ANTHROPOMETRIC AND PHYSIOLOGICAL FACTORS AFFECTING BATTED BALL SPEED OF ADOLESCENT BASEBALL PLAYERS

Peter J Sinclair[1], Matthew Hollings[1], Stephen Smith[2], Sean Hardy[3], Shane Cassel, Jonathan L Freeston[1]

Discipline of Exercise and Sport Science, The University of Sydney, Australia[1]
NSW Institute of Sport, Sydney, Australia[2]
Cricket NSW, Sydney, Australia[3]

Fifty-seven junior baseball players performed eight swings off a tee to record ball exit speed, as well as tests of grip strength, standing broad jump, lateral-to-medial (LM) jumps, chin-ups and chest pass with a medicine ball. The height, weight and age of each participant was also recorded. All anthropometric and physiological tests were significantly positively correlated with ball speed ($p < 0.05$). Collinearity between variables meant that only chest pass ($R^2 = 0.70$, $p = 0.000$), body mass ($\Delta R^2 = 0.03$, $\Delta p = 0.021$) and LM jump ($\Delta R^2 = 0.04$, $\Delta p = 0.005$) made independent contributions to a stepwise linear regression. These findings corroborate the expectation that upper body power is a major determinant of batting speed, with leg power adding an additional, independent contribution to performance.

KEY WORDS: baseball, batting, strength, power, anthropometry

INTRODUCTION: Batting is one of the key offensive skills required in baseball, with batted ball speed an important outcome variable influenced by both swing speed and ball impact location (Crisco, 2002). Faster batted ball velocities are a key performance indicator shown to distinguish between elite and novice level baseball players, potentially increasing the batter's chance to reach base safely and to promote run production (Spaniol et al., 2008). As such, there is strong reason for the measurement of batted ball speed as a key performance indicator for the evaluation of potential batting ability.

Bat swing speed is a major factor enabling ball exit speed; and muscular strength and power have been established as determinants of performance across several sports such as baseball (Szymanski et al., 2009), golf (Keogh et al., 2009) and ice hockey (Bezak and Pridal, 2017). There have, however, been some contrary results between studies. For example, Spaniol et al. (2006) found significant correlations between batting speed and grip strength ($r = 0.75$), upper body power ($r = 0.78$) and lower body power ($r = 0.70$) for a large cross-section of adolescent baseball players; while Miyaguchi and Demura (2012) demonstrated a significant correlation between one-repetition-maximum bench press and bat swing speed ($r = 0.59$) among national level high school baseball players. In contrast, when examining the effect of training these parameters across longitudinal studies, increases in strength and power from training have not translated into improvements in batting speed (Szymanski et al., 2006).

When investigating how anthropometric and physiological variables relate to a performance measure like batting, there are considerable collinearities between maturation, size and strength measures that make it difficult to identify the relative contribution of individual variables. The purpose of the present study was to partition out independent contributions of size, strength and power measures to identify those most strongly related to the batting performance of adolescent baseball players. It was hypothesised that upper body strength and lower body strength would both contribute to the production of batted ball speed.

METHODS: Fifty-seven baseball players were recruited from New South Wales state youth teams. Participants represented most of the highest-level players of their age groups in the state of NSW. Each player was recorded as being a right handed or left-handed batter and the dominant throwing hand was also recorded. As well as standard anthropometric measures of height, weight and arm span, the following performance measures were recorded from each participant:

- Grip Strength was measured using a Jamar hydraulic hand dynamometer. Participants were asked to apply maximum force on the dynamometer during three-second contractions with the elbow flexed at 90°. Two trials from the left and right hands were performed and the maximum value recorded for each hand.
- The maximum number of Chin-Ups able to be performed without rest. Each lift required the participant to raise the chin completely above the bar, return to full elbow extension, and pause briefly before attempting a subsequent lift.
- Standing Broad Jump consisted of two-legged jumps for maximum forward projection. Participants started behind a line and distance was recorded to the rear of the foot at landing. The maximum value from three trials was recorded.
- Lateral-to-Medial (LM) Jumps were performed by participants jumping to the left and right; jumping as far as possible off a single leg while landing on two feet. Dominant LM Jumps were recorded from right handed batters jumping off their right leg towards the left-hand side, and non-dominant LM jumps in the opposite direction. Distance was recorded from the inside of the take of foot to the outside of the same foot at landing. The maximum value for each leg was recorded after three trials on each leg.
- Chest Pass required participants to propel a 3 kg medicine ball forward as far as possible, using only their upper body without observable trunk flexion, and flight distance to the first bounce was measured. Once again, the maximum value from three trials was recorded.

