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Validity of Pitch Velocity and Strike Percentage to Assess Fatigue in Young Baseball Pitchers

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Abstract

Although coaches chart pitch velocity (PV) and strike percentage (SP) to assess pitcher fatigue levels, the validity of these tools has not been quantified in young pitchers. The purpose of this study was to compare PV and SP across levels of perceived fatigue in young pitchers. Data describing PV, first strike percentage (SP_{1st}), total strike percentage (SP_T) and perceived fatigue (PFL) throughout a simulated performance were recorded for 14 pitchers. Differences within PV, SP_{1st} , and SP_T were compared across PFLs utilizing repeated measures analysis of variance. PF was the independent variable and PV, SP_{1st}, and SP_T were the dependent variables. Results indicated no differences in PV across fatigue levels. SP_T increased significantly from PFL 0 to PFL 1 ($p = 0.0250$). SP_{1st} also increased significantly between PFL 0 and PFL 1 ($p = 0.0040$) before decreasing significantly for PFL 2 ($p < 0.001$). These results indicate that the tracking of PV may not be a valid tool for assessing fatigue. However, tracking both SP_{1st} and SP_T may be valid tools for assessing fatigue and may provide coaches with evidence of the onset of fatigue.

Key Words: Pitch Velocity; Strike Percentage; Fatigue; Baseball; Youth

1. Introduction

The baseball pitching motion is a dynamic total body movement that requires proper sequencing of complex segmental interactions to produce both velocity and accuracy (Putnam, 1993). One factor that is thought to influence the ability of a pitcher to properly sequence the segments involved in the movement is fatigue (Andrews, et al., 1976). Fatigue is thought to be the result of a complex interaction of multiple components (Lambert, et al., 2005). In baseball pitchers it may be any combination of mechanical, physiological, and psychological factors that contribute to decreased performance. Although our understanding of fatigue in pitching is limited, previous literature has indicated that it can have an effect on performance and possibly increase the likelihood of hyperangulation, impingement, and increased forces and moments experienced about the shoulder and elbow (Andrews, et al., 1976; Andrews and Wilk, 1994; Escamilla et al., 2007; Mair, 1996; Mullanet et al., 2005; Murray, et al., 2001; Thurston, 1998). As a result risk factors such as increased extension of the trunk, decreased shoulder flexion and shoulder internal rotation strength that have been associated with fatigue (Escamilla et al., 2007; Mullaney et al., 2005). Thus the ability of a coach to identify a fatigued pitcher may be crucial to both the outcome of the game and reducing the vulnerability of the pitcher to injury.

Tripp et al., (2007) observed fatigue in collegiate pitchers around the 60 pitch mark which is well below the current pitch count limit established by little league baseball of 85 pitches (Little League Online website, March 15, 2010), which may provide some indication that this pitch count is too high for youth baseball pitchers. Additionally, as collegiate pitchers fatigue following an average of 61 throws, they display variability in their pitching mechanics during the arm-cocking phase (Tripp, et al., 2007). This finding is particularly important, as the position of arm cocking has most often been linked to high injury rates in pitchers (Fleisig, et al., 1995).

Although high-speed motion capture techniques allow for the small changes in pitching mechanics to be measureable, these tools are not available to coaches during a competitive performance. Thus, coaches typically utilize a combination of subjective and objective methods to make informed decisions regarding a pitcher's performance and safety during a game. Subjectively, the coach may obtain verbal feedback from the pitcher and catcher and compare this feedback with performance variables such as strike percentage, pitch velocity, ball movement, and pitch count, to assess level of fatigue. However, investigations of adult pitchers have determined this assessment of pitcher fatigue may not be the most effective method (Escamilla et al., 2007; Mullaney et al., 2005, Thurston, 1998). Therefore, the purpose of this study was to investigate changes in pitch velocity and strike percentage in relation to fatigue level as young pitchers complete a simulated game pitching performance. This was done in an effort to provide an increased knowledge on how two objective measures used by coaches to assess level of fatigue in competitive settings may change and determine the validity of velocity and strike percentage as indicators of fatigue in young pitchers. It was hypothesized that both pitch velocity and strike percentage would be valid indicators of fatigue level in young pitchers.

