Kinematics and kinetics of youth baseball pitching with standard and lightweight balls

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Abstract

Because youth athletes are smaller and weaker than their adult counterparts, smaller equipment and fields are often used in youth sports. Previous research has shown that youth baseball pitchers use similar motions to older pitchers, but generate lower kinetics and angular velocities at the shoulder and elbow. The purpose of this study was to determine potential biomechanical benefits for youth pitchers to use lighter baseballs. Thirty-four youth (11.1 ± 0.7 years) pitchers pitched both standard [5 ounce (142 g)] and lightweight [4 ounce(113 g)] baseballs in a laboratory setting. Kinematic and kinetic parameters were measured with a six-camera high-speed motion analysis system. Three repeated measures MANOVAs were used to compare ($p < 0.05$) position, velocity, and kinetic parameters between the standard and lightweight baseballs. Subjective data were also collected. Pitching the lightweight ball produced no difference in arm position, but greater shoulder, elbow, and ball velocities. With the lightweight ball, pitchers produced decreased kinetics. *Post-hoc* analysis of the kinetic data revealed significant decreases in elbow varus torque and shoulder internal rotation torque. The data suggest that playing with lightweight baseballs may reduce the risk of overuse injury in the youth pitcher and also help develop arm speed. However, before introducing lightweight baseballs into the youth game, the effect of lighter, faster pitched balls for the batters and fielders should also be considered.

Keywords: shoulder, elbow, force, torque, velocity, biomechanics

Introduction

In a youth baseball season, one half of all pitchers experience shoulder or elbow pain (Lyman *et al.*, 2001; Lyman *et al.*, 2002). Along with elbow pain, radiographic changes (such as avulsion of medial epicondyle, osteochondritis of the capitellum and radial head, necrosis and sloughing of cartilage, and loose body formation) in the elbow are seen in 28% to 95% of all youth league pitchers (Gugenheim *et al.*, 1976; Larson *et al.*, 1976). While the rates of arm pain and radiographic changes in youth pitchers have remained fairly constant for decades (Lyman and Fleisig, 2005), we have seen an alarming increase in serious injuries at our sports medicine centre (Fleisig *et al.*, 2006). From 1995 to 1999, our senior author (JRA) operated on the elbows of 184 baseball pitchers, including 21 high school players. During the

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following five-year period, he operated on the elbows of 624 pitchers, including 124 high school pitchers. If the rate of surgery in high school pitchers is indeed rising, then preventing the initiation of injuries at the youth level is becoming even more important (Petty *et al.*, 2004). The high injury rate and the suggestion that the teaching of proper pitching mechanics at a young age can reduce injury risk and increase performance were vital reasons for this study.

Governing bodies of American football, basketball, soccer, and softball have reduced the size and/or weight of the ball used during play for youth athletes. The reasons proposed for allowing the use of smaller, lighter balls are three-fold: 1) to allow the pre-adolescent to achieve proper mechanics, thereby making the game more acceptable and enjoyable, 2) to assist the young athlete in developing and retaining sound motor recruitment during the forceful sports activity, and 3) to reduce the risk of injury to developing pre-adolescent musculoskeletal structures (American Academy of Pediatrics, 1994; Andrews & Fleisig, 1998; Fleisig *et al.*, 1999). Smaller soccer ball size has been implied for reduced risk of heading injury and goalie injury (Babbs, 2001; Boyd *et al.*, 2001; Queen *et al.*, 2003). Softer baseballs have been correlated with reduced risk of impact injury in youth baseball (Crisco *et al.*, 1997; Link *et al.*, 1998; Marshall *et al.*, 2003, Nicholls *et al.*, 2005; Vinger *et al.*, 1999; Yamamoto *et al.*, 2001). However, to date, no scientific publication has studied potential benefits of throwing smaller or lighter balls in any youth sport.

Youth baseball has made changes with respect to the field (base path, field dimensions, pitching distance, etc.) but youth pitchers continue to use baseballs with identical dimensions [9.0 in (23 mm) circumference] and weight specifications [5.0 oz (142 g)] to those used by Major League professionals. Fleisig *et al.* (1999) have suggested that by reducing the size and weight of the baseball, the youth pitcher might achieve the velocities needed to complete the necessary throws without compromising the proper mechanics. By maintaining proper mechanics throughout the formative years and into adolescence, the youth athlete would be assisted in sound motor recruitment, possibly preventing future throwing injuries (Andrews & Fleisig, 1998; DaSilva *et al.*, 1998; Dillman *et al.*, 1993; Fleisig *et al.*, 1989; Fleisig *et al.*, 1995; Fleisig *et al.*, 1999; Lyman & Fleisig, 2005).

