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ORIGINAL RESEARCH

THE RELATIONSHIP BETWEEN PITCHING VOLUME AND ARM SORENESS IN COLLEGIATE BASEBALL PITCHERS

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ABSTRACT

Background: Excessive baseball pitch volume has been associated with increased risk of injury in adolescents. However, many collegiate athletes report non-time loss injuries over the course of the season. It is unknown how pitch volume throughout a collegiate baseball season affects arm soreness.

Purpose: The primary purpose of this study was to determine the relationship between pitch volume and self-reported arm soreness. A secondary purpose was to determine the relationship between change in pitch volume and change in arm soreness over the course of the season for collegiate baseball pitchers.

Study Design: Prospective Cohort

Methods: Seven collegiate baseball pitchers volunteered to participate in a yearlong prospective study. The seven pitchers reported daily pitch volume and level of soreness from the fall through spring collegiate baseball season during practices and games. The athletic trainer, a member of the research team, tracked athletic exposures and injuries for the entire season. Frequency counts of athletic exposures were categorized by game, practice, conditioning and injury status. Frequency counts of pitch volume was categorized by game, game bullpen, practice bullpen, flat ground, long toss and warm-up pitches. The pitch volume and soreness levels for each athlete were used to determine the relationship between these two variables using a Pearson correlation.

Results: The seven pitchers were involved with 1,256 athletic exposures and a total of 54,151 throws, averaging 7,735 throws per player for the entire season. The pitch volume and self-reported arm soreness for the entire season revealed a correlation of $r = .72$ ($p = .004$). The relationship between change in pitch volume and change in arm soreness was $r = .635$ ($p = .001$) over the season.

Conclusion: There was a moderate significant correlation between arm soreness and pitch volume across the whole season. This relationship was maintained when evaluating weekly changes.

Level of Evidence: 4

Keywords: acute workload, non-time loss injury, overhead throwing, pitch counts

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INTRODUCTION

The incidence of injury in college baseball practices and games is 1.85 injuries/1000 athlete-exposures and 5.78 injuries/1000 athlete-exposures, respectively.[1] Self-reported episodes of pain are quite frequent in baseball.[2] In a youth baseball survey, nearly 50% of pitchers over the course of a season reported shoulder or elbow pain.[2] The majority (70%) of these complaints were recorded as mild, defined as pain in the elbow or shoulder joint without loss of league-sanctioned games or practice time.[2] A recent report stated that of all injuries reported to an athletic trainer in collegiate baseball 59.1% are non-time loss injuries.[3] Muscular soreness and pain are often associated with these "non-time loss injuries."

The relationship between pitch volume and upper extremity injury has been established for adolescent pitchers focusing on time-loss injuries.[2,4] Time-loss injuries are defined as any injury requiring removal from the current session, missing a day of practice or competition which may require physician referral or diagnostic procedures.[5-7] However, baseball pitchers also experience injuries which do not result in time-loss. These injuries are classified as "non-timel loss injuries" and are defined as any injury evaluated by the athletic trainer that did not necessitate removal from game or practice but required intervention or practice modification.[7]

A report of discomfort or soreness from athletic activity is a physiological response from exercises or may indicate a subclinical adaptation of an injury that is occurring. An excessive amount of soreness from physical activity is termed delayed onset muscle soreness.[8] Studies have suggested that soreness is also a moderate indicator of a level of fatigue and developing overload on the musculotendinous tissue.[9] Recently, attention has focused on acute changes in workload can increase the likelihood of an injury.[9] To date, the relative change in throwing volume to arm soreness in collegiate baseball players has not been reported. Therefore, this study evaluated if the level of soreness was related to throwing volume in collegiate pitchers. The primary purpose of this study was to determine the relationship between pitch volume and self-reported arm soreness. A secondary purpose was to determine the relationship between change in pitch volume and change in arm soreness over the course of the season for collegiate baseball pitchers.