2. Methods

2.1. Participants

A total of 14 youth baseball pitchers (age: 11.5 $\pm$ 3.1 years; height: 144.8 $\pm$ 10.1 cm; mass: 43.4 $\pm$4.6 kg) were recruited from the local sanctioned little league organization and participated in the study. All participants recruited were determined to have been free from injury for the last 12 months, had a minimum of two years and a maximum of seven years of pitching experience, and recommended for participation by their respective coaching staff. To be recommended by coaches, pitchers must have completed their competitive season within the past two weeks, and been deemed properly conditioned for performance in a competitive setting.

Testing protocols were approved by the University of Arkansas Institutional Review Board. Prior to inclusion, all participants (and their parents/guardians) were informed of the protocols to be used, as well as all possible risk and hazards associated with participating in the study. Following confirmation of understanding testing protocols, both the participants and their parents/guardians provided written consent.

2.2. Simulated Game

The testing protocol was designed to simulate a competitive performance. Participants were allowed to perform their personal pre-competition warm-up routine prior to completing the simulated game. During this warm-up time, participants were asked to dedicate 5 minutes to throwing off the indoor pitching mound used in the study in an effort to acclimate them to the indoor pitching surface. For this study, the warm-up period averaged 20 min across all pitchers and the average number of pitches thrown during the warm-up was 40 with a minimum of 25 pitches and a maximum of 55 pitches observed across the participants.

To determine how fatigue impacted both velocity and strike percentage in young baseball pitchers, it was necessary to induce fatigue. To achieve this, a simulated game protocol was utilized. Throughout this protocol, participants were instructed to throw based on provided game situations. To provide these situations, an expert with seven years of youth, high school, and collegiate coaching experience was recruited. Verbal feedback based on batter count (balls and strikes), simulated at-bat outcomes (base hit, walk, hit-by-pitch, and ground-outs/fly-outs), and simulated runners were provided to participants throughout the performance. Each inning began with no simulated runners on base and no outs. Each situation provided built on the previous situation (e.g. when a simulated batter was walked with no outs, the next simulated situation would be stated as "runner on first, nobody out", etc…). Based on the provided situations and feedback, the pitcher threw from the appropriate position (wind-up or stretch). An example of the situation progression provided throughout an inning for a single participant is shown in Table 1.

As in a competitive setting, the pitcher was required to produce three outs per inning in accordance with the standard rules of baseball. After a pitcher had successfully produced three outs, a rest period was provided in order to simulate the second half of the inning. This rest period averaged 18 minutes and ranged from a minimum time of 12 minutes to a maximum time of 24 minutes and was altered randomly throughout the simulated game. This randomized resting period was done to mimic the typical rest period during actual little league baseball games. Upon reaching a total pitch count of 85, pitchers were allowed to complete the situation that was currently in-progress (Little League Online website, March 15, 2010). No pitchers were allowed to throw more than 88 pitches.

Table 1. Example of situational progression provided to one participant throughout a single inning.

Situation	Delivery Utilized	Outs	Strikes Thrown	Balls Thrown	Total Pitches Thrown	Result
No runners on base	Wind-up	0	3	2	5	Batter was struck out
No runners on base	Wind-up	1	2	2	4	Single to left field
Runner on First Base	Stretch	1	1	2	3	Ground out to first base
Runner on second base	Stretch	2	2	1	3	Infield Single
Runners on first and third bases	Stretch	2	2	3	5	Fly-out to Centerfield
End of the Inning Totals		3	10	10	20	No runs on 2 hits and no errors

2.3. Perceived Fatigue

Throughout the simulated game, the level of perceived fatigue (PFL) was assessed through self-reporting procedures. Pitchers reported their perceived fatigue level as not fatigued (0), slightly fatigued (1), moderately fatigued (2), and severely fatigued (3). This scaling of perceived fatigue level was selected because it had previously been shown to be a valid tool for measuring levels of perceived fatigue (Kimura, et al., 2007). A secondary reason for selecting the current scale was that it limited the levels of fatigue to four (most PFL scales have additional levels, possibly making them more complex to interpret for youth). This was done in an effort to limit much of the response subjectivity for the young participants as possible (Eston, et al., 1994; Groslambert, and Mahon, 2006). Prior to completing the throwing protocol, participants were verbally explained the characteristics of each PFL level (Table 2).

Table 2. Description of provided explanations for perceived fatigue level (PFL) ratings.

