ORIGINAL ARTICLE

A controlled study on batted ball speed and available pitcher reaction time in slowpitch softball

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Objectives: To investigate safety risks in slowpitch softball by conducting laboratory and experimental studies on the performance of high tech softball bats with polyurethane softballs. To compare the results with the recommended safety standards.

Methods: ASTM standard compression testing of seven softball models was conducted. Using these seven softball models, bat/ball impact testing was performed using seven adult male softball players and six high tech softball bat models to determine mean batted ball speeds. Over 500 bat/ball impact measurements were recorded and analysed. Available pitcher reaction time was calculated from the mean batted ball speed measurements.

Results: According to the United States Specialty Sports Association and the Amateur Softball Association, the maximum initial batted ball speed should be 137.2 km/h, which corresponds to a minimum pitcher reaction time of 0.420 second. These experiments produced mean batted ball speeds of 134.0–159.7 km/h, which correspond to available pitcher reaction times of 0.409–0.361 second.

Conclusion: The use of high tech softball bats with polyurethane softballs can result in batted ball speeds that exceed the recommended safety limits, which correspond to decreased available pitcher reaction times.

In the past two years, there have been a number of catastrophic injuries and fatalities to softball pitchers as the result of batted balls hit directly back at them.¹ All of the reported fatalities were due to the pitcher being struck in the head region and suffering massive head or neck trauma. The combined use of high tech bats and polyurethane softballs appears to have created a highly dangerous aspect of what has been traditionally a relatively safe, recreational game. We theorise that unsafe batted ball speeds (BBSs), which lead to decreased available pitcher reaction times (APRTs), is the main reason for the increase in injuries and fatalities in slowpitch softball.

There are two major national softball associations in the United States, the United States Specialty Sports Association (USSSA) and the Amateur Softball Association (ASA). Both have adopted national testing standards based on the ASTM standard test method for measuring softball bat performance factor,² the ASTM standard test method for measuring the coefficient of restitution (COR) of baseballs and softballs,³ and the ASTM standard test method for compression-displacement of baseballs and softballs.⁴ According to the USSSA's bat performance test, a legal softball bat should have a bat performance factor of 1.2 or lower.⁵ According to the ASA 2000 test, a standard bat's initial BBS should not exceed 137.2 km/h.⁶ If the USSSA and ASA tests are compared, both recommend the same maximum BBS, as a bat performance factor of 1.2 yields, for a standard bat, a maximum initial BBS of 137.2 km/h.

On the basis of 137.2 km/h as the recommended "safe" initial BBS, the APRT can be calculated. Using the fact that the pitcher is approximately 15.24 m away from home plate and using a BBS of 137.2 km/h, the calculated APRT is 0.400 second, which allows a pitcher to avoid or catch a batted ball, without taking deceleration of the ball into account.

However, if deceleration due to air resistance is factored in, the resulting APRT would be higher. Based on baseball deceleration calculations performed by Adair⁷ and

substituting the physical properties of softballs, the deceleration due to air resistance in slowpitch softball can be calculated. If deceleration were taken into account for slowpitch softball, a softball would decelerate approximately 9.4% during the first 15.24 m of travel. Therefore the mean speed for a softball starting at 137.2 km/h would be 130.8 km/h—that is, $137.2 \times (1 - (0.094/2))$ km/h. Therefore the resultant APRT for an mean softball speed of 130.8 km/h would be 0.420 second.

The NCAA is currently testing a variety of bats on a specially designed batting machine located at the University of Massachusetts in Lowell.⁸ The goal is to decrease the exit speed to no more than 149.7 km/h in collegiate baseball. Based on a baseball pitcher being 16.76 m away from home plate at ball impact and using the calculations of Adair,⁷ a ball initially travelling at 149.7 km/h will travel at a mean speed of 143.7 km/h between the batter and the pitcher. This equates to an APRT of 0.420 second, which surprisingly matches the APRT desired for slowpitch softball.