METHODS

Participants

The study was a longitudinal observational study carried out over the fall and spring season of 2009-2010. The participants consisted of seven division I collegiate baseball pitchers from a single team in the Southeastern Conference. Participants were on average 20 $\pm$ 1 years old, weighed 90 $\pm$ 8.6 kg, and height 191 $\pm$ 7 cm. Two of these pitchers are categorized as starters, and five of these pitchers are categorized as relievers determined by their coaching staff for the spring season of 2010. One of the pitchers did not join the study until week two of the fall season. Inclusion criteria consisted of being a collegiate baseball pitcher for the University of Kentucky. The only exclusion criterion was if the athlete was injured and unable to participate at the beginning of the study. All testing and data collection were performed in a collegiate athletic training room. All participants volunteered for this study and signed approved informed consent forms (UK IRB #09-0545) before commencement.

Exposures

Three key variables were collected in this study: athletic exposure, self-reported soreness and self-reported pitch count. The pitcher's exposure was categorized into one of six categories based on what the individual athlete and team did for each day through the fall and spring seasons. "Injured-out" category indicated that athlete was unable to participate due to an injury or illness. "Injured-conditioning" indicating that the athlete could condition but not participate in practice or game. "Injured-practice only" indicates that the athlete was modified during practice due to an injury or illness. "Conditioning only" indicates that the team was only conditioning that day, but the athlete was able to participate in all conditioning activities. "Days off" indicate days of mandatory rest or recommended by the coaching staff. "Practice" indicated team practices that the athlete performed fully. During the fall season, a "Game" exposure was an inter-squad scrimmage and during the spring indicated a competition during an opposing team. The fall season consisted of 13 weeks and the spring season consisted of 20 weeks. The winter break between semesters was not included in this data.

Soreness

Soreness was recorded by the athlete using a 0-10 numeric rating scale comparable to a pain scale at the end of the practice or workout on a numeric scale with 0 = no soreness and 10 = to constant soreness in the arm that affects sleep.[10,11] There were three contextual levels of soreness that were reported: soreness at rest, soreness with baseball activity and soreness with non-baseball activity. Daily soreness was totaled from the three questions and recorded into the excel database for each athlete individually. Soreness can arise from any source such as, bone, ligament, fascia or muscle which can potentially reduce muscle function.[8] Previous research has demonstrated that elevated plasma creatine kinase (CK) levels are related to muscle damage. Recent studies have shown that as creatine kinase increases due to activity, muscle soreness and fatigue increases that can directly affect performance.[12]

Pitch Volume

To acquire pitch volume data during practice, each participant provided estimated pitch counts for each category of throwing activity. Pitch counts were divided into six different throwing activities: catch, long toss, flat ground, practice bullpen (on practice days), game bullpen (game day bullpen pitches), and game pitching. Catch was typically performed at 30-50% intensity at a distance of approximately 70 feet apart. Long toss was greater intensity at distances ranging from 120-150 feet with the intention to get the ball to the partner on the fly or on one hop. Flat ground pitching intensity varied at a distance of 60 feet. Bullpen during practice focus varied based on the day and athlete based on coaching instructions but was performed on a pitching mound. At the end of every day on the same sheet of paper the athlete recorded soreness, they estimated their pitch volume for each activity. The data were entered into an excel spreadsheet for each athlete each day. Game day bullpen followed the typical format to prepare the athlete to pitch in the game. The coaching staff and team recorded game and bullpen pitches as part of the typical records kept. This data was not estimated by the athlete, but recorded directly from the team records into the excel database. This data was collected daily using a simple paper data collection form which each participant completed immediately after each practice or game. Pilot testing revealed that athletes were within approximately 15% of their estimated values when compared to actual counts made by the research team. Self-reporting pitching volume is a limitation of the study but was the only way available at the time of the study to capture pitch volume.

Statistical Analysis

Athletic exposures were summed for all pitchers for each category described above with counts and percentages calculated for fall, spring and total season. Pitch counts for all pitchers for each type were summed with counts and percentages calculated for fall, spring, and total season. The total pitches and total soreness for each player for the entire season were used to determine the relationship between pitch count total volume and total soreness. Three separate correlations were performed for the fall, spring and total season to determine the degree of relationship between pitch volume and soreness.