PFL	Explanation Provided to Pitcher
0	Explained as the feeling of just completing a warm-up with normal breathing and heart rate, as well as normal feeling in the legs and throwing arm.
1	Explained as the feelings of increased breathing and heart rates but not enough to make participants out of breath, and noticeable feelings of fatigue within the legs and/or throwing arm.
2	Explained as increased breathing and heart rates to the point where participants were nearly out of breath, and noticeable feelings of fatigue within the legs and/or throwing arm.
3	Explained as increased breathing and heart rates to the point where participants were out of breath, and feelings of fatigue within the legs and/or throwing arm such that participants were unable to complete more than 10 additional pitches.

To assess the reliability of the PFL ratings for youth pitchers prior to this study, pilot data were collected during extended pitching practice sessions where team coaches rated the PFL of 10 participants. Pitch counts were collected for each PFL rated by the coach and the pitcher. Simple correlation analysis was conducted to examine the relationship between fatigue ratings of both coaches and player. A strong positive relationship between coach and player ratings was observed ($r = 0.81$, $p = 0.0054$). Additionally, mean difference testing was conducted for pitch count data that were collected for each PFL rated by the coach and the pitcher. Simple two tailed t-test analyses at each PFL were used to compare pitch counts across the pitcher and coaches PFL rating ($t_{(9)} = 1.412$, $p = 0.1916$). No differences were observed in these pilot data between pitcher and coach fatigue ratings with regard to the number of pitches thrown at each PFL. The results of the analysis of these pilot data indicate that both coaches and pitchers were similar in their assessment of fatigue level throughout pilot data collection.

2.4. Data Collection

Throughout the simulated game, pitchers reported their perceived fatigue level only when they progressed up the PFL rating scale resulting in one data point per PFL. Throughout the performance the velocity of every pitch was measured to the nearest meter per second with a calibrated portable radar gun (Jugs, Tualatin, OR) positioned 5 m directly to the right of the catcher and in the direction of the pitcher. The velocities of all pitches thrown were averaged across each of the reported PFLs. Balls and strikes thrown during the testing session were identified by a certified umpire with 5 yr of experience in the little league setting. The data were structured such that those data describing both first strike percentage and total strike percentage were calculated for each reported PFL. Total strike percentage was determined by taking the number of pitches passing within the strike-zone and dividing by the total number of pitches thrown at each of the reported PFLs. First strike percentage was determined by taking the number of strikes thrown on the first pitch of each simulated at-bat and dividing by the total number of first pitches thrown across all simulated at bats at each of the PFLs.

2.5. Statistical Analysis

To test for differences in both velocity and throwing accuracy across all PFLs, repeated measures analysis of variance (ANOVA) were utilized. In these analyses, PFL (0, 1, 2, and 3) was the independent variable and throwing velocity and accuracy were the dependent variables. Across all ANOVA analyses the overall alpha level was set at 0.05. Bonferroni post hoc procedures were utilized to determine between which PFL levels the dependent variables differed.

3. Results

The number of pitches thrown across each PFL, as well as the descriptive statistics associated with pitch velocity (PV), overall strike percentage (SP_T) and first strike percentage (SP_{1st}) for each PFL are displayed in Table 3. Across all participants, pitchers averaged 38% of pitches thrown from the wind-up and 62% of the pitches thrown from the stretch.

Table 3. Descriptive statistics of pitches thrown across each level of perceived fatigue (PFL).

Parameter	Mean (SD)	Max	Min
PFL 0			
Pitch Count	47.53 (10.87)	44.00	38.00
Velocity (mph)	40.53 (2.09)	60.00	31.00
Total Strike Percentage	50.80 (7.18)	61.00	37.00
1st Pitch Strike Percentage	55.48 (12.80)	82.00	37.00
PFL 1			
Pitch Count	22.20 (8.91)	35.00	10.00
Velocity (mph)	40.33 (2.19)	44.00	38.00
Total Strike Percentage	58.67 (4.26)	65.00	53.00
1st Pitch Strike Percentage	64.78 (13.06)	84.00	44.00
PFL 2			
Pitch Count	22.87 (13.24)	50.00	9.00
Velocity (mph)	40.40 (2.13)	44.00	37.00
Total Strike Percentage	52.41 (7.55)	58.00	35.00
1st Pitch Strike Percentage	49.83 (8.08)	67.00	41.00
PFL 3			
Pitch Count	5.00 (----)	5.00	5.00
Velocity (mph)	40.47 (2.26)	44.00	37.00
Total Strike Percentage	45.33 (19.22)	80.00	20.00
1st Pitch Strike Percentage	39.99 (35.52)	100.00	0.00

3.1. Pitch Velocity

The repeated measures ANOVA test showed that the within subject main effect was not different across any of the PFLs ($F_{(3,42)} = 0.220$, $p = 0.882$) for pitch velocity. In fact, PV averaged approximately 40 mi/hr across each of the perceived fatigue levels and never fell below or rose above 40 mi/hr.