A recent study investigated the APRT as a consideration in design constraints for baseballs and baseball bats for various age groups.⁹ It was found that, for the 16 year age group, a minimum reaction time of 0.409 second is necessary to reduce the potential for serious or catastrophic injury.

Another study investigated player safety concerning ball exit speed in baseball and concluded that the maximum safe BBS to which a pitcher can react is about 148 km/h.¹⁰ Again, with the use the calculations of Adair,⁷ a ball initially travelling at 148 km/h will travel at a mean speed of 142.1 km/h between the batter and the pitcher, which equates to an APRT of 0.425 second. In addition, it was concluded that a "certified" metal bat swung by an experienced hitter may produce ball exit velocities exceeding

Abbreviations: APRT, available pitcher reaction time; ASA, Amateur Softball Association; BBS, batted ball speed; COR, coefficient of restitution; USSSA, United States Specialty Sports Association

Figure 1 Controlled indoor environment field testing set up. BBS, Batted ball speed.

that demonstrated by a robotic hitting machine, which is currently used for bat testing standards.

Using the current standards for softball and baseball bat testing as a guide, we conducted a controlled study on BBS and APRT for slowpitch softball. The findings indicate that softball is perhaps more dangerous than most coaches, players, and parents think.

METHODS

This study took place in two parts. The first part compared six different softball models with various CORs and compression values from the following softball manufacturers: Worth 0.47 COR-2335 N/0.64 cm; Dudley 0.47 COR-2335 N/0.64 cm; Worth 0.47 COR-1668 N/0.64 cm; Dudley 0.44 COR-2335 N/0.64 cm; Worth 0.40 COR-2335 N/0.64 cm; Worth 0.40 COR-1668 N/0.64 cm. In addition, two state of the art 851 g aluminium multi-wall bats were tested: the DeMarini Doublewall Classic and the Miken Velocit-E.

The second part of the study compared the BBS values for a range of popular softball bat models representing the three most popular materials used for bat construction: aluminium, composite matrix, and titanium. In addition to the aluminium multi-wall bats from the first part of this study, the following softball bats were chosen: TPS Titanium, Easton Synergy, Miken Ultra II, and DeMarini Ultimate Weapon. One ball was chosen for this study (Worth 0.40COR-1668 N/0.64 cm) with an mean compression value

Table 2 Mean batted ball speed (BBS; km/h) for various bat types using a 1735 N/0.64 cm softball

	Mean BBS
Titanium	147.3
Composite	159.7
Aluminium multi-wall	141.7
Aluminium single wall	134.0

of 1735 N/0.64 cm. All softball bats and balls for both studies were purchased from retail sporting goods stores.

Softballs

All softballs were compression tested according to the ASTM laboratory standard for ball testing.⁴ Ball compression is defined as the amount of force necessary to compress a softball 0.64 cm and is measured in N/0.64 cm. All softballs were weighed and measured to determine if they complied with the rules of the national softball associations. According to the ASA rulebook, an official 30.48 cm softball may have a circumference of between 30.16 cm and 30.80 cm and weigh between 177.2 g and 198.4 g. According to the USSSA rulebook, an official 30.48 cm ball may have a circumference of between 30.16 cm and 30.80 cm and weigh between 170.1 g and 205.5g.

Batter constraints

Seven bat testers with various skill levels participated in both studies. For both studies, each tester was required to hit for four rounds with each bat with all BBS values recorded for each successful hit. For each round, at least seven recorded hits from each tester were required, but the number of swings for each round was limited to 10 to minimise fatigue. There was a mandatory five minute rest period between rounds. In addition, a thirty minute break after every four rounds of hitting was used to mitigate fatigue. To ensure accurate testing, the standard deviation of the top five (roughly 20%) averages from the four test rounds was

Table 3 Calculated available pitcher reaction time (APRT; seconds) using the BBS data from table 2

	Mean APRT
Titanium	0.372
Composite	0.361
Aluminium multi-wall	0.387
Aluminium single wall	0.409

Table 1 Mean batted ball speed (BBS), available pitcher reaction time (APRT), and ball compression, circumference, and weight