Measuring workloads on an athlete can occur by monitoring external workload such as distance running or in this study pitch volume. Internal workload can be assessed by monitoring physiological or psychological stressors such as heart rate or rating of perceived exertion.[13] Integrating these two measures of workload is often recommended to monitor changes in workload to assess the likelihood of injury in sports.[13,14] However, external workload alone has been used to predict future injuries.[15,16] It was not the intention of this study to predict injury but to determine how external workload of pitch volume during practice and games effect shoulder soreness. The weekly pitch volume and soreness volume had to be determined. The total pitches thrown by an individual pitcher for each week were determined by summing pitch volumes by week. Soreness scores were summed together from the three questions for each week for each player. For example, if an athlete reported a score of 2 for soreness at rest, a score of 5 soreness with baseball activity and a score of 3 soreness with non-baseball activity his total score for a day would 10 out of 30. The individual player's daily pitch counts and soreness scores were summed together to create a total number of pitches and soreness for each week. One of the pitchers did not start recording data until week three of the fall season. Therefore, the change scores for all subjects did not include the first two weeks of the fall season. The acute to chronic workload ratio of 1:4 has been used previously to investigate the relationship between external workload and increased risk of injury.[13] However, due to the relatively short fall season, the ratio 1:3 was used to investigate how a change in pitch volume correlated with change in soreness reported by the athletes. The acute to chronic external workload of pitch volume is calculated by dividing the current week pitch count volume (e.g., 300) divided by the average of the three previous weeks pitch volume (e.g., 150, 200, 250 equals an average of 200). This example would result in an equation of 300/200 = 1.5 acute to chronic pitch volume workload. A value greater than 1.0 indicates an increase in the acute workload of pitch counts. This is considered a negative training balance as the previous chronic training volume is below the acute workload for the current week. A value less than 1 indicated a decrease in acute workload indicating a positive training balance as the previous chronic training volume is above the acute workload for the current week.[14] A value of 1 indicates workload for the week remained the same as the average of the previous three weeks. A negative training balance has been associated with an increased risk of injury in cricket players.[14] The acute to chronic external workload calculation was repeated for each subsequent week for the fall season starting in the sixth week as the first two weeks were ignored as all subjects were not enrolled. This same calculation was performed for soreness. In the spring season, the same calculations were carried out starting in the fourth week of the spring season for pitch count and soreness.

RESULTS

Exposures

Athletic exposures by category are detailed in Table 1. The frequency counts of athletic exposures revealed that the majority of the exposures occur during practice regardless of the season accounting for 43% of the exposures. Days off or rest days accounted for the second most prevalent exposure which is mandated by the rules of college baseball. Sixty-four days or 4% of the total 1653 athletic exposures were missed practices or games. The non-time loss categories in which athletes were modified in practice or participating in conditioning accounted 206 days or 12% of the total exposures. The majority of these occurred during the fall season when athletes are not in the competitive season. During the spring season, only 12% of the athletic exposures of these seven pitchers were during a game situation. (Table 1)

Pitch Volume

The cumulative pitch volume for the seven pitchers is summed together and presented by type and season. (Table 2) There were a total of 54,151 pitches

Table 1. *Exposures during fall, spring and total season by category.*

	Injured out	Injured-cond.	Injured-Practice Only	Days off	Cond . only	Practice	Game
Fall							
Athletic Exposures	39	73	79	195	66	198	37
% of exposure	6%	11%	11%	28%	10%	29%	5%
Spring							
Athletic Exposures	25	15	39	202	55	514	116
% of exposure	3%	2%	4%	21%	6%	53%	12%
Total Season							
Athletic Exposures	64	88	118	397	121	712	153
% of exposure	4%	5%	7%	25%	7%	43%	9%

Cond. = Conditioning

Table 2. *Total pitch volume for fall, spring, and total season by pitch type.*

	Catch	Long toss	Flat ground	Practice Bullpen	Game bullpen	Game
Fall						
Total Pitch Counts	7605	3520	1283	2208	900	909
% of all throws	46%	21%	8%	13%	5%	6%
Spring						
Total Pitch Counts	16900	5575	2920	4777	2961	4593
% of all throws	45%	15%	8%	13%	8%	12%
Total season						
Total Pitch Counts	24505	9095	4203	6985	3861	5502
% of throws for entire season	45%	17%	8%	13%	7%	10%

