pitch guidelines, particularly those limiting the number of months pitched per year and the number of innings pitched per game within a month. Meanwhile, clinicians should be aware of cumulative and seasonal pitch volumes and implement injury-prevention programs that include GH IR strength exercises and hip ER ROM stretches.

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