Ball ID	Ball model	Ball COR	Multi-wall BBS (km/h)	APRT (seconds)	Ball compression (N/0.64 cm)	Ball circumference (cm)	Ball weight (g)
1	Worth	0.47	146.29	0.375	2371	29.79*	179.74
2	Dudley	0.47	142.91	0.384	2108	30.23	188.53
3	Worth	0.47	144.52	0.380	1668	29.85*	180.87
4	Dudley	0.44	143.07	0.383	2273	30.05*	183.71
5	Worth	0.40	147.58	0.372	2460	29.77*	181.16
6	Worth	0.40	143.39	0.383	1828	29.82*	174.35†
Mean			144.68	0.379	2118.10	29.92	181.39

The multi-wall bats used were the DeMarini Doublewall Classic and Miken Velocit-E.

*Fails the requirements for ASA and USSSA ball circumference.

†Fails the requirements for ASA ball weight.

COR, Coefficient of restitution; ASA, Amateur Softball Association; USSSA, United States Specialty Sports Association.

What is already known on this topic

Severe, even fatal, injuries have occurred to pitchers in slowpitch softball. Therefore it has been recommended that the initial BBS should not exceed 137.2 km/h.

required to be less than 3.2 km/h in order to be considered a valid test based on a statistical margin of error at the 98% confidence level.

Pitching machine

A Jugs Professional softball pitching machine capable of accurately and reliably pitching a softball in the 24–35 km/h range through the hitting zone was used. This range was used to simulate the actual pitch speeds that occur in a softball game. The height of the pitch (arc) did not exceed 3 m.

BBS measurements

A Jugs Professional radar gun accurate to within 0.8 km/h was used to measure BBS. The BBS readings were recorded approximately halfway between the batter's impact point and the pitching machine. The radar gun was mounted on a tripod parallel to and 1.2 m from the ground, 3 m from the back of home plate, perpendicular to the pitching line, and aimed at the shortstop fielding position for a right handed batter (fig 1). The radar gun set up can be easily transposed for a left handed batter during testing.

RESULTS

Table 1 shows the results for the first part of this study using various softball models along with two multi-wall bats. The mean BBSs, APRTs, ball compression values, ball circumferences, and ball weights are shown for the equipment tested. Looking at the bat performance results, mean BBS ranged from 142.91 to 147.58 km/h, and APRT was between 0.372 and 0.384 second. Looking at the ball properties, mean ball compression ranged from 1668 to 2460 N/0.64 cm, mean ball circumference ranged from 29.77 to 30.23 cm, and mean ball weight ranged from 174.35 to 188.53 g.

Table 2 lists the results for the second part of this study using one softball model along with six softball bat models with various construction properties. The bat type and mean BBS for each bat type are given.

In table 3, the BBS data from table 2 were used to calculate the APRT.

DISCUSSION

The main finding of this study is that BBS values in slowpitch softball exceed the recommended safety limits imposed on the sport.^{5–6} We describe how BBS directly correlates with

What this study adds

The use of high tech softball bats along with polyurethane softballs can result in BBSs that exceed the recommended safety limits, giving pitcher's insufficient time to react.

APRT, which is an increasing concern considering recently reported injuries and fatalities in slowpitch softball.¹

Another contributing factor in assessment of safety and injury risk is the recent introduction of high performance composite softball bats. When these bats are combined with the average polyurethane softball, they produce much faster BBSs, and therefore much lower APRTs, than recommended (tables 2 and 3). For example, the use of composite bats resulted in an APRT of 0.361 second, which is much lower than the recommended pitcher reaction times of 0.409–0.425 second.

There are several options that may be used to mitigate safety concerns. The use of lower compression softballs may greatly reduce BBSs and allow the pitcher enough time to react to most batted balls. Regulating the performance of softball bats may also greatly reduce BBSs. Another option for increasing APRT is to move the pitcher's mound back. The intent of this study was to shed light on a potentially serious safety concern in the sport with the ultimate goal of preventing injuries and fatalities.

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