% = percentage
Catch represents warm up throws, typically performed at 30-50% intensity at a distance of approximately 70 feet apart.

thrown by the seven participants representing an average of 7,735 throws per player for the entire college baseball season. Forty-five percent of all the pitches thrown were relative low intensity as they were in the "catch" category. A particularly interesting finding is that game pitches only accounted for 12% of all pitches during the spring season. Practice bullpen pitches equaled the game pitches during the competitive spring season but are usually not accounted for in the total volume of pitches thrown. Game day bullpens and game pitches during the spring season accounted for a total of 7554 across the seven pitchers. Bullpen pitches on game day accounted for 2961 (39%) of the total pitches thrown by these seven athletes. (Table 2)

Correlations

The pitch count and soreness data were examined for normality with a Q-Q plot in SPSS version 22. The data were found to be normally distributed and were confirmed with a Shapiro-Wilk test ($p > 0.169$). Pearson correlation between total pitch volume and soreness for the fall revealed a non-significant correlation of $r = -0.16$ ($R^2 = 0.026$, $p = 0.73$, Figure 1). The Pearson correlation for the same two variables in the spring season revealed a correlation of $r = 0.86$ ($R^2 = 0.75$, $p = 0.012$, Figure 1). When taking into account the entire season spanning the fall and spring the Pearson correlation between pitch counts and soreness was $r = .72$ ($R^2 = 0.52$, $p = .004$, Figure 2). The one week acute to chronic (three-week average) workload for pitch count and soreness is presented in Table 3. The Pearson correlation between the acute: chronic workload ratio for pitch count and soreness was $r = 0.64$ ($R^2 = 0.40$, $p = 0.001$)

DISCUSSION

The primary purpose of this study was to evaluate the relationship between pitch volume and self-reported arm soreness over the course of a collegiate baseball season. Previous literature in adolescent pitchers shows that there is a relationship between pitch volume and injury.[2] However, this is the first study to investigate the relationship between pitch volume and shoulder soreness among collegiate baseball pitchers. When examining the data for the fall, there was not a meaningful correlation between pitch volume and soreness. This is likely due to the fall being the off-season and throwing volume was the lowest for the whole year. The lower volume of throwing is due to less practice exposures (198/712 = 28%) and increased number of days in which athletes were out of completion (39/64 = 61%) or on limited participation (73/88 = 82%). (Table 1) The spring season, which is the competitive season accounting for 72% of all practices and 75% of games generated a significant correlation (r = 0.82) between pitch volume and soreness. This correlation remained moderately