While smaller and lighter baseballs might offer some advantages to youth baseball, they might be more dangerous. Decrease in ball weight may lead to increased velocity of the pitched ball and perhaps the subsequent batted ball. Increased pitched and batted ball velocities may increase the frequency and severity of injuries to youth batters and fielders (including the pitcher). Furthermore, decreasing the baseball size would increase the pressure from being hit by a ball. Thus decreasing both ball weight and size might be too dangerous, so the current study focused only on decreased ball weight during pitching.

In their literature review article, Escamilla *et al.* (2000) concluded that training with underweight and overweight baseballs could improve ball velocity for high school and collegiate pitchers. However, no previous studies have investigated the effects of varied weight baseballs with youth pitchers.

While a standard 5 oz baseball is not too heavy for an adult baseball player to throw, it may feel heavy to a youth baseball player. Theoretically, a young pitcher throwing a ball that feels heavy may change his arm angles to position the ball closer to the head, effectively decreasing the moment arm and torque needed to throw the ball. This is often described among coaches as 'pushing the ball', 'leading with the elbow', or 'throwing like a dart'. An example of this adjustment can be seen in the comparison of baseball and American football throwing. An American football weighs three times as much as a baseball (15 oz v. 5 oz). In a study of high school and college team athletes, quarterbacks held the ball closer to their heads during cocking, by producing greater shoulder horizontal adduction, greater elbow flexion, and less shoulder external rotation. If indeed a 5 oz ball is too heavy for a youth pitcher, he might 'push the ball' when pitching a 5 oz baseball, but throw with arm positions similar to an adult pitcher's when pitching a 4 oz ball.

It is also important to know whether a change in ball weight affects shoulder and elbow kinetics. Change in joint kinetics may be related to joint pain and subsequent injury, as common pitching injury mechanisms have been previously proposed involving shoulder internal rotation torque, elbow varus torque, elbow flexion torque, shoulder proximal force, and elbow proximal force (Fleisig *et al.*, 1995; Fleisig *et al.*, 1996a; Sabick *et al.*, 2004; Sabick *et al.*, 2005).

Thus, the purpose of this study was to investigate the effect of a lighter baseball on kinematic and kinetic values of youth pitchers. Three hypotheses were tested.

The first hypothesis examined changes in arm position with changes in ball weight. Specifically, the first hypothesis was that shoulder horizontal adduction, elbow flexion, and shoulder external rotation were different between pitching a standard 5 oz (142 g) baseball and a lightweight 4 oz (113 g) baseball.

The second hypothesis tested whether youth pitchers move the ball and the throwing arm faster when using a lighter baseball. Specifically, the second hypothesis was that ball velocity, elbow extension velocity, and shoulder internal rotation velocity were different between pitching a 5 oz and 4 oz baseball.

The third hypothesis examined kinetic differences between pitching different weight balls. Specifically, the third hypothesis was that shoulder internal rotation torque, elbow varus torque, elbow flexion torque, shoulder proximal force, and elbow proximal force were different between pitching a 5 oz and 4 oz baseball.

Investigating changes in biomechanics is paramount for determining potential benefits of using lightweight baseballs. In addition, it may be helpful to know whether young pitchers would be satisfied with using lightweight baseballs. Therefore, subjective data were also collected and assessed.

Methods

Subjects

Thirty-four youth pitchers, age 11.1 ± 0.7 years, height 1.54 ± 0.08 m, and mass 43.9 ± 8.4 kg (mean ± SD), were recruited from local youth baseball leagues in the Birmingham, Alabama area. All subjects were male. Each subject and his parental guardian were required to complete the provided informed consent, medical history, and physical information forms prior to the start of the study. All subjects were between 9 and 12 years old, with a minimum of 2 years of organised baseball experience. Subjects that had previous arm injuries or had a diagnosis of any musculoskeletal disorder were excluded from participation in the programme. The Arkansas State University Institutional Review Board for the Protection of Human Subjects approved this research project.