3.2. Overall Strike Percentage

For overall strike percentage (SP_T) across the various PFLs, model testing indicated that pitchers differed significantly ($F_{(3,42)} = 12.819$, $p < 0.001$, $1-\beta = 1.000$). Post-hoc results revealed that pitchers' SP_T for PFL 0 was significantly higher than their SP_T at PFL 3 ($p = 0.029$). In addition, SP_T for PFL 1 was significantly higher than SP_T for both PFL 2 ($p = 0.017$) and PFL 3 ($p < 0.001$) and SP_T for PFL 2 was significantly higher than SP_T for PFL

3 ($p = 0.004$). Finally, results of post hoc comparisons also revealed that SP_T for PFL 0 was significantly lower than SP_T for PFL 1 ($p = 0.004$). These results are displayed in Figure 1.

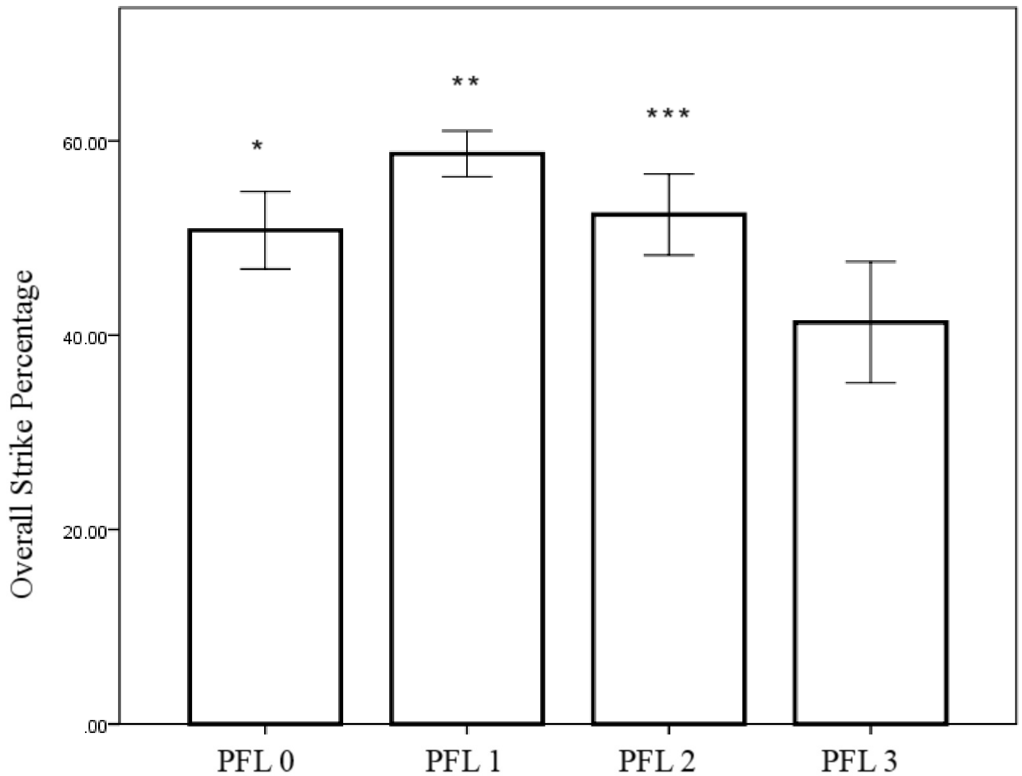

Figure 1. Results of repeated measures ANOVA testing for differences in overall strike percentage across all PFLs. Overall strike percentage was significantly higher for PFL 0 when compared to PFL 3 (*). Overall strike percentage PFL 1 was significantly higher when compared to all other PFL levels (**).Overall strike percentage PFL 2 was significantly higher when compared to PFL 3 (***)

3.3. First Strike Percentage

As displayed in Figure 2, analysis of first strike percentage (SP_{1st}) was similar to those observed for SP_T in that pitchers' SP_{1st} differed significantly somewhere across PFL levels ($F_{(3,42)} = 7.394$, $p < 0.001$, $1\text{-}\beta = 0.976$). Also similar to SP_T, post hoc analysis of SP_{1st} revealed pitchers had a significantly lower SP_{1st} at PFL 0 when compared to PFL 1 ($p = 0.004$) and significantly higher SP_{1st} when PFL 1 was compared to both PFL 2 ($p < 0.001$) and PFL 3 ($p = 0.001$). However, unlike SP_T, no difference was observed in SP_{1st} between PFL 0 and PFL 3.