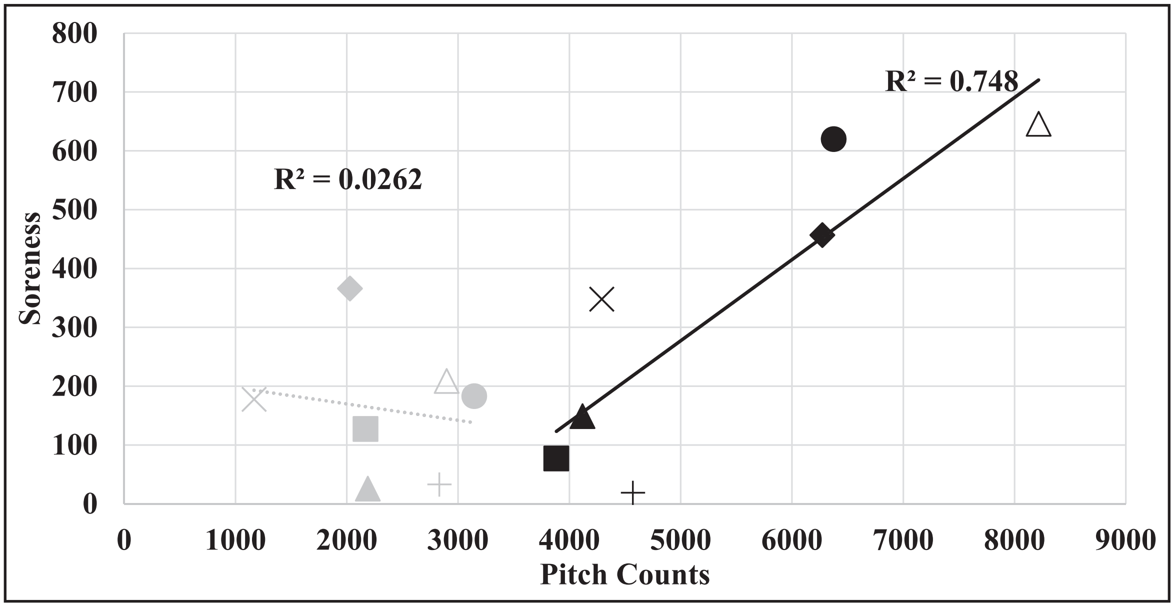

Figure 1. *Correlation of pitch counts and soreness for the fall and spring. Gray color represents fall and black color represents spring season.*
◆Subject 1 ▲Subject 2 ●Subject 3 ☐Subject 4 ×Subject 5 + Subject 6 △Subject 7

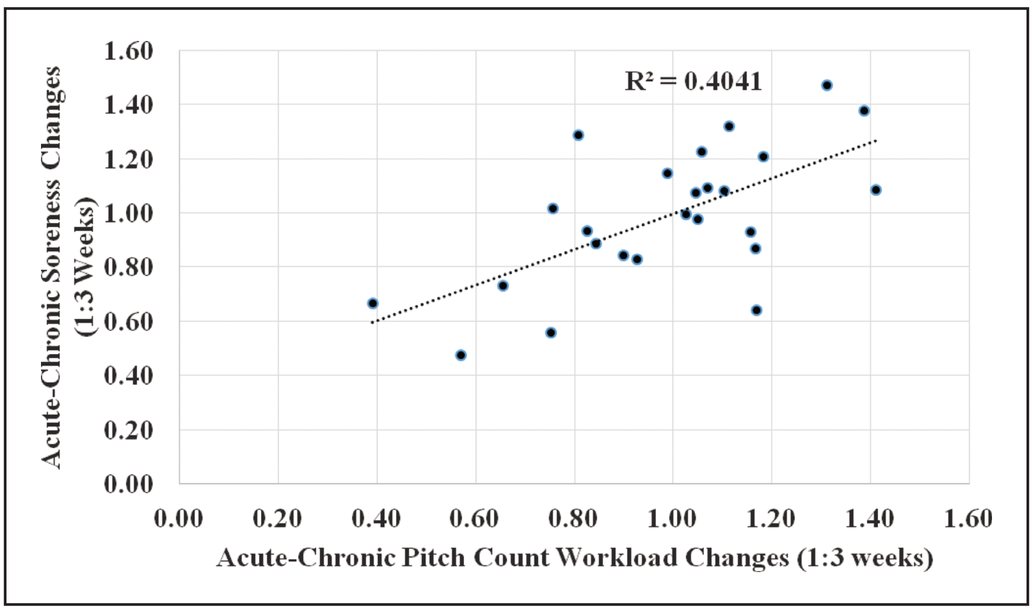

Figure 2. *Correlation of between acute:chronic workload for pitch count and soreness for the entire season. Acute represents the sum of pitches or total soreness for the current week. Chronic represents the average number of pitches per week or average total soreness per week for the previous three weeks.*

strong (r = 0.72) when combining the fall and spring seasons. It is clear that the spring season is accounting for the strong correlation between pitch volume and soreness for the entire season is due to the greater variability in both pitch volume and soreness levels.

This moderately strong relationship is not surprising based on anecdotal evidence reported by clinicians treating these athletes. However, this study demonstrates that spikes in soreness appear to be moderately related (r = .64) to spikes in pitching volume. Recent literature has indicated that over half (59%) of baseball injuries are non-time loss.[3] Arm soreness is a common ailment treated by clinicians. Tracking changes in throwing volumes throughout the season not just during games may provide valuable insight

Table 3. *The sum of the participant's pitches and soreness as measured on 0-10 numeric rating scale for each week during fall and spring season. The on acute (current week) to chronic (3-week average) workload ratio for pitch counts and soreness.*