Collection of motion data

A single-blind, randomised crossover experimental design was used. Although the subjects were informed that they would be pitching standard 5 oz and underweight 4 oz baseballs, they were given no information about the weight of any specific balls during testing trials. However the investigators knew that the baseballs with green seams and green lettering weighed 5 oz and the baseballs with blue seams and blue lettering weighed 4 oz. Each subject threw a first set of pitches with a randomly assigned baseball. To achieve crossover, the subject threw a second set of pitches with a ball of the other seam/lettering colour. This randomised design resulted in 19 subjects being tested throwing the 4 oz ball first and 15 throwing the 5 oz ball first.

All participants were tested in an indoor biomechanical laboratory using a previously described procedure (Dillman *et al.*, 1993; Fleisig *et al.*, 1995; Fleisig *et al.*, 1996b; Fleisig *et al.*, 1999). Each subject was required to wear tight fitting clothing (e.g. spandex shorts and sleeveless shirt). Reflective markers were attached bilaterally to the surface of the skin over the following bony landmarks: acromion, lateral humeral epicondyle, ulnar styloid process, greater trochanter, lateral femoral epicondyle, lateral malleolus, and distal end of the second metatarsal. A reflective marker was also attached to the radial styloid process of the throwing hand. As part of this procedure, each subject's throwing arm segment length was measured prior to biomechanical analysis. The upper arm length was measured from the acromion process to the lateral epicondyle of the humerus and the forearm length was measured from the humeral epicondyle to the radial styloid process.

Subjects were given an opportunity to familiarise themselves with the artificial youth pitching mound (Athletic Training Equipment Company, Inc., Sparks, NV) and were encouraged to prepare just as if they would be pitching in a normal game situation. Each subject pitched to an adult catcher positioned behind home plate at a regulation distance for that particular player's league. With the first assigned baseball, the subject took as many warm-up pitches as desired and then pitched 10 full-effort fastballs for data collection. After completing these trials with the first type of baseball, the subject was given a 15 minute rest period, after which the subject repeated the same process with the other ball.

A 3-dimensional automatic digitising system (Motion Analysis Corporation, Santa Rosa, CA) was used to capture each athlete's pitching motion. 6 electronically synchronised 240 Hz charged coupled device (CCD) cameras transmitted pixel images of the reflective markers directly into a video processor without being recorded onto video. Three-dimensional marker locations were calculated using computer software (Motion Analysis corporation Expertvision 3-D software, Santa Rosa, CA). Calibration of the 6-camera system was performed every morning before the first subject arrived and then again before the subjects arrived in the afternoon.

Analysis of kinematic and kinetic data

Kinematic parameters were calculated by modelling the body as a system of rigid segments, as previously described (Dillman *et al.*, 1993; Escamilla *et al.*, 2001; Fleisig *et al.*, 1996b; Fleisig *et al.*, 1999; Fleisig *et al.*, 2006). In each time frame of data, the throwing wrist joint was determined as the midpoint of the ulnar and radial styloid processes. Then a temporary upper torso reference frame was determined using the locations of both acromion markers and both greater trochanter markers. Each shoulder joint centre was then translated in the upper torso reference frame a small distance from the respective acromion marker. The upper torso reference frame was then recalculated, using shoulder joint centres instead of acromion markers. Next, a temporary reference frame was calculated for the throwing arm, using a vector from the shoulder joint centre to the lateral humeral epicondyle marker and this vector's cross-product with a vector from the epicondyle marker to the wrist joint. Shoulder external rotation was defined as the projection of the forearm in the sagittal plane of the upper torso reference frame. Shoulder horizontal adduction was defined as the projection of the upper arm in the transverse plane of the upper torso reference frame. Elbow flexion was defined as the angle between the distal directions of the upper arm and forearm.

Maximum shoulder external rotation, maximum shoulder horizontal adduction, and maximum elbow flexion was calculated for each pitch. These three upper extremity positions all occurred at about the same time, when the arm was cocked back (Figs. 1a and 1b). Maximum angular velocities of elbow extension and shoulder internal rotation were also measured. These parameters occurred near the time of ball release (Fig. 1c). The remaining kinematic parameter was ball velocity. Ball velocity was recorded directly with a Tribar Sport radar gun with an accuracy of ±0.2 m/s (Jugs Pitching Machine Company, Tualatin, OR). All ball velocities were recorded from a point directly behind the catcher for consistency of readings.