Ball speed was measured from participants hitting eight trials off a stationary tee and instructed to hit as fast as possible. Exit speed off the tee was measured using a Jugs Corporation cordless speed radar gun and the maximum value recorded.
Pearson's correlation between Ball Speed and each of the other variables was determined using SPSS Statistics (IBM, Version 24). A multiple linear regression analysis was subsequently performed using Ball Speed as the dependent variable and each of the other variables entered Stepwise. Regression models entered one variable at a time, commencing with the highest independent predictor. A p value less than 0.05 was required for subsequent independent variables to be introduced, and variables would have been removed from the regression if their p value had dropped below 0.1 in subsequent models.

RESULTS: Mean values for all participants are shown in Table 1. There was a significant correlation between Ball Speed and all other variables ($p < 0.05$).

Table 1: Mean and standard deviations of all measures and their correlations with Ball Speed

	Mean (S.D.)	Correlation with Ball Speed	Significance of Correlation
Age (Yrs)	15.1 (1.3)	0.54	0.000
Height (m)	1.77 (0.06)	0.56	0.000
Body Mass (kg)	73.4 (12.8)	0.72	0.000
Arm Span (m)	1.78 (0.08)	0.53	0.000
Dominant Grip Strength (N)	397 (70)	0.55	0.000
Non-dominant Grip Strength (N)	390 (66)	0.68	0.000
Chin-Ups	5.89 (4.67)	0.28	0.021
Broad Jump (m)	2.28 (0.22)	0.60	0.000
Dominant LM Jump (m)	1.74 (0.17)	0.53	0.000
Non-dominant LM Jump (m)	1.78 (0.18)	0.57	0.000
Chest Pass (m)	5.11 (0.79)	0.84	0.000
Ball Speed (m/s)	33.3 (3.1)		

Table 2 shows output from the Stepwise Regression analysis. Three models were analysed by the regression, with Chest Pass entering the first model, Chest Pass and Body Mass in the second model, and Chest Pass, Body Mass and Non-dominant LM Jump in the third model. Chest Pass alone (model 1) explained 70% of the variance in Ball Speed, while models 2 and 3 contributed only a further 3% and 4% respectively to the regression.

Table 2: Results from the Multiple Linear (Stepwise) Regression Analysis

Model Summary				Model Coefficients			
Model	R^2	ΔR^2	Δp		B	Std Error	p
1	0.70	0.70	0.000	(Constant)	61.1	5.4	0.000
				Chest Pass	11.6	1.0	0.000
2	0.73	0.03	0.021	(Constant)	58.1	5.3	0.000
				Chest Pass	9.2	1.4	0.000
				Body Mass	0.2	0.1	0.021
3	0.77	0.04	0.005	(Constant)	39.6	8.0	0.000
				Chest Pass	6.6	1.6	0.000
				Body Mass	0.3	0.1	0.002
				Non-dominant LM Jump	15.0	5.1	0.005

ΔR^2 and Δp are the change in R^2 and p for each model; B is the partial regression coefficient for each variable, Std Error is the standard error of B; p is the significance of each individual variable.

DISCUSSION: While all variables were significantly correlated with ball exit speed, collinearities between variables meant that they weren't all making independent contributions to performance. Indeed, with a group of adolescent athletes, performance increases would be expected as the body grows through normal maturation. It was for this reason that the stepwise regression was performed; to identify those variables making independent contributions to performance. Chest Pass, a measure of upper body power, was the variable most highly correlated with batted ball speed. After this variable had entered the regression in model 1, Body Mass and Non-dominant LM Jump were the only variables to make significant further contributions. For example, while grip strength was strongly correlated with batting performance, consistent with prior research (Spaniol 2006, Szymanski 2006), there was no further variance explained by grip strength beyond that already contributed by the strength required for Chest Pass. The three variables featured in Model 3 indicate that batting performance is largely determined by power of the upper body muscles (Chest Pass), overall body size (Body Mass), and lower body power (LM Jump) (Fig 1).

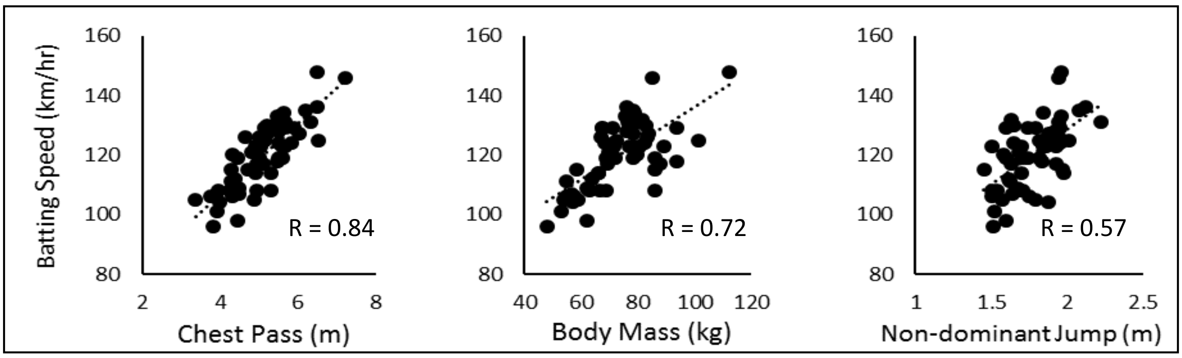

Figure 1. Correlation between Chest Pass, Body Mass, Non-dominant LM Jump and Ball Speed