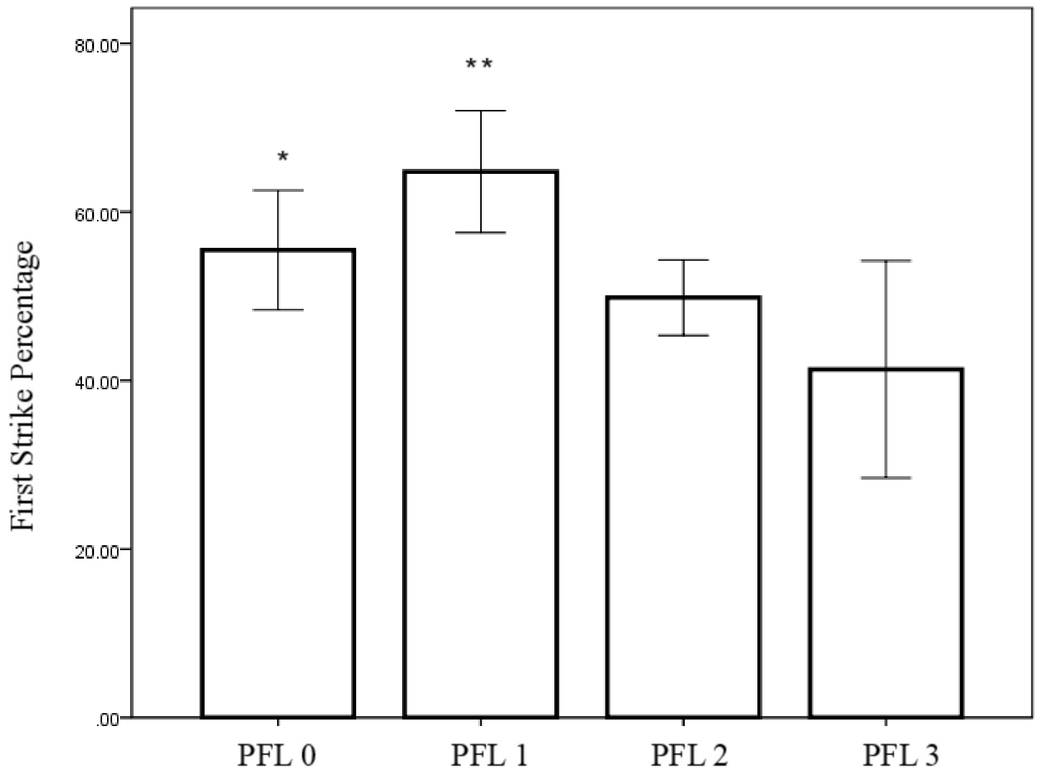

Figure 2. Results of repeated measures ANOVA testing for differences in first strike percentage across all PFLs. First strike percentage was significantly lower for PFL 0 when compared to PFL 1 (*). Overall strike percentage PFL 1 was significantly higher when compared to all other PFL levels (**).

4. Discussion

It has previously been shown that in the later stages of an extended pitching performance, pitchers alter both upper and lower body kinematics as they fatigue (Shimada, Ae, Fujii, Kawamura, & Takahashi, 2004; Stodden, Fleisig, McLean, Lyman, & Andrews, 2001). However, because these biomechanical alterations cannot be quantified without using high speed motion capture techniques, coaches typically utilize a combination of objective and subjective feedback to assess fatigue. With regard to visual feedback available, coaches commonly use pitch velocity and strike percentage to assess fatigue. Based on the results of this study, the assessment of both overall strike percentage and first strike percentage may be valid tools for determining pitcher fatigue levels, while assessment of pitch velocity is not.