Season	Week	Total Pitches	Total Soreness	Acute: Chronic Pitch Workload (1:3)	Acute: Chronic soreness Workload (1:3)
Fall	1	145	47	NC	NC
	2	357	69	NC	NC
	3	1317	73	-	-
	4	1217	97	-	-
	5	1600	88	-	-
	6	1628	104	1.18	1.21
	7	1634	104	1.10	1.08
	8	1715	121	1.06	1.23
	9	1537	91	0.93	0.83
	10	1883	98	1.16	0.93
	11	1829	113	1.07	1.09
	12	685	67	0.39	0.67
	13	835	44	0.57	0.47
Spring	1	1055	103	-	-
	2	1542	146	-	-
	3	1805	127	-	-
	4	2070	136	1.41	1.09
	5	2110	87	1.17	0.64
	6	2328	97	1.17	0.87
	7	1949	90	0.90	0.84
	8	1798	81	0.84	0.89
	9	2119	96	1.05	1.07
	10	2565	131	1.31	1.47
	11	2215	102	1.03	0.99
	12	2412	107	1.05	0.98
	13	2371	130	0.99	1.15
	14	1763	115	0.76	1.02
	15	1428	86	0.65	0.73
	16	1499	142	0.81	1.29
	17	1741	151	1.11	1.32
	18	2158	174	1.39	1.38
	19	1353	87	0.75	0.56
	20	1445	128	0.83	0.93

NC = not counted as all subjects were not enrolled yet.

- = the first three weeks in which averages were determined

1:3 represents the acute:chronic work ratio where 1 = current week pitch count or soreness sum for the week and 3 represent the average pitch count or soreness for the previous 3 weeks of athletic participation.

in minimizing arm soreness and may potentially reduce overuse injuries.

In previous youth baseball studies, pitch volume has been recorded utilizing pitch count logs, which were completed by coaches after each game and only reported game pitches.[2] This research led to a demonstration of high pitch counts exposing athletes to a higher risk of injury and generating pitch count limits in youth baseball. In this setting of only seven collegiate baseball pitchers, it was not feasible to investigate the risk of injury. Therefore, this study focused on what is commonly managed in the athletic training room, which is soreness. Shoulder soreness in baseball pitchers is an indication of subclinical adaptation in response to a load placed on the shoulder.[12]

The external workload of pitching was based on previous pitch volume research.[17] Self-reported daily pitch volume was instituted to limit recall bias and was most feasible for this study. These methods are similar to previous youth baseball research that recorded pitching logs except that in this study both practice and game pitch volume was recorded. This is more consistent with obtaining continuous workload as has been recommended.[14] Counting each pitch is more accurate, however, in a collegiate baseball setting, it was not feasible for the athletic trainer to count every single throw for all of the pitchers. Self-reporting pitch volume and arm soreness allowed the researchers to track daily workload and perceived soreness without undue burden on the athlete. Based on the results these seem to be reasonably useful and straightforward indicators of workload on the pitcher that are moderately correlated both for the entire season and over weekly intervals. Ultimately, the goal of future studies would be to use this information is to predict and prevent injuries.

Spikes in both external and internal acute workloads have increased the risk of injury.[14] Acute spikes in external workload creating a negative training balance indicated by an acute to chronic workload was found to increase the relative risk of injury in the subsequent week (RR = 2.1 CI_{95} 1.8 to 2.4). Similarly, acute spikes in internal workloads creating a negative training balance increases the relative risk of injury in subsequent week (RR = 2.2 CI_{95} 1.91 to 2.5). These results in cricket bowlers suggest that either internal or external workloads could be beneficial to track for injury risk.[14]

The recent consensus statement on monitoring athletic workloads has suggested that integrating both of these measures would be a better representation of total workload.[13] However, in the current study only external workload was measured. Total workload integrating internal with the external workload of pitch volume may have yielded a stronger correlation to arm soreness. It is apparent that a negative training stress measured from either internal or external workload over the previous training weeks, increased the relative risk of injury by two fold as 63% percent of the cricket bowlers' injuries occurred one week after a negative training balance.[14]