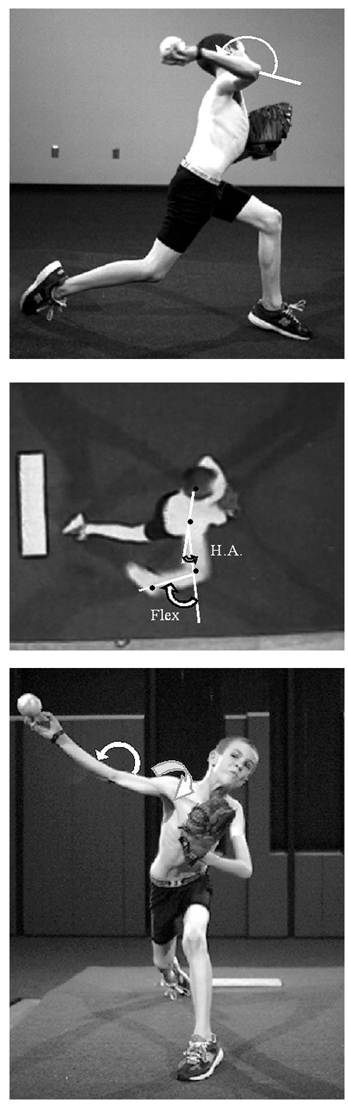

Figure 1 Kinematic parameters: (a) shoulder external rotation; (b) shoulder horizontal adduction ('H.A.') and elbow flexion ('Flex'); and (c) shoulder internal rotation velocity and elbow extension velocity.

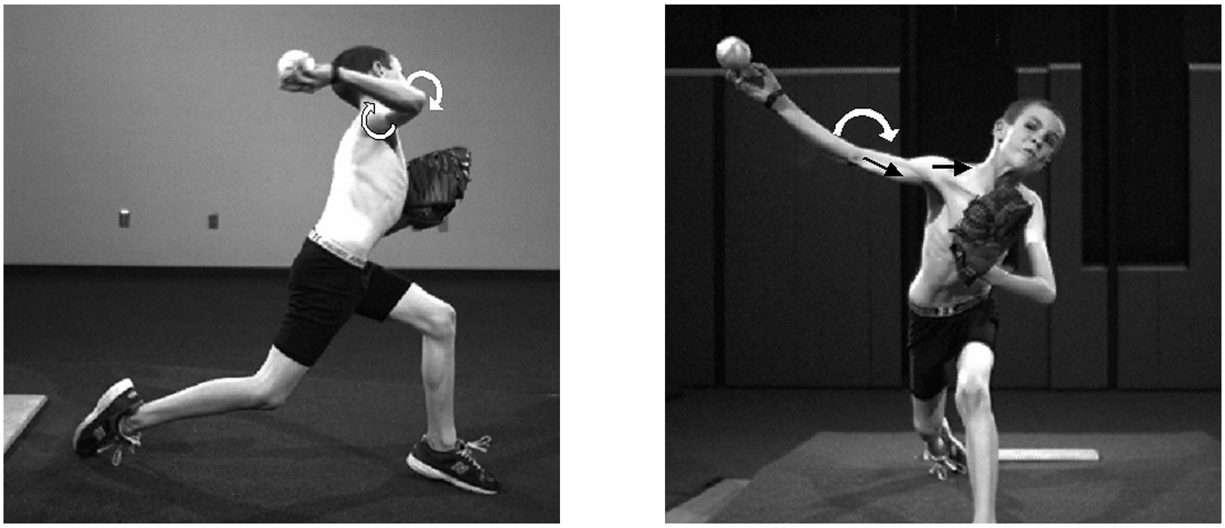

Figure 2 Kinetic parameters: (a) shoulder internal rotation torque and elbow varus torque; and (b) shoulder proximal force, elbow proximal force, and elbow flexion torque. Torques shown as curved white arrows, and forces shown as straight black lines.

Kinetic values were calculated at the shoulder and elbow using the kinematic data, documented cadaver body segment parameters, and inverse dynamics (Fleisig *et al.*, 1995; Fleisig *et al.*, 1996b; Fleisig *et al.*, 1999; Fleisig *et al.*, 2006). These values were expressed as the loads applied at the joint by the proximal segment onto the distal segment. Near the time of maximum external rotation, shoulder internal rotation torque and elbow varus torque were produced to stop the arm cocking and initiate arm acceleration (Fig. 2a). Near the time of ball release, proximal forces were produced at the shoulder and elbow to resist distraction of the distal segment (Fig. 2b). Near ball release, elbow flexion torque was produced as well, to terminate elbow extension (Fig. 2b).