4.1. Velocity

With regard to pitch velocity, it is commonly thought that velocity decreases as a pitcher fatigues and previous research supports this notion (Escamilla, Barrentine, Fleisig, Zheng, Takada, Kingsley, et al., 2007). However, additional research has shown that changes in pitch velocity throughout an extended performance can vary by individual and thus may not be an effective tool for assessing fatigue (Hirayama, Fujii, Koike, & Ae, 2007). The findings of the current study support this second postulation as there was no decrease in pitch velocity across the youth pitchers analyzed. Across each of the PFLs, average pitch velocity was consistently observed to be near 40 mph (17.88 m/s) with limited variability (SD ranged for each PFL from ±2.09 to ±2.26). These findings reveal that change in pitch velocity is a poor indicator that young pitchers are fatigued.

4.2. Strike Percentage

In terms of strike percentage, the findings of this study do support the idea of a decrease in accuracy being associated with fatigue. The observation of both significantly higher overall pitch accuracy as well as first strike percentage for PFL 1 (compared to PFL 2 and PFL 3) indicate that pitchers do experience decreased accuracy as they progressively fatigue through an extended pitching performance. This finding is important since the tracking of strike percentage is conducted by the coaching staff. Thus these variables may be able to provide coaches with more valid information as to the level of fatigue a pitcher experiences throughout performance.

A second, and perhaps more interesting finding regarding accuracy was that pitchers demonstrated significantly higher accuracy (both overall accuracy and first strike accuracy) when at PFL 1 when compared with PFL 0. This finding, while not supporting the notion of utilizing accuracy to assess fatigue because of the increase in accuracy, reveals an interesting paradigm that may relate to pre-competition warm-up. This increase in both overall pitch accuracy and first strike accuracy from PFL 0 to PFL 1 may indicate that young pitchers demonstrate inadequacy in their pre-competition warm-up. Young pitchers may not fully comprehend the idea of a proper warm-up and thus, do not participate in appropriate levels of pre-competition exertion. Based on these findings, it may be necessary for coaches to focus on increasing the level of pre-competition warm-up in an effort to allow pitchers to produce higher levels of overall accuracy at the onset of a performance.

4.3. Study Limitations

One of the primary limitations of this study was that although the research team utilized a four point PFL scale to minimize the subjectivity of participant responses as much as possible, the complete removal of participant subjectivity was impossible due to the nature of the perceived fatigue variable itself. We acknowledge that perceived fatigue is inherently a subjective measure. However, we feel that the four-point scale utilized does have advantages over both a PFL scale that has fewer than four response options and a PFL scale that has more than four response options. These advantages are more than likely related to scale measures such as reliability and validity when compared to scales with more limited response options as well as the overall complexity of the various scales for use with a sample of youth baseball pitchers when compared to scales with an increased number of response options.

A second limitation of this study is that during the simulated game protocol there was no physical batter. Although this may have had an impact on the perceptions of the participants during the simulated game, this was done in an effort to maximize safety. Also, at PFL 3, each pitcher threw only 5 pitches, limiting variability in the number of pitches thrown at PFL 3. As with not having a physical batter, this portion of the study was designed in an effort to maximize the safety of the participants and prevent a large number of pitches to be thrown at a high level of perceived fatigue. As the number of pitches thrown at PFL 3 was not analyzed relative to the number of pitches thrown at other PLF's it was determined that the increase in protection for the participants outweighed any potential negative impacts this protocol may have had on the results.

5. Conclusion

The findings of the current study shed additional light on how valid the assessment of pitch velocity and strike percentage may be in determining when young pitchers begin to fatigue. It appears that the use of pitch velocity may be ineffective when utilized to determine young pitchers' levels of fatigue. However, it may be beneficial for coaches to track pitch accuracy (both overall accuracy and first strike accuracy) throughout an extended performance in an effort to identify the onset of fatigue. In addition, these data may provide a baseline pitch number for future assessment of alterations in pitching biomechanics. However, further study in this area is needed to relate changes in pitching kinematics and kinetics to the observed alteration in first strike percentage observed across the various PFL levels.

6. Practical Applications

The practical applications associated with these findings are fundamental and apply to the everyday baseball coach as charting strike percentage is common in the baseball world. Therefore, it is suggested that coaches begin to utilize strike percentage assessments to monitor the fatigue levels of their young pitchers. Additionally, it is suggested that coaches begin to make record of the level of exertion their young pitchers reach warming-up prior to competition. By then analyzing both the amount of warm-up time and the strike percentage of their pitchers throughout the early stages of the game, coaches may be able to identify magnitudes of time or pitches for individual pitchers that are necessary for peak performance to occur at the onset of competition.

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