While it is not possible to statistically test this assertion, the authors note that non-dominant grip strength appeared to be more highly correlated with batting performance (r=0.68) than was dominant hand grip strength (r=0.55). It is likely that this factor was confounded by 14 of the athletes being right-hand dominant for throwing but reporting left-hand dominance for batting. If dominance had been determined by the throwing hand rather than the batting hand, then this finding would have been reversed; with strength of the dominant (throwing) hand producing a greater correlation with batting performance. The choice of hand should therefore be carefully considered in future research using grip strength as a measure of upper limb strength.

A similar finding applied to LM jumps, where non-dominant lateral jumps (eg a right-handed batter jumping off the left foot towards his right side) demonstrated similar correlations with ball speed to jumps off the opposite leg. This was contrary to expectations because right handed batters drive off their right foot towards the left during the batting action. Perhaps the importance of the non-dominant leg comes from its action in bracing the lower body, rapidly halting forward momentum, and facilitating transfer of momentum to the upper body. If this reasoning is correct, then it could be further hypothesised that eccentric ability of the non-dominant leg muscles would be more important to measure than the concentric performance measured in the present study. This may warrant further consideration in future research.

The importance of upper body strength for baseball has been emphasised by Chest Pass having the highest correlation with ball speed. Previous research has identified correlations between abdominal muscle thickness and batting performance (Tsuchikane et al., 2017). This suggests that abdominal rotation is a further strength measure that should be considered when evaluating the capabilities of baseball batters.

CONCLUSION: These findings corroborate the expectation that upper body power is a major determinant of batted ball speed. Body mass was also anticipated to determine performance and, while obviously correlated with Chest Pass ability (R = 0.71), makes only a small independent contribution beyond that of Chest Pass. Leg power makes an additional contribution to performance as measured by Non-dominant LM Jump. The present finding that power of the non-dominant leg made a significant prediction to batting performance may indicate the importance of leg power for halting forward motion and transferring momentum to the upper body. This finding warrants further investigation because, if supported, then it implies that eccentric leg power may be more important than the concentric test utilised for the present research.

REFERENCES:

Bežák, J., Přidal, V. (2017). Upper body strength and power are associated with shot speed in men's ice hockey. *Acta Gymnica*, 47, 78-83

Crisco, J.J., Greenwald, R.M., Blume, J.D., & Penna, L.H. (2002). Batting performance of wood and metal baseball bats. *Medicine & Science in Sports & Exercise*, 34, 1675-1684.

Keogh, J.W.L, Marnewick, M.C., Maulder, P.S., et al. (2009). Are anthropometric, flexibility, muscular strength, and endurance variables related to clubhead velocity in low- and high handicap golfers? *Journal of Strength and Conditioning Research*, 23, 1841-1850.

Miyaguchi K., Demura S. (2012). Relationship between upper-body strength and bat swing speed in high-school baseball players. *Journal of Strength and Conditioning Research* 26, 1786-1791.

Spaniol, F.J., Bonnette, R., Melrose, D., Bohling, M. (2006). Physiological predictors of bat speed and batted-ball velocity in NCAA Division I baseball players. NSCA 2006 Conference Abstracts. *Journal of Strength and Conditioning Research*, 20(4), e25.

Spaniol, F.J., Bonnette, R., Paluseo, J. (2008). The relationship between batted-ball velocity and batting performance of NCAA division I baseball players. NSCA 2008 Conference Abstracts. *Journal of Strength and Conditioning Research*, 22(6), 83.

Szymanski, D.J., McIntyre, J.S., Szymanski, J.M., Molloy, J.M., Madsen, N.H., and Pascoe, D.D. (2006). Effect of wrist and forearm training on linear bat-end, center of percussion, and hand velocities, and time to contact of high school baseball players. *Journal of Strength and Conditioning Research*, 20: 231–240.

Szymanski, DJ, DeRenne, C, and Spaniol, FJ. (2009). Contributing factors for increased bat swing velocity. *Journal of Strength and Conditioning Research*, 23, 1338-1352.

Tsuchikane, R., Higuchi, T., Suga, T., et al. (2017). Relationships between bat swing speed and muscle thickness and asymmetry in collegiate baseball players, *Sports*, 5, 33.