Negative training stress was observed in two of the seven pitchers that led to a time-loss injury within two weeks after returning to practice. Although not the focus of this study, it was noted that two individual athletes acute to chronic workload had a negative training stress that led to a time-loss injury. A reliever in the fall was averaging 65 throws a week for six weeks and then developed bronchitis, which reduced his throws to 54 and 45 for the next two weeks, respectively. In the subsequent two weeks, he threw an average of 71 pitches, which is a 1.25 acute to chronic workload change. This indicates that he increased his volume by 25% in both weeks over the previous three weeks. Midway through the second week, he reported elbow pain and was not able to participate in the last few weeks of fall ball due to elbow pain. A similar scenario occurred in the spring to a starting pitcher that developed mononuceleous in the 13th week of the 20-week spring season. After two weeks of no throwing in week 15 he participated in partial practice and threw 115 throws. Week 16 his volume increased to 401 throws resulting in a chronic workload of 39 throws over the previous three weeks. The dramatic increase in throwing volume was precipitated due to playoffs approaching. However, this represented a 10 fold increase in throwing volume (401/39 = 10.3) in one week due to the two weeks of negative training stress caused by his illness. In week 18 he reported shoulder pain to the medical staff, resulting in missing two full days and was limited on a third day. This is the first study to analyze acute to chronic external workloads in collegiate baseball players. In cricket, fast bowlers who have a high acute workload have an increased injury incidence over the next three weeks.[9] These examples support the need to monitor pitch volume throughout the season. Monitoring pitch count during a game only represents 12% of the total throws during a collegiate season.

Pitch counts during a game may not be an adequate representation of the workload for college pitchers. Game pitch volume for an entire season depends on if the player is a starter or reliever. Starters have been found to throw 1244 $\pm$ 387 and relievers 605 $\pm$ 182 pitches.[18] These values are consistent with the 4,593 game pitches recorded in the current study. Averaged over the seven pitchers during the spring season this equals 656 pitches. This is consistent as five of the seven pitchers were relievers. However, the 4,593 pitches only represents 12% of the total workload for the spring season. Over the course of the season, 45% of all throws were of relatively light intensity classified as "catch". However, the physical demands from flatground, long toss, and practice bullpens thrown by these seven pitchers which account for 20,283/54,151 (37.4%) pitches thrown are typically not taken into consideration by coaches and medical staff as measuring volume during practice is challenging. Practice pitch volume is four times greater than game pitch volume. It is clear that these practice volumes are critical to prepare the athlete for the demands of pitching while inadequate volume associated with acute spikes can lead to muscle soreness and in some cases time-loss injuries.

This study has several limitations that should be addressed in future research. One limitation of this study is that there is a small sample size. The data recorded was only external workloads of seven Division 1 collegiate baseball pitchers from the Midwest, for one season. Although positive correlations were found, future research should enroll a larger number of participants, incorporating internal with external workload measures and consider other rolling averages to identify the best predictive models for both time-loss and non-time loss injuries should be investigated. Another limitation is that the pitch volume totals are estimations and are not exact pitch counts. The recent advances in wearable technology will likely improve these estimates dramatically and reduce burden on athletes and researchers to monitor number of throws. Other measures of internal workload such as perceived exertion beyond soreness should be considered to identify best predictors of pitchers at risk for injury.

CONCLUSIONS

The primary purpose of this study was to examine the relationship between pitch volume and self-reported arm soreness. There was a moderate and significant correlation (r =.72) over the course of the entire season. As pitch volume and workload increased per week, soreness levels increased as well. This is relevant because current researchers have shown that an increase in workload is associated with injury and daily soreness is considered muscle damage, which can affect muscle function.[8] The secondary purpose was to evaluate the relationship between change in pitch volume and change in arm soreness over the course of the season for collegiate baseball pitchers. Researchers have shown that the greater the workload increases, the larger the increase of risk of injury the following week.[13] In this study, there was a significant and moderate correlation (r=.62) between weekly workload and soreness. Current literature shows that injury risks are not increased immediately after increases in workload, however three to four weeks after the increased acute load relative to previous weeks of training is when injury may occur.[9] The monitoring of acute and chronic workload can offer valuable insight into likelihood of injury.[13]

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