For each ball weight thrown by each subject, data from the fastest three pitches thrown for strikes were averaged and analysed. A repeated measures multivariate analysis of variance (MANOVA) was then used to analyse each of the three hypotheses. A repeated measures MANOVA was used to analyse differences in 3 arm position parameters (shoulder external rotation, shoulder horizontal adduction, elbow flexion) between the two ball weights. Repeated measures MANOVAs were also used to analyse differences in three velocity parameters (shoulder internal rotation, elbow extension, ball) and differences in five kinetic parameters (shoulder internal rotation torque, elbow varus torque, elbow flexion torque, shoulder proximal force, elbow proximal force) between the two ball weights. For each of these three repeated measures MANOVAs, an alpha level of 0.05 was used. When a significant difference was found, *post-hoc* univariate tests were performed comparing each variable to ball weight. Once again, an alpha level of 0.05 was used.

Subjective data

Each subject completed a post-trial questionnaire immediately following completion of the final session. For each of the following questions, the subject had to choose green ball, blue ball, or the same:

1 Which ball felt better to you?
2 Which ball do you think you threw the fastest?
3 Which ball do you think you threw more accurately?

Results

There was no significant difference (p = 0.567) in arm position between pitching the two ball weights. Arm position parameters are shown in Table 1.

Table 1 Arm position (mean ± SD) while throwing 5 oz and 4 oz baseballs.

	5 oz ball	4 oz ball
Maximum shoulder external rotation (°)	179 + 13	179 + 13
Maximum shoulder horizontal adduction (°)	19 ± 7	19 ± 7
Maximum elbow flexion (°)	98 ± 8	98 ± 9

Table 2 Differences in velocity parameters (mean ± SD) between throwing the 5 oz and 4 oz baseballs.

	5 oz ball	4 oz ball	p value
Maximum elbow extension velocity (deg s^{-1}) *	2060 + 310	2130 + 330	0.001
Maximum shoulder internal rotation velocity (deg s^{-1}) *	6950 + 1520	7250 + 1600	< 0.001
Ball speed (m s^{-1}) *	23.5 + 2.1	24.6 + 2.1	< 0.001

* Significant difference between 5 oz and 4 oz data.

Table 2 Kinetic differences (mean ± SD) between throwing 5 oz and 4 oz baseballs.

	5 oz ball	4 oz ball	p value
Elbow varus torque (N m) *	26.9 ± 7.2	24.4 ± 5.9	0.02
Shoulder internal rotation torque (N m) *	27.8 ± 7.8	25.4 ± 6.1	0.02
Elbow proximal force (N)	354± 84	347 ± 78	0.53
Shoulder proximal force (N)	391 ± 82	392 ± 91	0.87
Elbow flexion torque (N m)	12.0 ± 4.1	11.3 ± 4.2	0.29

* Significant difference between 5 oz and 4 oz data.

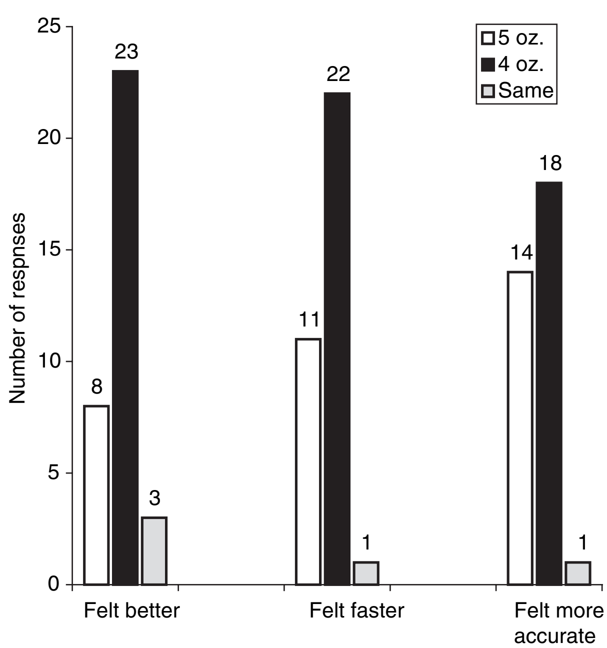

Figure 3 Subjective questionnaire responses.

Significantly higher velocities ($p < 0.001$) were produced when pitching the 4 oz baseball. *Post-hoc* analysis revealed significant differences in shoulder, elbow, and ball velocities (Table 2).

Joint kinetics were significantly less ($p = 0.042$) when pitching the 4 oz ball. *Post-hoc* analysis revealed significant differences in shoulder internal rotation torque and elbow flexion torque (Table 3).

The values in Fig. 3 represent the number of responses given to each of the three questions asked on the post-trial questionnaire. When asked which ball felt better to pitch, 68% preferred the 4 oz ball, 24% preferred the 5 oz ball, and 9% had no preference. When asked which ball they believed they pitched faster, 65% chose the 4 oz ball, 32% chose the 5 oz ball, and 3% said they were the same. In reality, 88% pitched the 4 oz faster, 9% pitched the two balls with the same velocity, and only one subject (3%) pitched the 5 oz ball faster. Interestingly, the one subject who threw the 5 oz ball faster believed he threw the 4 oz ball faster. When asked which ball they felt they pitched more accurately, 55% chose the 4 oz ball, 42% chose the 5 oz ball, and 3% said they were the same. As a group, the actual accuracy of the two balls was nearly identical. Out of 10 pitches thrown with each ball, the subjects averaged 5.7 ± 1.4 strikes with the 4 oz ball and 5.6 ± 1.7 strikes with the 5 oz ball.

Discussion

Results from this study did not support the hypothesis that youth pitchers would use different arm positions with a lighter ball. In fact, the arm positions in the current study with both the standard and lightweight baseball appeared to be similar to arm position previously measured with similar methods for high school, college, and professional pitchers (Table 4). Thus, neither baseball seems to result in youth pitchers 'pushing the ball'.

The second hypothesis was shown to be true; arm and ball velocity were significantly different for the two balls. With the lighter ball, the youth pitcher generated greater shoulder, elbow, and ball velocities. These velocities were closer to those achieved by higher level pitchers (Table 4). We believe that the lighter baseballs in the current study resulted in quicker firing and timing of the pitcher's fast-twitch muscle fibres, creating muscle firing patterns and joint velocities more similar to those needed to be an adult pitcher.

Table 4 Kinematic and kinetic parameters among different age groups (mean ± SD).

	Youth[a] (n = 34)	Youth [a] (n = 34)	High School [b] (n = 33)	College [b] (n = 115)	Professional [b] (n = 60)
Age range (years)	9–12	9–12	15–20	17–23	20–29
Weight of pitched ball (oz)	5	4	5	5	5
Arm cocking					
Maximum shoulder external rotation (°)	179 ± 13	179 ± 13	174 ± 9	173 ± 10	175 ± 11
Maximum shoulder horizontal adduction (°)	19 ± 7	19 ± 7	20 ± 9	20 ± 8	17 ± 9
Maximum elbow flexion (°)	98 ± 8	98 ± 9	100 ± 14	99 ± 15	98 ± 15
Elbow varus torque (N m)	26.9 ± 7.2	24.4 ± 5.9	48 ± 13	55 ± 12	64 ± 15
Shoulder internal rotation torque (N m)	27.8 ± 7.8	25.4 ± 6.1	51 ± 13	58 ± 12	68 ± 15
Arm acceleration					
Maximum elbow extension velocity (deg s^{-1})	2060 ± 310	2130 ± 330	2180 ± 340	2380 ± 300	2320 ± 300
Maximum shoulder internal rotation velocity (deg s^{-1})	6950 ± 1520	7250 ± 1600	6820 ± 1380	7430 ± 1270	7240 ± 1090
Near ball release					
Ball speed (m s^{-1})	23 ± 2	25 ± 2	33 ± 2	35 ± 2	37 ± 2
Elbow proximal force (N)	354 ± 84	347 ± 78	630 ± 140	770 ± 120	910 ± 140
Shoulder proximal force (N)	391 ± 82	392 ± 91	750 ± 170	910 ± 130	1070 ± 190
Elbow flexion torque (N m)	12.0 ± 4.1	11.3 ± 4.2	45 ± 9	52 ± 11	58 ± 13

[a] From current study
[b] From Fleisig et al., 1999

The third hypothesis proved to be true; shoulder and elbow kinetics were different between the two baseballs. Specifically, the youth pitcher produced lower kinetic values when throwing the lightweight baseball. This suggests that the developing adolescent could benefit from the ball weight reduction by decreasing stress placed on the shoulder and elbow. Of particular note was decreased elbow varus torque produced with the 4 oz baseball. This parameter is important because of the alarming increase in the number of ulnar collateral ligament reconstructions ('Tommy John surgeries') in adolescent pitchers (Petty *et al.*, 2004) and the fact that elbow varus torque has been described as the load that stresses the UCL (Fleisig *et al.*, 1995; Sabick *et al.*, 2004). Decreased elbow and shoulder kinetics may be especially beneficial for the pre-pubescent pitcher. Before physical maturity, a young athlete will have secondary ossification centres ('open growth plates') at the proximal and distal ends of the humerus, ulna, and other bones. The softer bone at these ossification centres may be vulnerable to injury from large torques and forces produced during pitching (Lyman *et al.*, 2001). Sabick *et al.* (2005) and Lyman and Fleisig (2005) suggested that repetitive internal rotation torque during pitching may be large enough to cause proximal humeral epiphysiolysis in the youth pitcher's shoulder. These groups also suggested that repetitive varus torque may be associated with osteochondritis dissecans (Sabick *et al.*, 2004) and medial epicondyle apophysitis of the immature elbow (Sabick *et al.*, 2004; Lyman and Fleisig, 2005). It is possible that by decreasing the forces and torques on the developing adolescent's throwing shoulder and elbow, a reduction in accumulated microtrauma could lead to a decreased risk in injury.

Results from the post-trial questionnaire are most intriguing, in that they report the subjective viewpoint of the young pitcher. A majority of subjects reported a strong preference for the lighter baseball. These results imply that using lighter baseballs were not a concern to most youth pitchers.

In an attempt to answer the kinematic and kinetic questions of this study, several more questions have arisen. If a change in the weight of the baseball for youth players is warranted, at what ages should pitchers switch to the standard weight baseball?

Would play with a 4 oz baseball result in less severe impact injuries to batters and fielders because of the lower ball mass or more severe impact injuries because of increased ball speed? Should a lighter (4 oz) baseball be manufactured with the same coefficient of restitution as a standard (5 oz) baseball, or should it be made slightly softer to reduce impact injuries?

More research would help answer some of these questions. Possible studies include:

1 Epidemiological research on the effects on injury rates and injury types when playing with lighter baseballs.
2 A study that analyses the accuracy of throwing a lighter baseball as opposed to a standard baseball. This would be important in that a reduction of pitches per game could reduce the microtrauma associated with overuse injuries.
3 A study on kinematic and kinetic changes with a lightweight baseball for the beginner baseball player (9 years and under).

Researchers and youth baseball organisations should work together to address these questions. Answers to the questions above, along with the information provided in this study, could be very beneficial in making the game safer, improving the quality of the game, and bringing baseball in conformity to how other sports have made accommodations for the younger athlete.

Conclusion

Many other youth sports (American football, basketball, etc.) reduce the size of the ball for the younger, smaller, weaker athlete. The smaller and lighter balls are designed to allow youth athletes the ability to accomplish their tasks (getting the basketball up to the rim, having the strength and hand size to throw an American football, etc.) without sacrificing proper mechanics or increasing the risk of injury. Baseball has fallen behind in this aspect. The 11-year-old athlete throws the same size and weight baseball that Major League player throws. Differences in strength and size between a professional pitcher and an 11-year-old are obvious.

Pitching injuries result from accumulated microtrauma in the throwing arm. Thus, it is believed that the risk of injury in a young pitcher's arm is related to both the number of pitches thrown (American Academy of Pediatrics, 1994; Andrews & Fleisig, 1998; DaSilva *et al.*, 1998; Fleisig *et al.*, 2006; Lyman *et al.*, 2001; Lyman *et al.*, 2002; Lyman & Fleisig, 2005; Olsen *et al.*, 2006; Petty *et al.*, 2004; Sabick *et al.*, 2004) and the loads on the elbow and shoulder during each pitch (Fleisig *et al.*, 1989; Fleisig *et al.*, 1995; Fleisig *et al.*, 1996a; Fleisig *et al.*, 1999; Fleisig *et al.*, 2006; Lyman & Fleisig, 2005; Sabick *et al.*, 2005). Data from this study suggest that pitching with a 4 oz baseball could reduce the loads on the elbow and shoulder of the youth pitcher, thereby reducing the risk of injury. Another potential benefit of the lightweight ball is helping the young pitcher develop arm speed while still maintaining good arm mechanics.

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